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Minerals Yearbook

U.S.
DEPARTMENT
OF THE
INTERIOR

BUREAU OF
MINES

1988

UNITED STATES DEPARTMENT OF THE INTERIOR • Manuel Lujan, Jr., Secretary

BUREAU OF MINES • T S Ary, Director

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1990

Foreword

This edition of the Minerals Yearbook discusses the performance of the worldwide minerals industry during 1988 and provides background information to assist in interpreting that performance. Contents of the individual yearbook volumes follow:

Volume I, Metals and Minerals, contains chapters on virtually all metallic and industrial mineral commodities important to the U.S. economy. In addition, it includes a survey methods and statistical summary of nonfuel minerals chapter and a chapter on mining and quarrying trends.

Volume II, Area Reports: Domestic, contains chapters on the minerals industry of each of the 50 States and Puerto Rico, Northern Marianas, Island Possessions, and Trust Territory. This volume also has a survey methods and statistical summary of nonfuel minerals chapter.

Volume III, Area Reports: International, contains the latest available mineral data on more than 150 foreign countries and discusses the importance of minerals to the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy.

The Bureau of Mines continually strives to improve the value of its publications to users. Therefore, constructive comments and suggestions by readers of the Yearbook will be welcomed.

T S Ary, *Director*

Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook, presents data on about 90 mineral commodities that were obtained as a result of the mineral information gathering activities of the Bureau of Mines.

The collection, compilation, and analysis of domestic minerals industries data were performed by the staffs of the Branches of Ferrous Metals, Nonferrous Metals, and Industrial Minerals of the Division of Mineral Commodities. Statistical data were compiled from information supplied by mineral producers and consumers in response to canvasses, and their voluntary response is gratefully appreciated. Information obtained from individual firms by means of Bureau of Mines canvasses has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonproprietary sources or when permission of the respondent has been granted.

The chapter "Survey Methods and Statistical Summary of Nonfuel Minerals" discusses in somewhat greater detail procedures for canvassing the minerals industry and the processing and evaluation of these data.

Other material appearing in this volume was obtained from the trade and technical press, industry contacts, and other sources; and this cooperation is gratefully acknowledged.

Statistics on world production were compiled in the Branch of Geographic Data, Division of International Minerals, from numerous sources including reports from the U.S. Department of State. U.S. foreign trade data were obtained from reports of the Bureau of the Census, U.S. Department of Commerce. Data on production costs for several commodities were supplied by the Bureau of Mines, Minerals Availability systems.

The Bureau of Mines has been assisted in collecting mine production data and other supporting information by numerous cooperating State agencies. These organizations are listed in the acknowledgments of Volume II.

V. Anthony Cammarota, Jr., *Chief, Division of Mineral Commodities*

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Survey Methods and Statistical Summary of Nonfuel Minerals

By Gloria L. Walker[1] and Stephen D. Smith[2]

SURVEY METHODS

The Bureau of Mines Information and Analysis Directorate collects worldwide data on virtually every commercially important nonfuel mineral commodity. These data form the base for tracking and assessing the health of the minerals sector of the U.S. economy.

This data collection activity was instituted by the 47th Congress in an appropriations act of August 7, 1882 (22 Stat. 329), to place the collection of mineral statistics on an annual basis. The most recent authority for the Bureau of Mines Information and Analysis activity is the National Materials and Minerals Policy, Research and Development Act of 1980 (Public Law 96–479, 96th Congress), which strengthens protection for proprietary data provided to the U.S. Department of the Interior by persons or firms engaged in any phase of mineral or mineral-material production or consumption.

Data Collection Surveys

The Bureau begins the collection of domestic nonfuel minerals and materials statistics by appraising the information requirements of Government and private organizations of the United States. Information needs that can be satisfied by data from the minerals industries are expressed as questions on Bureau of Mines survey forms. Figure 1 shows a typical survey form, "Alumina" (6–1013–A). Specific questions about the production, consumption, shipments, etc., of mineral commodities are structured in the survey forms to provide meaningful aggregated data. Thus, the entire mineral economic cycle from production through consumption is covered by 169 monthly, quarterly, semiannual, and annual surveys.

After the survey form has been designed, a list of the appropriate establishments to be canvassed is developed. Many sources are used to determine which companies, mines, plants, and other operations should be included on the list to produce meaningful National and State totals for the survey. Bureau of Mines State Mineral Officers, State geologists, Federal organizations (e.g., Mine Safety and Health Administration), trade associations, and industry publications and directories are some of the sources that are explored to develop and update survey listings. With few exceptions, a complete canvass of the entire list of establishments is employed rather than a random sample. The iron and steel scrap industry is an example of one of the exceptions where a sampling plan is used rather than a complete canvass of the population.

Before mailing, the survey form must be approved by the Office of Management and Budget (OMB). Under the Paperwork Reduction Act of 1980, OMB approves the need to collect the data and protects industry from unwarranted Government paperwork.

The Bureau publishes a "Survey Forms Catalog," which describes the content of each form. Copies of the catalog may be obtained by contacting the Office of Statistical Standards, U.S. Bureau of Mines, 2401 E Street, N.W., Mail Stop 9701, Washington, DC 20241.

Survey Processing

Approximately 26,000 establishments yield more than 53,000 responses to 169 surveys annually. Each completed survey form returned to the Bureau undergoes extensive scrutiny to ensure the highest possible accuracy of the mineral data. The statistical staff investigates all surveys to certify that no error is introduced by reporting in units other than those specified on the survey form. Relationships between related measures, such as produced crude ore and marketable crude ore, are analyzed for consistency. Internal numerical relationships of column and row totals are validated, and currently reported data are checked against prior reports to detect possible errors or omissions.

For the majority of the surveys, which are automated, the forms are reviewed to certify that data are complete and correct before entering into the computer. The computer is programmed to conduct a series of automated checks to verify mathematical consistency and to identify discrepancies between the data reported and logically acceptable responses.

The Bureau of Mines is modernizing and automating all of its survey processing and data dissemination methods. Automation of the commodity data systems supports the processing of individual surveys and the preparation of statistical tables for publication. A central data base includes the minerals data gathered through surveys and pertinent data accumulated from other sources. The data base allows Bureau personnel to retrieve the data required for analysis of mineral problems and for answering specific user questions.

Survey Responses.—To enable the reader to better understand the basis on which the statistics are calculated, each commodity chapter of the "Minerals Yearbook" includes a section entitled "Domestic Data Coverage." This section briefly describes the data sources, the number of establishments surveyed, the response percentage, and the method of estimating the production or consumption for nonrespondents.

To produce reliable aggregated data, the Bureau employs efficient procedures for handling instances of nonresponse. Failure to return the initial survey form results in a second mailing of the form. If the second form is not returned, telephone calls are made to the nonrespondents. These followup calls provide the necessary data to complete the survey forms, to verify questionable entries, and to encourage nonrespondents to either complete and return survey forms or to provide the information orally. Periodic visits to important minerals establishments are also made by Bureau commodity specialists or State Mineral Officers in order to gather missing data and indi-

FIGURE 1

A TYPICAL SURVEY FORM

Form 6-1013-A
Nonfer. (9-86)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20241

Form Approved
O.M.B. No. 1032-0004.
INDIVIDUAL COMPANY
DATA—PROPRIETARY

Unless authorization is granted in the section above the signature, the data furnished in this report will be treated in confidence by the Department of the Interior, except that they may be disclosed to Federal defense agencies, or to the Congress upon official request for appropriate purposes.

C04

ALUMINA

(Please correct if name or address has changed.)

Please reply to the following questions and return this form as promptly as possible in the enclosed envelope.
If exact data are not available, enter your best estimates and mark "estimated". Submit a separate report for each plant.

"Collection of non-fuel minerals information is authorized by Public Law 96-479 and the Defense Production Act. This information is used to support executive policy decisions pertaining to emergency preparedness and defense and analyses for minerals legislation and industrial trends. The Bureau relies on your voluntary and timely response to assure that its information is complete and accurate."

1. Location of plant: Nearest city or town ______ County ______ State ______

2. Production, Consumption, Shipments, and Stocks of Alumina and Primary Alumina Products During the Year.
Report gross weights of each product in Columns 3-7.

Product (1)	Code	Average Al_2O_3 content (Percent) (2)	Stocks beginning of year (Metric tons) (3)	Production during year (Metric tons) (4)	Consumption during year (Metric tons) (5)	Shipments during year: Quantity (Metric tons) (6)	Shipments during year: Value ($000) (7)	Stocks end of year (Metric tons) (8)
Calcined alumina	201							
Commercial alumina trihydrate	202							
Litho or light hydrate	203							
Activated alumina	204							
Tabular alumina	205							
Other (specify) ______								

3. Shipments of Alumina During Year by Consuming Industries.
The total quantity of shipments reported should equal the total of the shipments reported in Section 2, Column (6).

Product (1)	Code	Quantity (Metric tons): Calcined (2)	Trihydrate (3)	Activated (4)	Tabular (5)	Other (6)
Abrasive	301					
Aluminum	302					
Chemical	303					
Refractory:						
Brick and shapes	305					
Monolithic	306					
Calcium aluminate cement	307					
Other (specify) ______						

OVER

4. Consumption of Aluminum-Bearing Materials in the Manufacture of Alumina.

Material (1)	Code	Quantity (Metric tons) (2)	Value at Plant (3)
Bauxite, Domestic	401		$
Bauxite, Foreign:			
Jamaica	402		
Guinea	403		
Surinam	404		
Brazil	405		
Guyana	406		
Dominican Republic	407		
Other Countries (specify) ______			
______			
______			
Total foreign	419		
Other materials (specify) ______			
______			

5. Consumption and Stocks of Bauxite.
The quantity in Section 5, Column 3, Line 505, should equal the quantity reported in Section 4, Column 2, Line 401.
The quantity in Section 5, Column 3, Line 515, should equal the quantity reported in Section 4, Column 2, Line 419.

Kind of ore (1)	Code	Stocks beginning of year (Metric tons) (2)	Consumption during year (Metric tons) (3)	Stocks end of year (Metric tons) (4)
Domestic:				
Undried	501			
Dried	502			
Activated	503			
Calcined or sintered	504			
Total domestic	505			
Foreign:				
Undried or partially dried	506			
Dried	507			
Other (specify) ______				
Total foreign	515			

Remarks:

PUBLICATIONS: Annual statistical information is published for aluminum and bauxite. If you desire a copy of one or both of these commodity reports, please check the appropriate box. ☐ (1) Aluminum ☐ (2) Bauxite ☐ (3) Both

Name of person to be contacted regarding this report: | Tel. area code | No. | Ext.

Address No. Street | City | State | Zip

May tabulations be published which could indirectly reveal the data reported above?
Value data ☐ (1) Yes ☐ (2) No Other (including quantity) data ☐ (1) Yes ☐ (2) No

Signature | Title | Date

cate the importance of the establishment's reports in producing accurate National, State, and county statistics. By describing the use of these statistics and showing the impact of nonresponse, the Bureau hopes to encourage respondents to give a complete and accurate reply.

The OMB "Guidelines for Reducing Reporting Burden" stipulates that the minimum acceptable response rate shall be 75% of the panel surveyed. In addition, the Bureau strives for a minimum reporting level of 75% of the quantity produced or consumed (depending on the survey) for certain key statistics. Response rates are periodically reviewed. For those surveys not meeting the minimum reporting level, procedures are developed and implemented to improve response rates.

Estimation for Nonresponse.—When efforts to obtain a response to a survey fail, it becomes necessary to employ estimation or imputation techniques to account for the missing data. These techniques prove to be most effective when the response rate is relatively high. Some of the estimation methods depend upon knowledge of prior establishment reporting, while other techniques rely on external information to estimate the missing data. Survey forms received after publication cutoff dates are edited and necessary imputations are made for missing data. The data base is updated, and these revisions are reflected in later publications.

Protection of Proprietary Data.—The Bureau of Mines relies on the cooperation of the U. S. minerals industry to provide the mineral data that are presented in this and other Bureau publications. Without a strong response to survey requests, the Bureau would not be able to present reliable statistics. The Bureau in turn respects the proprietary nature of the data received from the individual companies and establishments. To insure that proprietary rights will not be violated, the Bureau analyzes each of the aggregated statistics to determine if the statistics of an individual establishment can be deduced from the aggregated statistics. For example, if there are only two significant producers of a commodity in a given State, the Bureau will not publish that total because either producer could readily estimate the production of the other. It is this obligation to protect proprietary information that results in the "Withheld" or "W" entries in the "Minerals Yearbook" tables. However, if a company gives permission in writing, the Bureau may release data otherwise withheld because of proprietary considerations as long as the data from other producers in an aggregated cell are protected from disclosure.

International Data

Each commodity chapter in Volume I of the "Minerals Yearbook" contains a "World Review" section that usually includes a world production table. These tables are prepared by country specialists in the Bureau of Mines Division of International Minerals. The data are gathered from various sources, including published reports of foreign government mineral and statistical agencies, international organizations, the U.S. Department of State, the United Nations, the Organization of Petroleum Exporting Countries, and personal contact by specialists traveling abroad. Each February an annual "Minerals Questionnaire" is sent through the Department of State to more than 130 U.S. Embassies asking them to provide by May estimates of mineral production for the host country for the preceding year. Missing data are estimated by Bureau country specialists based upon historical trends and specialists' knowledge of current production capabilities in each country.

Publications

The "Minerals Yearbook" provides the definitive historical record for mineral statistics used by Government and industry in assessing U.S. mineral supply and the characteristics of U.S. mineral demand. Also, it provides worldwide information on the production and consumption of minerals in foreign countries. Beginning with the 1988 edition, the "Minerals Yearbook" format has been enlarged to an 8.5″ × 11″ size with each chapter published as an individual report.

Volume I of the "Minerals Yearbook" provides annual data on nonfuel mineral commodities in an authoritative and complete reference source.

Volume II of the "Minerals Yearbook" contains information organized by State.

Volume III of the "Minerals Yearbook" contains information organized by country and regions. It includes the mineral supply and trade position of each country, details on mineral development and foreign investment policies, structure of the mining industry, infrastructure, and industry outlook.

"Mineral Facts and Problems," last published in 1985, is a one-volume reference source containing worldwide production information and demand forecasts for all nonfuel minerals. Each commodity chapter covers the structure of the industry, uses of the commodity, reserves and resources, technology, supply-demand relationships, byproducts and coproducts, strategic considerations, economic and operating factors, and forecasts. Each chapter also compares the United States and world reserves with cumulative demands to appraise the adequacy of world mineral supplies. "Mineral Facts and Problems" is particularly useful in educating new people in the industry and in familiarizing people with a new commodity. Its commodity forecasts provide unique insight into future developments for each commodity.

"Mineral Industry Surveys" provide periodic data designed to give timely statistical information on production, distribution, stocks, and consumption of significant mineral commodities. These reports are issued monthly for 22 commodities and quarterly for 11 commodities. Annual surveys are issued periodically throughout the year as information becomes available. Electronic publication has been initiated for several commodities on an experimental basis to enhance timeliness.

"Mineral Commodity Summaries," an up-to-date summary of about 85 nonfuel mineral commodities, is the earliest Government publication to furnish estimates covering the previous year's nonfuel mineral industry data. It contains information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics.

"State Mineral Summaries" combine the preliminary annual area reports into a single volume and is a companion publication to "Mineral Commodity Summaries." These summaries have been prepared in cooperation with State geological surveys or related agencies. Individual State summaries are published separately as State Mineral Industry Surveys each February for the preceding year. Copies can be obtained from the appropriate State Activities field office.

"Mineral Perspective" is an intermittent series issued to inform the Bureau's audience of developments in the mineral industries and markets of a foreign country or region of the world. Recent publications in this series include country-by-country reviews of Latin America, the Far East, and South Asia.

"Minerals and Materials/A Bimonthly Survey" is being replaced by a new publication called "Minerals Today" that will continue to provide timely information on mineral commodities in terms of major economic variables—consumption, production, imports, exports, inventories, and prices—and on other current issues such as the environment and land use.

"Information Circulars" are primarily concerned with Bureau economic reviews and interpretative analyses. The series also includes surveys of mining and operating activities, guides to marketing of mineral commodities, and compilations of historical or statistical and economic data of minerals.

To purchase Volumes I, II, and III of the "Minerals Yearbook," "Mineral Facts and Problems," and "Minerals Today" contact the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. For free publications of individual chapters of the "Minerals Yearbook," the "Mineral Industry Surveys," the "Mineral Commodity Summaries," the "State Mineral Summaries," the "Mineral Perspective," and "Information Circulars" contact Publications Distribution, Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236.

STATISTICAL SUMMARY

This chapter summarizes data on crude nonfuel mineral production for the United States, its island possessions, and the Commonwealth of Puerto Rico. Also included are tables that show the principal nonfuel mineral commodities exported from and imported into the United States and that compare world and U.S. mineral production. The detailed data from which these tables were derived are contained in the individual commodity chapters of Volume I and in the State chapters of Volume II of this edition of the Minerals Yearbook.

Although crude mineral production may be measured at any of several stages of extraction and processing, the stage of measurement used in this chapter is what is termed "mine output." It usually refers to minerals or ores in the form in which they are first extracted from the ground, but customarily includes the output from auxiliary processing at or near the mines.

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. For copper, gold, lead, silver, tin, and zinc, the quantities are recorded on a mine basis (as the recoverable content of ore sold or treated). However, the values assigned to these quantities are based on the average selling price of refined metal, not the mine value. Mercury is measured as recovered metal and valued at the average New York price for the metal.

The weight or volume units shown are those customarily used in the particular industries producing the commodities. Values shown are in current dollars, with no adjustments made to compensate for changes in the purchasing power of the dollar.

[1] Operations Research Analyst, Office of Statistical Standards, author of "Survey Methods."

[2] Mineral data assistant, Section of Ferrous Metal Data. The author was assisted in the preparation of the "Statistical Summary" by Barbara M. Carrico, Chief, Section of Nonferrous Metals Data; Sarah P. Guerrino, Chief, Section of Ferrous Metals Data; Barbara E. Gunn, Chief, Section of Industrial Minerals Data; William L. Zajac, Chief, Branch of Geographic Data.

TABLE 1

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
METALS							
Bauxite	metric tons, dried equivalent	510,074	$10,361	575,574	[r]$10,916	587,889	$10,566
Beryllium concentrates	short tons	W	W	W	W	5,851	6
Copper (recoverable content of ores, etc.)	metric tons	1,147,277	1,670,660	[r]1,243,638	[r]2,261,833	1,419,645	3,771,570
Gold (recoverable content of ores, etc.)	troy ounces	3,739,015	1,376,855	[r]4,947,040	[r]2,216,027	6,459,539	2,831,281
Iron ore (includes byproduct material)[2]	thousand metric tons	41,991	1,472,511	47,983	1,503,087	57,113	1,716,661
Iron oxide pigments, crude	short tons	40,987	2,908	42,773	3,598	43,774	3,815
Lead (recoverable content of ores, etc.)	metric tons	339,793	165,150	[r]311,381	[r]246,720	384,983	315,222
Magnesium metal	short tons	138,493	423,788	137,123	381,914	156,509	469,767
Manganiferous ore (5% to 35% Mn)	short tons, gross weight	14,320	W	[r]W	W	W	W
Molybdenum (content of ore and concentrate)	thousand pounds	95,006	240,484	69,868	179,286	99,738	266,899
Nickel (content of ore and concentrate)	short tons	1,175	W	—	—	—	—
Silver (recoverable content of ores, etc.)	troy ounces	34,523,896	188,846	[r]39,896,541	[r]279,675	53,415,677	349,339
Tungsten (content of ore and concentrate)	metric tons	817	5,774	W	W	W	W
Zinc (recoverable content of ores, etc.)	do.	202,983	170,050	[r]216,327	[r]199,924	244,314	324,249
Combined value of antimony (1986), mercury, platinum-group metals (1987–88), rare-earth metal concentrates, tin, titanium concentrates (ilmenite and rutile), vanadium, zircon concentrates, and values indicated by symbol W		XX	[r]96,394	XX	[r]139,596	XX	159,409
Total[3]		**XX**	**[r]5,824,000**	**XX**	**[r]7,423,000**	**XX**	**10,219,000**
INDUSTRIAL MINERALS (EXCEPT FUELS)							
Abrasives[4]	short tons	W	W	12,773	957	14,675	1,183
Asbestos	metric tons	51,437	17,367	50,600	17,198	W	W
Barite	thousand short tons	297	12,326	448	15,810	445	15,512
Boron minerals	do.	1,251	426,086	1,385	475,092	1,267	429,667
Bromine[e]	thousand pounds	310,000	93,000	335,000	107,000	360,000	144,000
Cement:							
Masonry	thousand short tons	3,525	231,551	3,680	259,926	3,574	243,941
Portland	do.	75,181	3,759,942	74,868	3,646,561	74,074	3,575,906
Clays	short tons	44,619,581	1,095,179	47,657,286	1,202,284	49,069,375	1,400,820
Diatomite	thousand short tons	628	128,362	658	134,239	693	143,774
Emery	short tons	2,878	W	1,945	W	W	W
Feldspar	do.	735,000	26,100	720,000	26,100	715,484	28,082
Fluorspar	do.	[e]78,000	W	68,839	11,725	W	W
Garnet (abrasive)	do.	32,296	2,603	42,277	4,350	46,855	4,707
Gem stones		NA	9,247	NA	21,389	NA	43,508
Gypsum	thousand short tons	15,403	99,570	15,612	106,977	16,390	109,205

See footnotes at end of table.

TABLE 1—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
INDUSTRIAL MINERALS (EXCEPT FUELS)—Continued							
Helium:							
Crude	million cubic feet	432	$9,504	730	$16,068	W	W
Grade-A	do.	1,941	72,788	2,230	82,540	2,574	$95,238
Iodine	pounds	W	W	W	W	2,238,152	W
Lime	thousand short tons	14,474	757,867	15,733	786,125	17,293	828,007
Mica (scrap)	do.	148	7,108	161	8,201	143	6,793
Peat	do.	1,038	23,988	958	r21,020	929	19,933
Perlite	do.	507	15,646	533	16,494	576	17,652
Phosphate rock	metric tons	40,320,000	897,131	40,954,000	793,280	45,389,000	887,809
Potassium salts (K_2O equivalent)	thousand metric tons	1,147	152,000	1,485	195,700	1,427	240,300
Pumice	thousand short tons	554	5,756	392	4,493	389	4,129
Salt	do.	36,663	665,400	36,493	684,170	37,997	680,174
Sand and gravel:							
Construction	do.	883,000	2,747,200	e895,200	e3,002,500	923,400	3,126,000
Industrial	do.	27,420	359,300	28,010	364,100	28,480	388,000
Sodium carbonate (natural)	do.	W	W	8,891	593,685	9,632	644,973
Sodium sulfate (natural)	do.	396	34,102	382	33,086	398	31,377
Stone:[5]							
Crushed	do.	e1,023,200	e4,255,000	1,200,100	5,248,600	e1,247,800	e5,558,000
Dimension	short tons	e1,163,347	e173,269	1,183,849	190,153	e1,189,333	e196,289
Sulfur, Frasch process	thousand metric tons	4,180	508,512	3,610	386,834	4,341	430,814
Talc and pyrophyllite	short tons	1,302,179	31,227	r1,281,789	r28,872	1,376,560	29,444
Tripoli	do.	117,174	918	114,926	975	110,152	864
Vermiculite	do.	317,000	34,400	302,926	33,105	303,544	33,948
Combined value of aplite, asphalt (native, 1986), calcium chloride (natural), graphite (natural, 1988), kyanite, lithium minerals, magnesite, magnesium compounds,[6] marl (greensand), olivine, pyrites, staurolite, wollastonite, and values indicated by symbol W		XX	994,446	XX	r374,832	XX	442,620
Total[3]		**XX**	**17,647,000**	**XX**	**r18,894,000**	**XX**	**19,803,000**
Grand total[3]		**XX**	**r23,471,000**	**XX**	**r26,317,000**	**XX**	**30,022,000**

e Estimated. r Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; value included with "Combined value" figure. XX Not applicable.
[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2] Shipments are not comparable to those of previous years owing to the inclusion of byproduct material in the new series.
[3] Data may not add to totals shown because of independent rounding.
[4] Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.
[5] Excludes abrasive stone and bituminous limestone and sandstone; all included elsewhere in table.
[6] Excludes values that must be concealed to avoid disclosing company proprietary data.

TABLE 2

NONFUEL MINERALS PRODUCED IN THE UNITED STATES AND PRINCIPAL PRODUCING STATES IN 1988

Mineral	Principal producing States, in order of quantity	Other producing States
Abrasives[1]	OH, AR, IN, WI.	
Antimony (content of ores, etc.)	ID.	
Aplite	VA.	
Asbestos	CA and VT.	
Barite	NV, GA, MO, CA	TN.
Bauxite	AR, AL, GA.	
Beryllium concentrate	UT.	
Boron minerals	CA.	
Bromine	AR and MI.	
Calcium chloride (natural)	MI, CA, WA.	
Cement:		
Masonry	FL, IN, PA, AL	All other States except AK, CT, DE, MA, MN, NV, NH, NJ, NC, ND, RI, VT, WI.
Portland	CA, TX, PA, MI	All other States except CT, DE, MA, MN, NH, NJ, NC, ND, RI, VT, WI.
Clays	GA, OH, NC, TX	All other States except AK, DE, HI, NH, RI, VT, WI.
Copper (content of ores, etc.)	AZ, NM, UT, MT	CA, CO, ID, IL, MI, MO, NV, TN.
Diatomite	CA, NV, WA, OR	AZ.
Emery	NY.	
Feldspar	NC, CT, CA, GA	OK, SD.
Fluorspar	IL and NV.	
Garnet (abrasive)	ID, NY, ME.	
Gold (content of ores, etc.)	NV, CA, SD, UT	AZ, AK, CO, ID, MI, MT, NM, OR, SC, WA.
Graphite (natural)	MT.	
Gypsum	OK, IA, MI, TX	AR, AZ, CA, CO, IN, KS, LA, MT, NV, NM, NY, OH, SD, UT, VA, WA, WY.
Helium	KS, WY, TX, NM.	
Iodine	OK.	
Iron ore (includes byproduct)	MN, MI, MO, UT	CA, MT, NM, NY, SD, TX.
Iron oxide pigments (crude)	MI, GA, MO, VA.	
Kyanite	VA.	
Lead (content of ores, etc.)	MO, ID, CO, MT	AZ, IL, NV, NY, NM, TN.
Lime	OH, MO, PA, AL	All other States except AK, CT, DE, FL, GA, KS, ME, MS, NH, NJ, NM, NY, NC, RI, SC, VT.
Lithium minerals	NC and NV.	
Magnesite	NV.	
Magnesium compounds	MI, CA, UT, FL	DE, TX.
Magnesium metal	TX, WA, UT.	
Manganiferous ore	SC.	
Marl (greensand)	NJ and DE.	
Mercury	NV, UT, CA.	
Mica (scrap)	NC, SD, GA, SC	CT, NM, PA.
Molybdenum	AZ, CO, MT, UT	CA.

See footnote at end of table.

TABLE 2—Continued

NONFUEL MINERALS PRODUCED IN THE UNITED STATES AND PRINCIPAL PRODUCING STATES IN 1988

Mineral	Principal producing States, in order of quantity	Other producing States
Olivine	NC and WA.	
Peat	MI, FL, IN, IL	CA, CO, GA, IA, MA, MD, MN, MT, NJ, NC, OH, PA, SC, WA, WI, WV.
Perlite	NM, AZ, CA, ID	CO, NV.
Phosphate rock	FL, NC, ID, UT	MT, TN.
Platinum-group metals	MT.	
Potassium salts	MN, CA, UT.	
Pumice	OR, NM, ID, CA	AZ, HI, KS.
Pyrites (ore and concentrate)	AZ.	
Rare-earth metal concentrate	CA and FL.	
Salt	LA, TX, NY, OH	AL, AZ, CA, KS, MI, NV, NM, ND, OK, UT, WV.
Sand and gravel:		
Construction	IL, MI, CA, NJ	All other States.
Industrial	CA, MI, TX, OH	All other States except AK, DE, HI, IA, KY, ME, NH, NM, ND, OR, SD, VT, WY.
Silver (content of ores, etc.)	NV, ID, MT, AZ	AK, CA, CO, IL, MI, MN, MO, NY, OR, SC, SD, TN, UT.
Sodium carbonate (natural)	WY and CA.	
Sodium sulfate (natural)	CA, TX, UT.	
Staurolite	FL.	
Stone:		
Crushed	PA, FL, TX, VA	All other States except DE.
Dimension	IN, GA, VT, NH	All other States except AK, DE, FL, HI, KY, LA, MS, NE, NV, NJ, ND, OR, RI, WV, WY.
Sulfur (Frasch)	TX and LA.	
Talc and pyrophyllite	MT, VT, TX, NY	AL, AR, CA, GA, NC, VA, OR.
Tin	AK and AZ.	
Titanium concentrates	FL.	
Tripoli	IL, OK, AR, PA.	
Tungsten (content of ores, etc.)	CA.	
Vanadium (content of ores, etc.)	ID, CO, UT.	
Vermiculite (crude)	SC, MT, VA.	
Wollastonite	NY.	
Zinc (content of ores, etc.)	TN, NY, MO, MT	CO, ID, IL, KY.
Zircon concentrate	FL, NJ, AL.	

[1] Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

TABLE 3

VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 1988

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Alabama	$459,495	21	1.53	Cement (portland), stone (crushed), lime, sand and gravel (construction).
Alaska	118,694	40	.40	Gold, sand and gravel (construction), stone (crushed), cement (portland).
Arizona	2,773,411	1	9.24	Copper, molybdenum, sand and gravel (construction), cement (portland).
Arkansas	306,789	29	1.02	Bromine, stone (crushed), cement (portland), sand and gravel (construction).
California	2,708,768	2	9.02	Sand and gravel (construction), cement (portland), boron minerals, gold.
Colorado	364,005	25	1.21	Molybdenum, gold, sand and gravel (construction), cement (portland).
Connecticut	118,116	41	.39	Stone (crushed), sand and gravel (construction), feldspar, sand and gravel (industrial).
Delaware [1]	5,999	50	.02	Magnesium compounds, sand and gravel (construction), marl (greensand), gem stones.
Florida	1,391,881	6	4.64	Phosphate rock, stone (crushed), cement (portland), sand and gravel (construction).
Georgia	1,373,825	7	4.58	Clays, stone (crushed), cement (portland), sand and gravel (construction).
Hawaii	74,932	45	.25	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Idaho	290,616	31	.97	Phosphate rock, silver, gold, sand and gravel (construction).
Illinois	587,626	16	1.96	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial).
Indiana	406,389	24	1.35	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Iowa	290,256	32	.97	Stone (crushed), cement (portland), sand and gravel (construction), gypsum (crude).
Kansas	291,713	30	.97	Cement (portland), stone (crushed), salt, helium (Grade-A).
Kentucky	344,979	28	1.15	Lime, cement (portland), sand and gravel (construction), clays.
Louisiana	434,536	23	1.45	Sulfur (Frasch), salt, sand and gravel (construction), stone (crushed).
Maine	67,760	46	.23	Sand and gravel (construction), cement (portland), stone (dimension), stone (crushed).
Maryland	362,921	26	1.21	Stone (crushed), sand and gravel (construction), cement (portland), cement (masonry).
Massachusetts	192,238	37	.64	Stone (crushed), sand and gravel (construction), stone (dimension), lime.
Michigan	1,587,561	4	5.29	Iron ore (includes byproduct material), cement (portland), sand and gravel (construction), magnesium compounds.
Minnesota	1,267,499	8	4.22	Iron ore (includes byproduct material), sand and gravel (construction), stone (crushed), stone (dimension).
Mississippi	103,400	42	.34	Sand and gravel (construction), clays, cement (portland), stone (crushed).
Missouri	967,949	12	3.22	Lead, cement (portland), stone (crushed), lime.

See footnote at end of table.

TABLE 3—Continued

VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 1988

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Montana	$548,161	18	1.83	Copper, gold, platinum-group metals, silver.
Nebraska	91,192	43	.30	Cement (portland), sand and gravel (construction), stone (crushed), lime.
Nevada	1,944,566	3	6.48	Gold, silver, sand and gravel (construction), cement (portland).
New Hampshire[1]	53,060	47	.18	Sand and gravel (construction), stone (dimension), stone (crushed), clays.
New Jersey	241,832	34	.81	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), zircon concentrates.
New Mexico	1,018,532	10	3.39	Copper, potassium salts, sand and gravel (construction), silver.
New York	695,700	15	2.32	Stone (crushed), cement (portland), salt, sand and gravel (construction).
North Carolina	529,434	19	1.76	Stone (crushed), phosphate rock, lithium minerals, sand and gravel (construction).
North Dakota	18,807	48	.06	Sand and gravel (construction), lime, salt, clays.
Ohio	737,252	13	2.46	Stone (crushed), sand and gravel (construction), salt, lime.
Oklahoma	220,137	35	.73	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial).
Oregon	178,188	38	.59	Stone (crushed), sand and gravel (construction), cement (portland), lime.
Pennsylvania	1,042,493	9	3.47	Stone (crushed), cement (portland), sand and gravel (construction), lime.
Rhode Island[1]	17,248	49	.06	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), gem stones.
South Carolina	357,802	27	1.19	Cement (portland), stone (crushed), clays, gold.
South Dakota	285,719	33	.95	Gold, cement (portland), stone (crushed), sand and gravel (construction).
Tennessee	585,649	17	1.95	Stone (crushed), zinc, cement (portland), clays.
Texas	1,468,818	5	4.89	Cement (portland), stone (crushed), magnesium metal, sulfur (Frasch).
Utah	1,014,847	11	3.38	Copper, gold, magnesium metal, sand and gravel (construction).
Vermont	76,945	44	.26	Stone (dimension), stone (crushed), sand and gravel (construction), talc and pyrophyllite.
Virginia	494,512	20	1.65	Stone (crushed), sand and gravel (construction), cement (portland), lime.
Washington	459,334	22	1.53	Magnesium metal, gold, sand and gravel (construction), stone (crushed).
West Virginia	127,455	39	.42	Stone (crushed), cement (portland), sand and gravel (industrial), sand and gravel (construction).
Wisconsin	204,873	36	.68	Stone (crushed), sand and gravel (construction), lime, sand and gravel (industrial).
Wyoming	709,812	14	2.36	Sodium carbonate (natural), clays, helium (Grade-A), stone (crushed).
Undistributed	7,812	—	.03	
Total[2]	**30,022,000**	**XX**	**100.00**	

XX Not applicable.
[1] Partial total, excludes values that must be concealed to avoid disclosing company proprietary data. Concealed values included with "Undistributed" figure.
[2] Data may not add to totals shown because of independent rounding.

TABLE 4

VALUE OF NONFUEL MINERAL PRODUCTION PER CAPITA AND PER SQUARE MILE IN 1988, BY STATE

State	Area (square miles)	Population (thousands)	Total (thousands)	Per square mile		Per capita	
				Dollars	Rank	Dollars	Rank
Alabama	51,705	4,102	$459,495	8,887	26	112	19
Alaska	591,004	524	118,694	201	50	227	10
Arizona	114,000	3,489	2,773,411	24,328	4	795	3
Arkansas	53,187	2,395	306,789	5,768	32	128	15
California	158,706	28,314	2,708,768	17,068	12	96	25
Colorado	104,091	3,301	364,005	3,497	41	110	20
Connecticut	5,018	3,233	118,116	23,538	6	37	45
Delaware	2,044	660	[1] 5,999	2,935	44	9	50
Flordia	58,664	12,335	1,391,881	23,726	5	113	18
Georgia	58,910	6,342	1,373,825	23,321	7	217	11
Hawaii	6,471	1,098	74,932	11,580	20	68	33
Idaho	83,564	1,003	290,616	3,478	42	290	9
Illinois	56,345	11,614	587,626	10,429	23	51	40
Indiana	36,185	5,556	406,389	11,231	22	73	32
Iowa	56,275	2,834	290,256	5,158	36	102	22
Kansas	82,277	2,495	291,713	3,545	40	117	17
Kentucky	40,409	3,727	344,979	8,537	27	93	26
Louisiana	47,751	4,408	434,536	9,100	25	99	24
Maine	33,265	1,205	67,760	2,037	46	56	39
Maryland	10,460	4,622	362,921	34,696	1	79	31
Massachusetts	8,284	5,889	192,238	23,206	8	33	46
Michigan	58,527	9,240	1,587,561	27,125	3	172	13
Minnesota	84,402	4,307	1,267,499	15,017	13	294	8
Mississippi	47,689	2,620	103,400	2,168	45	39	43
Missouri	69,697	5,141	967,949	13,888	17	188	12
Montana	147,046	805	548,161	3,728	37	681	4
Nebraska	77,355	1,602	91,192	1,179	48	57	38
Nevada	110,561	1,054	1,944,566	17,588	11	1,845	1
New Hampshire	9,279	1,085	[1] 53,060	5,718	33	49	41
New Jersey	7,787	7,721	241,832	31,056	2	31	47
New Mexico	121,593	1,507	1,018,532	8,377	28	676	5
New York	49,107	17,909	695,700	14,167	15	39	44
North Carolina	52,669	6,489	529,434	10,052	24	82	30
North Dakota	70,703	667	18,807	266	49	28	48
Ohio	41,330	10,855	737,252	17,838	10	68	35
Oklahoma	69,956	3,242	220,137	3,147	43	68	36
Oregon	97,073	2,767	178,188	1,836	47	64	37
Pennsylvania	45,308	12,001	1,042,493	23,009	9	87	28
Rhode Island	1,212	993	[1] 17,248	14,231	14	17	49
South Carolina	31,113	3,470	357,802	11,500	21	103	21
South Dakota	77,116	713	285,719	3,705	38	401	7
Tennessee	42,144	4,895	585,649	13,896	16	120	16

See footnote at end of table.

TABLE 4—Continued

VALUE OF NONFUEL MINERAL PRODUCTION PER CAPITA AND PER SQUARE MILE IN 1988, BY STATE

State	Area (square miles)	Population (thousands)	Total (thousands)	Per square mile		Per capita	
				Dollars	Rank	Dollars	Rank
Texas	266,807	16,841	$1,468,818	5,505	34	87	27
Utah	84,899	1,690	1,014,847	11,954	19	601	6
Vermont	9,614	557	76,945	8,003	29	138	14
Virginia	40,767	6,015	494,512	12,130	18	82	29
Washington	68,138	4,648	459,334	6,741	31	99	23
West Virginia	24,231	1,876	127,455	5,260	35	68	34
Wisconsin	56,153	4,855	204,873	3,648	39	42	42
Wyoming	97,809	479	709,812	7,257	30	1,482	2
Undistributed	XX	XX	7,812	XX	XX	XX	XX
Total[2] or average	**3,618,700**	**245,190**	**[3]30,022,000**	**8,296**	**XX**	**122**	**XX**

XX Not applicable.
[1] Partial total, excludes values that must be concealed to avoid disclosing company proprietary data. Concealed values included with "Undistributed" figure.
[2] Excludes Washington, DC (which has no mineral production), with an area of 69 square miles and a population of 617,000.
[3] Data do not add to total shown because of independent rounding.

TABLE 5

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
ALABAMA							
Cement:							
Masonry	thousand short tons	267	$18,165	291	$17,626	273	$16,457
Portland	do.	3,477	153,629	3,600	160,878	3,524	157,214
Clays[2]	short tons	2,077,427	14,828	2,238,971	16,217	2,516,210	16,039
Gem stones		NA	1	NA	7	NA	5
Lime	thousand short tons	1,180	50,377	1,232	52,200	1,450	66,576
Sand and gravel:							
Construction	do.	10,781	30,807	[e]10,300	[e]35,600	11,742	41,417
Industrial	do.	433	3,388	580	5,025	871	8,507
Stone:							
Crushed	do.	[e]24,000	[e]120,500	30,018	146,247	[e]29,700	[e]140,100
Dimension	short tons	[e]7,797	[e]968	W	W	W	W
Combined value of bauxite, clays (bentonite), salt, talc and pyrophyllite (1988), zircon concentrates (1988), and values indicated by symbol W		XX	12,553	XX	12,843	XX	13,180
Total		**XX**	**405,216**	**XX**	**446,643**	**XX**	**459,495**
ALASKA							
Gem stones		NA	$25	NA	$86	NA	$50
Gold (recoverable content of ores, etc.)	troy ounces	48,271	17,775	86,548	38,769	135,340	59,320
Sand and gravel (construction)	thousand short tons	27,762	61,954	[e]27,200	[e]73,400	17,200	48,749
Silver (recoverable content of ores, etc.)	troy ounces	W	W	[r]15,812	[r]111	20,589	135
Stone (crushed)	thousand short tons	[e]2,000	[e]8,500	2,033	8,945	[e]1,800	[e]8,400
Combined value of cement (portland), tin, and value indicated by symbol W		XX	3,226	XX	4,010	XX	2,040
Total		**XX**	**91,480**	**XX**	**[r]125,321**	**XX**	**118,694**
ARIZONA							
Clays	short tons	201,110	$1,366	218,151	$1,905	185,620	$1,590
Copper (recoverable content of ores, etc.)	metric tons	789,175	1,149,193	[r]751,073	[r]1,365,994	845,445	2,246,093
Diatomite	thousand short tons	—	—	—	—	8	1,208
Gem stones		NA	2,533	NA	3,000	NA	3,300
Gold (recoverable content of ores, etc.)	troy ounces	W	W	[r]57,592	[r]25,798	146,259	64,106
Gypsum	thousand short tons	260	1,820	W	W	W	W
Lime	do.	505	21,016	546	21,932	674	29,637
Molybdenum	thousand pounds	29,382	75,607	W	W	W	W
Perlite	thousand short tons	W	W	49	1,361	W	W
Pumice	do.	2	30	1	7	1	7
Sand and gravel:							
Construction	do.	40,468	140,004	[e]38,100	[e]141,300	32,399	123,854
Industrial	do.	W	W	W	W	119	3,045
Silver (recoverable content of ores, etc.)	troy ounces	4,506,197	24,649	[r]3,661,277	[r]25,666	4,888,951	31,974
Stone:							
Crushed	thousand short tons	[e]5,600	[e]25,100	7,712	33,999	[e]7,400	[e]33,000
Dimension	short tons	W	W	—	—	W	[e]1
Combined value of cement, lead (1988), pyrites (1987-88), salt, tin (1988), and values indicated by symbol W		XX	118,505	XX	[r]129,398	XX	235,596
Total		**XX**	**1,559,823**	**XX**	**[r]1,750,360**	**XX**	**2,773,411**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
ARKANSAS							
Abrasives[3]	short tons	W	W	W	W	1,235	$429
Clays	do.	[2]974,373	[2]$8,998	908,394	$8,651	930,863	15,376
Gem stones		NA	522	NA	1,800	NA	2,300
Sand and gravel:							
Construction	thousand short tons	8,571	26,999	[e]7,200	[e]23,900	7,722	26,201
Industrial	do.	400	3,975	505	5,147	669	6,784
Stone:							
Crushed	do.	[e]15,500	[e]58,500	15,234	63,847	[e]17,100	[e]70,100
Dimension	short tons	[e]5,145	[e]305	10,541	629	[e]10,541	[e]629
Combined value of bauxite, bromine,[e] cement, clays (fire clay, 1986), gypsum, lime, talc and pyrophyllite, tripoli, and values indicated by symbol W		XX	[r]163,708	XX	160,188	XX	184,970
Total		**XX**	**[r]263,007**	**XX**	**264,162**	**XX**	**306,789**
CALIFORNIA							
Boron minerals	thousand short tons	1,251	$426,086	1,385	$475,092	1,267	$429,667
Cement:							
Masonry	do.	W	W	W	W	8	730
Portland	do.	9,490	578,502	9,937	593,859	10,423	601,152
Clays	short tons	[2]2,449,136	[2]33,289	2,296,332	33,045	2,221,693	31,620
Gem stones		NA	418	NA	3,367	NA	3,365
Gold (recoverable content of ores, etc.)	troy ounces	425,617	156,729	602,605	269,937	721,512	316,246
Gypsum	thousand short tons	1,378	10,777	1,468	11,719	1,490	11,222
Lime	do.	371	24,187	465	25,745	699	30,356
Mercury	76 pound flasks	—	—	([4])	([4])	W	W
Peat	thousand short tons	W	W	W	W	2	119
Pumice	do.	46	1,263	42	1,539	35	1,245
Sand and gravel:							
Construction	do.	128,407	498,456	[e]141,600	[e]561,300	141,946	622,074
Industrial	do.	2,364	44,813	2,241	41,472	2,444	42,078
Silver (recoverable content of ores, etc.)	troy ounces	155,176	849	121,817	854	481,376	3,148
Stone:							
Crushed	thousand short tons	[e]38,500	[e]159,300	44,315	186,504	[e]49,100	[e]275,000
Dimension	short tons	[e]22,749	[e]2,582	33,335	4,554	[e]42,048	[e]5,991
Talc and pyrophyllite	thousand short tons	64	1,528	W	W	W	W
Combined value of asbestos, barite (1987-88), calcium chloride (natural), cement (masonry 1987-88), clays (ball clay, 1986), copper (1986, 1988), diatomite, feldspar, iron ore (includes byproduct material, 1988), magnesium compounds, molybdenum, perlite, potassium salts, rare-earth metal concentrates, salt, sodium carbonate (natural), sodium sulfate (natural), tungsten ore and concentrate, wollastonite (1986-87), and values indicated by symbol W		XX	330,638	XX	342,298	XX	334,755
Total		**XX**	**2,269,417**	**XX**	**2,551,285**	**XX**	**2,708,768**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
COLORADO							
Clays	short tons	242,333	$1,523	292,050	$1,763	272,790	$1,890
Copper (recoverable content of ores, etc.)	metric tons	W	W	W	W	898	2,386
Gem stones		NA	100	NA	100	NA	100
Gold (recoverable content of ores, etc.)	troy ounces	120,347	44,317	178,795	80,091	164,809	72,237
Sand and gravel (construction)	thousand short tons	23,233	70,095	[e]22,800	[e]84,300	21,566	69,882
Silver (recoverable content of ores, etc.)	troy ounces	644,574	3,526	860,562	6,033	854,413	5,588
Stone:							
Crushed	thousand short tons	[e]8,000	[e]30,700	8,045	33,465	[e]10,600	[e]42,400
Dimension	short tons	[e]3,600	[e]255	3,000	133	[e]3,450	[e]143
Combined value of cement, gypsum, lead, lime, molybdenum, peat, perlite, pyrites (1987), sand and gravel (industrial), tungsten ore and concentrate (1986), vanadium, zinc, and values indicated by symbol W		XX	219,492	XX	167,104	XX	169,379
Total		**XX**	**370,008**	**XX**	**372,989**	**XX**	**364,005**
CONNECTICUT							
Clays	short tons	156,680	$975	W	W	W	W
Gem stones		NA	2	NA	$2	NA	$2
Sand and gravel (construction)	thousand short tons	7,254	25,984	[e]8,400	[e]37,000	8,275	32,102
Stone:							
Crushed	do.	[e]7,700	[e]45,800	11,412	76,668	[e]11,400	[e]76,900
Dimension	short tons	[e]24,425	[e]1,653	18,140	1,646	[e]19,718	[e]1,914
Combined value of feldspar, mica (scrap), sand and gravel (industrial), and values indicated by symbol W		XX	6,040	XX	6,959	XX	7,198
Total		**XX**	**80,454**	**XX**	**122,275**	**XX**	**118,116**
DELAWARE							
Gem stones		NA	$1	NA	$1	NA	$1
Marl (greensand)	short tons	1,068	12	W	W	750	10
Sand and gravel (construction)	thousand short tons	1,547	4,156	[e]2,300	[e]6,400	1,933	5,988
Total[5]		**XX**	**4,169**	**XX**	**6,401**	**XX**	**5,999**
FLORIDA							
Cement:							
Masonry	thousand short tons	352	$21,269	390	$24,069	411	$25,892
Portland	do.	3,189	147,643	3,565	165,944	3,682	168,719
Clays	short tons	725,903	43,261	597,187	39,496	591,855	44,423
Peat	thousand short tons	365	5,743	363	6,068	266	5,091
Sand and gravel:							
Construction	do.	28,233	67,898	[e]30,000	[e]74,900	18,654	53,083
Industrial	do.	1,467	14,930	1,884	19,713	636	6,928
Stone (crushed)	do.	[e]69,000	[e]288,200	[6]78,992	[6]350,537	[e,6]83,200	[e,6]374,400
Combined value of gem stones, lime (1986), magnesium compounds (1988), phosphate rock, rare-earth metal concentrates, staurolite, stone (crushed marl, 1987-88), titanium concentrates, (ilmenite and rutile), and zircon concentrates		XX	700,919	XX	665,510	XX	713,345
Total		**XX**	**1,289,863**	**XX**	**1,346,237**	**XX**	**1,391,881**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
GEORGIA							
Clays	short tons	9,826,662	$669,200	10,454,740	$756,093	11,325,528	$908,771
Gem stones		NA	20	NA	20	NA	20
Sand and gravel (construction)	thousand short tons	8,126	23,222	e9,000	e26,900	9,526	30,185
Stone:							
Crushed	do.	e56,700	e293,100	60,834	318,903	e57,400	e317,200
Dimension	short tons	e198,905	e20,678	179,207	21,683	e190,472	e27,768
Talc and pyrophyllite	do.	8,800	61	20,100	286	26,000	260
Combined value of barite, bauxite (1987-88), cement, feldspar, iron oxide pigments (crude), kyanite (1986), mica (scrap), peat, sand and gravel (industrial), and values indicated by symbol W		XX	85,174	XX	88,485	XX	89,621
Total		**XX**	**1,091,455**	**XX**	**1,212,370**	**XX**	**1,373,825**
HAWAII							
Cement:							
Masonry	thousand short tons	7	$1,078	10	$1,559	10	$1,531
Portland	do.	287	24,253	324	26,550	354	28,880
Gem stones		NA	25	NA	25	NA	W
Lime	thousand short tons	3	W	3	W	W	W
Sand and gravel (construction)	do.	605	2,666	e700	e3,500	652	3,173
Stone (crushed)	do.	e7,100	e42,100	5,732	41,548	e5,700	e41,000
Combined value of other industrial minerals and values indicated by symbol W		XX	290	XX	297	XX	348
Total		**XX**	**70,412**	**XX**	**73,479**	**XX**	**74,932**
IDAHO							
Clays[2]	short tons	1,644	W	21,781	$229,835	9,391	W
Copper (recoverable content of ores, etc.)	metric tons	W	W	W	W	2,269	$6,028
Gem stones		NA	$305	NA	507	NA	500
Gold (recoverable content of ores, etc.)	troy ounces	70,440	25,938	97,773	43,797	103,463	45,349
Lead (recoverable content of ores, etc.)	metric tons	9,951	4,836	W	W	W	W
Lime	thousand short tons	89	4,729	97	5,149	W	W
Phosphate rock	metric tons	4,235,000	82,332	3,411,000	47,072	4,706,000	81,011
Sand and gravel:							
Construction	thousand short tons	5,708	14,830	e7,200	e28,000	6,914	19,897
Industrial	do.	W	W	W	W	483	5,089
Silver (recoverable content of ores, etc.)	troy ounces	11,206,851	61,301	W	W	10,934,631	71,512
Stone (crushed)	thousand short tons	e3,700	e12,700	3,852	15,346	e3,400	e13,100
Zinc (recoverable content of ores, etc.)	metric tons	351	294	W	W	W	W
Combined value of antimony (1986, 1988), cement, clays (bentonite, common, fire clay (1986), kaolin), garnet (abrasive), molybdenum (1986-87), perlite, pumice, stone (dimension), vanadium, and values indicated by symbol W		XX	66,783	XX	129,272	XX	48,130
Total		**XX**	**274,048**	**XX**	**269,373**	**XX**	**290,616**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
		ILLINOIS					
Cement (portland)	thousand short tons	2,118	$83,783	2,119	$86,210	2,307	$101,760
Clays[2]	short tons	282,993	1,092	232,949	977	180,306	704
Gem stones		NA	15	NA	15	NA	30
Sand and gravel:							
Construction	thousand short tons	27,867	82,523	[e]28,300	[e]93,300	30,098	93,504
Industrial	do.	4,039	52,133	4,346	45,547	4,328	56,142
Stone:							
Crushed	do.	[e]44,200	[e]179,600	52,102	216,212	[e]57,900	[e]251,200
Dimension	short tons	[e]1,750	[e]107	W	W	[e]1,175	[e]129
Combined value of cement (masonry), clays (fuller's earth), copper, fluorspar, lead, lime, peat, silver, tripoli, zinc, and value indicated by symbol W		XX	70,272	XX	74,945	XX	84,157
Total		**XX**	**469,525**	**XX**	**517,206**	**XX**	**587,626**
		INDIANA					
Cement:							
Masonry	thousand short tons	395	$22,936	422	$32,299	405	$27,442
Portland	do.	2,136	92,327	2,320	103,177	2,315	107,179
Clays	short tons	743,859	3,044	[2]1,036,669	[2]4,056	1,141,813	4,630
Gem stones		NA	1	NA	10	NA	10
Peat	thousand short tons	79	W	44	W	54	W
Sand and gravel:							
Construction	do.	19,642	61,232	[e]18,900	[e]65,200	25,923	79,985
Industrial	do.	193	1,490	230	1,357	362	1,829
Stone:							
Crushed	do.	[e][6]22,600	[e][6]76,500	31,067	106,770	[e]36,600	[e]130,000
Dimension	short tons	[e]190,995	[e]20,252	183,609	23,115	[e]195,444	[e]24,956
Combined value of abrasives, clays (fire clay, 1987), gypsum, lime, stone (crushed marl, 1986), and values indicated by symbol W		XX	27,566	XX	27,881	XX	30,358
Total		**XX**	**305,348**	**XX**	**363,865**	**XX**	**406,389**
		IOWA					
Cement:							
Masonry	thousand short tons	48	$3,199	W	W	W	W
Portland	do.	1,819	86,984	2,139	$104,457	2,029	$98,930
Clays	short tons	486,309	1,421	472,788	1,495	445,248	1,588
Gem stones		NA	20	NA	W	NA	W
Gypsum	thousand short tons	1,826	12,602	1,874	12,887	2,047	13,710
Peat	do.	14	381	24	W	14	433
Sand and gravel (construction)	do.	14,511	40,418	[e]19,000	[e]63,800	11,880	36,087
Stone:							
Crushed	do.	[e]23,400	[e]98,000	25,991	110,106	[e]29,200	[e]128,500
Dimension	short tons	W	W	W	W	W	[e]588
Combined value of other industrial minerals and values indicated by symbol W		XX	5,707	XX	12,332	XX	10,420
Total		**XX**	**248,732**	**XX**	**305,077**	**XX**	**290,256**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
KANSAS							
Cement:							
Masonry	thousand short tons	51	$3,264	52	$3,150	50	$2,988
Portland	do.	1,763	91,110	1,697	81,045	1,569	72,805
Clays	short tons	903,448	5,295	[2]603,680	[2]2,576	[2]612,597	[2]2,632
Gem stones		NA	3	NA	3	NA	3
Salt[7]	thousand short tons	1,656	68,887	1,689	70,148	1,284	55,753
Sand and gravel:							
Construction	do.	15,609	33,721	[e]15,600	[e]37,800	10,760	25,329
Industrial	do.	132	1,155	127	1,400	W	W
Stone:							
Crushed	do.	[e]16,600	[e]60,300	19,319	69,628	[e]17,300	[e]72,700
Dimension	short tons	W	W	11,423	445	[e]6,889	[e]219
Combined value of clays (bentonite, 1987-88), gypsum, helium (crude and Grade-A), pumice, salt (brine), and values indicated by symbol W		XX	53,910	XX	53,409	XX	59,284
Total		**XX**	**317,645**	**XX**	**319,604**	**XX**	**291,713**
KENTUCKY							
Clays[2]	short tons	721,111	$3,450	1,030,518	$8,821	840,317	$3,217
Gem stones		NA	3	NA	3	NA	3
Sand and gravel (construction)	thousand short tons	7,194	16,986	[e]7,100	[e]15,200	6,325	15,243
Stone (crushed)	do.	[e] [6]38,400	[e] [6]137,000	43,330	173,222	[e]50,700	[e]207,900
Zinc (recoverable content of ores, etc.)	metric tons	W	W	10	9	W	W
Combined value of cement, clays (ball clay, fire clay), lime, sand and gravel (industrial, 1986-87), stone (crushed sandstone, 1986), and values indicated by symbol W		XX	109,826	XX	[r]98,508	XX	118,616
Total		**XX**	**267,265**	**XX**	**290,335**	**XX**	**344,979**
LOUISIANA							
Clays	short tons	331,982	$7,670	356,904	$9,192	[2]375,778	[2]$9,535
Gem stones		NA	1	NA	1	NA	3
Salt	thousand short tons	11,608	103,611	12,498	108,999	14,274	108,982
Sand and gravel:							
Construction	do.	14,292	46,134	[e]12,200	[e]43,600	14,233	52,820
Industrial	do.	256	4,225	289	3,997	318	4,786
Stone (crushed)[6]	do.	[e]5,400	[e]25,300	4,390	36,514	[e]3,700	[e]29,200
Sulfur (Frasch)	thousand metric tons	1,602	W	1,458	W	1,719	W
Combined value of cement (masonry (1987-88), portland), gypsum (1987-88), lime, stone (crushed miscellaneous), and values indicated by symbol W		XX	259,857	XX	221,918	XX	229,210
Total		**XX**	**446,798**	**XX**	**424,221**	**XX**	**434,536**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
MAINE							
Clays	short tons	46,000	$90	W	W	W	W
Gem stones		NA	200	NA	$1,172	NA	**$150**
Sand and gravel (construction)	thousand short tons	8,572	22,843	[e]8,600	[e]22,100	10,183	33,007
Stone:							
Crushed	do.	[e]1,600	[e]4,400	2,010	7,532	[e]1,400	[e]5,300
Dimension	short tons	W	W	7,512	5,924	[e]7,512	[e]5,924
Combined value of cement, garnet (abrasive), peat (1986), and values indicated by symbol W		XX	25,326	XX	28,729	XX	23,379
Total		**XX**	**52,859**	**XX**	**65,457**	**XX**	**67,760**
MARYLAND							
Cement (portland)	thousand short tons	1,785	$89,799	1,829	$90,020	1,808	$89,083
Clays	short tons	[2]361,729	[2]1,757	383,054	1,940	394,443	2,016
Gem stones		NA	5	NA	5	NA	5
Lime	thousand short tons	10	546	9	486	6	329
Peat	do.	W	W	W	W	7	W
Sand and gravel (construction)	do.	18,173	86,925	[e]19,600	[e]92,900	19,266	95,169
Stone:							
Crushed	do.	[e]26,400	[e]126,000	30,136	151,579	[e]32,700	[e]167,000
Dimension	short tons	[e]20,505	[e]1,286	22,843	1,516	[e]20,729	[e]1,515
Combined value of cement (masonry), clays (ball clay, 1986), sand and gravel (industrial), and values indicated by symbol W		XX	7,027	XX	6,688	XX	7,804
Total		**XX**	**313,345**	**XX**	**345,134**	**XX**	**362,921**
MASSACHUSETTS							
Clays	short tons	139,995	$871	W	W	W	W
Gem stones		NA	W	NA	$1	NA	**$1**
Sand and gravel:							
Construction	thousand short tons	19,200	60,464	[e]21,800	[e]75,300	22,168	79,364
Industrial	do.	45	739	56	922	W	W
Stone:							
Crushed	do.	[e]10,000	[e]50,000	14,907	78,969	[e]17,500	[e]91,900
Dimension	short tons	[e]78,728	[e]14,928	76,579	12,747	W	W
Combined value of lime, peat, and values indicated by symbol W		XX	7,395	XX	8,583	XX	20,973
Total		**XX**	**134,397**	**XX**	**176,522**	**XX**	**192,238**
MICHIGAN							
Cement:							
Masonry	thousand short tons	257	$17,026	263	$23,004	265	$22,915
Portland	do.	4,713	216,120	4,755	207,332	5,253	231,141
Clays	short tons	1,402,446	5,684	1,333,498	5,338	1,375,816	4,432
Gem stones		NA	25	NA	25	NA	25
Gypsum	thousand short tons	1,979	11,052	1,977	12,190	1,958	11,630

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
MICHIGAN—Continued							
Iron ore	thousand metric tons	11,133	W	12,509	W	14,623	W
Lime	thousand short tons	556	$27,257	569	$30,320	714	$36,088
Peat	do.	324	6,599	281	5,290	342	6,256
Sand and gravel:							
Construction	do.	42,514	91,886	[e]42,800	[e]105,300	53,508	138,171
Industrial	do.	3,343	29,493	2,792	22,451	3,045	27,150
Stone:							
Crushed	do.	[e]27,800	[e]83,900	37,909	109,514	[e]38,800	[e]120,300
Dimension	short tons	[e]5,863	[e]148	W	W	W	W
Combined value of bromine,[e] calcium chloride (natural), copper, gold, iron oxide pigments (crude), magnesium compounds, salt, silver, and values indicated by symbol W		XX	750,393	XX	844,846	XX	989,453
Total		**XX**	**1,239,583**	**XX**	**1,365,610**	**XX**	**1,587,561**
MINNESOTA							
Gem stones		NA	$5	NA	$40	NA	$40
Iron ore	thousand metric tons	29,241	1,017,261	[r]34,274	1,012,788	40,735	1,134,539
Peat	thousand short tons	W	W	30	W	29	1,027
Sand and gravel (construction)	do.	24,055	53,116	[e]25,200	[e]67,400	33,769	72,678
Stone:							
Crushed	do.	[e]8,300	[e]26,300	8,995	29,246	[e]8,300	[e]28,200
Dimension	short tons	[e]27,973	[e]10,507	41,354	12,967	[e]45,000	[e]13,000
Combined value of clays, lime, sand and gravel (industrial), and values indicated by symbol W		XX	20,438	XX	20,308	XX	18,015
Total		**XX**	**1,127,627**	**XX**	**1,142,749**	**XX**	**1,267,499**
MISSISSIPPI							
Clays[2]	short tons	927,716	$13,538	1,123,325	$26,933	1,093,316	$24,564
Gem stones		NA	1	NA	1	NA	1
Sand and gravel (construction)	thousand short tons	15,080	42,809	[e]14,700	[e]47,000	13,314	38,806
Stone (crushed)	do.	[e]1,600	[e]4,400	1,492	9,621	[e]1,500	[e]9,000
Combined value of cement, clays (ball clay and fuller's earth, 1986), and sand and gravel (industrial)		XX	40,347	XX	26,524	XX	31,029
Total		**XX**	**101,095**	**XX**	**110,079**	**XX**	**103,400**
MISSOURI							
Barite	thousand short tons	W	W	27	$2,030	26	$1,930
Cement:							
Masonry	do.	167	$7,816	167	10,027	153	6,310
Portland	do.	4,642	179,184	5,110	185,317	4,679	184,755
Clays[2]	short tons	1,320,767	6,650	1,475,837	10,415	1,581,864	12,171
Iron ore	thousand metric tons	816	W	756	W	816	W
Lead (recoverable content of ores, etc.)	metric tons	319,900	155,481	W	W	353,194	289,194

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
MISSOURI—Continued							
Sand and gravel:							
Construction	thousand short tons	9,746	$24,065	e10,900	e$30,400	11,217	$32,941
Industrial	do.	517	6,230	622	7,786	744	9,876
Silver (recoverable content of ores, etc.)	troy ounces	1,459,185	7,982	1,180,584	8,276	1,460,271	9,550
Stone:							
Crushed	thousand short tons	e51,200	e170,500	54,910	184,824	e52,100	e183,000
Dimension	short tons	W	W	3,212	454	e3,644	e547
Zinc (recoverable content of ores, etc.)	metric tons	37,919	31,767	34,956	32,306	41,322	54,842
Combined value of clays (fuller's earth), copper, gem stones, iron oxide pigments (crude), lime, and values indicated by symbol W		XX	158,910	XX	391,206	XX	182,833
Total		**XX**	**748,585**	**XX**	**863,041**	**XX**	**967,949**
MONTANA							
Clays	short tons	221,819	$5,882	[2]28,879	[2]$98	[2]101,194	[2]$1,416
Gem stones		NA	480	NA	1,302	NA	1,602
Gold (recoverable content of ores, etc.)	troy ounces	W	W	234,365	104,984	294,976	129,291
Gypsum	thousand short tons	W	W	24	W	27	W
Lead (recoverable content of ores, etc.)	metric tons	W	W	W	W	8,266	6,768
Sand and gravel (construction)	thousand short tons	8,066	19,391	e6,800	e18,800	7,984	20,225
Silver (recoverable content of ores, etc.)	troy ounces	4,773,264	26,110	r5,937,155	r41,619	6,186,074	40,457
Stone (crushed)	thousand short tons	e [6]2,200	e [6]6,200	1,463	3,585	e1,800	e4,500
Talc and pyrophyllite	short tons	W	W	r356,231	r11,334	377,789	11,309
Zinc (recoverable content of ores, etc.)	metric tons	—	—	W	W	18,935	25,130
Combined value of barite (1987), cement, clays (fire clay, 1987-88), copper, graphite (natural, 1988), iron ore, lime, molybdenum, peat, phosphate rock, platinum-group metals, (1987-88), sand and gravel (industrial), stone (crushed traprock, 1986, dimension), vermiculite, zinc, and values indicated by symbol W		XX	179,870	XX	186,456	XX	307,463
Total		**XX**	**237,933**	**XX**	**r368,178**	**XX**	**548,161**
NEBRASKA							
Clays	short tons	221,153	$668	223,728	$721	237,459	$786
Gem stones		NA	10	NA	10	NA	10
Sand and gravel (construction)	thousand short tons	9,675	23,912	e10,300	e26,300	11,229	28,928
Stone (crushed)	do.	e4,000	e17,900	4,316	19,461	e4,900	e22,000
Combined value of cement, lime, and sand and gravel (industrial)		XX	51,598	XX	43,256	XX	39,468
Total		**XX**	**94,088**	**XX**	**89,748**	**XX**	**91,192**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
NEVADA							
Barite	thousand short tons	184	$3,005	308	$4,778	319	$5,053
Clays[2]	short tons	10,313	584	[r]11,799	[r]810	28,865	2,143
Gem stones		NA	213	NA	280	NA	280
Gold (recoverable content of ores, etc.)	troy ounces	2,098,980	[r]772,928	2,679,470	1,200,269	3,675,526	1,611,020
Gypsum	thousand short tons	1,236	8,221	W	W	W	W
Perlite	do.	4	122	W	W	5	142
Sand and gravel:							
Construction	do.	12,197	35,692	[e]10,600	[e]30,700	15,729	50,928
Industrial	do.	518	W	578	W	602	W
Silver (recoverable content of ores, etc.)	troy ounces	6,408,783	35,056	[r]12,186,692	[r]85,429	19,535,223	127,760
Stone (crushed)	thousand short tons	[e]1,500	[e]7,000	[6]1,264	[6]5,700	[e 6]1,300	[e 6]5,700
Combined value of cement (portland), clays (fuller's earth (1986–87), kaolin), copper (1986, 1988), diatomite, fluorspar, iron ore (1986), lime, lithium minerals, magnesite, mercury, salt, stone (crushed dolomite, 1987–88), and values indicated by symbol W		XX	114,529	XX	[r]118,825	XX	141,540
Total		**XX**	**977,350**	**XX**	**[r]1,446,791**	**XX**	**1,944,566**
NEW HAMPSHIRE							
Gem stones		NA	W	NA	$310	NA	$100
Sand and gravel (construction)	thousand short tons	8,418	$26,089	[e]9,100	[e]33,300	9,089	32,614
Stone:							
Crushed	do.	[e]1,800	[e]5,900	2,479	10,386	[e]2,400	[e]9,800
Dimension	short tons	[e]82,294	[e]6,451	67,479	10,684	[e]73,393	[e]10,546
Combined value of other industrial minerals and value indicated by symbol W		XX	137	XX	([8])	XX	([8])
Total		**XX**	**38,577**	**XX**	**[5]54,680**	**XX**	**[5]53,060**
NEW JERSEY							
Clays	short tons	132,524	$2,066	[2]5,985	[2]$140	[2]16,484	[2]$368
Gem stones		NA	3	NA	3	NA	3
Peat	thousand short tons	W	542	32	614	43	797
Sand and gravel:							
Construction	do.	13,999	53,746	[e]15,200	[e]61,200	18,318	74,183
Industrial	do.	2,341	29,878	2,112	27,872	1,860	25,437
Stone (crushed)	do.	[e]15,300	[e]95,400	[6]17,576	[6]111,951	[e 6]19,300	[e 6]123,500
Combined value of other industrial minerals		XX	4,613	XX	12,444	XX	17,544
Total		**XX**	**186,248**	**XX**	**214,224**	**XX**	**241,832**
NEW MEXICO							
Clays	short tons	60,184	$170	51,248	$141	31,476	$83
Copper (recoverable content of ores, etc.)	metric tons	W	W	[r]246,532	[r]448,373	258,660	687,182
Gem stones		NA	200	NA	200	NA	200
Gold (recoverable content of ores, etc.)	troy ounces	39,856	14,677	W	W	W	W

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
NEW MEXICO—Continued							
Lead (recoverable content of ores, etc.)	metric tons	10	5	W	W	W	W
Perlite	thousand short tons	433	13,727	437	13,611	458	14,294
Potassium salts	thousand metric tons	987	132,900	1,323	174,200	1,271	213,800
Pumice	thousand short tons	255	2,370	87	991	84	852
Sand and gravel (construction)	do.	8,471	25,862	[e]8,600	[e]31,000	8,787	31,367
Stone:							
Crushed	do.	[e]3,900	[e]15,300	4,503	15,919	[e]3,500	[e]13,900
Dimension	short tons	[e]21,615	[e]378	21,893	626	[e]21,893	[e]626
Combined value of cement, gypsum, helium (Grade-A), iron ore (includes byproduct material), mica (scrap), molybdenum, pyrites (1987), salt, silver, and values indicated by symbol W		XX	[r]406,723	XX	[r]52,783	XX	56,228
Total		**XX**	**[r]612,312**	**XX**	**[r]737,844**	**XX**	**1,018,532**
NEW YORK							
Clays	short tons	618,968	$3,075	672,635	$3,562	607,786	$3,654
Emery	do.	2,878	W	1,945	W	W	W
Gem stones		NA	100	NA	135	NA	200
Peat	thousand short tons	W	W	1	34	W	W
Salt	do.	5,071	122,601	4,918	119,962	4,614	127,994
Sand and gravel:							
Construction	do.	31,172	103,748	[e]31,400	[e]112,900	33,884	124,341
Industrial	do.	59	1,164	58	651	53	625
Stone:							
Crushed	do.	[e]40,600	[e]196,600	38,103	188,694	[e]39,900	[e]193,500
Dimension	short tons	[e]15,637	[e]3,002	38,553	5,822	[e]30,751	[e]4,333
Combined value of cement, garnet (abrasive), gypsum, iron ore (includes byproduct material, 1988), lead, silver, talc and pyrophyllite, wollastonite, zinc, and values indicated by symbol W		XX	247,272	XX	218,620	XX	241,053
Total		**XX**	**677,562**	**XX**	**650,380**	**XX**	**695,700**
NORTH CAROLINA							
Clays	short tons	2,657,679	$10,970	3,229,053	$15,282	3,174,766	$16,349
Feldspar	do.	526,672	15,568	512,386	15,562	507,986	17,312
Gem stones		NA	551	NA	550	NA	688
Gold (recoverable content of ores, etc.)	troy ounces	12	4	—	—	—	—
Mica (scrap)	thousand short tons	89	4,641	100	5,607	87	4,512
Peat	do.	15	W	W	W	21	W
Sand and gravel:							
Construction	do.	7,543	23,127	[e]8,600	[e]30,100	11,076	38,459
Industrial	do.	1,464	16,656	1,184	15,329	1,246	15,953
Stone:							
Crushed	do.	[e]43,500	[e]206,500	48,847	237,181	[e]50,500	[e]250,000
Dimension	short tons	[e]41,418	[e]6,633	32,669	5,128	[e]31,977	[e]5,026
Talc and pyrophyllite	do.	82,694	1,552	W	W	W	W
Combined value of lithium minerals, olivine, phosphate rock, and values indicated by symbol W		XX	180,528	XX	152,178	XX	181,135
Total		**XX**	**466,730**	**XX**	**476,917**	**XX**	**529,434**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
NORTH DAKOTA							
Clays	short tons	W	W	50,101	$100	84,787	$147
Gem stones		NA	$2	NA	2	NA	2
Lime	thousand short tons	74	7,359	127	11,912	108	7,094
Sand and gravel (construction)	do.	5,135	10,741	[e]4,900	[e]10,200	3,772	8,079
Combined value of peat, salt, sand and gravel (industrial, 1986–87), stone (crushed miscellaneous), and value indicated by symbol W		XX	2,700	XX	4,097	XX	3,485
Total		**XX**	**20,802**	**XX**	**26,311**	**XX**	**18,807**
OHIO							
Cement:							
Masonry	thousand short tons	138	$11,540	139	$11,964	129	$11,140
Portland	do.	1,706	79,383	1,748	83,661	1,424	70,816
Clays	short tons	2,832,785	11,515	3,187,270	12,714	3,709,454	14,423
Gem stones		NA	10	NA	10	NA	10
Lime	thousand short tons	1,648	81,103	1,926	93,108	2,065	87,431
Peat	do.	6	W	W	W	W	W
Salt	do.	4,115	126,757	3,276	104,099	3,795	115,860
Sand and gravel:							
Construction	do.	36,806	126,747	[e]36,400	[e]136,900	46,104	156,318
Industrial	do.	1,221	21,183	1,249	21,292	1,361	23,441
Stone:							
Crushed	do.	[e]39,300	[e]147,300	51,590	300,096	[e]48,000	[e]252,000
Dimension	short tons	[e]35,698	[e]2,708	47,816	2,427	[e]38,300	[e]3,137
Combined value of abrasives, gypsum, and values indicated by symbol W		XX	1,738	XX	2,510	XX	2,676
Total		**XX**	**609,984**	**XX**	**768,781**	**XX**	**737,252**
OKLAHOMA							
Cement:							
Masonry	thousand short tons	50	$3,198	41	$2,436	W	W
Portland	do.	1,579	69,075	1,415	54,870	1,432	$42,131
Clays	short tons	992,702	2,329	797,301	1,783	754,054	1,803
Gem stones		NA	2	NA	8	NA	18
Gypsum	thousand short tons	1,683	9,855	1,828	13,336	2,173	13,393
Iodine	pounds	W	W	W	W	2,238,152	W
Sand and gravel:							
Construction	thousand short tons	10,366	24,585	[e]10,500	[e]24,200	9,273	22,654
Industrial	do.	1,203	16,454	1,243	17,078	1,268	17,381
Stone:							
Crushed	do.	[e]30,900	[e]102,100	[6]25,155	[6]83,732	[e] [6]26,300	[e] [6]92,000
Dimension	short tons	[e]18,503	[e]913	8,311	861	[e]7,746	[e]785
Combined value of feldspar, lime, pumice (1986), salt, stone (crushed dolomite, 1987–88), tripoli, and values indicated by symbol W		XX	18,504	XX	24,915	XX	29,972
Total		**XX**	**247,015**	**XX**	**223,219**	**XX**	**220,137**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
OREGON							
Clays	short tons	203,596	$289	267,824	$986	248,021	$1,049
Gem stones		NA	350	NA	350	NA	894
Nickel (content of ores and concentrates)	short tons	1,175	W	—	—	—	—
Sand and gravel (construction)	thousand short tons	13,441	42,597	e13,000	e42,200	14,880	52,657
Stone (crushed)	do.	e15,100	e53,400	20,663	73,902	e22,200	e77,600
Talc and pyrophyllite	short tons	58	41	150	14	W	W
Combined value of cement, diatomite, gold, lime, pumice, silver (1987–88), stone (dimension, 1986, 1988), and values indicated by symbol W		XX	29,755	XX	43,544	XX	45,988
Total		**XX**	**126,432**	**XX**	**160,996**	**XX**	**178,188**
PENNSYLVANIA							
Cement:							
Masonry	thousand short tons	391	$26,683	397	$30,464	391	$28,713
Portland	do.	6,290	324,187	6,325	334,709	6,309	329,634
Clays[2]	short tons	1,233,791	5,061	1,206,121	4,751	1,375,836	5,843
Gem stones		NA	5	NA	5	NA	5
Lime	thousand short tons	1,417	81,234	1,574	93,430	1,641	91,214
Peat	do.	19	532	18	513	21	736
Sand and gravel:							
Construction	do.	15,373	68,880	e14,800	e72,900	19,826	91,966
Industrial	do.	688	10,091	W	W	W	W
Stone:							
Crushed	do.	e63,700	e317,100	97,213	458,676	e104,600	e470,700
Dimension	short tons	e72,352	e8,100	60,118	10,177	e59,022	e9,584
Combined value of clays (kaolin), mica (scrap), tripoli and values indicated by symbol W		XX	1,185	XX	r10,872	XX	14,098
Total		**XX**	**843,058**	**XX**	**r1,016,497**	**XX**	**1,042,493**
RHODE ISLAND							
Gem stones		NA	W	NA	$1	NA	$1
Sand and gravel:							
Construction	thousand short tons	2,269	$8,252	e2,700	e10,900	1,853	7,847
Industrial	do.	22	143	W	W	W	W
Stone (crushed)	do.	e 6 1,000	e 6 5,700	1,228	7,797	e1,500	e9,400
Combined value of other industrial minerals and values indicated by symbol W		XX	101	XX	(8)	XX	(8)
Total		**XX**	**14,196**	**XX**	**5 18,698**	**XX**	**5 17,248**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
				SOUTH CAROLINA			
Cement (portland)	thousand short tons	2,306	$109,529	2,567	$117,878	2,533	$118,670
Clays	short tons	[2]1,986,253	[2]37,980	[2]2,193,540	[2]38,244	2,058,927	40,541
Gem stones		NA	10	NA	10	NA	10
Manganiferous ore	short tons	14,320	W	[r]W	W	W	W
Sand and gravel:							
Construction	thousand short tons	7,200	19,783	[e]7,500	[e]19,500	7,529	20,751
Industrial	do.	800	14,081	844	15,188	859	15,271
Stone:							
Crushed	do.	[e]18,200	[e]76,700	[6]24,278	[6]105,387	[e 6]23,500	[e 6]105,800
Dimension	short tons	[e]7,550	[e]533	2,319	312	[e]353	[e]31
Combined value of cement (masonry), clays (fuller's earth, 1986-87), gold, mica (scrap), peat, silver, stone (crushed shell, 1987-88), vermiculite, and values indicated by symbol W		XX	37,273	XX	44,806	XX	56,728
Total		**XX**	**295,889**	**XX**	**341,325**	**XX**	**357,802**
				SOUTH DAKOTA			
Cement:							
Masonry	thousand short tons	4	W	4	W	4	W
Portland	do.	635	W	519	W	490	W
Clays[2]	short tons	118,718	$375	W	W	W	W
Gem stones		NA	100	NA	$100	NA	$100
Gold (recoverable content of ores, etc.)	troy ounces	W	W	W	W	449,514	197,026
Gypsum	thousand short tons	31	268	W	W	W	W
Sand and gravel (construction)	do.	9,713	19,853	[e]9,600	[e]19,100	7,929	18,681
Silver (recoverable content of ores, etc.)	troy ounces	W	W	W	W	84,398	552
Stone:							
Crushed	thousand short tons	[e]3,600	[e]12,600	5,070	18,515	[e]5,500	[e]20,600
Dimension	short tons	[e]54,934	[e]18,399	50,718	18,209	[e]43,297	[e]16,472
Combined value of beryllium concentrates (1986-87), clays (bentonite, 1986, common, 1987-88), iron ore (1988), lime, mica, (scrap), and values indicated by symbol W		XX	181,291	XX	206,968	XX	32,288
Total		**XX**	**232,886**	**XX**	**262,892**	**XX**	**285,719**
				TENNESSEE			
Clays[2]	short tons	1,164,290	$25,228	1,260,873	$25,480	1,285,002	$27,696
Phosphate rock	metric tons	1,231,000	21,191	W	W	W	W
Sand and gravel:							
Construction	thousand short tons	7,360	24,592	[e]7,900	[e]28,900	6,836	23,343
Industrial	do.	488	5,523	W	W	W	W
Stone:							
Crushed	do.	[e 6]40,700	[e 6]175,600	51,406	227,263	[e]52,200	[e]235,000
Dimension	short tons	[e]5,598	[e]1,553	3,360	573	[e]3,942	[e]567
Zinc (recoverable content of ores, etc.)	metric tons	102,118	85,550	115,699	106,926	119,954	159,201
Combined value of barite, cement, clays (bentonite, 1988, fuller's earth), copper, gem stones, lead (1987-88), lime, pyrites (1986-87), silver, stone (crushed granite, 1986), and values indicated by symbol W		XX	136,610	XX	138,670	XX	139,842
Total		**XX**	**475,847**	**XX**	**527,812**	**XX**	**585,649**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
TEXAS							
Cement:							
Masonry	thousand short tons	209	$15,790	172	$11,283	136	$10,800
Portland	do.	8,883	412,697	7,318	319,996	7,000	292,256
Clays[2]	short tons	2,514,546	11,724	[r]3,315,424	[r]14,825	2,992,166	17,468
Gem stones		NA	297	NA	345	NA	340
Gypsum	thousand short tons	2,131	14,982	1,874	14,254	1,943	15,790
Lime	do.	1,173	62,670	1,140	59,027	1,192	55,935
Salt	do.	8,520	62,996	7,810	60,857	7,802	62,925
Sand and gravel:							
Construction	do.	59,562	209,855	[e]48,200	[e]178,600	50,370	171,167
Industrial	do.	1,302	18,274	1,509	22,843	1,631	26,645
Stone:							
Crushed	do.	[e]84,200	[e]301,500	84,347	276,477	[e]82,000	[e]271,300
Dimension	short tons	[e]49,457	[e]15,407	75,426	10,030	[e]66,354	[e]8,310
Sulfur (Frasch)	thousand metric tons	2,506	W	2,152	W	2,622	W
Talc and pyrophyllite	short tons	282,744	6,456	255,039	4,380	260,950	4,466
Combined value of asphalt (native, 1986), clays (ball clay, fuller's earth, 1986–87, kaolin), fluorspar (1986), helium (crude and Grade-A), iron ore, magnesium compounds, magnesium metal, sodium sulfate (natural), and values indicated by symbol W		XX	579,340	XX	[r]457,814	XX	531,416
Total		**XX**	**1,711,988**	**XX**	**[r]1,430,731**	**XX**	**1,468,818**
UTAH							
Beryllium concentrates	short tons	6,533	$7	6,062	$6	5,851	$6
Cement (portland)	thousand short tons	1,014	58,431	935	50,565	772	39,664
Clays	short tons	304,547	2,048	315,154	1,959	340,156	2,469
Gem stones		NA	96	NA	105	NA	370
Gypsum	thousand short tons	284	2,478	W	W	W	W
Lime	do.	232	13,079	562	17,894	365	17,252
Salt	do.	1,112	31,830	1,108	34,264	1,006	35,294
Sand and gravel:							
Construction	do.	16,452	39,763	[e]21,000	[e]56,700	17,843	49,796
Industrial	do.	6	123	6	11	3	60
Stone:							
Crushed	do.	[e]4,500	[e]14,100	7,989	23,606	[e]7,300	[e]20,600
Dimension	short tons	W	W	2,004	93	[e]2,004	[e]93
Vermiculite	do.	W	153	—	—	—	—
Combined value of asphalt (native, 1986), cement (masonry), copper, gold, iron ore, magnesium compounds, magnesium metal, mercury, molybdenum (1987–88), phosphate rock, potassium salts, silver, sodium sulfate (natural, 1986, 1988), stone (dimension, 1986), vanadium, and values indicated by symbol W		XX	212,330	XX	514,661	XX	849,243
Total		**XX**	**374,438**	**XX**	**699,864**	**XX**	**1,014,847**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
VERMONT							
Gem stones		NA	W	NA	$10	NA	$10
Sand and gravel (construction)	thousand short tons	4,834	$11,226	[e]4,700	[e]10,800	6,047	17,478
Stone:							
Crushed	do.	[e]1,600	[e]7,600	[6]2,159	[6]20,400	[e] [6]2,000	[e] [6]18,000
Dimension	short tons	[e]104,610	[e]27,075	103,923	30,074	[e]105,000	[e]30,500
Combined value of asbestos, stone (crushed granite, 1987-88), talc and pyrophyllite, and value indicated by symbol W		XX	9,310	XX	[r]12,160	XX	10,957
Total		**XX**	**55,211**	**XX**	**[r]73,444**	**XX**	**76,945**
VIRGINIA							
Clays	short tons	899,977	$7,700	[2]1,174,442	[2]$6,291	[2]1,113,459	[2]$6,614
Gem stones		NA	20	NA	20	NA	20
Lime	thousand short tons	624	27,362	699	29,435	741	33,875
Sand and gravel (construction)	do.	11,670	46,488	[e]12,100	[e]43,400	12,551	42,573
Stone:							
Crushed	do.	[e]52,000	[e]224,700	60,376	295,903	[e]66,000	[e]326,700
Dimension	short tons	[e]9,542	[e]3,128	9,077	2,720	[e]10,000	[e]2,900
Combined value of aplite, cement, clays (fuller's earth, 1987-88), gypsum, iron oxide pigments (crude), kyanite, sand and gravel (industrial), talc and pyrophyllite (1987-88), and vermiculite		XX	83,639	XX	83,673	XX	81,830
Total		**XX**	**393,037**	**XX**	**461,442**	**XX**	**494,512**
WASHINGTON							
Cement:							
Masonry	thousand short tons	6	$530	W	W	W	W
Portland	do.	1,212	59,091	1,282	$63,600	979	$48,233
Clays	short tons	252,145	1,560	415,593	2,356	415,487	2,235
Gem stones		NA	200	NA	200	NA	200
Peat	thousand short tons	W	W	7	191	5	142
Sand and gravel:							
Construction	do.	26,342	76,387	[e]25,300	[e]78,900	31,170	94,402
Industrial	do.	W	W	294	5,186	W	W
Stone:							
Crushed	do.	[e]9,000	[e]34,100	14,754	49,618	[e]13,900	[e]48,700
Dimension	short tons	[e]1,223	[e]69	297	42	[e]697	[e]60
Combined value of calcium chloride (natural), copper (1987), diatomite, gold, gypsum, lime, magnesium metal, olivine, silver, and values indicated by symbol W		XX	204,688	XX	[r]238,341	XX	265,362
Total		**XX**	**376,625**	**XX**	**[r]438,434**	**XX**	**459,334**

See footnotes at end of table.

TABLE 5—Continued

NONFUEL MINERAL PRODUCTION[1] IN THE UNITED STATES, BY STATE

Mineral		1986		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
WEST VIRGINIA							
Clays	short tons	214,980	$470	266,037	$565	263,973	$586
Gem stones		NA	1	NA	1	NA	1
Sand and gravel (construction)	thousand short tons	1,501	5,365	[e]1,000	[e]3,200	1,653	6,099
Stone (crushed)	do.	[e]9,800	[e]37,500	12,458	50,947	[e]11,600	[e]47,600
Combined value of cement, lime (1987–88), peat (1987–88), salt, and sand and gravel (industrial)		XX	86,473	XX	89,308	XX	73,169
Total		**XX**	**129,809**	**XX**	**144,021**	**XX**	**127,455**
WISCONSIN							
Gem stones		NA	$15	NA	$15	NA	$15
Lime	thousand short tons	350	19,715	393	21,733	452	23,986
Peat	do.	9	W	9	[r]237	11	270
Sand and gravel:							
Construction	do.	24,913	59,325	[e]23,900	[e]57,000	25,048	60,080
Industrial	do.	1,194	12,399	1,314	15,168	1,351	15,458
Stone:							
Crushed	do.	[e]18,700	[e]57,600	[6]22,757	[6]71,776	[e] [6]28,500	[e] [6]98,300
Dimension	short tons	[e]22,912	[e]2,878	36,903	3,697	[e]49,900	[e]6,200
Combined value of abrasives, cement (masonry, 1986–87, portland, 1986–87), stone (crushed traprock, 1987–88), and value indicated by symbol W		XX	12,600	XX	[r]16,846	XX	564
Total		**XX**	**164,532**	**XX**	**[r]186,472**	**XX**	**204,873**
WYOMING							
Clays	short tons	1,761,635	$51,823	[2]2,127,645	[2]$62,031	[2]2,357,616	[2]$72,174
Gem stones		NA	225	NA	150	NA	150
Lime	thousand short tons	25	1,689	29	1,560	26	1,640
Sand and gravel (construction)	do.	3,377	10,977	[e]2,600	[e]9,000	3,413	11,351
Stone (crushed)	do.	[e] [6]1,700	[e] [6]5,900	3,171	15,049	[e]2,500	[e]11,400
Combined value of beryllium concentrates (1986), cement, clays (common, 1987–88), gypsum, helium (Grade-A), sodium carbonate (natural), and stone (crushed granite, 1986)		XX	484,196	XX	557,265	XX	613,097
Total		**XX**	**554,810**	**XX**	**645,055**	**XX**	**709,812**

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data, value included with "Combined value" figure. XX Not applicable.
[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2] Excludes certain clays; kind and value included with "Combined value" figure.
[3] Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.
[4] Less than 1/2 unit.
[5] Partial total, excludes values that must be concealed to avoid disclosing company proprietary data.
[6] Excludes certain stones; kind and value included with "Combined value" figure.
[7] Excludes salt in brines; value included with "Combined value" figure.
[8] Value excluded to avoid disclosing company proprietary data.

TABLE 6

MINERAL PRODUCTION[1] IN THE ISLANDS ADMINISTERED BY THE UNITED STATES

Mineral		1986[e] Quantity	1986[e] Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
American Samoa: Stone (crushed)	thousand short tons	([2])	$400	W	W	—	—
Guam: Stone (crushed)	do.	700	3,300	354	$2,289	—	—
Virgin Islands: Stone (crushed)	do.	200	1,500	345	2,741	—	—

[e] Estimated. W Withheld to avoid disclosing company proprietary data.
[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2] Less than 1/2 unit.

TABLE 7

MINERAL PRODUCTION[1] IN THE COMMONWEALTH OF PUERTO RICO

Mineral		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
Cement (portland)	thousand short tons	W	W	1,296	$106,185	1,397	$113,966
Clays	short tons	110,997	$223	148,029	318	163,382	365
Lime	thousand short tons	24	3,291	25	3,558	25	3,802
Salt	do.	40	880	40	900	40	900
Sand and gravel (industrial)	do.	31	624	67	W	31	624
Stone (crushed)	do.	[e]5,400	[e]26,000	8,480	41,299	[e]9,350	[e]47,400
Total[2]		**XX**	**31,018**	**XX**	**152,260**	**XX**	**167,057**

[e] Estimated. W Withheld to avoid disclosing company proprietary data; not included in "Total." XX Not applicable.
[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2] Total does not include value of items not available or withheld.

TABLE 8

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)
METALS					
Aluminum:					
Ingots, slabs, crude	metric tons	[r]281,816	[r]$415,013	400,057	$925,572
Scrap	do.	[r]368,510	[r]409,712	486,615	774,277
Plates, sheets, bars, etc.	do.	251,572	647,890	334,395	995,767
Castings and forgings	do.	6,902	65,504	16,964	111,168
Aluminum sulfate	do.	1,857	1,535	3,492	1,982
Other aluminum compounds	do.	46,419	40,587	57,931	57,158
Antimony, metal and alloys, crude	short tons	876	2,817	688	1,793
Bauxite including bauxite concentrate	thousand metric tons	201	[r]15,230	63	10,451
Beryllium	pounds	170,408	5,013	82,889	6,894
Bismuth, metals and alloys	do.	83,685	641	323,604	1,213
Cadmium metal	metric tons	241	660	613	3,697
Chromium:					
Ore and concentrate:					
Exports	thousand metric tons	1	707	4	1,430
Reexports	do.	5	352	1	320
Chromium ferroalloys	do.	5	5,730	8	12,503
Cobalt (content)	thousand pounds	806	7,007	1,197	10,131
Copper:					
Ore, concentrate, composition metal, unrefined (copper content)	metric tons	[r]143,087	[r]182,627	248,864	496,257
Scrap	do.	108,535	104,920	119,773	164,933
Refined copper and semimanufactures	do.	114,721	427,843	197,995	891,910
Other copper manufactures	do.	3,723	9,511	2,350	7,861
Ferroalloys not elsewhere listed:					
Ferrophosphorous	short tons	34,699	4,334	21,363	3,434
Ferroalloys, n.e.c.	do.	19,073	14,938	12,871	18,981
Gold:					
Ore and base bullion	troy ounces	1,557,794	674,658	1,829,432	776,340
Bullion, refined	do.	2,288,404	1,304,186	8,723,623	3,882,757
Iron ore	thousand metric tons	5,093	198,254	5,286	193,796
Iron and steel:					
Pig iron	short tons	50,072	4,897	71,454	7,790
Iron and steel products (major):					
Steel mill products	do.	1,093,982	949,597	2,065,955	1,702,286
Other steel products	do.	225,587	482,464	380,741	723,111
Iron and steel scrap: Ferrous scrap including rerolling materials, ships, boats, other vessels for scrapping	thousand short tons	10,670	996,145	10,470	1,402,833

See footnotes at end of table.

TABLE 8—Continued

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)
METALS—Continued					
Lead:					
Ore and concentrate	metric tons	8,764	$3,333	20,902	$10,678
Pigs, bars, cathodes, sheets, etc.	do.	10,116	11,945	13,594	15,919
Scrap	do.	52,823	15,670	81,910	23,212
Magnesium, metal and alloys, scrap, semimanufactured forms, n.e.c.	short tons	[r]48,702	[r]130,730	54,897	145,312
Manganese:					
Ore and concentrate	do.	63,270	4,225	67,991	5,496
Ferromanganese	do.	2,851	2,144	3,442	2,950
Silicomanganese	do.	697	493	7,467	4,975
Metal	do.	5,775	9,748	9,859	16,242
Molybdenum:					
Ore and concentrate (molybdenum content)	thousand pounds	40,514	98,381	51,807	148,237
Metal and alloys, crude and scrap	do.	513	3,504	995	6,686
Wire	do.	573	9,043	839	12,984
Semimanufactured forms, n.e.c.	do.	282	8,167	451	9,362
Powder	do.	2,145	8,866	1,340	5,889
Ferromolybdenum	do.	161	605	113	382
Compounds	do.	2,696	11,146	8,350	21,828
Nickel:[1]					
Primary (unwrought commercially pure, cathodes, ferronickel, powder and flakes)	short tons	2,507	19,165	2,721	29,146
Wrought (bars, rods, angles, shapes, sections, plates, sheets, strip; tubes, pipes, blanks, fittings hollow bar; wire)	do.	9,887	87,595	12,741	135,560
Compound catalysts and waste and scrap	do.	15,525	34,213	17,594	57,824
Platinum-group metals:					
Ore and scrap	troy ounces	276,727	84,578	272,835	88,651
Palladium, rhodium, iridium, osmiridium, ruthenium, osmium (metal and alloys including scrap)	do.	341,362	93,626	396,382	97,830
Platinum (metal and alloys)	do.	90,208	46,765	256,319	123,541
Rare-earth metals: Ferrocerium and alloys	metric tons	82	653	38	341
Selenium	kilograms	162,217	1,686	243,096	3,197
Silicon:					
Ferrosilicon	short tons	15,049	11,647	28,912	25,379
Silicon carbide, crude and in grains (including reexports)	do.	5,254	7,825	3,542	4,867
Silver:					
Ore, concentrate, waste, sweepings	thousand troy ounces	15,853	113,182	17,833	112,057
Bullion, refined	do.	11,240	79,123	14,269	94,029
Tantalum:					
Ore, metal, other forms	thousand pounds	[r]516	18,665	701	25,872
Powder	do.	193	16,129	278	23,758

See footnotes at end of table.

TABLE 8—Continued

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
METALS—Continued					
Tin:					
Ingots, pigs, bars, etc.: Exports	metric tons	1,318	$9,456	1,209	$9,838
Tinplate and terneplate	do.	209,526	106,156	297,629	295,002
Titanium:					
Ore and concentrate	short tons	4,435	1,395	10,326	3,729
Unwrought and scrap metal	do.	5,922	12,721	6,922	25,428
Intermediate mill shapes and mill products, n.e.c.	do.	4,704	84,737	5,249	105,270
Pigments and oxides	do.	133,057	210,185	135,474	234,122
Tungsten (tungsten content):					
Ore and concentrate	metric tons	2	31	153	1,815
Carbide powder	do.	383	9,063	618	15,340
Alloy powder	do.	669	13,319	759	17,616
Vanadium:					
Pentoxide, etc.	thousand pounds	2,922	5,566	2,440	8,604
Ferrovanadium	do.	872	4,081	1,258	6,732
Zinc:					
Slabs, pigs, or blocks	metric tons	1,082	2,114	482	933
Sheets, plates, strips, other forms, n.e.c.	do.	1,732	2,337	3,814	4,416
Waste, scrap, dust (zinc content)	do.	90,204	49,482	105,953	69,981
Semifabricated forms, n.e.c.	do.	7,096	12,534	7,764	12,792
Ore and concentrate	do.	16,921	8,304	33,590	19,699
Zirconium:					
Ore and concentrate	do.	20,054	6,802	21,794	12,339
Oxide	do.	1,206	3,948	1,809	5,464
Metals, alloys, other forms	do.	1,225	62,892	1,257	62,646
INDUSTRIAL MINERALS					
Abrasives (includes reexports):					
Industrial diamond, natural or synthetic:					
Powder or dust	thousand carats	56,792	92,858	74,533	115,430
Other	do.	2,542	27,592	2,994	29,342
Diamond grinding wheels	do.	493	5,964	537	6,759
Other natural and artificial metallic abrasives and products		XX	[2]124,984	XX	[2]149,322
Asbestos:					
Exports:					
Unmanufactured	metric tons	59,136	15,818	31,334	8,410
Products		XX	178,953	XX	192,846
Reexports:					
Unmanufactured	metric tons	948	331	210	58
Products		XX	1,649	XX	2,012
Barite: Natural barium sulfate	short tons	9,083	716	226	353

See footnotes at end of table.

TABLE 8—Continued

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
INDUSTRIAL MINERALS—Continued					
Boron:					
Boric acid	short tons	66,614	$34,180	62,186	$35,301
Sodium borates, refined	do.	608,893	243,600	601,857	240,800
Bromine compounds	thousand pounds	48,300	18,000	30,700	13,000
Calcium:					
Other calcium compounds including precipitated calcium carbonate	short tons	49,978	40,705	18,306	10,703
Chloride	do.	34,718	6,657	18,710	5,532
Dicalcium phosphate	do.	83,362	53,456	114,496	78,411
Cement: Hydraulic and clinker	do.	52,009	9,563	101,000	8,907
Clays:					
Kaolin and china clay	thousand short tons	2,026	340,475	2,362	334,931
Bentonite	do.	539	40,596	626	48,409
Other	do.	761	131,897	909	133,226
Diatomite	do.	139	33,075	162	39,374
Feldspar, leucite, nepheline syenite	short tons	9,634	691	13,712	769
Flourspar	do.	2,860	340,315	3,457	381,572
Gem stones (including reexports):					
Diamonds	thousand carats	2,530	968,100	2,135	1,227,900
Pearls		XX	1,860	XX	14,500
Other		XX	140,300	XX	175,500
Graphite, natural	short tons	12,897	6,218	12,200	5,815
Gypsum:					
Crude, crushed, or calcined	thousand short tons	127	15,629	271	19,362
Manufactured, wallboard and plaster articles		XX	16,432	XX	17,051
Helium	million cubic feet	494	18,278	663	24,863
Lime	short tons	12,644	2,971	14,908	3,113
Lithium compounds:					
Lithium carbonate	thousand pounds	12,750	16,751	15,627	21,061
Lithium hydroxide	do.	6,930	11,033	8,352	15,069
Other lithium compounds	do.	2,688	7,062	3,404	7,291
Magnesium compounds:					
Magnesite, dead-burned	short tons	14,131	3,240	40,516	9,262
Magnesite, crude, caustic-calcined, lump or ground	do.	22,396	14,167	23,203	13,322
Mica:					
Waste, scrap, ground	thousand pounds	11,154	1,534	13,870	1,990
Block, film, splittings	do.	170	145	138	228
Manufactured, cut or stamped, built-up	do.	NA	4,748	NA	6,148
Mineral-earth pigments, iron oxide, natural and synthetic	short tons	22,249	31,689	24,213	33,014
Nitrogen compounds (major)	thousand short tons	10,901	NA	11,250	NA
Phosphate rock	thousand metric tons	8,454	194,691	8,092	206,984

See footnotes at end of table.

TABLE 8—Continued

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987		1988	
		Quantity	Value (thousands)	Quantity	Value (thousands)
INDUSTRIAL MINERALS—Continued					
Phosphatic fertilizers:					
Phosphoric acid	thousand metric tons	500	$85,912	434	NA
Superphosphates	do.	1,160	192,308	917	NA
Diammonium phosphates	do.	5,647	890,801	5,954	NA
Elemental phosphorous	metric tons	20,302	30,796	18,642	$27,539
Pigments and compounds: Zinc oxide (metal content)	do.	265	531	530	822
Potash:					
Potassium chloride	do.	511,590	NA	400,831	NA
Potassium sulfate	do.	230,899	NA	178,498	NA
Quartz crystal:					
Cultured	thousand pounds	448	6,954	417	7,162
Natural	do.	139	708	95	431
Salt:					
Crude and refined	thousand short tons	541	8,217	884	10,858
Shipments to noncontiguous territories	do.	NA	NA	NA	NA
Sand and gravel:					
Construction:					
Sand	do.	593	7,610	506	7,476
Gravel	do.	544	2,923	459	3,572
Industrial sand	do.	758	21,253	1,060	30,843
Sodium compounds:					
Sodium carbonate	do.	2,224	253,200	2,467	286,945
Sodium sulfate	do.	122	10,554	85	8,737
Stone:					
Crushed	do.	3,320	26,063	3,642	30,413
Dimension	do.	NA	20,470	NA	32,219
Sulfur, crude	thousand metric tons	1,242	139,431	1,223	131,863
Talc, crude and ground	thousand short tons	318	21,040	421	29,091
Total		**XX**	**13,426,441**	**XX**	**19,596,526**

[r] Revised. NA Not available. XX Not applicable.
[1] Not comparable to prior years owing to regrouping of nickel forms.
[2] Silicon carbide (crude and refined) has been deducted and is shown separately elsewhere in this table.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
METALS					
Aluminium:					
Metal	metric tons	[r]1,245,638	[r]$1,852,304	1,027,246	$2,197,785
Scrap	do.	[r]188,667	[r]202,333	200,517	318,015
Plates, sheets, bars, etc.	do.	415,211	840,409	392,459	1,028,213
Aluminium oxide (alumina)	thousand metric tons	4,068	581,864	4,634	851,851
Antimony:					
Ore and concentrate (antimony content)	short tons	5,634	5,732	8,867	4,109
Sulfide including needle or liquated	do.	102	112	179	432
Metal	do.	9,701	18,171	18,303	34,837
Oxide	do.	[r]11,325	20,024	12,731	20,164
Arsenic:					
White (As_2O_3 content)	metric tons	26,843	16,800	28,056	16,461
Metallic	do.	631	3,471	600	2,642
Bauxite, crude	thousand metric tons	9,156	NA	9,944	NA
Beryllium ore	short tons	2,302	1,944	975	911
Bismuth, metals and alloys (gross weight)	pounds	3,484,713	8,769	3,618,727	18,354
Cadmium metal	metric tons	2,701	7,818	2,482	31,081
Calcium metal	pounds	776,225	1,918	1,464,794	3,024
Cesium compounds and chloride	do.	73,892	4,033	49,867	1,583
Chromium:					
Ore and concentrate (Cr_2O_3 content)	thousand metric tons	208	[r]23,775	270	42,317
Ferrochromium (gross weight)	do.	295	150,269	422	353,053
Ferrochromium-silicon	do.	7	4,920	10	5,461
Metal	do.	4	24,096	4	29,656
Cobalt:					
Metal	thousand pounds	18,612	122,791	14,683	105,547
Oxide (gross weight)	do.	795	5,293	743	5,692
Salts and compounds (gross weight)	do.	903	2,004	937	2,772
Columbium ore	do.	4,581	6,612	3,723	7,561
Copper (copper content):					
Ore and concentrate	metric tons	2,339	2,013	2,776	7,917
Matte	do.	6,869	9,339	5,462	10,399
Blister	do.	24,084	41,976	98,453	197,621
Refined in ingots, etc.	do.	[r]469,159	[r]734,647	331,671	810,495
Scrap	do.	33,123	[r]45,121	37,152	87,124
Ferroalloys not elsewhere listed, including spiegeleisen	short tons	3,940	22,722	4,859	26,792
Gallium	kilograms	12,490	4,874	12,160	4,341
Germanium	do.	17,498	10,491	19,291	13,539

See footnotes at end of table.

TABLE 9—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
METALS—Continued					
Gold:					
Ore and base bullion	troy ounces	1,420,200	$580,025	1,124,328	$469,417
Bullion, refined	do.	2,423,053	1,052,941	1,851,748	799,901
Hafnium	short tons	1	180	4	764
Indium	thousand troy ounces	1,522	9,796	1,224	13,386
Iron ore (usable)	thousand metric tons	16,849	408,783	20,183	484,543
Iron and steel:					
Pig iron	short tons	354,712	52,500	652,555	85,730
Iron and steel products (major):					
Steel mill products	do.	20,350,816	8,567,164	20,774,712	8,932,276
Other products	do.	1,020,073	1,143,999	1,219,974	1,585,904
Scrap including tinplate	thousand short tons	843	82,016	1,038	133,577
Lead:					
Ore, flue dust, matte (lead content)	metric tons	873	308	20,606	11,224
Base bullion (lead content)	do.	10,827	7,239	4,046	2,743
Pigs and bars (lead content)	do.	185,673	123,157	148,604	107,484
Reclaimed scrap, etc. (lead content)	do.	6,587	3,128	7,289	3,339
Sheets, pipe, shot	do.	2,793	5,301	3,445	3,280
Magnesium:					
Metal and scrap	short tons	6,832	16,223	8,713	19,330
Alloys (magnesium content)	do.	2,921	8,624	4,638	12,702
Sheets, tubing, ribbons, wire, other forms (magnesium content)	do.	2,208	6,117	2,530	7,225
Manganese:					
Ore (35% or more contained manganese)	do.	340,539	15,079	511,695	29,074
Ferromanganese	do.	367,675	113,630	531,281	212,221
Ferrosilicon-manganese (manganese content)	do.	124,315	58,461	152,884	91,928
Metal	do.	8,925	9,600	11,730	14,946
Mercury:					
Compounds	pounds	475,015	2,136	658,195	4,194
Metal	76-pound flasks	18,451	3,860	9,558	2,798
Molybdenum:					
Ore and concentrate (molybdenum content)	thousand pounds	1,264	3,109	169	349
Waste and scrap		NA	2,545	NA	3,276
Metal:					
Unwrought (molybdenum content)	do.	174	2,308	296	3,752
Wrought (gross weight)	do.	158	2,801	119	3,457
Ferromolybdenum (gross weight)	do.	3,815	8,042	3,704	8,504
Material in chief value molybdenum (molybdenum content)	do.	5,248	15,497	965	2,863
Compounds (gross weight)	do.	6,711	13,407	7,361	15,015

See footnotes at end of table.

TABLE 9—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
METALS—Continued					
Nickel:					
Cathodes, pellets, briquets, and shot	short tons	113,249	$455,126	112,576	$1,024,106
Plates, bars, etc.	do.	5,444	54,861	5,337	62,421
Slurry	do.	5,241	24,754	9,067	51,512
Scrap	do.	7,567	25,133	9,261	58,037
Powder and flakes	do.	11,977	60,406	10,984	100,743
Ferronickel	do.	45,398	57,481	44,576	116,990
Oxide	do.	2,278	4,277	3,397	26,009
Platinum-group metals:					
Unwrought:					
Grains and nuggets (platinum)	troy ounces	821	368	19,345	8,601
Sponge (platinum)	do.	1,124,018	621,321	1,371,704	710,520
Sweepings, waste, scrap	do.	624,916	106,920	410,270	84,257
Iridium	do.	11,814	4,319	18,288	6,132
Palladium	do.	1,529,161	210,670	1,487,740	198,924
Rhodium	do.	211,466	249,811	230,331	236,879
Ruthenium	do.	84,399	6,269	120,381	7,680
Other platinum-group metals	do.	17,620	6,204	4,266	1,732
Semimanufactured:					
Platinum	do.	45,804	24,840	113,187	62,314
Palladium	do.	151,499	22,312	212,369	27,387
Rhodium	do.	829	649	6,261	2,696
Other platinum-group metals	do.	4,200	925	2,954	805
Rare-earth metals:					
Ferrocerium and other cerium alloys	kilograms	94,829	1,294	100,662	1,348
Monazite	metric tons	1,121	627	1,924	1,154
Metals including scandium and yttrium	kilograms	13,490	1,350	20,087	907
Rhenium:					
Metal including scrap	pounds	7,436	2,072	6,821	3,161
Ammonium perrhenate (rhenium content)	do.	7,225	2,122	5,979	3,414
Selenium and selenium compounds (selenium content)	kilograms	495,862	10,108	474,234	11,140
Silicon:					
Metal (over 96% silicon content)	short tons	36,930	74,298	62,030	108,717
Ferrosilicon	do.	230,658	108,749	230,897	158,176
Silver:					
Ore and base bullion	thousand troy ounces	2,681	18,019	6,151	35,508
Bullion, refined	do.	67,959	460,235	72,662	476,181
Sweepings, waste, doré	do.	11,186	76,372	9,825	65,835
Tantalum ore	thousand pounds	697	5,186	1,410	15,027
Tellurium (gross weight)	kilograms	26,700	808	76,890	2,689

See footnotes at end of table.

TABLE 9—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
METALS—Continued					
Thallium	pounds	3,138	$89	1,780	$98
Tin:					
Concentrate (tin content)	metric tons	2,953	9,509	2,837	7,913
Dross, skimmings, scrap, residure, tin alloys, n.s.p.f.	do.	2,270	9,241	1,542	6,054
Tinfoil, powder, flitters, etc.		XX	1,854	XX	1,013
Tin compounds	metric tons	838	5,162	838	5,439
Titanium:					
Ilmenite[1]	short tons	789,585	94,987	913,608	112,378
Rutile	do.	218,188	72,113	254,770	93,949
Metal	do.	4,521	29,759	7,339	52,288
Ferrotitanium and ferrosilicon-titanium	do.	1,425	2,521	1,711	6,180
Pigments	do.	192,043	236,945	204,443	291,832
Tungsten ore and concentrate (tungsten content)	metric tons	4,414	23,964	8,045	48,265
Vanadium (vanadium content):					
Ferrovanadium	thousand pounds	685	3,777	238	2,271
Pentoxide	do.	457	2,210	482	2,948
Vanadium-bearing materials	do.	4,528	5,903	4,465	7,107
Zinc:					
Ore and concentrates (zinc content)	metric tons	46,464	12,322	62,966	25,746
Blocks, pigs, slabs	do.	705,985	581,221	749,133	833,531
Sheets, etc.	do.	960	1,384	4,100	5,395
Fume (zinc content)	do.	16	18	100	27
Waste and scrap	do.	4,025	1,928	5,727	3,615
Dross and skimmings	do.	6,711	3,443	6,246	4,252
Dust, powder, flakes	do.	7,001	7,940	7,652	11,958
Manufactured		XX	1,570	XX	1,416
Zirconium:					
Ore including zirconium sand	metric tons	67,917	10,243	76,331	20,004
Metal, scrap, compounds	do.	4,233	25,592	4,207	23,286
INDUSTRIAL MINERALS					
Abrasives:					
Diamond (industrial)	thousand carats	48,877	r95,535	71,147	130,300
Other		XX	329,105	XX	371,407
Asbestos	metric tons	93,763	22,022	85,326	21,528
Barite:					
Crude and ground	thousand short tons	837	29,519	1,263	83,634
Witherite	short tons	436	144	1,377	253
Chemicals	do.	42,537	22,072	66,360	22,506

See footnotes at end of table.

TABLE 9—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
INDUSTRIAL MINERALS—Continued					
Boron:					
Boric acid (contained boric oxide)	short tons	2,240	$2,899	3,030	$2,020
Colemanite (contained boron oxide)	thousand short tons	8	2,763	19	7,790
Ulexite	do.	52	20,597	34	7,480
Bromine (contained in compounds)	thousand pounds	25,326	19,237	43,358	43,392
Calcium chloride:					
Crude	short tons	229,964	20,917	221,926	21,216
Other	do.	1,282	706	3,530	1,797
Cement: Hydraulic and clinker	thousand short tons	17,726	r606,588	17,488	616,107
Clays	short tons	37,679	9,392	36,208	8,835
Cryolite	do.	13,605	7,693	9,735	7,310
Feldspar:					
Crude	do.	344	4	75	8
Ground and crushed	do.	r4,455	r442	6,752	657
Fluorspar	do.	585,901	48,429	759,646	71,678
Gem stones:					
Diamond	thousand carats	9,121	3,423,094	10,397	4,305,762
Emeralds	do.	2,075	141,575	2,216	174,632
Other		XX	524,851	XX	582,949
Graphite, natural	short tons	47,768	17,654	59,378	23,238
Gypsum:					
Crude, ground, calcined	thousand short tons	9,719	59,555	9,681	59,836
Manufactured		XX	104,026	XX	98,333
Iodine, crude	thousand pounds	2,542	17,595	2,771	21,944
Lime:					
Hydrated	short tons	39,734	3,021	54,419	4,031
Other	do.	138,171	7,558	155,497	8,541
Lithium:					
Ore	do.	18,174	3,987	15,830	3,489
Compounds	do.	2,309	6,485	3,595	7,629
Magnesium compounds:					
Crude magnesite	do.	3,318	733	9,006	1,728
Lump or ground caustic-calcined magnesia	do.	42,011	4,575	22,850	2,371
Refractory magnesia, dead-burned, fused magnesite dead-burned dolomite	do.	223,555	43,539	278,008	46,667
Compounds	do.	70,746	20,593	104,782	25,881

See footnotes at end of table.

TABLE 9—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
INDUSTRIAL MINERALS—Continued					
Mica:					
Waste, scrap, ground	thousand pounds	21,142	$3,928	26,732	$5,561
Block, film, splittings	do.	2,460	1,230	3,535	2,083
Manufactured, cut or stamped, built-up	do.	1,645	5,125	1,657	5,679
Mineral-earth pigments, iron oxide:					
Ocher, crude and refined	short tons	59	99	371	34
Siennas, crude and refined	do.	289	177	99	30
Umber, crude and refined	do.	6,123	1,058	4,974	849
Vandyke brown	do.	1,576	342	1,633	314
Other natural and refined	do.	1,598	769	1,429	906
Synthetic	do.	32,679	18,235	34,405	24,996
Nepheline syenite:					
Crude	do.	3,720	142	2,882	111
Ground, crushed, etc.	do.	304,965	11,259	306,962	11,122
Nitrogen compounds (major) including urea	thousand short tons	7,065	582,553	7,904	796,087
Peat:					
Fertilizer-grade	short tons	500,142	69,076	577,177	73,072
Poultry- and stable-grade	do.	14,373	1,890	12,469	1,493
Phosphates, crude and apatite	thousand metric tons	464	18,816	673	25,911
Phosphatic fertilizers:					
Fertilizer and fertilizer materials	do.	55	7,820	27	6,802
Elemental phosphorous	do.	4	6,609	249	NA
Other	do.	53	8,514	106	16,515
Pigments and salts:					
Lead pigments and compounds	metric tons	21,213	21,145	19,442	22,291
Zinc pigments and compounds	do.	68,672	60,078	88,227	97,454
Potash	do.	6,706,200	432,700	6,963,900	622,900
Pumice:					
Crude and unmanufactured	short tons	17,353	2,414	30,722	4,386
Wholly or partly manufactured	do.	1,201	380	2,080	631
Manufactured, n.s.p.f.		XX	899	XX	704
Quartz crystal (Brazilian lacas)	thousand pounds	146	157	215	180
Salt	thousand short tons	5,716	66,936	5,474	77,357
Sand and gravel:					
Industrial sand	do.	104	1,071	43	1,900
Other sand and gravel	do.	283	2,367	351	3,163
Sodium compounds:					
Sodium carbonate	do.	150	18,334	133	15,999
Sodium sulfate	do.	138	10,363	150	11,943

See footnotes at end of table.

TABLE 9—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS

Mineral		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
INDUSTRIAL MINERALS—Continued					
Stone:					
Crushed	thousand short tons	3,595	$12,500	3,244	$14,815
Dimension		XX	439,278	XX	517,835
Calcium carbonate fines	thousand short tons	263	1,524	358	1,973
Strontium:					
Minerals	short tons	42,469	3,670	45,462	3,502
Compounds	do.	10,004	7,307	14,434	9,313
Sulfur and compounds, sulfur ore and other forms, n.e.s.	thousand metric tons	1,599	152,096	1,996	185,864
Talc, unmanufactured	thousand short tons	53	10,348	87,514	12,268
Total[2]		**XX**	**28,534,000**	**XX**	**33,904,000**

[r] Revised. NA Not available. XX Not applicable.
[1] Includes titanium slag averaging about 70% TiO_2. For details, see "Titanium" chapter.
[2] Data may not add to totals shown because of independent rounding.

TABLE 10

COMPARISON OF WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES

(Thousand short tons unless otherwise specified)

Mineral		1987			1988[p]		
		World production[1]	U.S. production	U.S. percent of world production	World production[1]	U.S. production	U.S. percent of world production
METALS, MINE BASIS							
Antimony (content of ore and concentrate)	short tons	76,112	—	—	78,196	W	NA
Arsenic trioxide[2]	metric tons	53,696	—	—	55,103	—	—
Bauxite[3]	thousand metric tons	93,969	576	1	98,859	588	1
Beryl	short tons	9,303	6,062	65	9,143	5,858	64
Bismuth	thousand pounds	6,372	W	NA	6,106	W	NA
Chromite	thousand metric tons	10,917	—	—	11,666	—	—
Cobalt (content of ore and concentrate)	thousand pounds	100,870	—	—	96,781	—	—
Columbium-tantalum concentrate (gross weight)	do.	49,570	—	—	85,834	—	—
Copper (content of ore and concentrate)	thousand metric tons	8,328	1,244	15	8,453	1,420	17
Gold (content of ore and concentrate)	thousand troy ounces	53,034	4,947	9	58,454	6,460	11
Iron ore (gross weight)	thousand metric tons	888,050	47,568	5	916,574	57,515	6
Lead (content of ore and concentrate)	do.	3,429	319	9	3,426	394	12
Manganese ore (gross weight)		26,160	—	—	26,303	—	—
Mercury	thousand 76-pound flasks	172	W	NA	167	W	NA
Molybdenum (content of ore and concentrate)	thousand pounds	196,537	75,117	38	208,880	94,911	45
Nickel (content of ore and concentrate)		896	—	—	920	—	—
Platinum-group metals[3]	thousand troy ounces	8,593	W	NA	8,668	W	NA
Silver (content of ore and concentrate)	do.	443,050	39,790	9	443,330	53,416	12
Tin (content of ore and concentrate)	metric tons	177,205	W	NA	200,798	W	NA
Titanium concentrates (gross weight):							
Ilmenite		4,274	W	NA	4,345	W	NA
Rutile		485	W	NA	480	W	NA
Tungsten (content of ore and concentrate)	metric tons	42,174	34	([4])	43,236	W	NA
Vanadium (content of ore and concentrate)	short tons	31,315	W	NA	33,660	W	NA
Zinc (content of ore and concentrate)	thousand metric tons	7,242	233	3	6,977	256	4
METALS, SMELTER BASIS							
Aluminum (primary)	do.	16,378	3,343	20	17,304	3,944	23
Cadmium	metric tons	18,996	1,515	8	19,823	1,885	10
Cobalt	thousand pounds	59,188	—	—	55,696	—	—
Copper (primary and secondary)[5]	thousand metric tons	8,914	1,249	14	9,023	1,363	15
Iron, pig		566,520	48,308	9	593,949	55,745	9
Lead (primary and secondary)[6]	thousand metric tons	5,687	1,084	19	5,716	1,129	20
Magnesium (primary)		361	137	38	372	157	42
Nickel[7]		840	—	—	889	—	—
Selenium[8]	kilograms	1,228,632	W	NA	1,502,671	285,600	19
Steel, raw		808,198	89,151	11	856,973	99,924	12
Tellurium[8]	kilograms	73,762	W	NA	63,681	W	NA
Tin	metric tons	187,373	[9]3,927	2	204,340	[9]1,467	1
Zinc (primary and secondary)	thousand metric tons	7014	344	5	7,109	330	5

See footnotes at end of table.

TABLE 10—Continued

COMPARISON OF WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES

(Thousand short tons unless otherwise specified)

Mineral		1987 World production[1]	1987 U.S. production	1987 U.S. percent of world production	1988[p] World production[1]	1988[p] U.S. production	1988[p] U.S. percent of world production
INDUSTRIAL MINERALS							
Asbestos	thousand metric tons	4,256	51	1	4,361	18	([4])
Barite		5,197	[10]448	9	5,844	[10]445	8
Boron minerals		2,975	1,385	47	3,043	1,267	42
Bromine	thousand pounds	857,530	[10]335,000	39	892,230	[10]360,000	40
Cement, hydraulic		1,151,060	[11]79,501	7	1,212,724	[11]78,252	6
Clays:							
Bentonite[2]		9,734	[10]2,806	29	10,016	[10]3,165	32
Fuller's earth[8]		2,658	[10]2,057	77	2,832	[10]2,175	77
Kaolin[2]		26,455	[10]8,827	33	28,365	[10]9,891	35
Diamond, natural	thousand carats	87,615	—	—	93,999	—	—
Diatomite		2,003	658	33	2,036	693	34
Feldspar		4,705	720	15	4,728	715	15
Fluorspar		5,461	70	1	5,709	70	1
Graphite	short tons	728,904	—	—	741,220	—	—
Gypsum		99,634	15,612	16	104,923	16,390	16
Iodine, crude	thousand pounds	27,748	W	NA	32,222	2,200	7
Lime		124,776	[10 11]15,758	13	131,212	[10 11]17,318	13
Magnesite, crude		13,370	W	NA	13,358	W	NA
Mica (including scrap and ground)	thousand pounds	637,984	321,100	50	595,960	286,400	48
Nitrogen: N content of ammonia		103,944	13,230	13	109,022	13,930	13
Peat		207,779	955	([4])	207,597	900	([4])
Perlite		1,927	[10]533	28	2,037	[10]576	28
Phosphate rock (gross weight)	thousand metric tons	144,228	40,954	28	163,673	45,389	28
Potash (K_2O equivalent)	do.	30,470	1,262	4	31,429	1,521	5
Pumice[8]		11,888	[10]392	3	11,945	[10]389	3
Salt		196,956	[10 11]36,532	19	202,905	[10 11]38,037	19
Sodium compounds, n.e.s. (natural and manufactured):							
Carbonate		33,330	8,891	27	34,258	9,632	28
Sulfate		5,101	814	16	5,080	788	16
Strontium[8]	short tons	199,993	—	—	211,185	—	—
Sulfur, all forms	thousand metric tons	56,940	10,538	19	58,396	10,746	18
Talc and pyrophyllite		8,435	1,349	16	8,432	1,377	16
Vermiculite[8]		598	[10]303	51	596	[10]304	51

[p] Preliminary. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in world total.

[1] The reporting of world production of natural corundum was dropped from the 1987 edition of the Minerals Yearbook, therefore, corundum no longer appears in this table. For those commodities for which U.S. data are withheld to avoid disclosing company proprietary data, the world total excludes U.S. output and the U.S. percent of world production cannot be reported.

[2] World total does not include an estimate for China.

[3] U.S. figures represent dried bauxite equivalent of crude ore; to the extent possible, individual country figures that are included in the world total are also on the dried bauxite eqiuivalent basis, but for some countries available data are insufficient to permit this adjustment.

[4] Less than 0.5%.

[5] Primary and secondary blister and anode copper, including electrowon refined copper that is not included as blister or anode.

[6] Includes bullion.

[7] Refined nickel plus nickel content of ferronickel and nickel oxide.

[8] World total does not include estimates for output in the U.S.S.R. or China.

[9] Includes tin content of alloys made directly from ore.

[10] Quantity sold or used by producers.

[11] Includes Puerto Rico.

Mining and Quarrying Trends in the Metals and Industrial Minerals Industries

By Arnold O. Tanner[1]

The domestic mining industry gained more strength in 1988 as the healthy comeback that became evident in 1987 continued and grew for many commodities. The increasing and more stable commodity prices, still predominantly in the metals sector, reinforced both the new ways of conducting business and the use of technological advancements in successfully lowering operating costs during the last 4 to 6 years. Some commodities and companies still struggled to survive, but increases in productivity and profits were becoming more common.

MINING HIGHLIGHTS

Production Overview

Changes in Output.—Raw nonfuel minerals produced in the United States during 1988 had an estimated value of over $30.5 billion, an increase of about $4.2 billion over the 1987 value. This was the sixth consecutive year that the value had increased. Except for a decrease in 1982, the value had increased each year since 1971, or 16 of 17 years. The value of raw metals production increased substantially as it had in 1987, when it made a healthy rebound from the slow years following the drastic fall in 1982. Metal mine production was in a slump from 1982 to 1987, when production significantly recovered. This recovery continued throughout 1988. Industrial minerals growth was still comparatively flat yet somewhat healthier than that of 1987.

High prices in 1988 spurred increased production for most major metals, with copper among the strongest of performers. Even iron ore, trailing behind the improvement of other metals, increased production value as a result of increased volume. Iron ore mines operated at or near capacity in order to meet higher demand while iron ore prices remained virtually the same. Late 1988 prices for base metals, with few exceptions, declined somewhat but remained high by historical standards.[2] Openings and expansions of mines and processing plants again exceeded closings. Despite a construction industry slowdown in early 1988, demand for building and construction materials was strong by yearend. The crushed stone industry had record production while the cement industry nearly equaled production records set in 1986 and 1987.

Domestic metal mine production increased significantly for the following: copper, gold, iron ore, lead, magnesium, molybdenum, silicon, silver, titanium, tungsten, and zinc. Bauxite production increased slightly, while beryllium decreased by about the same proportion. Industrial minerals with significantly increased production included bromine, iodine, lime, magnesium compounds, phosphate rock, potash, and soda ash. Modest increases occurred for clays, construction sand and gravel, and crushed stone. Industrial sand and gravel, salt, and talc had small gains. Feldspar, fluorspar, and sulfur held fairly even with 1987 production. Small declines occurred for boron, cement, and gypsum, while asbestos dropped significantly.

Gold remained the strongest contender among the metals in both domestic and international metal mining, as had been the case for a number of years. The main difference in 1988 was that, because of many companies' increased competitiveness and higher, more profitable prices, many of the base metal markets and prices were exceptionally active after many years of lackluster performance. Gold production continued to expand, partially as a result of the increasing use of heap leaching, and more companies were processing their sulfide ores by roasting, or with new, expensive autoclaves. A few operations were making preparations to use bioleaching methods to preoxidize these ores, which were previously labeled "waste" by some operations. Gold output in the United States increased from about 4.95 million troy ounces in 1987 to almost 6.46 million ounces in 1988, almost a 31% increase. This followed 1987's 33% rise and 1986's 45-year record increase of 54%. Nevada was responsible for much of this increase; 30% of U.S. gold production came from Nevada. The United States remained the third largest primary gold producer in the world, behind the Republic of South Africa and the U.S.S.R. It attained this status when it overtook Canada in 1986. During 1988, gold bullion imports fell 25% to 1.8 million ounces, and exports increased 364% to 8.44 million ounces.

Interest in precious metals as bullion and commemorative coins surged in the United States and in many countries of the world, with platinum and palladium coins increasing in popularity. According to the Gold Institute, during 1987, and for the first time in recent history, the United States used more gold than any other nation for the minting of gold money: 1.7 million troy ounces out of a worldwide, 46-country total of 6.2 million ounces. Most of the U.S. coins were produced with gold from U.S. mines. Precious metal mining had a very definite, positive effect on the Nation's economy.

Management Concerns.—In 1988, one significant issue throughout the mining industry remained the same as that of 1987: increasing its competitiveness in the world market. After several years of recovery, the industry was building confidence. Production and profit levels probably would not return to those of the 1970's and early 1980's, but with continued efforts the industry appeared likely to remain competitive. The industry's sometimes massive restructurings, the imaginative and often bold cost-cutting measures, the development of closer customer ties, the trend toward a teamwork-oriented relationship between labor and management, and the use of more innovative and efficient technologies were paying off. Increasing the industry's competitiveness in the world market, and more importantly, maintaining it, was a common theme at upbeat mining conferences throughout the year.

Much of the legislation that was critical to the mining industry was not completed in 1988. Issues that most concerned the industry were still regulatory costs and possible tax increases for mining. The possible revision of the Mining Law of 1872 became a major issue during 1988 and appeared headed for considerable contention in 1989. Regulatory concerns remained the same: controls on acid rain, ground water, and mine waste. Clean air legislation also was expected to be an important issue. The summer's heat wave and drought in the nation's farm belt added to the already growing concerns of global warming.

Equipment Sales

The value of shipments by the U.S. mining machinery industry, measured in constant dollars, rose more than 3% in 1988 above its 1987 level. Comparatively high levels of industrial production and of investment in capital equipment in the United States helped stimulate both mine production and sales of mining machinery. U.S. exports of mining machinery ran about $300 million, a 10% increase over 1987 levels. A lower exchange rate for the U.S. dollar made U.S. suppliers competitive with those in other mining machinery producing countries. U.S. imports of mining machinery, again affected by the lower valued dollar, grew about 2% to $240 million. This contrasted sharply with the situation in 1987, when imports of mining equipment rose 26% above those of 1986.[3]

GOVERNMENT ACTIONS

Statutory and Regulatory Changes

Coinage.—The United States Mint authorization bill for the fiscal year (FY) ending September 30, 1988 (Public Law 100-274), included a "Buy American" provision. The bill required Mint procurements to favor U.S. bidders over the producers and suppliers of Canadian goods and services. The bill was, in part, in reaction to the Canadian Mint's partial Buy-Canadian procurement procedures. The U.S. bill excluded gold and silver from the Buy-American requirement, but it presumably would apply to nickel, copper, and zinc produced in Canada. Certain language in the new law, plus added comments and instructions from the President, reduced the likelihood of substantial conflict with Canada or the Nation's international obligations. The law permitted the Treasury Secretary to waive the Buy-American provision when he determined that compliance would be inconsistent with the public interest or would be unreasonably costly.[4]

Two acts of Congress provided for the minting of commemorative coins. One law honored Congress itself and was called the Bicentennial of the United States Congress Commemorative Coin Act (Public Law 100-673). It called for up to 1 million $5 gold coins, up to 3 million $1 silver coins, and 4 million half-dollar clad coins. The half-dollar coins would be legal tender and would be considered numismatic items. The Secretary of the Treasury could obtain the needed silver only from Government stockpiles. The other coin statute, the Dwight David Eisenhower Commemorative Coin Act of 1988 (Public Law 100-467) authorized 4 million $1 silver coins of 90% silver and 10% copper. These coins had the same bullion source restrictions, and were also legal tender and numismatic.

Trade.—The Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418) was enacted to enhance the competitiveness of U.S. industry. This comprehensive act included provisions to increase exports; institute international financial policies; improve the nation's technological capabilities; require evaluation of the impact of new legislation on the competitiveness of the United States; and modify customs and tariff laws, and education, training, patent, and transportation practices. The act required further studies and coordination by a 12-member Competitiveness Policy Council to identify problem areas in technology as they pertained to commercialization and to provide policy recommendations to the Congress, the President, and the Federal agencies. The act also made both permanent and temporary changes in tariffs on many goods, including iron and steel slab and tungsten ore. It required that U.S. tariff schedules use the nomenclature of the internationally established Harmonized System, effective January 1, 1989. As part of this act, the National Bureau of Standards of the U.S. Department of Commerce officially became the National Institute of Standards and Technology (NIST). In addition to its existing duties, NIST was to help industry develop technology and procedures to improve product quality, to modernize manufacturing processes, and to ensure product reliability, manufacturability, functionality, and cost-effectiveness. Additionally, NIST was to facilitate, throughout the United States, more rapid commercialization of products based on new scientific discoveries, especially by small- and medium-sized companies.

Another provision in the trade bill called for the Federal Government to use the metric system as its preferred system for weights and measurements. It required Federal agencies to use the metric system in terms of trade and commerce, especially in regard to procurements, grants and other business-related activities, so long as the conversion did not harm the competitive position of U.S. industrial interests. The act also required the Federal Government to encourage and help American industry convert to metric measurements. However, the law, which was to be implemented by 1992, stopped short of requiring private industry or state and local governments to convert to the metric system in their own dealings. The United States was one of three of the world's industrialized nations that had not converted to the metric system. Burma and Liberia remained on the pound-and-foot system. World trade was increasingly being geared toward the metric system of measurement. As stated in the act, industry in the United States was often at a competitive disadvantage when dealing in international markets because of its nonstandard measurement system. U.S. industry was sometimes excluded from trade when it was unable to deliver goods which were measured in metric terms. Additionally, the European Community was considering a ban on imports not based on metric measurements after 1992.[5]

In September, the President signed the United States-Canada Free Trade Agreement (FTA), which would eliminate all tariffs and most nontariff barriers between the two countries by 1999, and thereby create the world's largest open market. The FTA established criteria to provide free trade in energy, eliminate barriers against trade in services, protect intellectual property, and prevent production standards from being a barrier to trade. It also established rules of origin to prevent third parties from benefiting from the FTA. One key issue that remained unresolved was a definition of "unfair subsidies," which both sides agreed to negotiate over the next 5 to 7 years. Opposition to the FTA from the Canadian Parliament's minority parties was quite strong. The Liberals and the New Democrats threatened its adoption when they called for a national election, which was held in November. However, the Progressive Conservative Party remained in power and approved the agreement before yearend. In 1987, U.S.-Canadian bilateral trade totaled $161 billion. The expansion of trade was expected to generate 5% higher growth for Canada and up to 1% higher growth for the United States by the end of the century. For the United States, that would translate into 750,000 jobs and $2.4 billion in exports.[6]

National Defense Stockpile.—Responsibility for the National Defense Stockpile (NDS) was transferred from the Federal Emergency Management Agency and the General Services Administration to the Department of Defense (DOD). Within DOD, the Defense Logistics Agency was to handle the buying, selling, and storing of NDS materials. DOD planned to streamline the stockpile and to place emphasis on defense needs first and industrial needs second, and also on materials that could quickly be manufactured into "end products" or usable material. The Bureau of Mines and other agencies were to cooperate with the DOD in developing an annual materials plan for Congress, detailing the materials to be bought and sold.

The National Defense Authorization Act of 1989 (Public Law 100–456) authorized the stockpile manager, in FY 1989, to dispose of 19 materials determined to be in excess of stockpile requirements. Value of the materials disposed of was to be limited to $180 million. The same amount was to be spent to purchase and upgrade materials, with at least $20 million to be obligated for new upgrade programs.

The Treasury and Postal Service appropriations bill for FY 1989 (Public Law 100–440) authorized the sale of 2.5 million troy ounces of NDS silver. The bill directed the Treasury Secretary to reduce the amount sold if written determination was submitted to Congress "that such a sale severely disrupts the domestic market for silver." More favorable to the mining industry was the Federal Government's continued reduction of silver in the NDS by its successful silver coinage programs. Nearly one-fourth of the silver stockpile had been consumed since March 1986. By using the stockpile for its commemorative coins, the Government avoided competing in the domestic marketplace, reduced the carrying costs of the metals, and generated profits that went toward reducing the national deficit.[7]

Research.—The President signed the National Superconductivity and Competitiveness Act of 1988 (Public Law 100–697) into law in November. This act was meant to enhance the Nation's economic competitiveness and strategic well-being by promoting the development of commercial, military, and space applications for superconductivity. The bill established a nationwide program for the Federal Government to collaborate with the private industrial and academic sectors in developing the applications as rapidly as possible. Because full commercial exploitation of the new superconductors was expected to require 10 to 20 years, the act called for long-term Federal commitments to research and development programs. Under the new law, the White House's Office of Science and Technology Policy was to establish a 5-year "national action plan" to research and develop new high-temperature superconducting materials, to establish appropriate goals and priorities, and to monitor those efforts annually in cooperation with the National Critical Materials Council. Agencies to be included in this work were NIST, the Departments of Energy and Defense, the National Aeronautics and Space Administration, and the National Science Foundation. The President was to establish a program of international cooperation that would include the exchange of basic information and data, as well as the development of international standards for the use of these materials.

The Mining and Mineral Resources Research Institute Act of 1984 was reauthorized by the Amendments of 1988 (Public Law 100–483) through the end of fiscal year 1994. The Mineral Institute program encouraged State support for basic research in mineral sciences and engineering through allotment grants to research-oriented schools of higher learning. Allotment grants were based on two State or non-Federal dollars for each Federal dollar contributed. The Office of Mineral Institutes of the Bureau of Mines was the administrative mechanism for channeling funds to the academic departments. New grants of up to $400,000 were made annually on the basis of proposals received from each institute and approved by the Office of Mineral Institutes. In 1988, 32 institutions were eligible to participate in the program. In addition, research grants totalling $15,000,000 were included in the program for joint Government-industry-university cooperation. To facilitate such cooperation, five Generic Mineral Technology Centers were established in the early 1980's. The centers focused on research in mine systems design and ground control, comminution, pyrometallurgy, mineral industry waste treatment and recovery, and respirable dust. Two additional centers, which dealt with marine mineral technology and mine land reclamation, were being formatted during 1988. Each center had at least one lead institution to coordinate research activities in that area, provide for annual seminars, and operate reference centers for disseminating results of the technology center's particular area of research.

Taxation.—The Technical Tax Corrections Act (Public Law 100-647) provided some relief to bulk users of diesel fuel. The act included an exemption from the excise tax for off-road business users of diesel fuel purchased after December 31, 1988. After registering with and getting approval from the Treasury Department, exempt users could purchase diesel fuel tax-free from a qualified producer. Another provision of the act extended the research and development tax credit through the end of 1989. It gave business and industry a 20% credit on research and development expenditures.[8]

Mining Hall of Fame.—The National Mining Hall of Fame and Museum in Leadville, CO, won approval in the closing days of Congress for its Federal charter, which was a provision of Public Law 100-655. Federal charters make an organization's articles of incorporation law, and charters are limited to groups organized and operated in the public interest. Congress issued its first charter in the 19th century, and since then had granted them to about 50 other groups, including the American Red Cross and the Boy Scouts of America. Upon completion, the facility was to include a hands-on research center and museum, a Hall of Fame honoring the mining industry's pioneers, and a meeting facility for national and international mining and environmental symposiums. An initial 25 individuals who were important to the birth and growth of the U.S. mining industry were inducted into the National Mining Hall of Fame. These included inventors of important mining techniques and technologies, mine developers, and people who in other ways were instrumental in the progress of the domestic mining industry. Future members were to be honored annually. The list of inductees, some of whom lived in the 19th century, included President Herbert C. Hoover, Herman Frasch, Daniel Guggenheim, George Hearst, and Daniel C. Jackling.

Court Rulings

Mining and Processing Waste.—During the summer, the U.S. Circuit Court for the District of Columbia upheld a 1986 Environmental Protection Agency (EPA) decision that waste generated in the mining and milling of nonfuel minerals did not constitute hazardous waste under the terms of the Resource Conservation and Recovery Act (RCRA). An American Mining Congress representative estimated that the ruling covered more than 80% of the mining industry's waste. The situation was different for mineral processing wastes. In a related ruling, the same court ordered EPA to discontinue the exemption for six wastes from the smelting and refining of aluminum, copper, ferroalloys, lead, and zinc. These wastes would now fall under RCRA subtitle C on handling, storage, and disposal standards. EPA also was ordered to complete a study of mineral processing wastes and to reinterpret the Bevill Amendment as it applies to smelting and refining wastes. The Bevill Amendment, enacted in 1980, exempted mining and mineral processing wastes from regulation as hazardous wastes until they could be studied. Initially, EPA had listed only 15 wastes that it felt met this criteria. As a result of public comments, the tentative list of exempted wastes had grown to 46 by the end of 1988. The wastes remaining in the Bevill exclusion would be studied and included in a report to Congress. This was to be followed 6 months later by a regulation determining and deciding the regulatory fate of these wastes. Mineral industry processing wastes not falling under the Bevill exclusion would be subject to regulation under subtitle C after the rule was finalized.[9]

Public Land Use.—A U.S. District Court judge for the District of Columbia dismissed a suit by the National Wildlife Federation (NWF) that had prevented the Department of the Interior from opening more than 180 million acres of public land to multiple-use management for over 3 years. The lawsuit had challenged the Bureau of Land Management's (BLM) procedures for terminating land classification and revoking withdrawals. In recent decades, BLM had placed special restrictions on use of public lands until a comprehensive statute was adopted for long-term management of the lands. After careful review, using the Federal Land Policy and Management Act of 1976, BLM determined that the restrictions were no longer needed on the 180 million acres in question. It then terminated a number of classifications and withdrawals, returning the lands to multiple use. In dismissing the suit, the judge ruled that the NWF lacked "standing" because it failed to show informational and procedural injury, as well as environmental harm to its members. Environmental groups had hoped to keep the lands tied up until they could secure passage of Federal laws designating much of the property as wilderness or placing some restrictions on its use.[10]

Indian Rights.—In a suit brought by several Indian tribes in northwestern California to halt the upgrading of a logging road proposed by the U.S. Forest Service, the U.S. Supreme Court ruled that religious objections by American Indians could not halt development on Federal lands. The court ruled that even if development would virtually destroy the Indians' ability to practice religion, the Constitution did not provide a principle that could justify upholding the Indians' claim that it would violate their First Amendment rights to exercise their religion. The ruling was likely to set a precedent for a number of mining projects in New Mexico, Arizona, Nevada, and Montana that also had been challenged and held up by other Indian groups.[11]

EXPLORATION

Mineral exploration in the United States showed some signs of renewed interest during 1988. The pursuit of gold and other precious metals remained strong and even increased. Some commodity prices that had revived in 1987 remained healthy in 1988 and were joined by others in a generally healthier market. The overall downtrend in exploration of recent years appeared to have bottomed out, with a small awakening of prospecting interest. Exploration for platinum was increasing. Small quantities of platinum had been showing up in some copper concentrates, which lead to exploration efforts in some copper porphyry environments. Some interest was shown in exploration for lead, zinc, tungsten, and tin, but gold continued to receive the most attention. Its activity even increased above the relatively high 1987 levels.

Seismic Analysis

The integration of shallow reflection seismic data into the drill-hole planning phase of mineral exploration can help reduce overall exploration costs, because boreholes can be sited in the most geologically advantageous areas, thereby reducing the number of boreholes. Terrahunt Geoscience Ltd. of the United Kingdom developed the SRS,[12] a new shallow-reflection seismic system to provide a rapid, economical means of distinguishing geological structures within the first 100 meters of the surface. Environmental impact was said to be minimal, and the system was relatively quiet. The preferred energy source was the Buffalo gun, using 12-gauge blank cartridges in shotholes drilled to a depth of 1 meter with portable hammer-rotary hand drills. A computer logged the seismic data on floppy disks, and the output was produced in the form of seismic cross sections showing major subsurface reflectors. Under good field conditions, 600 to 800 meters of continuous profile data could be completed per day.[13]

Trace Gas Detection

Borehole.—New prospecting methods of a similar nature were under evaluation in Sweden and Czechoslovakia. The methods involved testing for what one company, Boliden Contech of Sweden, called "geogas." The techniques were based on the hypothesis that some underground metallic elements rise to the Earth's surface in gaseous form, not just as particles in water. The procedure was based on more than 10 years of experimental research and field work by Boliden's prospecting department and the Institute of Physics at Lund, Sweden. Boliden exploration crews used an inverted funnel with a membrane at the small end to trap microflows of gases ascending to the surface. Analysis of elements on the membrane would help indicate areas of anomalously high base metal and gold content. Boliden developed the geogas technique mostly to achieve a more thorough examination of the Skellefte ore field in northern Sweden at depth, while optimizing expensive drilling. The company claimed success in locating copper, lead, and arsenic mineralization at a mine in Skellefte. Drilling in a prospect in Saudi Arabia confirmed gold mineralization where several other geophysical methods had failed to define the area of mineralization. Gold was associated with arsenic in the drill cores and cuttings, so the geogas method was used to detect arsenic. Boliden said the ascending arsenic-containing gas helped indicate the location and extent of the ore body.[14]

Geofyzika Brno, a Czechoslovakian company, was doing similar work on a gaseous mechanism of elemental transport. In addition to prospecting for metals, especially polymetallic ores such as copper, uranium, nickel, and molybdenum, Geofyzika Brno's "atmogeochemical" methods were applied to some nonmetallic deposits such as fluorite dikes. The company said that the advantage of its method was not only its time and economic effectiveness but also its ability to penetrate to considerable depth.[15]

Airborne.—Another gas detection method was undergoing airborne testing with the expectation that it could be applied to mineral and hydrocarbon exploration and to pollution detection. Skyborne Exploration Canada Ltd.'s Skylar system was an advanced laser-radar system that utilized differential spectral absorption to detect a wide variety of trace gases. Many different types of mineral deposits emit a characteristic vapor that is detectible. For example, hydrogen sulfide can indicate massive sulfide deposits, and mercury or iodine vapor can indicate some base and precious metal deposits. Ground-based surveys using sensitive instruments such as gas chromatographs and mass spectrometers had already proven useful in some initial discoveries of mineral deposits and were more sensitive than the airborne laser sensor. However, the airborne technology could make possible the exploration of larger areas faster, more efficiently, more comprehensively, and more economically than ground-based surveys. Airborne gas-concentration measurements would also extend the range of such surveys into remote, inhospitable terrain such as the Arctic environment. In the Skylar system, two laser beams, one for the targeted gas and the other a control beam, were set at selected frequencies and transmitted from the aircraft to points on a line just above the Earth's surface. The beams reflected off the ground and were received back on the aircraft. If present, any of the gas to be measured would absorb some of the first laser beam. The difference in the intensity of the two separate pulses would indicate the concentration of the target gas present. Skylar was designed to perform up to 200 measurements per second when flying at an altitude of 400 feet. At a speed of 80 miles per hour each measurement would be performed every 6 inches, allowing small anomalies to be detected. The potential mineral deposits would be displayed in real time on a video display for the system operator and recorded in a computer for further processing.[16]

Organic Analysis

Bacterial Concentrations.—Two innovative and relatively inexpensive exploration techniques, initially being used for gold exploration, were being pursued: one by Cereus Exploration Technologies Inc. of Nevada, among other companies, and the other by a scientist from the Geological Survey of Canada (GSC) in Ottawa. Cereus Exploration measured the concentrations of *Bacillus cereus* bacteria in the top 6 inches of soil. A high *B. cereus* bacteria count indicates nearby metals, because soil fungi are fighting off the toxic effects of the metals. The fungi protect themselves by producing penicillin, which kills off most bacteria. However, *B. cereus* is resistent to penicillin, so high counts of this organism could indicate the presence of metals. Soil samples were chemically analyzed, after which a computer was used to put all the soil information together into one analysis. Additional tests could narrow the possible types of metal present. Genprobe Technologies of Vancouver, B.C., Canada, began prototype development of Gold Probe, a chemical probe instrument for measuring the quantity of *B. cereus* spores in soil.

Plant Absorption.—At GSC the tips of tree-top branches were being analyzed. A geologist, using garden snips and a helicopter, cut new tree growth to determine the probable gold content of the soil where the tree grows. If the method proves to be useful, it would be of particular value in areas of rough terrain where ground access is difficult.[17]

Instrumentation

Surveying Aid.—The hand-held Brunton pocket transit was redesigned after remaining basically unchanged since its introduction over 90 years ago. The new pocket transit, the Com/Pro 90, could be used as the original one was. It also had numerous new features, according to the Brunton Co. of Riverton, WY. It was designed to take advantage of the latest in state-of-the-art magnetics, mechanics, materials, and manufacturing. The new transit had a single high-energy, rare-earth magnet, replacing a two-magnet system that sometimes caused pointing errors. Also, the instrument could be used over a wider range of latitudes without having to recalibrate the needle. The company claimed that the hand-held transit was made of tough composite materials that were more resilient than earlier metallic versions, and that they were completely nonmagnetic, thus eliminating any related pointing errors. In addition, the more fully waterproofed instrument could be opened for repair or calibration without destroying the parts. The new transit was claimed to be accurate to 0.5° and weighed 9 ounces. As before, it could be applied to a variety of functions throughout the life of a mining operation, including rough surveying, claim staking, dip and strike measurement, preliminary mine mapping, underground surveying, and mine reclamation.[18]

Computers and Software.—Appropriate software for the computer operations of mine engineering staffs can help companies increase productivity and improve a mine's overall performance. The Eastern U.S. Exploration unit of Chevron Resources Co. successfully used Techbase, a flexible, integrated data base management system for personal computers, developed by Minesoft Ltd. The developer claimed the system had no practical limit to the amount of data it could store, retrieve, and manipulate. Techbase included a broad spectrum of application packages designed to meet the needs of all phases of mining industry work. Chevron chose it because of its exploration capabilities and its flexibility to solve problems associated with data base management. The company used the software primarily on massive sulfide projects that required both general exploration and ore-reserve estimation capabilities. Chevron personnel entered general data from the laboratory and geophysical data from the field via a modem and loaded it into the Techbase system. They then generated summary statistics, histograms, and cumulative frequency plots, and plotted geochemical and geophysical data as both profiles and plans. The system included a contouring package that was useful for data evaluation. It was also effective on more advanced projects using drill-hole data. Following entry of all drill and rock-type data, the system would define the top and bottom of the rock or ore types, construct a block model, and insert surfaces. Proper descriptive values were added, resulting in grades for individual blocks, by ore type, within the block model. An optimized pit could then be drawn based on the recoverable values within the blocks. The use of such a system allowed Chevron to use fewer drafting specialists in doing more work with broader application. It also gave the staff time to do more statistical work than had been done in the past.[19]

The combination of lower cost personal computers and the growing field of inexpensive software gave an increasing number of field geologists, mining engineers, and other mine personnel more access to the advantages of computer analysis and processing in their jobs. Two basic categories of software were available. Public-domain software was free to copy and could usually be modified by the user to suit his needs. The author often did not maintain or update this type. A special category was those programs created with the support of public money. These included programs written by employees of the U.S. Geological Survey, other Government organizations and Government contractors. Another category was shareware or user-supported software, which was not free but was generally relatively inexpensive and was more likely to be current and be supported by the author. Programs were available for general applications such as data base management, mapping, statistical analysis, and graphics, as well as for special disciplines such as geology, hydrology, hazardous-waste management, geophysics, geological engineering, and coal seam and ore body modeling. Sources of inexpensive geological and engineering software were electronic bulletin boards, some professional organizations, the Federal Government's National Technical Information Service, computer and geological magazines, mining departments at universities, and some small companies that had emerged over the past few years.[20]

Core-Drill Control.—Adjustments in the pathways for core drilling are common, more so as the hole deepens, whether directing a drill in a specific direction or redirecting a deviated one back on course. Historically most hole corrections, both major and minor, have been made with deflection wedges. However, wedges have drawbacks: They are costly, are not always accurate, create doglegs, and can get dislodged and break the drill equipment as well as threaten loss of the hole. The Navi-Drill was a relatively new directional-drilling tool that was a redesign of similar larger-diameter devices used successfully in the oil industry. Navi-Drill, a hydraulically driven downhole motor and drill head, could be used to drill in both vertical and horizontal directions to a precise location, according to the developer, Boyles Bros. Drilling Co. of Salt Lake City, UT. The device required no wedges at the "kickoff" points and achieved a smooth transition in shifting the course for the ore drill. Navi-Drill drilled off a 50- to 75-foot cement plug and could develop a continuous arc at the rate of 5° per 100 feet to get the drill hole on target. Powered by circulating fluids, the downhole motor drove the bit without drill-rod rotation. A spring-loaded deflection shoe acted as the directional control and delivered a constant side pressure to the drill-hole wall, forcing the bit to sidetrack or move in the opposite direction. As the drill advanced to the desired deflection, its progress was monitored by closely spaced survey tests. When the deflection was accomplished, the smaller-sized drill rod and Navi-Drill were removed and the hole was reamed out to its original diameter to continue coring. Navi-Drill bits had a highly variable down-hole life that depended on drilling conditions.[21]

X-Ray Analysis.—A new approach to gold assay, aimed at replacing the traditional, expensive fire assay technique, was developed in the United Kingdom by Interlect Instruments Ltd. The Aztec gold ore analyzer employed the X-ray fluorescence technique, whereby gold "K" X-rays were excited by high-energy X-rays. The system comprised a custom-designed automatic sample changer; state-of-the-art electronics; a high-sensitivity, low-noise detector; and a standalone fast computer. The technique was nondestructive, so repeat measurements could be made any time. Sample preparation, done by volume and the use of an automatic density-correction component, required no weighing. The Aztec analyzer was claimed to be the first viable alternative for high throughput applications. It could measure gold in an ore from zero to 100,000 grams per ton with a precision of about one-half gram in 100 seconds or to one-quarter of 1 gram in 400 seconds. Up to 528 samples could be loaded into the instrument, which then automatically could analyze each sample in sequence, unattended until finished. The benefits of the Aztec over fire assay included reduced sample handling, reduced method errors, fast turnaround time, and greater safety for workers. Interlect claimed that overall costs were less because Aztec eliminated some chemical and high electric power usage and it reduced labor, as there was no furnacing, weighing, or calculating. In addition to requiring fewer personnel, the system had a lower potential for hazardous emissions.[22]

DEVELOPMENT

The rate of development of new mining properties, other than those of gold, remained somewhat slow in 1988, similar to that of 1987. Expanded operations and modernization of existing properties, reopening of mines closed during the last several years, and redevelopment of previously mined properties took precedence over the development of new mining ventures. Gold again was the exception in all situations; about 36 gold mines, many brand new, began production in the

United States in 1988. Mines came online in Arizona, California, Colorado, Idaho, Montana, Nevada, South Carolina, and South Dakota.

East Coast Gold Mining

Development work was completed on the Ridgeway Mine in South Carolina, and its first gold was poured in early December. This joint venture of BP Minerals America and Galactic Resources Ltd. consisted of two gold deposits with a total of 56.2 million tons of ore and an average of 0.032 ounces of gold per ton. The ore bodies were well suited to open pit mining with low waste-to-ore stripping ratios, averaging 0.74:1, and minimal pre-production stripping. With a 15,000 ton-per-day planned throughput, the Ridgeway project would be the largest gold mill in the Western Hemisphere. Conventional carbon-in-leach processing technology was being used, and management estimated that the average gold recovery would be about 82%. BP said that the Ridgeway project would help revive South Carolina's heritage as a gold mining state, noting that the discovery of Carolina gold in 1799 sparked the first American gold rush. The Ridgeway Mine was one of a handful of east coast gold mines and was expected to produce an average of 135,000 ounces of gold per year during its 10- to 12-year life.[23]

Habitat Preservation

The Colosseum gold mine in California went into full production and by the end of the year was producing at an annual rate of about 70,000 ounces of gold and 30,000 ounces of silver. The operator, Bond International Gold Inc., reported ore reserves to be 10.5 million tons, averaging 0.062 troy ounces of gold per ton. At the projected processing rate of 1.2 million tons of ore per year, the mine had an estimated life of 9 years. Bond met a number of special challenges to get the mine on line, because Colosseum was located in the environmentally sensitive area, East Mohave National Scenic Area. This area was designated as an "area of critical environmental concern," because wilderness study areas bordered the property on the north and west sides. Many mitigation measures were set forth in the mining permits and, with the help of knowledgeable consultants, Bond carefully designed the operation to have minimal impact. Additionally, the company added a full-time environmental specialist to the staff.

Protecting the environment continued to be a very prominent issue in the United States, and almost all parties concerned agreed that the environment would receive more attention in the future. The bulk of the mining industry appeared to be doing its work responsibly. In general, its representatives said that those with strong environmental concerns should be reasonable and realistic concerning the protective measures that can be taken. Bond responded to the many concerns about the Colosseum site and took many actions to ensure it would cause a minimum impact on all affected lands. Among the measures taken were the protection of the desert tortoise's habitat and of the migration routes for the bighorn sheep. Bond built a special watering fountain for the bighorn sheep and a watering trough and valve system for other local wildlife. The tailings pond was fenced to keep animals out. The existing public access road was in a special ecological area, so it was closed and vegetation was planted to encourage the return of wildlife. The new road was oxidized (treated) to help it blend in with the area and appear to be an old road. It was also the only corridor to the mine for access, water, and power. All structures were painted tan colors or otherwise made to blend in with the desert landscape as naturally as possible. Birds were provided safe perches on all utility poles, and extensive dust-control measures were employed throughout the whole operation, from the access road on through the beneficiation circuit. Ground water quality was monitored through several downstream test wells, and some local animals were tested for lead levels in their tissues. Three archaeological sites were discovered and, subsequently, properly excavated. All topsoil was to be continually stockpiled for future reclamation.[24]

Alaskan Development

In Alaska, mine development spending in 1987 had quadrupled to $100 million, its highest level ever. About 90% was spent on the Red Dog zinc mine north of Noatak in northwestern Alaska and the Greens Creek silver-gold mine near Juneau, Alaska. Red Dog, scheduled for production to start in 1989, was the largest known unmined zinc reserve in the world, and second only to the original Broken Hill deposit in Australia. At Greens Creek, production was also scheduled to start in 1989. It was projected to be the largest silver producer in the United States, and mine concentrates had been presold to smelters in Europe and Asia.[25]

Computer-Aided Design

Mine design and planning methods and techniques had been greatly influenced by computer technology over the last 20 years. Computerization of such related tasks had significantly reduced the time required to complete projects and also reduced error rates, especially for repetitive operations. The changes allowed the mining engineer more time to spend on the more productive, conceptual aspects of mine design and planning. The computer had become an essential, flexible tool, not only for the mining engineer, but also for the geologist and the metallurgist. Few if any mines are now designed without the assistance of a computer at some stage. The personal, or micro, computer was available to most professionals and was becoming the system of choice as it became more powerful and its network capability grew. Although computer hardware and software were evolving fairly rapidly, the systems were upwardly compatible to a large extent. Therefore, current purchases would not soon become obsolete. Software, not equipment, was the key to computer-aided design and planning, and the choices available to the engineer were wide and varied. Sometimes the challenge lay in choosing the most appropriate application for a particular job. One example of a comprehensive system was NUmine, which was undergoing development at the University of Nottingham in the United Kingdom. Versatility was one of the goals for the modular structured system, one in which different aspects were separately written, but integrated so that the modules interacted. It could be tailored to meet the requirements of any given combination of geology and mining methods, making it potentially useful for any situation. All modules were linked via a relational data base system that allowed for flexible retrieval and manipulation.[26]

A new generation of computer software, using enhanced three-dimensional (3–D) modeling techniques, permitted accurate graphical representation of mining activities, ranging from geological interpretation of ore deposits to mine design and operation. LYNX Geosystems of Vancouver, BC, Canada, the developer of one system, claimed that it provided a level of accuracy, understanding, and economy of operation not available before to the mining industry. It was designed to include working with complex, discrete ore deposits. The LYNX technique for "three-dimensional solids modeling" represents surfaces, volumes, and volumes of intersection; traditional 3–D block modeling was used to represent the variation of grades within the volumes enclosed by surfaces. In this application, 3–D block modeling was used to represent the spatial ore distribution. Three-dimensional solids modeling provided accurate volumetric analysis capabilities; hence, tonnage yields could be calculated. It relieved the 3–D block model of the need to approximate surfaces and volumes. Three-dimensional solids modelling was designed to accurately represent geological and mining surfaces, the distribution of volumes within them, and the three-dimensional volumetric intersection of surfaces. Using the new application's surface and volume capabilities, along with the grade distribution capabilities of 3–D block modelling, mine management was provided with greater flexibility in mining operations. Mine design and planning models could be redefined to reflect changing market conditions or alternative mining methods without the overhead of redefining the 3–D-block grade model.[27]

UNDERGROUND MINING

Shaft Lining

A new shaft lining method was initially developed by Foster-Miller Inc., Waltham, MA, for military purposes. Subsequently, Foster-Miller decided to modify it for potentially broader usage in conventional mining development. The system modification was designed to attain lining placement rates of up to 30 meters per hour. It incorporated a continuous, pressurized, slipform that placed a shaft lining made of polyurethane foam, instead of concrete, shotcrete, or welded steel casings as are used in other conventional lining methods. The lining system could be advanced up the shaft, as in a raised bore shaft, behind or separately from the boring machine. Movement and position were initiated and maintained either by its gripper mechanisms, or, where wall rock was stable, by pushing off the freshly laid liner by means of the polymer pumping pressure alone. The equipment was engineered for mechanical simplicity so that the entire operation could be executed by remote control; because of this it was inherently safer than conventional systems for the workers. The slipform and the operating bulkhead were designed to place a 100-millimeter-thick liner within a smooth machine-bored shaft, but the system could adapt to moderate slough zones of unstable shaft wall 75 millimeters deep and still maintain full pressure. Thicker problem areas demanded use of the grippers for movement, and all voids had to be filled with the foam before proceeding on. Some of the criteria that Foster-Miller had to meet were rapid mixing and gel times, low concentrations of toxic fumes, flame retardance, high rigidity, and exceptional toughness.[28]

All-Electric Operation

Inco Ltd. led in technological innovation when it reopened the Crean Hill nickel mine in Sudbury, Ontario, Canada. Management decided to convert Crean Hill to an all-electric operation to achieve lower operating costs than in other Sudbury area mines. The company claimed that using state-of-the-art machinery that could be controlled by programmable computers provided better working conditions and reduced the physical effort required of the miners. While diesel-powered units cost less, the electric machinery involved lower capital costs for ventilation and air conditioning systems; Inco stated that the higher capital cost also would be offset because electrically powered equipment typically costs less to maintain than diesel. Additionally, electric motors produce not only no exhaust gases or particulate emissions but also generate less heat, reducing the need for circulation of cooled air within the mine. Power for drilling operations was produced by electrohydraulic and electric power units, and ore was hauled by electric load-haul-dump vehicles (LHD). The LHD's ran by a cable system in development drifts and a trolley wire system in the main drifts. A long conveyor system could not be used because the drifts in the mine were not originally designed to facilitate them. The surface control room operator could monitor (partly by video displays) and control ore transport functions, ventilation, mine pumps, the sandfill plant, and radio communications.[29]

Drilling Equipment

Fully hydraulic machines for diamond drilling underground have received more widespread acceptance in recent years. Improved reliability, greater operator familiarity with the equipment, and appropriate incentives to operators to achieve the safety and cost gains that hydraulics deliver all helped increase the popularity of these machines. Electrohydraulic equipment is generally considered safer, and less costly to operate, than pneumatic systems. All-hydraulic machines with mechanized rod tripping (the passage of drill-string equipment in the borehole) offer greater safety in round-tripping operations, are inherently quiet, and can be remotely operated. Additionally, the work station is healthier because it is free of mist from compressed air. The Homestake Mine in South Dakota has used hydraulic diamond-core drilling equipment in the mine's exploration program for several years. Two all-hydraulic LM37 drills, developed by Longyear Co., Minneapolis, MN, were used. Homestake officials found that the drills had greater depth capacity than the company's screwfeed machines, reasonably low downtime and spares cost, inherently safe rod handling, and high productivity. On holes of 120 meters or more, the LM37 hydraulic drills produced approximately twice as much footage as the screwfeed drills, mostly because of greater power at the chuck, in the same period of time. Longyear claimed that downtimes of less than 5% over a year of operation were common with users other than Homestake. Homestake used one of the drills for shorter and more numerous holes, and this caused above-average wear and downtime. However, the company's No. 1 drill was down only 3% of the time in its 3 years of use. Faster and safer moves and set-ups were possible, especially with the help of certain accessories. Electric power was more economical to use than air power, and an experienced driller could hold down diamond-bit replacement costs.[30]

Continuous Miners

Consolidation Coal (Consol) was one step closer to a true continuous miner with the development of the Satellite Miner. The miner was equipped with a built-in roof bolter that operated simultaneously with the miner and was used in conjunction with a mobile continuous conveyor of Consol's own design, called the Tramveyor System. On Consol's Satellite Miner, the bolters were mounted on traversing sliding beams and connected to the continuous miner by another beam, giving the bolters independent movement. Some previous models of integrated miner-bolters had to share power with the mining machine, so the two operations were performed sequentially. The power problem was solved by converting the continuous miner from hydraulic to electric, thus freeing a power source for the bolters without adding more or larger pumps and motors. The miner advanced 4 feet while two bolts were driven home, and this process could be repeated for a distance of up to 200 feet. The Tramveyor System was made up of 270 2-foot-long, overlapping hinged sections. Hydraulic jacks, operated by four 30-horsepower motors, were positioned on each side of each section, for raising the unit to the conveyor mode and lowering it to the tramming mode. With a 20-foot turning radius, the unit could handle 90° corners. In a trial run done at Consol's Bailey mine in southwestern Pennsylvania, the Satellite Miner lifted production from 500 tons of coal per shift to 575 to 600 tons. With the Tramveyor System added, average shift production increased to as much as 750 tons. Consol further claimed that the Tramveyor had 90% availability at the Bailey Mine. A second test was planned with a 720-foot version behind the Satellite Miner in a mine in Ireland.[31]

Continuous miners are common in coal mines but thus far have seen limited use in hard-rock applications. Dresser Industries Inc.'s Jeffery Div., Columbus, OH, in cooperation with Cleveland Potash Ltd. of the United Kingdom designed and produced a new fixed-drum continuous miner, the 1060HP, for both hard rock and coal. The continuous miner was initially targeted for use in Cleveland's Boulby Mine in Cleveland, England. A major design objective was the ability to produce 2 million metric tons of potash between major overhauls. The company designed the miner to operate at to 4,160 volts to enable it to provide high productivity in hard-cutting, high, and thick-seam applications. The 1060HP miner had a simple, low-pressure hydraulic system with one pump, and the entire system was powered by electric motors. Dresser claimed that the miner's crawler-mounted design achieved excellent traction and, consequently, greater productivity than other continuous miners in its 6- to 15.5-foot-high cutting range. The transport speed of the 1060HP was 85 feet per minute, compared with the 45-foot-per-minute average of other, similar machines. The main frame had no flat areas to allow material buildup, and the cutting-head assembly design allowed cuttings to drop through. The operator cab was ergonomically designed for maximum visibility and comfort. Sound-deadening materials and a 36-millimeter-thick, bulletproof glass windscreen were used in the cab's construction. Additional 1060HP's were to be built for U.S. mines, including FMC Corp.'s trona mining operations in Wyoming.[32]

Longwall Cutting

The Bureau of Mines tried some fairly simple modifications to longwall shearer machines at several coal mines with very positive results. The rotation of the shearers was reversed from the conventional roof-to-floor rotation to floor-to-roof rotation. The results showed improvements in product size and tram speed and reductions in released gas and respirable dust. Despite many changes in shearer design and face hardware over the years, conventional drum rotation direction had remained unchanged. Most results from the tests were positive, and most problems encountered were solved. Applicability and the degree of benefit derived from using the technique was partly dependent on geological and operating conditions. Reverse drum rotation was suitable only for medium- and thin-seamed deposits. In thick seams of 7 feet and more, large slabs of rock could be caught by the drum and thrown over the body of the machine. The hazard potential depended upon the clearance between the top of the machine and the roof. Benefits found included an 18% average decrease in coal fines, a 13% average increase in tram speed (production rate) during cutting, a 40% average reduction in dust levels at the machine operator's position, and a 70% reduction in respirable quartz dust levels downwind of the shearer. Shearer modifications to reverse rotation usually cost a minimal amount, mostly for the labor involved in changing the cutting drums so that they would cut in the opposite direction.[33]

Bolting

Cable Bolts.—An unusual bolting machine, the Tamrock EDH 695 cable bolting machine, was one of several innovative additions to Europe's largest zinc-lead mine, the Tara Mine in Ireland. No other manufacturer offered such a product, and it was only the fifth in operation anywhere in the world. The EDH 695 drilled holes and introduced cement grout, and then fed steel cable into the holes from a reel on the machine. The dry cement was mixed with water on the machine, because the water/cement ratio was critical for successful bolting, and the cement was introduced into the hole through a flexible reeled hose. At the Tara Mine, twin 15-millimeter-diameter, seven-strand steel cables were inserted in each hole. Each cable had a yield strength of 25 tons. Twin cables were used rather than one cable of larger diameter because thin cable is easier to reel. The main purpose of the cable bolter was to lend support to the hanging wall, or in the vernacular, "stitching" it. This new machine generally reinforced the strata to a depth of 17 meters but could go as far as 25 meters, and if necessary 40 meters. The mine's previous equipment had a depth limit of 20 meters.[34]

Load Measurement.—Bureau of Mines researchers developed an ultrasonic measurement system for roof-bolt load determinations. Torque wrench tests are needed on roof bolts to detect any that are improperly installed or overly stressed or strained. However, these tests can reduce the bolt's anchorage capacity, create potential safety hazards, have limited accuracy, and cannot be used to analyze in situ loads of resin-grouted bolts. The Bureau developed the Bolt Mike, which was capable of determining roof bolt loads without mechanically affecting the bolts. Also, it could be used on resin-grouted bolts. The system consisted of a portable ultrasonic pulse-echo instrument and a transducer to connect the instrument to the bolt. The bolt to be measured needed some special preparation; it had to have a signal reflector, such as a small hole drilled in the end of the bolt, and the bolt head had to be smoothed to allow firm attachment to the transducer. An electrical pulse was sent from the instrument to the transducer, which converted the pulse into a high-pitched sound wave. The time for the sound wave to reflect back to the transducer was used to automatically calculate the bolt length. After a series of these measurements, strain values in the bolt could be obtained, and load, stress, and torque values could be calculated. The Bureau's instrument was capable of correcting for environmental parameters such as temperatures, material properties, and signal amplitude variations. The latest commercial version, the Bolt Mike S-1, automatically calculated stress, load, and torque and could monitor three separate sections of a roof bolt simultaneously. During field testing, highly accurate measurements on resin-grouted and point-anchored roof bolts were achieved. Continuing Bureau investigations were being expanded to include roof truss systems and resin-grouted combination bolts.[35]

SURFACE MINING

Equipment Monitors

Fluids Analyzers.—Proper preventive maintenance of mining machinery helps avoid costly repairs and downtime. In the modern minerals industry the emphasis on maintenance procedures shifted some years back from repair-dominated to "planned maintenance," and has more recently been changing to "condition-based" maintenance. One indicator of machine condition is the metal-particle content in the machine's fluids. One example of a real-time continuous monitoring system was introduced by Haulpak Div., Komatsu Dresser Co., Peoria, IL. Metalert was a magnetic chip-detector system that monitored ferrous metal disintegration in machine fluids on line. The system was designed for use with engines, transmissions, power takeoffs, and any other components that contain gears or bearings running in oil or other fluids. It consisted of a sensor, externally threaded for easy installation into the drain plug of the host machine, and a dash-mounted or hand-held electronic monitor. Metalert measured particle quantity, size, and rate of generation. It had four different sensitivity levels, making it possible to measure the severity of wear, or to monitor components with different norms for metal wear. The mining equipment version monitored up to eight major components simultaneously, and the hand-held unit, with just one channel, was designed for periodic monitoring of stationary equipment such as conveyor and crusher drive gearboxes. One of the first applications was at a major open pit gold mine in southern California. Equipment deterioration was detected in one 85-ton truck's drive gear and another truck's differential before costly major damages could occur.[36]

Component Sensors.—Marathon LeTourneau Co., Longview, TX, developed a microprocessor-based vehicle monitoring-and-maintenance system to help prevent catastrophic equipment failures in the opencast mining industry. The Vital Signs Monitor (VSM) continuously tracked a vehicle's engine, cooling, hydraulic and electrical systems. A remote processing unit (RPU) could scan up to 96 different inputs from sensors on the equipment 250 times per second, in search of out-of-limit conditions. The condition was displayed in plain language on a digital readout as an alarm sounded, alerting the operator to shut down the equipment. All alarm-condition information was stored in the memory of the RPU. The data either could be retrieved for on-site troubleshooting or sent to a remote computer for diagnostic trend or failure analyses and hard-copy printouts. Additionally, the VSM could be linked to a base station via a radio or dispatch system for real-time access to the vital signs of the equipment. In an effort to reduce machine wear and tear and extend vehicle life, Marathon LeTourneau designed its Load Weighing System (LWS) that worked in conjunction with the VSM. Sensors beneath the bed of the truck kept track of the accumulating weight of the vehicle during loading. The devices could detect overloading, which could damage the vehicle, as well as underloading, which would lower production. The LWS could also be linked to a central radio dispatch to give management a precise picture of each vehicle load or collective load totals in real time.[37]

External Guidance.—To increase mine efficiency and gold recovery, Meridian Minerals Inc. planned use of the LaserPlane machine-guidance system at its Royal/Mountain King gold mine in California. The system could be used to control ore and waste loading, establish bench height, and maintain haul-road grades. Surface coal mines in Wyoming's Powder River Basin were using the LaserPlane, which had two main components, a laser transmitter and a receiver. Its operation was simple; the transmitter was set up in an appropriate location within the pit or on the pit rim, the laser beam was focused on the active pit area, and the receiver was programmed to display position information to the operator. For example, the unit could be set to display green or red lights when a machine was digging on or off grade, respectively, or arrows to indicate whether the current digging elevation was too high or too low. LaserPlane could also assist the equipment operator in maintaining ore grade control. After drill samples had been assayed and plotted, elevations of the upper and lower limits of ore zones and lenses could be identified, and the transmitter set up accordingly. As blasted rock was loaded, the LaserPlane display enabled the operator to stay within the top, bottom, and lateral boundaries of the ore zone without need for external flags or marks.[38]

Excavator Drills

A number of rock drills were on the market that could be fitted to excavators, but often the conversion kits were complicated and the transition from bucket to drill wasn't as smooth as would be hoped. Many machines simply did not provide impressive drilling capacity. A new system of this type was introduced by the Swedish company Atlas Copco AB. The company claimed that it overcame both problems. The HDU (hydraulic drilling unit) was intended to complement an operator's existing drilling machines, rather than to be used as a substitute for purpose-built rigs, although Atlas Copco believed it was capable of partially fulfilling this latter function. Changeover was facilitated by a quick-release attachment, and air and hydraulic hoses were fitted with quick couplings. The company said that with some rudimentary training, workers could change the equipment in only a few minutes. The HDU was suited virtually to any 8- to 30-ton backhoe or excavator.[39]

Blasting Control

Responding to a need to make nonelectric initiation systems more reliable, Atlas Powder Co., Dallas, TX, developed a redundant nonelectric blast initiation system that ensured all charges were set off. Redoing misfired sectors of a blast area is not only a safety problem but also costs time and money. The system had multiple signal paths to blastholes instead of the traditional one. This promoted more reliable firing while avoiding the problems caused by cut initiation lines. According to Atlas, unofficial figures gathered from the blasting industry suggested that nearly 10% of all nonelectric shots had misfires. The system consisted of at least two nonelectric initiation paths to each blasthole, and double redundancy was also possible. Five hundred blasts were achieved without any cutoffs in field testing at two major coal mines in Tennessee and a number of gold mines in Nevada. Some 30,000 units were shot during testing.[40]

Continuous Excavators

Two continuous surface mining machines were announced in 1988, one using a drum cutterhead of standard modular components, and the other a bucketwheel. Voest-Alpine Maschinenbau GmbH of Austria introduced the Voest-Alpine Surface Miner (VASM), type VASM 2. This drum cutterhead machine was designed to cut medium-hard overburden and minerals, such as anthracite, phosphate, gypsum, and limestone with compressive strengths ranging from 2,200 to 11,600 pounds per square inch (psi). The state-of-the-art cutterhead performed lateral to-and-fro movements at variable speed with a variable number of picks, making it adaptable to many rock conditions as well as able to produce different lump sizes. The VASM 2 was electrically powered via a trailing cable and crawler-mounted. It conveyed the mined material directly onto trucks or downstream continuous haulage equipment. At an Austrian mine, trial tests were conducted on gypsum with compressive strengths ranging from 5,800 to 10,600 psi. Grain size was small enough to eliminate primary crushing.[41]

Krupp Industrietechik GmbH of the Federal Republic of Germany marketed the Satterwhite bucketwheel surface miner, which was suitable for unconsolidated to medium-hard materials, such as hard coal. Krupp claimed that its compact bucketwheel was capable of high-performance digging in extremely sticky ground, and in layered or jointed rock, and that it had five to six times better ability to dig than conventional bucketwheel excavators. As with the VASM 2, it could load materials directly to trucks or other transportation means. Skids arranged behind the bucketwheel transmitted the digging forces directly into the ground, helping to promote optimum crawler traction. Mined material was discharged from the buckets by means of a movable back on the bucket, which made operation with sticky materials fairly smooth.[42]

Rock Breakers

The British engineering company Dudley Shearing Machine Manufacturing Co. Ltd. produced a novel device for fragmenting oversize rocks up to 6 feet in diameter. The Dudley Rock Cracker had a pair of 6-foot-wide jaws that delivered a maximum 500 tons of crushing power, which Dudley said was the largest and most powerful machine of its kind in use in the mineral extractive industries. The Rock Cracker was hydraulically operated from and easily fitted to excavators of 35 tons or more. It was powered by the carrier's own hydraulic system and did not interfere with the carrier's normal operation and capacity. The company claimed that the hardest rocks, even those without fault grains, presented no problems to the Cracker, which rotated 90° left and 15° right, allowing it to pick up material and crush it at any angle. Dudley claimed that up to four boulders per minute could be reduced to rubble.[43]

Another rock breaker was introduced by Tidco Engineering Group of New Zealand. The Terminator, an impact hammer rock breaker, was claimed to be the only hammer to rival a drop ball in energy; the Terminator G70 model had 52,000 foot pounds of impact energy. The breaker could be mounted on all common hydraulic loaders and excavators by means of quick-attach couplers. In operation, the hammer weight was hydraulically raised to a predetermined height and released, falling under the influence of gravity to hit the striker pin placed on the rock to be broken. An electronic protection system prevented the hammer weight from being raised until the striker pin was in position.[44]

Ore Transport

Truck haulage constitutes a very flexible ore transport system for open pits, but it has progressively become a more costly part of mine budgets. In-pit crushing has been a growing trend because it reduces materials to a conveyable size at the mine site. Conveyor systems are more economical for transporting and dumping mined materials at very high volumetric rates, but they are not well adapted to some surface-mine designs because of high angles out of the pit. Most conventional elevating conveyors must be routed along approximately 15° conveying angles, and this can be expensive and very inconvenient at some mines. Continental Conveyor & Equipment Co. Inc., Winfield, AL, installed its High Angle Conveyor (HAC) system at a metal/nonmetal mine for the first time in the Majdanpek copper mine in Yugoslavia. Two previous installations took place in coal mines in Wyoming. The conveying angle at Majdanpek was 35.5°, but an HAC was capable of conveying materials up to a 90° angle. As the Majdanpek pit deepened, a second HAC would be installed at a lower elevation to dump onto the first. Ore was conveyed by the sandwich belt principle: Two ordinary belts sandwiched the conveyed material. All conventional conveyor hardware was used. Hugging pressure was applied to the conveyed material at the material-to-belt interface so that the material would not slide back at the design conveying angle. Belt overlap sealed the material to prevent spillage. The required material-hugging pressure varied according to the conveying angle, material characteristics, and the dynamics of the specific HAC system design.[45]

Cominco American Resources Inc. used a creative approach to solve a problem it encountered at its Buckhorn open pit gold mine in northeastern Nevada. The company needed to agglomerate the fines in the kaolinite-clay-rich crushed ore with cement before the agglomerate was distributed on the heap leach pad. The agglomerated ore tended to continue tumbling in the traditional drum tumbler instead of discharging out of it. In place of a tumbler, Cominco American set up a series of cascading conveyors that simultaneously mixed the cement and ore and carried it to a radial stacker, which then stacked it in 25- to 35-foot lifts on the leach pad.[46]

REMOTE MINING

Government Research

In Situ Leaching.—The Bureau of Mines worked on a variety of new and advanced mining methods to make underground mining safer; to make economic those ore bodies that were previously of too low a grade or too deeply buried; and to increase productivity in a time of growing worldwide competitiveness. The Bureau estimated that a productivity improvement of 40% or more might be required of U.S. mines during the 1990's if the industry was to compete with foreign mining operations. A major focus of the Bureau's research programs was the development of innovative technologies to help ensure the future profitability of the U.S. mining industry. Two projects that offered the most promise for significant steps forward involved leaching technologies: in situ leaching, and a variation of the same, underground stope leaching. In situ leach mining involves injecting chemical solvents into an ore body through vertical injection wells and recovering metals in solution via other "recovery" wells. This method was the most promising because it essentially eliminated the ore extraction and crushing steps of conventional mining, reducing labor and energy costs substantially. In situ leach mining had already proved profitable in the mining of uranium at some operations, but it was in an earlier stage of development for base metals. The control and monitoring of leach solutions in fractured and partially saturated base metal formations was a major challenge facing researchers. This was more difficult than was control of leach solutions in uranium sands, and recovery of all solutions was essential, both from economical and environmental standpoints. The Bureau participated in a cooperative copper mining research project to test a process for the in situ mining of copper, as described below.

Stope Leaching.—Stope leaching was in an earlier stage of development, but also was very promising. It combined leaching technologies with underground mining. The mine work, far less than that of a non-leaching operation, was needed to prepare the mine stope for the process. Twenty-five percent of the ore at the bottom of an ore deposit would be removed conventionally to allow the rest of the ore above to "swell" as it either naturally caved or was progressively fractured by blasting. Leaching agents would then be introduced at the top of the stope, and the metal-laden solutions retrieved at the bottom and pumped to the surface for processing. This method could be of particular use in deposits not amenable to in situ leaching, such as those that had little fracturing or poor permeabilities. Geophysics had been successfully used to monitor leaching solutions, but more research was needed to gauge the movement of leaching solutions through dry or partially saturated rubble, and fluid flow models were being evaluated by the Bureau at a leaching operation in a block-caved zone at the San Manuel Mine in Arizona.[47]

Private Operations

Copper Recovery.—A small number of companies were doing their own pioneering work involving in situ leach mining. One of these was the Kocide Chemical Corp., Houston, TX, at the historic Van Dyke property in Arizona. Conventional mining had exhausted most copper reserves on the property by the end of World War II. A depleted mine adjacent to the Van Dyke property yielded copper for many years via leaching of rock in the abandoned mine workings. Kocide felt that in-place leaching was the only practical and safe method of recovering the remaining low grade copper at Van Dyke. The first phase of the project would be about 2 years of leaching from the original mine workings, after which the company would consider expansion of the leaching area into the surrounding mineralized zones. Expansion would require true in situ leaching, which is leaching of the metal values from ore in its natural geologic state. The copper from the ores was to be recovered from the pregnant leach solutions by cementing it onto scrap iron. The material then would be trucked to Kocide's Casa Grande facility for conversion into various agricultural products. Strict requirements for monitoring and control of the mine were issued by the Arizona Department of Environmental Quality to insure protection of the environment.[48]

Technology Services.—Another example of interest within the private sector was the formation of an in situ leaching technology company, a joint venture between BHP Engineering, a division of the large Australian multinational mining company BHP-Utah, and In-Situ Inc. of the United States. The two companies joined together to provide complete services worldwide for the recovery of minerals by in situ or solution mining techniques. Besides copper and uranium, solution mining could be applied to a wide range of minerals, such as lithium, magnesium, molybdenum, nahcolite, potash, salt, and trona. Officials of the joint venture noted that the technology included strict environmental monitoring and control to ensure containment of the lixiviants (solvents) and said that it had access to unique patented lixiviant systems that were environmentally friendly.[49]

Public-Private Venture.—The Bureau of Mines and the Santa Cruz Joint Venture, owned 50% each by subsidiaries of ASARCO Incorporated, New York, NY, and Freeport-McMoRan Gold Co., New Orleans, LA, signed a cooperative agreement to undertake an in situ leach mining research project at the deep, low-grade Santa Cruz copper deposit in Arizona. If successful, the project, which was expected to take several years, could provide technology suitable for approximately a dozen large copper oxide deposits in Arizona alone. Commercial mine design concepts were prepared using the algorithms and model provided in the Draft Generic In Situ Copper Mine Design Manual, prepared for the Bureau by Science Applications International Corp. (SAIC). SAIC also designed a large-scale field experiment for the Santa Cruz site, using the unit-cell concept. A unit cell was a wellfield consisting of one injection well surrounded by four production wells that formed a square. Two unit adjacent cells were planned for Santa Cruz with its production wells 160 feet apart. This field test would allow validation of the algorithms used in preparation of the commercial design and would also demonstrate whether an in situ facility could be operated as designed and within budget for a sustained period. Validation of the model would consist of comparison of actual versus calculated construction and operating costs, as well as verification of such technical parameters as flow rate and fluid control. The project would demonstrate the technical feasibility of in situ extraction of copper. The Santa Cruz deposit was located between 1,400 and 2,600 feet below the surface and was effectively separated from the overlying sources of ground water by a thick layer of bedrock. The site's surface area would not be disturbed by excavation or the deposition of mine waste.[50]

Dredging

Dredging technology was in the midst of significant change, with several new technologies emerging and under study. Industry representatives said that mining was beginning to displace traditional marine dredging as the most important market for dredge systems. They claimed that some changes improved mineral recovery rates, making previously uneconomic deposits fully viable. Applications included not only the traditional field of alluvial and beach sands mining, but also aggregate, coal, gold tailings, oil sands, phosphate rock, tin, and silica sand recovery. As land-based sand and gravel resources continued to decline in the United Kingdom and Northern Europe, dredging of marine resources was making an increased contribution to the countries' growing demand for aggregates.[51] The Australian dredge designer, Neumann Equipment Pty. Ltd., developed a new bucketwheel-design suction dredger that was successfully used at Indonesian gold operations with clay problems. The dredge master had a substantial amount of control over all operations. This combined with the high-tech bucketwheel's cutting movements and accompanying suction, dislodged and transported the clay from the cutting head through the suction line.[52]

The dual wheel excavator (DWE) was a new dredge cutter assembly that its originator, Ellicott Machine Corp. International, Baltimore, MD, claimed was capable of producing up to three times as much material as a conventional cutter suction dredge with the same drive power. The company said that in just 3 years the DWE was replacing the bucketwheel on a majority of new dredges and was being selected to replace Ellicott's and many competitors' units during upgrades. The DWE assembly bore only a passing resemblance to the standard conventional bucketwheel, which was mounted between two supporting arms. The dual wheels were mounted on both sides of an assembly that enclosed the drive unit, suction pipe, and the structural supports that attached to the dredge ladder. The eight buckets on each wheel were much narrower than those of the standard excavator, increasing breakout force. The DWE was designed to simplify maintenance, and Ellicott said that the swing mechanism could be serviced in less than an hour rather than the usual days. Ellicott also designed a backhoe-attachment version of the DWE. It could be attached to most manufacturer's backhoes having sufficient size and power to support it. The machine could provide continuous underwater excavation and material transport without the interruption from the swinging, booming, and bucket-curling typical of normal backhoe operations. This version made possible small dredging projects or hard-to-reach alluvial deposits by taking advantage of the mobility of the track-mounted backhoe and its ability to walk to a project.[53]

Extraterrestrial Mining

Several companies were doing groundwork for the frontier of extraterrestrial mining, first of all on the Moon and possibly nearby asteroids. Many useful materials on the Moon could be used for space construction, industry, and propellant production. Experts in the field noted that mineral resources on Earth would not have to be relied on for lunar settlement and exploration because, among other elements, iron, aluminum, and titanium metals, as well as high volumes of oxygen and silicon, are contained in lunar soil. According to one expert, the time frame for such a project would be "within our lifetime," with a lunar base possibly in place around or soon after the turn of the century if funds were to be made available. Astrominers could be mining on the Moon, or possibly even on Mars and its moons, by early in the 21st century. The Nation's space mission planners intended to decide early in the 1990's upon the major focus of the civilian space program, and mining considerations were featured strongly in the deliberations.

Studies developed by the Space Studies Institute (SSI) of Princeton, NJ, showed that the initial cost of placing the exploration start-up components in space and on the surface of the Moon was roughly equivalent to the cost of two large North Sea oil rigs. SSI was geared to applying the practical side of mineral exploration and extraction in space and, specifically, on asteroids and the Moon. Most Moon mining initially would be used to support human presence on the Moon, but technology was already in development for transporting quantities of lunar minerals back to Earth. One study by another group noted that 45% of the near-Earth asteroids contain substantial portions of nickel, iron, cobalt, and platinum-group metals. While nickel, iron, and cobalt would be used in space, the platinum-group metals could be sent to Earth in the form of concentrates to help finance additional space mining projects.[54]

BENEFICIATION

Economic Studies

The efficiency of a processing operation can be improved, for the most part, in two different ways, either by increasing revenue or reducing costs. In times of crisis, cost cutting receives priority if a plant is able to find ways to reduce the costs of power, labor, and supplies. At a concentrator that is already well designed and run, raising revenue is more often the goal, and is first attempted by increasing the throughput. After throughput, the metallurgical criteria of recovery and grade follow in importance. Marketing the concentrates to smelters that offer the best terms, and the processing of byproduct minerals also can raise needed revenue. In recent years the development of large-capacity equipment has continued. Where previously many parallel circuits were employed, one or two circuits using the largest compatible equipment were becoming more common. Single high-tonnage circuits were simpler to operate, required less labor, and made easier and less expensive the installation of on-stream analysis and computer control. On the downside, any breakdown could mean 100% loss of production, as opposed to only a fraction of the loss that could occur with multiple circuits. Concentrator maintenance became a higher priority at these operations.[55]

On-Stream Analysis

Advances in process control were responsible for recent significant increases in concentrator productivity, and the on-stream analyzer was a most important tool that greatly influenced concentrator economics. Concentrator operations were maturing a great deal with the combination of computer-based control systems and on-stream analysis, which not only cut operating costs, but, more importantly, increased recoveries, grades, and throughputs. This was accomplished mainly by ironing out natural and operator-induced fluctuations. The rapid response time of on-stream analysis systems also facilitated plant metallurgists' testing of new reagents. The earliest multistream X-ray diffraction units were being superseded by smaller, more versatile X-ray fluorescence analyzers. The latter were capable of detecting elements of ever-lower atomic number and bringing the benefits of on-stream analysis within reach of the small operator.[56] Units that detected mineral concentrations instead of individual elements still relied on X-ray diffraction for detection and measurement.

Expert Systems

On-stream analyzers under expert system-based control create a source of essential real-time information that is fundamental to understanding both the dynamic behavior and economic performance of a process. Outokumpu Oy of Finland used its Courier analyzer system with a new software package developed at the Pyasalmi Mine to assist the operator in planning his control action. The program's objective was to enhance economic results through greater efficiency and to standardize procedures for each shift. It was a form of expert system that prompted the operators to use the most suitable control adjustments (setpoint changes) needed to achieve a desired objective. It could, for example, tell what series of changes would decrease the circulating load in a flotation circuit or improve a concentrate grade. Process experience was systematically gathered into the computer's memory; the system accumulated its own knowledge from its previous operations. To determine the correct control measures for each operating point in the process, the software package continuously monitored the setpoint changes and the resulting impact on the process. The software classified the data according to preselected criteria and presented the results for the operator. The current process state was compared with an ideal "best state" condition previously determined from historic shift-average data, which had been classified according to equivalent process states and control targets. The system's suggested course of action was displayed for the operator, who was able to compare the performance of his own control strategy with those of other operators, his own previous efforts, and the previous best state.[57]

Automated Flotation

Century Oils Ltd. of the United Kingdom claimed to have achieved complete automation of flotation circuits with its Autoflote system. The first applications were for optimizing coal recovery, but Century said that the system was equally appropriate to metalliferous applications. Autoflote was a computer-controlled system that recognized the changing characteristics of flotation streams, including feeds from multiple sources, and used this information to adjust the system to meet preset conditions. It was an integrated monitoring and control system that could be tailored for site-specific circuit limitations and automatically would take appropriate actions to optimize recovery. The system controlled ore sampling and stream dilution lines, reagent dosage, pulp level, froth depth, and backflushing of sample lines to avoid downtime caused by blockages and fouling, as well as other optional parameters. The sensors utilized optical transmission techniques, and requirements for moving parts in the sample and dilution lines were minimal because constant slurry streams were maintained by gravity.[58]

Grinding

Microprocessor Controls.—In an effort to reduce the higher costs of grinding, especially energy consumption, attention was being paid to sophisticated control systems for crushers and crushing plants. Svedala-Arbra AB of Sweden marketed a third-generation, computerized version of its automatic regulation systems for cone and gyratory crushers. Compact microprocessor technology was used to promote very sensitive registration of the load on the crusher and allow immediate responses to be made if required. This added control was designed to permit the machine to be run more consistently close to maximum power draw and load, with the opening size at or near minimum to ensure maximum output of fine material.[59]

Slurry Process.—Nordberg Inc. of Milwaukee, WI, developed and activated a new crushing process that was called WaterFlush Technology at a recently opened Brazilian lead-zinc mine. In the WaterFlush circuit, water was added to the tertiary cone crusher, rather than at the grinding mills, as was common practice. Central to the process was the Nordberg's new W F Cone Crusher, which incorporated special seals, internal components, lubricants to handle large flows of water, and special speed and throw combinations to maximize performance. During crushing, enough water was added to produce a product slurry of 30% to 50% solids by weight, which flushed fines through the crusher, preventing buildup on the liners. In the absence of fines, the crusher product has a significant proportion of thin flaky particles. The company stated that during subsequent ball milling, flaky particles break very easily, reducing the power requirement per ton of ore milled. A lower power requirement would permit use of smaller grinding mills, reducing both capital and operating costs in new installations. In established grinding plants, throughput would be increased because the crushed material would be easier to grind and old rod mills could possibly be eliminated.[60]

Image Analysis.—Image analysis provides quantitative mineralogical data, and several automatic image analysis systems have been developed for determining mineral characteristics that bear on mineral behavior during processing. One system, MP–SEM–IPS, developed in the Canmet laboratories of the Department of Energy, Mines and Resources in Ottawa, Canada, consisted of an electron microprobe that produced an image, an energy-dispersive X-ray analyzer for mineral identification, and a Pontron SEM–IPS image analyzer that determined mineral characteristics. The system identified the minerals automatically and determined mineral properties that affected the processing of different ores. Within the same ore, some mineral forms (e.g. inclusions), when small enough, require more grinding than other forms (e.g. discrete grains) that are larger, in order to be recovered, and the percentage of the mineral's population in that form must be high enough to economically justify the additional grinding.[61]

Semiautogenous Grinding.—The move to autogenous grinding (AG) and, in particular, semiautogenous grinding (SAG) was thought by industry representatives likely to continue. SAG milling eliminated secondary and tertiary crushing, promoting simplicity of plant design and construction, lower operating and maintenance staff requirements, and greater ease of control. Skega AB of Sweden developed a new liner, the Poly-Met liner, to decrease liner costs in AG and SAG mills. These liners had steel plates bonded to the leading edges of rubber lifter bars, in an effort to combine the best properties of steel and rubber. Steel imbedded in rubber wears less due to the rubber's cushioning effect, and this in turn allows harder steel alloys to be used. The company claimed that tests showed an increase in liner life of about 50%, reducing liner costs and improving mill availability. Poly-Met liners had been installed in six mills in the United States and Canada, and five concentrators were awaiting installation. The company said that even if their wear life was equal to that of all-steel units, Poly-Met liners would still cost no more to use.[62]

The Barmac crusher, a vertical impact crusher, was developed in the late 1960's and early 1970's by two engineers from New Zealand. It gained popularity, especially for construction aggregate processing, only slowly until 1981, when P. L. Tidmarsh Ltd. of New Zealand, now Tidco International, marketed the machine more extensively than previous manufacturers. One new market was in North America, presently through Barmac America. Since 1981, the crusher's use has increased in mining and mineral processing operations, including gold mines in Australia, chromite mines in the Republic of South Africa, a dolomite quarry in Scotland, and an iron ore mine in Chile. The Barmac crusher, the Rotopactor, was a high-intensity autogenous grinding machine that had both a crushing and a "glancing" grinding action. Ore was reduced to ball-mill feed size, allowing the elimination of rod mills in many applications. Stone-on-stone crushing rather than stone-on-metal was the operating mechanism; it relied on midair, rather than anvil or bed, impact, and wear parts consumption was negligible. A rotor accelerated the maximum size 57-millimeter feed to 70 meters per second in 11 milliseconds. Collision with material already flying about in the crushing chamber occurred with high intensity many times until the desired size was achieved. A high proportion of very fine material was also produced. The internal design caused a stone bed to build up that protected the interior mechanisms from high wear and insulated the chamber liners from the violent stone impact. The Rotopactor's compact design allowed it to be slotted into existing processing systems with minimal disruption. Some internal redesign resulted in the Barmac Duopactor, which produced almost twice as much as its predecessor, without requiring additional power or wear parts. The Duopactor Cascade, another variation, accepted a maximum feed size of 100 millimeters. Other refinements under development included an increase in the machine's feed size and fine grinding capabilities.[63]

Flotation

Cobalt Recovery.—The Bureau of Mines developed a mineral beneficiation process for the recovery of cobalt from Missouri lead ores. The amount of cobalt contained in a year's production of the ores was equal to about 15% of the Nation's annual consumption of this strategic and critical metal. The cobalt from these ores had always been lost as an impurity in the copper, lead, and zinc concentrates and in the mill tailings because no technology existed that could recover it with minimum impact on present production. The Bureau's recovery method used a combination of fine grinding and froth flotation to remove about 60% of the cobalt from the copper concentrates made from the copper-bearing lead ores. After a grinding and cleaning, or mineral "polishing" stage, flotation collectors were added to float the copper mineral away from the cobalt mineral. This stage was repeated five times to raise the grade of the cobalt to that of concentrates that were imported from Africa. The cobalt removal process also enhanced the original copper concentrate because it reduced the magnesium oxide and iron content.[64]

Column Flotation.—Column flotation cells were used less frequently in rougher flotation circuits than in cleaner circuits, where a single column cell was equivalent to two to five stages of conventional cleaning. This absence was partly the result of the physical difficulty at many concentrators of accommodating tall columns. A professor from the University of Newcastle, Australia, developed a short (1 meter high) column that retained the deep froth of a conventional column but reduced the volume of pulp to the absolute minimum. Tests of a 550-millimeter pilot unit with a variety of minerals at Mount Isa Mines in Australia were said to result in concentrate grades approaching those obtained with four conventional cleaning stages at higher recoveries. A 1.7-meter-diameter unit was being built.[65]

Separation

KHD Humboldt Wedag AG of the Federal Republic of Germany used the latest achievements in the field of superconducting magnetic separation in upgrading its Descos magnetic separator. The separator essentially consisted of a drum separator with a built-in superconducting magnet system and a closed-loop refrigerating plant for liquefying the helium that cooled the magnet. According to KHD, the Turkish magnesite producer Magnesit Anonim Serketi, which was involved in testing the drum separator, was the first to use this type of machine on an industrial scale for the beneficiation of coarse-grained ores. A prototype machine, minus the superconducting technology, had been successfully used several years previously on bauxite and andalusite. The machine had an extremely high flux density of up to 3.2 Tesla at the drum surface, which enabled KHD's Tutluca mine to separate feebly magnetic serpentine from the nonmagnetic magnesite. The main advantages of Descos were the low energy costs that resulted from the superconducting magnet system, not exceeding 1.5 kilowatts per ton of throughput, and the infrequent required servicing, which occurred at intervals of 7,500 operating hours for the magnet system and refrigerating circuit.[66]

Leaching

Bioleaching.—U.S. Gold Corp.'s Tonkin Springs gold mine in Nevada was incorporating bioleaching into its new gold processing operations. In the new 1,500-ton-per-day carbon-in-leach mill, a bacteria vat leach unit was to be used as a preoxidation step to free gold from sulfides. This allowed mining of the property's sulfide gold ore, which was of greater quantity than the oxide ore. Oxide deposits were conventionally heap leached and then processed in a portable processing plant. The use of microorganisms to aid in the recovery of valuable metals was generating considerable interest in the mining industry. Studies up to this time had focused on the leaching bacterium *Thiobacillus ferrooxidans* (TF), which feeds on sulfide minerals and ferrous iron. Until recently, commercial applications of bacterial leaching had been mostly limited to copper and uranium. Nevada had heavy concentrations of gold-laden sulfide ores, and unless a mining operation could afford the higher costs and some additional environmental problems that came with roasting or autoclave use, the ore was often written off as waste. Only at a pilot plant at the Fairview Mine in South Africa was this pioneering technique already being used on a large scale for gold sulfide ores. There, complete conversion to the process was planned.[67] Elsewhere, research work was conducted on other leaching bacteria that grow at higher temperatures than TF does. TF easily grows at moderate temperatures but is inactivate at temperatures exceeding 40° C. Excessive heat is a problem when bioleaching ores with high sulfur content. The heat released by the feasting organism slows bacterial activity. Addition of a cooling system to the TF tank could add substantially to operating costs. Another advantage to using the high-temperature bacteria was a much faster reaction rate.[68]

Cyanide Recovery.—Golconda Engineering and Mining Services Pty. Ltd. of Western Australia introduced into the North American market a cyanide regeneration process (CRP) that it claimed had the potential to provide substantial savings to U.S. and Canadian mining industries, as well as an environmentally acceptable wastewater discharge. Golconda said that the CRP system could regenerate up to 95% of the cyanide remaining in liquors after gold production. The cyanide liquor went through an acidifying and special clarification process, after which it passed through a system of series and parallel aeration and absorption columns. There the cyanide was recovered by using air to strip the cyanide gas from the liquor. The cyanide gas was converted to sodium cyanide in an alkaline solution, after which the solution was pumped back into the processing circuit. Following regeneration, and prior to discharge, the cyanide-free acidified liquor was passed through a series of carbon columns, where any residual gold was removed. During a year of testing, treated liquors at Golconda's Beaconsfield gold project in Tasmania were discharged into the

Tamar River with levels of free cyanide less than detectable limits and total cyanide less than 3.0 parts per million.[69]

HEALTH AND SAFETY

Safety Data

Preliminary injury statistics compiled by the Mine Safety and Health Administration for 1988 showed that mine fatalities were about 28% lower than in 1987. Forty-eight personnel died in metal and industrial mineral mining operations versus 67 in 1987. This was one less than the historic low of 49 that occurred in 1986. All 1987 figures cited are final tabulations. The average number of employees increased by about 5.4%, up from a 1.86% average increase in 1987, and employee-hours increased by about 4.8%, continuing 1987's upward turn of 3.24%. Total reported injuries increased for the third consecutive year, climbing to about 7.1 per 200,000 employee hours, up from a 6.32 rate of 1987. All figures include independent contractors.

Sheathed Explosive

The use of a sheathed rock-breaker explosive charge, developed by Bureau of Mines researchers, was approved by the Mine Safety and Health Administration for mines where explosive gases or materials, such as methane and coal dust, were a problem. The device was developed both to simplify work and decrease downtime, as well as for safety purposes. When a rock was large enough to need special blasting before work at a mine face could continue, the sheathed explosive could simply be placed on or attached to the rock and set off within 10 to 15 seconds instead of the 1 or more hours that drilling and blasting the obstruction could take. The prototype charge was shaped like a short cylinder 7 inches in diameter and 0.87 inch high and consisted of 1.5 pounds of permissible water gel explosive, entirely encased in a 0.5-inch-thick layer of damp salt. All was encased in a very durable latex rubber housing reinforced with cheesecloth, allowing rough handling and some flexibility for the charge to conform to irregular rock surfaces. Upon firing, the salt scattered and acted as a flame retardant while the detonation shock broke the rock. In test explosions with limestone boulders ranging in size from 2,700 to 25,000 pounds (two explosives used), no significant amount of flyrock was observed. The sheathed charge was not yet commercially available, but several companies were interested in producing it.

Atmospheric Monitors

Three advanced computer programs, specifically designed to help determine dust control measures for continuous miners and longwall shearers, as well as control of methane gas, were developed by the Bureau of Mines. The software was the first offering in a planned series of Bureau expert systems. The programs obtained input about a control problem from the user, analyzed it, and then suggested various practical approaches to the solution. The continuous miner system first determined the respirable dust source and then followed with questions about the mine's ventilation system, the mining sequence, and compliance with Federal standards. If a problem with the roof bolter was indicated, attention was directed to bolter maintenance problems and solutions. The longwall shearer system consisted of three parts: the basic dust control measures every longwall operation should use; advice on several more refined approaches if compliance cannot be achieved with the basic measures; and an a la carte menu for users with specific interests. The expert system for methane control was designed to provide advice on methane drainage techniques, frictional ignitions, and outbursts of gas. The system required inputs of readily available data, such as methane flow rates, bedding depth, existence of faults, ventilation rates, and mining method. If any of this information was unavailable to the system user, the system provided typical values.[70]

Dust Suppression

Surface blasthole drilling can produce considerable respirable quartz dust, especially harmful to the driller and the drill helper. The Bureau of Mines developed a new concept to improve the overall effectiveness of dry-cyclone, filter-type collection systems and investigated a new concept to improve wet drilling efficiency and wet dust suppression systems. Researchers believed that some type of dust agglomerator could control the dust. For the agglomeration device they used a pelletizer with a capacity of 1,000 pounds per hour. The pin-type agglomerator was a horizontal, stationary-shell, cylindrical agitation pelletizer. As pins inside the shell rotated, a spinning motion was imparted to the dust particles. The particles became coated with a binder and collided with other particles and coalesced into dust-free micropellets. Under certain conditions the subsequent addition of small amounts of water as a spray reduced dust levels 65% to 73%, while the pelletizer produced pellets ranging in size from 1 to 10 millimeters in diameter. Another method of controlling the dust is to inject water into the bailing air. This method is very effective but the dust-water slurry reduces drill-bit life by 50% or more. To overcome this problem, the water was directed away from the drill bit by ejecting it into the drill stem annulus. All drill cuttings traveled through this annulus and were dampened. The air carrying the cuttings was deflected while they were picked up by the water. At the mine where the water separator was tested, monzonite, sandstone, limestone, and iron ore were drilled with steel-tooth bits. Average bit life was reported to be 1,938 feet per bit without water separation and 9,000 feet per bit with it.[71]

Dust Removal

A different type of dust problem was dealt with by Climavent Ltd. of the United Kingdom. Washrooms and locker rooms used by mining personnel who work in dust-laden environments or handle powdery materials can be difficult to maintain in a hygienic condition. Climavent introduced a changing room in which workers could remove any dust in their clothing. The dedusting "cabin" was specifically designed for mining, quarrying, and minerals processing operations in which dust contamination of workers is a daily problem. Also, it could be used for recovery of valuable minerals, or for the containment of any hazardous substances within the plant working area. The Climavent cabin, constructed of insulated plastic-coated steel, was a self-contained transportable unit with up to 4 vacuum extraction points. Each point consisted of an isolating valve and dust extraction head with flexible hose connection. Background dust was extracted by a ventilating fan.[72]

Fire Detectors

The Bureau of Mines developed a novel prototype fire detector that could be used to discriminate between smoke produced by a fire and smoke produced by a diesel engine. The detector utilized pyrolysis, which was the chemical decomposition of a material by the action of heat. A sample of smoke-laden gas was passed through a short, heated tube. Within the tube fire smoke particles pyrolized into finer and more plentiful quantities, while diesel smoke particles were unaffected. The detector was designed for use in mines where the detection of fires could be complicated by the background levels of diesel emissions and other products of combustion. The smoke detector was successfully tested in a series of intermediate-scale fire tests and was scheduled for installation in a diesel-operated coal mine for further testing and evaluation.[73]

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TABLE 1

MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES, BY TYPE

(Million short tons)

Type and year	Surface			Underground			All mines[1]		
	Crude ore	Waste	Total[1]	Crude ore	Waste	Total[1]	Crude ore	Waste	Total
Metals:									
1983	380	557	938	47	6	53	427	564	991
1984	420	614	1,030	57	10	67	476	624	1,100
1985	411	499	911	48	9	57	459	508	968
1986	418	615	1,030	52	7	59	470	622	1,090
1987	489	825	1,310	43	6	49	532	831	1,360
Industrial minerals:									
1983[2]	1,070	155	1,230	62	1	62	1,130	155	1,290
1984[3]	1,060	286	1,340	40	1	41	1,100	287	1,390
1985[2]	1,260	450	1,710	54	2	56	1,320	452	1,770
1986[3]	1,130	380	1,510	34	1	35	1,160	380	1,540
1987[2]	1,430	452	1,880	77	1	78	1,510	453	1,960
Total metals and industrial minerals:[1]									
1983	1,450	712	2,160	109	7	116	1,560	719	2,280
1984	1,480	901	2,380	97	11	108	1,570	912	2,490
1985	1,670	950	2,620	102	11	113	1,770	961	2,740
1986	1,550	995	2,540	86	7	93	1,630	1,000	2,630
1987	1,920	1,280	3,200	120	7	126	2,040	1,280	3,320

[1] Data may not add to totals shown because of independent rounding.
[2] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1983, 1985, and 1987 because of biennial canvassing.
[3] Crushed and broken and dimension stone data were not available for 1984 and 1986 because of biennial canvassing.

TABLE 2

MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES[1] IN THE UNITED STATES IN 1987, BY COMMODITY

(Thousand short tons)

Commodity	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]
METALS									
Bauxite	1,090	W	1,090	—	—	—	1,090	W	1,090
Copper	208,000	503,000	711,000	17,400	504	17,900	22,500	504,000	729,000
Gold:									
Lode	76,900	196,000	272,000	3,570	912	4,480	80,400	197,000	277,000
Placer	16,700	10,400	27,100	—	—	—	16,700	10,400	27,100
Iron ore	162,000	40,400	202,000	W	W	W	162,000	40,400	202,000
Lead	W	W	W	5,800	2,870	8,670	5,800	2,870	867
Silver	10,300	18,700	29,000	3,970	1,340	5,310	14,300	20,100	34,400
Zinc	—	—	—	5,180	W	5,180	5,180	W	5,180
Other[3]	14,300	56,900	71,100	6,650	395	7,050	20,900	57,200	78,200
Total metals[2]	**489,000**	**825,000**	**1,310,000**	**42,600**	**6,020**	**48,600**	**532,000**	**831,000**	**1,360,000**
INDUSTRIAL MINERALS									
Abrasives[4]	106	W	106	W	W	W	106	W	106
Asbestos	51	610	661	—	—	—	51	610	661
Barite	687	159	846	—	—	—	687	159	846
Clays	47,200	e41,100	88,300	78	e1	79	47,300	e41,100	88,400
Diatomite	1,210	3,530	4,740	—	—	—	1,210	3,530	4,740
Feldspar	1,380	183	1,560	—	—	—	1,380	183	1,560
Gypsum	12,600	1,570	14,200	3,300	W	3,301	15,900	1,570	17,500
Mica (scrap)	95	W	95	—	—	—	95	W	95
Perlite	604	339	942	9	—	9	613	339	952
Phosphate rock	164,000	289,000	453,000	W	—	W	164,000	289,000	453,000
Potassium salts	—	—	—	10,500	W	10,500	10,500	W	10,500
Pumice[5]	215	W	215	—	—	—	215	W	215
Salt	2,100	—	2,100	9,610	—	96,100	11,700	—	11,700
Sand and gravel[6]	28,100	—	28,100	—	—	—	27,100	—	28,100
Sodium carbonate (natural)	—	—	—	12,100	W	12,100	12,100	W	12,100
Stone:									
Crushed and broken	1,160,000	95,400	1,260,000	40,800	286	41,100	1,200,000	95,700	1,300,000
Dimension	2,530	1,340	3,870	W	—	W	2,430	1,340	3,870
Talc, soapstone, pyrophyllite	1,220	W	1,220	120	—	120	1,340	W	1,340
Vermiculite	558	—	558	—	—	—	558	—	558
Other[7]	4,950	18,500	23,400	509	305	814	5,460	18,800	24,200
Total industrial minerals[2]	**1,430,000**	**452,000**	**1,880,000**	**77,000**	**591**	**77,600**	**1,510,000**	**453,000**	**1,960,000**
Grand total[2]	**1,920,000**	**1,280,000**	**3,200,000**	**120,000**	**6,610**	**126,000**	**2,040,000**	**1,280,000**	**3,320,000**

e Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Excludes materials from wells, ponds, or pumping operations.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes antimony, beryllium, magnesium, manganese, mercury, molybdenum, platinum-group metals, rare-earth metals, tin, titanium (ilmenite), tungsten, uranium, and metal items indicated by symbol W.
[4] Includes emery and tripoli.
[5] Excludes volcanic cinder and scoria.
[6] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.
[7] Includes aplite, boron minerals, fluorspar, iron oxide pigments (crude), kyanite, magnesite, marl (greensand), pyrite, wollastonite, and industrial minerals indicated by symbol W.

TABLE 3

MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES[1] (INCLUDING SAND AND GRAVEL[2] AND STONE) IN THE UNITED STATES IN 1987, BY STATES

(Thousand short tons)

State	Surface			Underground			All mines[3]		
	Crude ore	Waste	Total[3]	Crude ore	Waste	Total[3]	Crude ore	Waste	Total
Alabama	31,700	4,420	36,200	W	W	W	31,700	4,420	36,200
Alaska	12,400	5,930	18,400	—	W	W	12,400	5,930	18,400
Arizona	147,000	179,000	325,000	11,800	435	12,200	158,000	179,000	337,000
Arkansas	17,900	6,020	23,900	—	—	—	17,900	6,020	23,900
California	68,100	74,200	142,000	911	47	957	69,000	74,300	143,000
Colorado	11,500	7,390	18,900	5,430	306	5,730	17,000	7,700	24,700
Connecticut	11,900	1,090	13,000	—	—	—	11,900	1,090	13,000
Florida	233,000	253,000	487,000	—	—	—	233,000	253,000	487,000
Georgia	70,900	14,200	85,200	W	W	W	70,900	14,200	85,200
Hawaii	5,750	470	6,220	—	—	—	5,750	470	6,220
Idaho	16,800	45,900	62,700	416	209	625	17,200	46,100	63,300
Illinois	55,400	4,540	60,000	1,650	23	1,680	57,100	4,570	61,700
Indiana	32,200	3,600	35,800	1,260	W	1,260	33,400	3,600	37,000
Iowa	25,100	2,330	27,400	3,260	19	3,280	28,300	2,350	30,700
Kansas	18,600	1,980	20,600	2,340	9	2,350	21,000	2,000	23,000
Kentucky	32,400	3,470	35,900	12,000	85	12,000	44,400	3,550	47,900
Louisiana	6,700	687	7,390	W	—	—	6,700	687	7,390
Maine	2,080	215	2,290	—	—	—	2,080	215	2,290
Maryland	26,900	2,530	29,400	W	W	W	26,900	2,530	29,400
Massachusetts	15,300	1,430	16,700	—	—	—	15,300	1,430	16,700
Michigan	84,100	4,720	88,800	5,870	455	6,320	89,900	5,180	95,100
Minnesota	131,000	41,000	172,000	—	—	0	131,000	41,000	172,000
Mississippi	2,640	1,100	3,740	—	—	0	2,640	1,100	3,740
Missouri	51,600	5,480	57,100	12,000	2,980	14,900	63,600	8,460	72,000
Montana	30,100	32,300	62,400	3,500	19	3,520	33,600	32,300	65,900
Nebraska	3,230	439	3,670	1,330	9	1,340	4,560	449	5,000
Nevada	57,700	119,000	177,000	53	30	83	57,800	119,000	177,000
New Hampshire	2,640	297	2,940	—	—	—	2,640	297	2,940
New Jersey	20,700	1,620	22,300	—	—	—	20,700	1,620	22,300
New Mexico	38,200	203,000	242,000	10,500	276	10,800	48,700	204,000	252,000
New York	39,300	3,810	43,100	4,380	—	4,380	43,700	3,810	47,500
North Carolina	35,700	45,400	111,000	—	—	—	65,700	45,400	111,000
North Dakota	125	50	175	—	—	—	125	50	175
Ohio	56,200	7,000	63,200	2,640	W	2,640	58,900	7,000	65,900
Oklahoma	29,300	3,620	32,900	W	W	W	29,300	3,620	32,900
Oregon	20,800	1,720	22,500	16	([4])	16	20,800	1,720	22,600
Pennsylvania	96,400	8,880	105,000	2,810	20	2,830	99,200	8,900	108,000
Rhode Island	1,270	101	1,370	—	—	—	1,270	101	1,370
South Carolina	28,400	4,050	32,400	—	—	—	28,400	4,050	32,400
South Dakota	7,100	13,600	20,700	W	W	W	7,100	13,600	20,700

See footnotes at end of table.

TABLE 3—Continued

MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES[1] (INCLUDING SAND AND GRAVEL[2] AND STONE) IN THE UNITED STATES IN 1987, BY STATES

(Thousand short tons)

State	Surface			Underground			All mines[3]		
	Crude ore	Waste	Total[3]	Crude ore	Waste	Total[3]	Crude ore	Waste	Total[3]
Tennessee	51,600	7,830	59,500	9,330	67	9,400	61,000	7,900	68,900
Texas	91,400	9,850	101,000	W	W	W	91,400	9,850	101,000
Utah	35,800	124,000	160,000	614	314	928	36,400	124,000	16,100
Vermont	2,950	474	3,430	W	W	W	2,950	474	3,430
Virginia	62,500	6,340	68,800	W	W	W	62,500	6,340	68,800
Washington	15,370	1,550	16,900	574	W	574	15,900	1,550	17,500
West Virginia	11,800	1,140	13,000	1,420	10	1,430	13,200	1,150	14,400
Wisconsin	24,200	1,910	26,100	W	W	W	24,200	1,910	26,100
Wyoming	5,820	13,500	19,400	12,100	W	12,100	17,900	13,500	31,500
Undistributed	9,840	977	10,800	13,400	1,300	14,700	23,300	2,270	25,500
Total[3 5]	**1,920,000**	**1,280,000**	**3,200,000**	**120,000**	**6,610**	**126,000**	**2,040,000**	**1,280,000**	**3,320,000**

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1] Excludes material from wells, ponds, or pumping operations.
[2] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.
[3] Data may not add to totals shown because of independent rounding.
[4] Less than 1/2 unit.
[5] Includes estimated data in table 2.

TABLE 4

VALUE OF PRINCIPAL MINERAL PRODUCTS AND BYPRODUCTS OF SURFACE AND UNDERGROUND ORES MINED IN THE UNITED STATES IN 1987

(Value per ton)

Ore	Surface			Underground			All mines		
	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total
METALS									
Bauxite	W	W	W	—	—	—	W	W	W
Copper	$10.27	$1.15	$11.42	$3.88	$.36	$4.24	$9.64	$1.07	$10.72
Gold:									
Lode	20.49	1.88	22.37	39.72	5.53	45.25	21.25	2.03	23.28
Placer	4.53	.01	4.54	—	—	—	4.53	.01	4.54
Iron ore	6.31	—	6.31	W	W	W	6.31	—	6.31
Lead	W	W	W	35.73	20.29	56.02	35.73	20.29	56.02
Silver	5.35	3.92	9.27	23.83	10.20	34.03	10.43	5.64	16.07
Zinc	—	—	—	27.35	W	27.35	27.35	W	27.35
Average[1]	10.05	.88	10.93	20.85	3.90	24.75	10.89	1.12	12.01
INDUSTRIAL MINERALS									
Abrasives[2]	15.56	W	15.56	W	W	W	15.56	W	15.56
Asbestos	339.87	—	339.87	—	—	—	339.87	—	339.87
Barite	29.30	—	29.30	—	—	—	29.30	—	29.30
Clays	25.27	.12	25.39	5.77	—	5.77	25.23	.12	25.35
Diatomite	128.50	—	128.50	—	—	—	128.50	—	128.50
Feldspar	18.54	34.25	52.79	—	—	—	18.54	34.25	52.79
Gypsum	6.77	W	6.77	6.75	W	6.75	6.77	W	6.77
Mica (scrap)	48.89	W	48.89	—	—	—	48.89	W	48.89
Perlite	21.14	—	21.14	10.39	—	10.39	20.95	—	20.95
Phosphate rock	3.63	—	3.63	W	—	W	3.63	—	3.63
Potassium salts	—	—	—	16.57	W	16.57	16.57	W	16.57
Pumice[3]	14.85	W	14.85	—	—	—	14.85	W	14.85
Salt	W	W	W	13.54	W	13.54	13.54	W	13.54
Sand and gravel[4]	13.01	W	13.01	—	—	—	13.01	W	13.01
Sodium carbonate (natural)	—	—	—	42.45	W	42.45	42.45	W	42.45
Stone:									
Crushed and broken	4.33	—	4.33	5.73	—	5.73	4.38	—	4.38
Dimension	70.49	—	70.49	W	—	W	70.49	—	70.49
Talc, soapstone, pyrophyllite	18.50	1.60	20.10	34.23	—	34.23	19.89	1.46	21.35
Vermiculite	109.29	—	109.29	—	—	—	109.29	—	109.29
Average[1]	5.68	.07	5.75	15.11	.03	15.13	6.14	.07	6.21
Average, metals and industrial minerals[1]	6.89	.29	7.18	15.66	1.51	17.18	7.39	.36	7.76
Average, industrial minerals (excluding sand and gravel and stone)[1]	9.97	.70	10.68	22.84	2.25	25.09	11.12	.84	11.97
Average, metals and industrial minerals (excluding sand and gravel)[1]	6.80	.30	7.10	17.31	1.51	18.82	7.42	.37	7.78

W Withheld to avoid disclosing company proprietary data.
[1] Includes unpublished data.
[2] Includes emery and tripoli.
[3] Excludes volcanic cinder and scoria.
[4] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.

TABLE 5

CRUDE ORE AND TOTAL MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 1987, BY COMMODITY

(Percent)

Commodity	Crude ore		Total material	
	Surface	Underground	Surface	Underground
METALS				
Bauxite	100.0	—	100.0	—
Copper	92.3	7.7	97.5	2.5
Gold:				
Lode	95.6	4.4	98.4	1.6
Placer	100.0	—	100.0	—
Iron ore	99.3	.7	99.4	.6
Lead	—	100.0	W	[1] 100.0
Silver	72.2	27.8	84.5	15.5
Zinc	—	100.0	—	100.0
Average [2]	**92.0**	**8.0**	**96.4**	**3.6**
INDUSTRIAL MINERALS				
Abrasives [3]	[4] 100.0	W	[4] 100.0	W
Asbestos	100.0	—	100.0	—
Barite	100.0	—	100.0	—
Clays	[4] 100.0	W	[4] 100.0	W
Diatomite	100.0	—	100.0	—
Feldspar	100.0	—	100.0	—
Gypsum	79.2	20.8	81.0	19.0
Mica (scrap)	100.0	—	100.0	—
Perlite	98.5	1.5	99.0	1.0
Phosphate rock	100.0	—	100.0	—
Potassium salts	—	100.0	—	100.0
Pumice [5]	100.0	—	100.0	—
Salt	18.0	82.0	18.0	82.0
Sand and gravel [6]	100.0	—	100.0	—
Sodium carbonate (natural)	—	100.0	—	100.0
Stone:				
Crushed and broken	96.6	3.4	96.8	3.2
Dimension	[4] 100.0	W	[4] 100.0	W
Talc, soapstone, pyrophyllite	91.1	8.9	92.0	8.0
Vermiculite	100.0	—	100.0	—
Average [2]	**94.9**	**5.1**	**96.0**	**4.0**
Average, metals and industrial minerals [2]	**94.1**	**5.9**	**96.2**	**3.8**

W Withheld to avoid disclosing company proprietary data; included with "Surface" or "Underground."
[1] Includes surface; the Bureau of Mines is not at liberty to publish separately.
[2] Includes unpublished data.
[3] Includes emery and tripoli.
[4] Includes underground; the Bureau of Mines is not at liberty to publish separately.
[5] Excludes volcanic cinder and scoria.
[6] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.

TABLE 6

CRUDE ORE AND TOTAL MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 1987, BY STATE

(Percent)

State	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Alabama	[1] 100.0	W	[1] 100.0	W
Alaska	100.0	—	[1] 100.0	W
Arizona	92.6	7.4	96.4	3.6
Arkansas	100.0	—	100.0	—
California	98.7	1.3	99.3	.7
Colorado	68.0	32.0	76.8	23.2
Connecticut	100.0	—	100.0	—
Delaware	100.0	—	100.0	—
Florida	100.0	—	100.0	—
Georgia	[1] 100.0	W	[1] 100.0	W
Hawaii	100.0	—	100.0	—
Idaho	97.6	2.4	99.0	1.0
Illinois	97.1	2.9	97.3	2.7
Indiana	[1] 100.0	W	[1] 100.0	W
Iowa	[1] 100.0	W	[1] 100.0	W
Kansas	88.8	11.2	89.8	10.2
Kentucky	73.0	27.0	74.9	25.1
Louisiana	69.0	31.0	71.0	29.0
Maine	100.0	—	100.0	—
Maryland	87.9	12.1	88.7	11.3
Massachusetts	100.0	—	100.0	—
Michigan	[1] 100.0	W	[1] 100.0	W
Minnesota	100.0	—	100.0	—
Mississippi	100.0	—	100.0	—
Missouri	81.2	18.8	79.3	20.7
Montana	89.6	10.4	94.7	5.3
Nebraska	70.8	29.2	73.2	26.8
Nevada	99.9	.1	100.0	—
New Hampshire	100.0	—	100.0	—
New Jersey	100.0	—	100.0	—
New Mexico	78.4	21.6	95.7	4.3
New York	90.0	10.0	90.8	9.2
North Carolina	100.0	—	100.0	—
North Dakota	100.0	—	100.0	—
Ohio	[1] 100.0	W	[1] 100.0	W
Oklahoma	98.7	1.3	98.8	1.2
Oregon	99.9	.1	99.9	.1
Pennsylvania	97.2	2.8	97.4	2.6
Rhode Island	100.0	—	100.0	—
South Carolina	100.0	—	100.0	—

See footnotes at end of table.

TABLE 6—Continued

CRUDE ORE AND TOTAL MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 1987, BY STATE

(Percent)

State	Crude ore		Total material	
	Surface	Underground	Surface	Underground
South Dakota	[1] 100.0	W	[1] 100.0	W
Tennessee	84.7	15.3	86.3	13.7
Texas	99.6	.4	99.6	.4
Utah	98.3	1.7	99.4	.6
Vermont	98.8	1.2	98.9	1.1
Virginia	[1] 100.0	W	[1] 100.0	W
Washington	[1] 100.0	W	[1] 100.0	W
West Virginia	89.3	10.7	90.1	9.9
Wisconsin	99.5	.5	99.5	.5
Wyoming	32.5	67.5	61.4	38.6
Average [2]	**94.1**	**5.9**	**96.2**	**3.8**

W Withheld to avoid disclosing company proprietary data; included with "Surface."
[1] Includes underground; the Bureau of Mines is not at liberty to publish separately.
[2] Includes unpublished data.

TABLE 7

NUMBER OF DOMESTIC METAL AND INDUSTRIAL MINERAL MINES[1] IN THE UNITED STATES IN 1987, BY COMMODITY

Commodity	Total number of mines	Less than 1,000 tons	1,000 to 10,000 tons	10,000 to 100,000 tons	100,000 to 1,000,000 tons	1,000,000 to 10,000,000 tons	More than 10,000,000 tons
METALS							
Bauxite	6	—	—	4	2	—	—
Copper	23	3	1	1	1	8	9
Gold:							
Lode	121	10	25	11	48	27	—
Placer	31	5	7	9	5	5	—
Iron ore	18	—	2	4	1	5	6
Lead	10	—	1	1	4	4	—
Silver	19	6	1	4	4	4	—
Zinc	9	1	—	—	6	2	—
Other[2]	39	12	8	10	8	1	0
Total	**276**	**37**	**45**	**44**	**79**	**56**	**15**
INDUSTRIAL MINERALS							
Abrasives[3]	13	6	2	5	—	—	—
Asbestos	3	—	2	1	—	—	—
Barite	13	—	5	6	2	—	—
Clays	914	37	178	556	143	—	—
Diatomite	10	—	—	6	4	—	—
Feldspar	14	—	1	7	6	—	—
Gypsum	61	—	4	16	41	—	—
Mica (scrap)	9	—	3	6	—	—	—
Perlite	13	1	4	6	2	—	—
Phosphate rock	29	—	—	2	7	13	7
Potassium salts	5	—	—	—	2	3	—
Pumice[4]	17	2	8	7	—	—	—
Salt	16	—	2	3	7	4	—
Sand and gravel[5]	168	5	23	71	68	1	—
Sodium carbonate (natural)	5	—	—	—	—	5	—
Stone:							
Crushed	5,444	866	907	1,719	1,662	290	—
Dimension	268	42	149	77	—	—	—
Talc, soapstone, pyrophyllite	31	4	8	12	7	—	—
Vermiculite	5	—	—	3	2	—	—
Other[6]	35	15	6	7	6	1	0
Total	**7,073**	**978**	**1,302**	**2,510**	**1,959**	**317**	**7**
Grand total	**7,349**	**1,015**	**1,347**	**2,554**	**2,038**	**373**	**22**

[1] Excludes wells, ponds, or pumping operations.
[2] Includes beryllium, magnesium, manganese, mercury, molybdenum, platinum-group metals, rare-earth metals, tin, titanium (ilmenite), and uranium.
[3] Includes abrasive stone, emery, garnet, millstones, and tripoli.
[4] Excludes volcanic cinder and scoria.
[5] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.
[6] Includes aplite, boron minerals, fluorspar, iron oxide pigments, kyanite, magnesite, marl (greensand), pyrite, and wollastonite.

TABLE 8

TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL[1] MINES IN THE UNITED STATES IN 1987, IN ORDER OF OUTPUT OF CRUDE ORE

Mine	State	Operator	Commodity	Mining method
		METALS		
Morenci	Arizona	Phelps Dodge Corp.	Copper	Open pit.
Sierrita	do.	Duval Sierrita Corp.	do.	Do.
Hibbing Taconite	Minnesota	Pickands Mather & Co.	Iron ore	Do.
Minntac	do.	USX Corp.	do.	Do.
Empire	Michigan	Empire Iron Mining Co.	do.	Do.
Bingham Canyon	Utah	Kennecot, Utah Copper Div.	Copper	Do.
Pinto Valley	Arizona	Pinto Valley Copper Corp.	do.	Do.
Hoyt Lakes	Minnesota	LTV Steel Co. Inc.	Iron ore	Do.
Bagdad	Arizona	Cyprus Bagdad Copper Co.	Copper	Do.
Tyrone	New Mexico	Phelps Dodge Corp. and Burro Chief Copper Co.	do.	Do.
San Manuel	Arizona	Magma Copper Co.	do.	Caving and open pit.
Chino	New Mexico	Chino Mines Co.	do.	Open pit.
Continental	Montana	Montana Resources Inc.	do.	Do.
Tilden	Michigan	Tilden Mining Co.	Iron ore	Do.
Ray Pit	Arizona	ASARCO Incorporated	Copper	Do.
Thunderbird	Minnesota	Oglebay Norton Co.	Iron ore	Do.
Zortman-Landusky	Montana	Pegasus Gold Inc.	Lode gold	Do.
Round Mountain	Nevada	Round Mountain Gold Corp.	do.	Do.
Mission Complex[2]	Arizona	ASARCO Incorporated	Copper	Do.
Nation Pellet Project—St. Louis	Minnesota	Hanna Mining Co.	Iron ore	Do.
Green Cove	Florida	Associated Minerals Corp.	Titanium	Dredging.
Minorca	Minnesota	Inland Steel Mining Co.	Iron ore	Open pit.
Nation Pellet Project—Itasca	do.	Hanna Mining Co.	do.	Do.
Thompson Creek	Idaho	Cyprus Thompson Creek Co.	Molybdenum	Do.
Nome	Alaska	Alaska Gold Co.	Placer gold	Dredging and open pit.
		INDUSTRIAL MINERALS[3]		
Suwanne	Florida	Occidental Chemical Agricultural Products, Inc.	Phosphate rock	Open pit.
Kingsford	do.	International Minerals & Chemical Corp.	do.	Do.
Ft. Green	do.	Agrico Chemical Co.	do.	Do.
Noralyn	do.	International Minerals & Chemical Corp.	do.	Do.
Swift Creek	do.	Occidental Chemical Agricultural Products, Inc.	do.	Do.
Lee Creek	North Carolina	Texasgulf Chemical Co.	do.	Dredging.
Haynsworth	Florida	American Cyanamid Co.	do.	Open pit.
Ft. Meade	do.	Mobil Mining and Minerals Co.	do.	Do.
Payne Creek	do.	Agrico Chemical Co.	do.	Do.

See footnotes at end of table.

TABLE 8—Continued

TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL[1] MINES IN THE UNITED STATES IN 1987, IN ORDER OF OUTPUT OF CRUDE ORE

Mine	State	Operator	Commodity	Mining method
Calcite	Michigan	Michigan Mineral Associates	Stone	Open quarry.
Beckman	Texas	Redland Worth Corp.	do.	Do.
Stoneport	Michigan	Presque Isle Corp.	do.	Do.
McCook	Illinois	Vulcan Materials Co.	do.	Do.
Pennsuco	Florida	Tarmac Florida Inc.	do.	Dredging.
FEC Hialea	do.	Rinker Materials Corp.	do.	Open quarry.
Hookers	do.	W. R. Grace & Co.	Phosphate rock	Open pit.
Georgetown	Texas	Texas Crushed Stone Co.	Stone	Open quarry.
Clear Spring	Florida	International Minerals & Chemical Corp.	Phosphate rock	Open pit.
Thornton	Illinois	General Dynamics Corp.	Stone	Open quarry.
International	New Mexico	International Minerals & Chemical Corp.	Potassium salts	Stopes.
New Braunfels	Texas	Parker Bros and Co. Inc.	Stone	Open quarry.
McCoy	Pennsylvania	Glasgow Inc.	do.	Do.
St. Genevieve	Missouri	Tower Rock Stone Co.	do.	Do.
Kennsworth	Georgia	Vulcan Materials Co.	do.	Do.
Rockland	Florida	USS Agri-Chemicals Inc.	Phosphate rock	Open pit.

[1] Excludes brines and materials from wells.
[2] Includes Eisenhower, Mission, and Pima.
[3] Includes industrial sand and gravel. Construction sand and gravel were not available for 1987 because of biennial canvassing.

TABLE 9

TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL[1] MINES IN THE UNITED STATES IN 1987, IN ORDER OF OUTPUT OF TOTAL MATERIALS HANDLED

Mine	State	Operator	Commodity	Mining method
		METALS		
Tyrone	New Mexico	Phelps Dodge Corp.	Copper	Open pit.
Bingham Canyon	Utah	Kennecot, Utah Copper Div.	do.	Do.
Morenci	Arizona	Phelps Dodge Corp.	do.	Do.
Chino	New Mexico	Chino Mines Co.	do.	Do.
Bagdad	Arizona	Cyprus Bagdad Copper Co.	do.	Do.
Pinto Valley	do.	Pinto Valley Copper Corp.	do.	Do.
Hoyt Lakes	Minnesota	LTV Steel Co. Inc.	Iron ore	Do.
Sierrita	Arizona	Duval Sierrita Corp.	Copper	Do.
San Manuel	do.	Magma Copper Co.	do.	Caving and open pit.
Ray Pit	do.	ASARCO Incorporated	do.	Open pit.
Hibbing Taconite	Minnesota	Pickands Mather & Co.	Iron ore	Do.
Thompson Creek	Idaho	Cyprus Thompson Creek Co.	Molybdenum	Do.
Continental	Montana	Montana Resources Inc.	Copper	Do.
Minntac	Minnesota	USX Corp.	Iron ore	Do.
Empire	Michigan	Empire Iron Mining Co.	do.	Do.
Candelaria	Nevada	Nerco Minerals Co.	Silver	Do.
Mesquite	California	Gold Fields Mining Corp.	Lode gold	Do.
McCoy	Nevada	Echo Bay Mining Co.	do.	Do.
Mission Complex[2]	Arizona	ASARCO Incorporated	Copper	Do.
Homestake	South Dakota	Homestake Mining Co.	Lode gold	Do.
Zortman-Landusky	Montana	Pegasus Gold Inc.	do.	Do.
McLaughlin	California	Homestake Mining Co.	do.	Do.
Thunderbird	Minnesota	Oglebay Norton Co.	Iron ore	Do.
Golden Sunlight	Montana	Golden Sunlight Mines Inc.	Lode gold	Do.
Fortitude and Surprise	Nevada	Battle Mountain Gold Co.	do.	Do.
		INDUSTRIAL MINERALS[3]		
Suwannee	Florida	Occidental Chemical Agricultural Products, Inc.	Phosphate rock	Open pit.
Ft. Green	do.	Agrico Chemical Co.	do.	Do.
Kingsford	do.	International Minerals & Chemical Corp.	do.	Do.
Lee Creek	North Carolina	Texasgulf Chemical Co.	do.	Dredging.
Noralyn	Florida	International Minerals & Chemical Corp.	do.	Open pit.
Haynsworth	do.	American Cyanamid Co.	do.	Do.
Clear Spring	do.	International Minerals & Chemical Corp.	do.	Do.
Payne Creek	do.	Agrico Chemical Co.	do.	Do.
Ft. Meade	do.	Mobil Oil Corp.	do.	Do.
Hookers	do.	W. R. Grace & Co.	do.	Do.
Boron	California	U.S. Borax and Chemical Co.	Boron	Do.

See footnotes at end of table.

TABLE 9—Continued

TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL[1] MINES IN THE UNITED STATES IN 1987, IN ORDER OF OUTPUT OF TOTAL MATERIALS HANDLED

Mine	State	Operator	Commodity	Mining method
Swift Creek	Florida	Occidental Chemical Agricultural Products, Inc.	Phosphate rock	Open pit.
Gay	Idaho	J. R. Simplot Co.	do.	Do.
Ft. Meade	Florida	Gardinier Inc.	do.	Do.
Calcite	Michigan	Michigan Mineral Associates	Stone	Open quarry.
Silver City	Florida	Estech Inc.	Phosphate rock	Open pit.
Beckman	Texas	Redland Worth Corp.	Stone	Open quarry.
Stoneport	Michigan	Presque Isle Corp.	do.	Do.
McCook	Illinois	Vulcan Materials Co.	do.	Do.
Pennsuco	Florida	Tarmac Florida Inc.	do.	Dredging.
FEC Hialea	do.	Rinker Materials Corp.	do.	Open quarry.
Georgetown	Texas	Texas Crushed Stone Co.	do.	Do.
Watson	Florida	Estech Inc.	Phosphate rock	Open pit.
Henry	Idaho	Monsanto Co.	do.	Do.
Thornton	Illinois	General Dynamics Corp.	Stone	Open quarry.

[1] Excludes brines and materials from wells.
[2] Includes Eisenhower, Mission, and Pima.
[3] Includes industrial sand and gravel. Construction sand and gravel were not available for 1987 because of biennial canvassing.

TABLE 10

ORE TREATED OR SOLD PER UNIT OF MARKETABLE PRODUCT AT SURFACE AND UNDERGROUND MINES[1] IN THE UNITED STATES IN 1987, BY COMMODITY

Commodity		Surface			Underground			Total[2]		
		Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product	Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product	Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product
METALS										
Bauxite	thousand long tons	1,090	566	1.9:1	—	—	—	1,090	566	1.9:1
Copper	thousand short tons	208,000	1,290	160.6:1	22,600	53	425.3:1	230,000	1,350	171.1:1
Gold:										
Lode	thousand troy ounces	85,200	3,900	21.9:1	3,520	312	11.3:1	88,700	4,210	21.1:1
Placer	do.	16,000	168	95.5:1	—	—	—	16,000	168	95.5:1
Iron ore	thousand long tons	235,000	38,600	6.1:1	W	W	W	235,000	38,600	6.1:1
Lead	thousand short tons	—	—	—	5,840	290	20.1:1	5,840	290	20.1:1
Silver	thousand troy ounces	10,300	7,880	1.3:1	3,910	13,300	.3:1	14,200	21,200	.7:1
Zinc	thousand short tons	—	—	—	5,180	169	30.7:1	5,180	169	30.7:1
INDUSTRIAL MINERALS										
Abrasives[3]	do.	105	105	1.0:1	W	W	W	105	105	1.0:1
Asbestos	do.	51	46	1.1:1	—	—	—	51	46	1.1:1
Barite	do.	486	328	1.5:1	—	—	—	486	328	1.5:1
Clays	do.	47,200	46,800	1.0:1	78	78	1.0:1	47,300	46,900	1.0:1
Diatomite	do.	1,050	657	1.6:1	—	—	—	1,050	657	1.6:1
Feldspar	do.	1,370	706	1.9:1	—	—	—	1,370	706	1.9:1
Gypsum	do.	12,500	12,300	1.0:1	3,300	3,300	1.0:1	15,800	15,600	1.0:1
Mica (scrap)	do.	95	95	1.0:1	—	—	—	95	95	1.0:1
Perlite	do.	773	529	1.5:1	14	5	3.0:1	787	533	1.5:1
Phosphate rock	do.	217,000	44,900	4.8:1	W	W	W	217,000	44,900	4.8:1
Potassium salts	do.	—	—	—	10,500	1,140	9.2:1	10,500	1,140	9.2:1
Pumice[4]	do.	194	187	1.0:1	—	—	—	194	187	1.0:1
Salt	do.	W	W	W	9,520	9,500	1.0:1	9,520	9,500	1.0:1
Sand and gravel[5]	do.	28,100	28,100	1.0:1	—	—	—	28,100	28,100	1.0:1
Sodium carbonate (natural)	do.	—	—	—	12,100	7,890	1.5:1	12,100	7,890	1.5:1
Stone:										
Crushed and broken	do.	1,160,000	1,160,000	1.0:1	40,800	40,800	1.0:1	1,200,000	1,200,000	1.0:1
Dimension	do.	2,530	1,150	2.2:1	W	W	W	2,530	1,150	2.2:1
Talc, soapstone, pyrophyllite	do.	1,230	1,050	1.2:1	120	120	1.0:1	1,350	1,170	1.2:1
Vermiculite	do.	303	303	1.0:1	—	—	—	303	303	1.0:1

W Withheld to avoid disclosing company proprietary data.
[1] Excludes wells, ponds, and pumping operations.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes emery and tripoli.
[4] Excludes volcanic cinder and scoria.
[5] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.

TABLE 11

MATERIAL HANDLED PER UNIT OF MARKETABLE PRODUCT AT SURFACE AND UNDERGROUND MINES[1] IN THE UNITED STATES IN 1987, BY COMMODITY

Commodity		Surface			Underground			Total[2]		
		Total material handled[3] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[4]	Total material handled[3] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[4]	Total material handled[3] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[4]
METALS										
Bauxite	thousand long tons	4,900	566	8.6:1	—	—	—	4,900	566	8.6:1
Copper	thousand short tons	711,000	1,290	550.1:1	17,900	53	337.1:1	729,000	1,350	541.7:1
Gold:										
Lode	thousand troy ounces	272,000	3,900	69.9:1	4,480	312	14.3:1	277,000	4,210	65.8:1
Placer	do.	27,100	168	161.7:1	—	—	—	27,100	168	161.7:1
Iron ore	thousand long tons	202,000	38,600	5.2:1	W	W	W	202,000	38,600	5.2:1
Lead	thousand short tons	W	W	W	8,670	290	29.9:1	8,670	290	29.9:1
Silver	thousand troy ounces	29,000	7,880	3.7:1	5,310	13,300	.4:1	34,400	21,200	1.6:1
Zinc	thousand short tons	—	—	—	5,230	169	30.9:1	5,230	169	30.9:1
INDUSTRIAL MINERALS										
Abrasives[5]	do.	298	105	2.8:1	W	W	W	298	105	2.8:1
Asbestos	do.	661	46	14.4:1	—	—	—	661	46	14.4:1
Barite	do.	846	328	2.6:1	—	—	—	846	328	2.6:1
Clays	do.	88,300	46,800	1.9:1	79	78	1.0:1	88,400	46,900	1.9:1
Diatomite	do.	4,740	657	7.2:1	—	—	—	4,740	657	7.2:1
Feldspar	do.	1,560	706	2.2:1	—	—	—	1,560	706	2.2:1
Gypsum	do.	14,200	12,300	1.2:1	3,310	3,300	1.0:1	17,500	15,600	1.1:1
Mica (scrap)	do.	195	95	2.1:1	—	—	—	195	95	2.1:1
Perlite	do.	942	529	1.8:1	9	5	2.0:1	952	533	1.8:1
Phosphate rock	do.	453,000	44,900	10.1:1	W	W	W	453,000	44,900	10.1:1
Potassium salts	do.	—	—	—	10,700	1,140	9.4:1	10,700	1,140	9.4:1
Pumice[6]	do.	237	187	1.3:1	—	—	—	237	187	1.3:1
Salt	do.	W	W	W	9,610	9,500	1.0:1	9,610	9,510	1.0:1
Sand and gravel[7]	do.	28,100	28,100	1.0:1	—	—	—	28,100	28,100	1.0:1
Sodium carbonate (natural)	do.	—	—	—	12,200	7,890	1.5:1	12,200	7,890	1.5:1
Stone:										
Crushed and broken	do.	1,260,000	1,160,000	1.1:1	41,100	40,800	1.0:1	1,300,000	1,200,000	1.1:1
Dimension	do.	3,870	1,150	3.4:1	W	W	W	3,870	1,150	3.4:1
Talc, soapstone, pyrophyllite	do.	1,380	1,050	1.3:1	120	120	1.0:1	1,500	1,170	1.3:1
Vermiculite	do.	558	303	1.8:1	—	—	—	558	303	1.8:1

W Withheld to avoid disclosing company proprietary data.
[1] Excludes wells, ponds, and pumping operations.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes material from exploration and development activities.
[4] Material from development and exploration activities is excluded from the ratio calculation.
[5] Includes emery and tripoli.
[6] Excludes volcanic cinder and scoria.
[7] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.

TABLE 12

MINING METHODS USED IN OPEN PIT MINING IN THE UNITED STATES IN 1987, BY COMMODITY

(Percent)

Commodity	Total material handled	
	Preceded by drilling and blasting	Not preceded by drilling and blasting[1]
METALS		
Bauxite	95	5
Beryllium	—	100
Copper	99	1
Gold:		
Lode	98	2
Placer	—	100
Iron ore	97	3
Lead	25	75
Magnesium	100	—
Manganiferous ore	—	100
Mercury	—	100
Molybdenum	99	1
Rare-earth metals	100	—
Silver	100	—
Tin	—	100
Titanium (ilmenite)	—	100
INDUSTRIAL MINERALS		
Abrasives[2]	81	19
Aplite	15	85
Asbestos	100	—
Barite	91	9
Boron	100	—
Clays	—	100
Diatomite	—	100
Feldspar	93	7
Greensand (marl)	87	13
Gypsum	97	3
Iron oxide	91	9
Kyanite	100	—
Magnesite	100	—
Mica (scrap)	43	57
Perlite	11	89
Phosphate rock	1	99
Pumice[3]	24	76
Pyrite	100	—
Salt	—	100
Sand and gravel[4]	—	100

See footnotes at end of table.

TABLE 12—Continued

MINING METHODS USED IN OPEN PIT MINING IN THE UNITED STATES IN 1987, BY COMMODITY

(Percent)

Commodity	Total material handled	
	Preceded by drilling and blasting	Not preceded by drilling and blasting[1]
Stone:		
Crushed and broken	98	2
Dimension	13	87
Talc, soapstone, pyrophyllite	96	4
Vermiculite	3	97
Average	**77**	**23**

[1] Includes drilling or cutting without blasting, dredging, or mechanical excavation and nonfloat washing, and other surface mining methods.
[2] Includes abrasive stone and millstones.
[3] Excludes volcanic cinder and scoria.
[4] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1987 because of biennial canvassing.

TABLE 13

EXPLORATION AND DEVELOPMENT ACTIVITY IN THE UNITED STATES IN 1987, BY METHOD

	Metals		Industrial minerals		Total[1]	
	Feet	Percent of total[2]	Feet	Percent of total[2]	Feet	Percent of total[2]
EXPLORATION						
Churn drilling	111,000	2.6	—	—	111,000	2.5
Diamond drilling	409,000	9.8	111,000	38.7	520,000	11.6
Percussion drilling	906,000	21.6	—	—	906,000	20.3
Rotary drilling	2,460,000	58.6	112,000	39.0	2,570,000	57.4
Other drilling	202,000	4.8	58,900	20.5	261,000	5.8
Trenching	103,000	2.5	5,250	1.8	109,000	2.4
Total[1]	**4,190,000**	**100.0**	**287,000**	**100.0**	**4,480,000**	**100.0**
DEVELOPMENT						
Drifting, crosscutting, or tunneling	222,000	37.4	6,550	83.7	229,000	38.0
Raising	37,000	6.2	1,280	16.3	38,300	6.4
Shaft and winze sinking	3,420	.6	—	—	3,420	.6
Solution mining	331,000	55.8	—	—	331,000	55.1
Total[1]	**594,000**	**100.0**	**7,830**	**100.0**	**601,000**	**100.0**
Grand total[1]	**4,780,000**	**XX**	**295,000**	**XX**	**5,080,000**	**XX**

XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Based on unrounded footage.

TABLE 14

EXPLORATION AND DEVELOPMENT IN THE UNITED STATES IN 1987, BY COMMODITY

(Feet)

Commodity	Exploration							Development				
	Churn drilling	Diamond drilling	Percussion drilling	Rotary drilling	Other drilling	Trenching	Total[1]	Drifting, crosscutting, or tunneling	Raising	Shaft and winze sinking	Solution mining	Total[1]
METALS												
Antimony	—	—	—	—	—	—	—	150	—	—	—	150
Copper	—	34,300	—	W	—	([2])	34,300	30,500	18,900	3	W	49,400
Gold:												
Lode	W	268,000	739,000	1,360,000	95,100	99,200	2,570,000	91,700	10,700	3,090	—	106,000
Placer	W	—	—	24,800	W	4,040	28,800	—	—	—	—	—
Lead	11,400	24,100	W	W	14,300	180	50,000	53,500	—	—	—	53,500
Molybdenum	—	W	—	—	25,900	—	25,900	—	—	—	—	—
Silver	—	31,400	W	52,000	150	—	83,500	24,600	W	308	—	25,000
Tungsten	—	—	30	—	—	35	65	—	—	10	—	10
Other[3]	99,500	51,200	167,000	1,020,000	66,600	—	1,400,000	21,500	7,380	10	331,000	360,000
Total[1]	**111,000**	**409,000**	**906,000**	**2,460,000**	**202,000**	**103,000**	**4,190,000**	**222,000**	**37,000**	**3,420**	**331,000**	**594,000**
INDUSTRIAL MINERALS												
Diatomite	—	—	—	1,500	—	—	1,500	—	—	—	—	—
Perlite	—	—	—	4,000	—	—	4,000	—	—	—	—	—
Phosphate rock	—	—	—	3,240	W	—	3,240	—	—	—	—	—
Other[4]	—	111,000	—	103,000	58,900	5,250	278,000	6,550	1,280	—	—	7,830
Total[1]	**—**	**111,000**	**—**	**112,000**	**58,900**	**5,250**	**287,000**	**6,550**	**1,280**	**—**	**—**	**7,830**
Grand total[1]	**111,000**	**520,000**	**906,000**	**2,570,000**	**261,000**	**109,000**	**4,480,000**	**229,000**	**38,300**	**3,420**	**331,000**	**601,000**

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Data may not add to totals shown because of independent rounding.

[2] "Trenching" data for Copper included with Lode Gold to avoid disclosing company proprietary data.

[3] Includes bauxite, beryllium, iron ore, uranium, zinc, and metals items indicated by symbol W.

[4] Includes abrasives, boron minerals, fluorspar, gypsum, lime, sodium carbonate (natural), sulfur (Frasch), talc, soapstone, and pyrophyllite, wollastonite, and mineral items indicated by symbol W.

TABLE 15

EXPLORATION AND DEVELOPMENT IN THE UNITED STATES IN 1987, BY STATE

(Feet)

State	Exploration							Development				
	Churn drilling	Diamond drilling	Percussion drilling	Rotary drilling	Other drilling	Trench-ing	Total[1]	Drifting, cross-cutting, or tunneling	Rais-ing	Shaft and winze sinking	Solution mining	Total[1]
Alaska	W	13,600	—	30,800	W	4,930	49,300	W	W	—	—	—
Arizona	—	46,900	51,700	44,700	W	W	143,000	35,200	21,800	—	W	57,000
California	W	3,500	5,900	175,000	—	165	184,000	1,610	721	2,760	—	5,080
Colorado	—	129,000	71,700	28,800	1,700	2,410	233,000	28,400	2,350	298	—	31,100
Idaho	—	17,300	—	222,000	—	400	239,000	W	W	W	—	—
Missouri	11,400	21,900	—	—	14,300	—	47,600	54,600	—	—	—	54,600
Montana	—	33,900	—	13,500	W	6,280	53,700	2,500	1,320	W	—	3,820
Nevada	98,600	49,400	735,000	1,010,000	44,800	91,000	2,020,000	W	W	—	—	—
New Mexico	—	10,200	([2])	89,100	26,900	W	126,000	8,390	W	—	—	8,390
Oregon	—	—	—	4,820	—	—	4,820	—	—	—	—	—
South Dakota	—	3,950	20,000	25,100	—	—	49,100	W	W	W	—	—
Texas	—	—	—	442,000	—	—	442,000	—	—	—	W	—
Utah	—	W	22,500	83,300	—	—	106,000	W	W	—	—	—
Washington	—	W	—	—	25,000	—	25,000	W	W	—	—	—
Wyoming	—	—	—	381,000	—	—	381,000	W	W	—	W	—
Undistributed[3]	850	191,000	—	22,500	148,000	3,500	366,000	97,800	12,100	367	331,000	441,000
Total[1]	**111,000**	**520,000**	**906,000**	**2,570,000**	**261,000**	**109,000**	**4,480,000**	**229,000**	**38,300**	**3,420**	**331,000**	**601,000**

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Data may not add to totals shown because of independent rounding.
[2] "Percussion drilling" data for New Mexico included with Nevada to avoid disclosing company proprietary data.
[3] Includes Alabama, Arkansas, Florida, Illinois, Kentucky, Michigan, Minnesota, New York, Oklahoma, Tennessee, and items indicated by symbol W.

TABLE 16

TOTAL MATERIAL (ORE AND WASTE) PRODUCED BY MINE DEVELOPMENT IN THE UNITED STATES IN 1987, BY COMMODITY AND STATE

(Thousand short tons)

	Drifting, crosscutting, or tunneling	Raising	Shaft and winze sinking	Stripping	Total [1]
COMMODITY					
METALS					
Antimony	([2])	—	—	—	([2])
Copper	183	35	([2])	96,900	97,100
Gold (lode)	668	30	31	15,900	16,700
Iron ore	W	—	—	4,780	4,780
Lead	2,670	—	—	—	2,670
Silver	1,070	W	2	([2])	1,080
Tungsten	—	—	([2])	—	([2])
Uranium	125	39	W	—	164
Other [3]	117	63	([2])	3,820	4,000
Total [1]	**4,830**	**166**	**33**	**121,000**	**126,000**
INDUSTRIAL MINERALS					
Barite	—	—	—	129	129
Pumice	—	—	—	8	8
Other [4]	62	6	—	487	555
Total [1]	**62**	**6**	**—**	**625**	**693**
Grand total [1]	**4,890**	**172**	**33**	**122,000**	**127,000**
STATE					
Alaska	W	W	—	20	20
Arizona	255	W	—	W	255
Arkansas	—	—	—	3,890	3,890
California	6	3	W	W	9
Colorado	182	6	1	W	189
Hawaii	—	—	—	([2])	([2])
Idaho	80	W	([2])	30	110
Missouri	2,740	—	—	—	2,740
Montana	9	W	W	—	9
Nevada	W	W	—	15,600	15,600
New Mexico	75	W	—	W	75
South Carolina	—	—	—	37	37
Undistributed [5]	1,550	164	31	102,000	104,000
Total [1]	**4,890**	**172**	**33**	**122,000**	**127,000**

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed."
[1] Data may not add to total shown because of independent rounding.
[2] Less than 1/2 unit.
[3] Includes bauxite, gold (placer), zinc, and metal items indicated by symbol W.
[4] Includes abrasives, feldspar, fluorspar, gypsum, millstones, sodium carbonate (natural), and mineral items indicated by symbol W.
[5] Includes Alabama, Illinois, Kansas, Kentucky, Michigan, Minnesota, New York, North Carolina, Oklahoma, South Dakota, Utah, Washington, Wyoming, and items indicated by symbol W.

TABLE 17

U.S. INDUSTRIAL CONSUMPTION OF EXPLOSIVES

(Thousand pounds)

Year	Coal mining[1]	Metal mining[1]	Quarrying and nonmetal mining[1]	Total mineral industry	Construction work and other uses[2]	Total industrial
1983	2,126,263	481,129	467,710	3,075,102	655,150	3,730,252
1984	2,758,659	437,217	479,873	3,675,749	681,109	4,356,858
1985	2,289,600	382,410	510,500	3,182,510	666,141	3,848,651
1986	2,566,337	319,844	585,220	3,471,401	451,435	3,922,836
1987	3,220,762	340,283	482,911	4,043,956	454,301	4,498,257

[1] Some quantities of this use are included with "Construction work and other uses" to avoid disclosing company proprietary data.
[2] Includes some quantities from "Coal mining," "Metal mining," and "Quarrying and nonmetal mining."

TABLE 18

U.S. CONSUMPTION OF EXPLOSIVES IN THE MINERALS INDUSTRY

(Thousand pounds)

Year	Coal mining	Metal mining	Quarrying and nonmetal mining	Total
		PERMISSIBLE EXPLOSIVES		
1983	35,181	311	657	36,149
1984	37,721	195	345	38,261
1985	34,563	117	481	35,161
1986	34,971	7	155	35,133
1987	33,391	—	248	33,639
		OTHER HIGH EXPLOSIVES		
1983	17,964	8,861	31,833	58,658
1984	20,357	7,771	29,658	57,786
1985	21,705	9,466	55,470	86,641
1986	18,004	7,027	63,249	88,280
1987	23,171	9,013	62,250	94,434
		WATER GEL AND SLURRIES		
1983	94,578	49,699	94,261	238,538
1984	99,340	78,959	102,849	281,148
1985[1]	133,858	66,653	80,283	280,794
1986[1]	180,201	57,153	128,854	366,208
1987[1]	195,737	63,125	160,412	419,274
		AMMONIUM NITRATE: FUEL-MIXED AND UNPROCESSED		
1983	1,978,540	422,258	340,959	2,741,757
1984	2,601,241	350,292	347,021	3,298,554
1985[1]	2,099,474	306,174	374,266	2,779,914
1986[1]	2,333,161	255,657	392,962	2,981,780
1987[1]	2,968,463	268,145	260,001	3,496,609
		TOTAL		
1983	2,126,263	481,129	467,710	3,075,102
1984	2,758,659	437,217	479,873	3,675,749
1985	2,289,600	382,410	510,500	3,182,510
1986	2,566,337	319,844	585,220	3,471,401
1987	3,220,762	340,283	482,911	4,043,956

[1] Data for 1985-87 are not comparable to data for prior years. Higher strength blasting agents classification was discontinued. Blasting agents formerly in that classification are now included in "Water gels and slurries."

ABRASIVE MATERIALS

By Gordon T. Austin[1]

The combined value of production of natural abrasives, which includes tripoli, special silica stone, garnet, staurolite, and emery, increased about 9% in 1988. In the case of emery, the increase was due to an increase in unit value of the material produced. The increase in the value of garnet and staurolite production was simply the result of an increase in the quantity of materials produced. However, special silica stone experienced both an increase in unit value and quantity produced.

The nonmetallic manufactured abrasives industry, which includes only silicon carbide and fused aluminum oxide in the reported statistics, enjoyed the best production year since 1981 in terms of total quantity produced. Production increased 22% in quantity and 16% in value compared with those of 1987.

The metallic abrasives industry, which includes the primary producers of steel shot and grit, chilled and annealed iron shot and grit, cut wire shot and grit, and shot and grit reclaimed by primary producers, experienced the fourth year of sales increases in both quantity and value. Shipments increased 18% in 1988 but were still about 3% below the 10-year high of 264,135 short tons in 1979.

The United States continued as the largest single manufacturer, exporter, importer, and consumer of synthetic industrial diamond in the world. The estimated apparent U.S. consumption of industrial diamond stones rebounded from the 48-year low in 1987 with an increase of 185% to 3.9 million carats in 1988.

DOMESTIC DATA COVERAGE

Domestic production data for abrasive materials are developed by the Bureau of Mines from seven separate, voluntary surveys. Of the 61 operations canvassed, producing natural and manufactured abrasives, all responded, representing 100% of the total production shown in tables 1, 5, 6, 8, 14, 15, and 16.

FOREIGN TRADE

The total value of abrasive materials, exports plus reexports, was $300.9 million, an increase of 16% compared with the 1987 value. The average total

TABLE 1

SALIENT U.S. ABRASIVES STATISTICS

		1984	1985	1986	1987	1988
Natural abrasives production by producers:						
Tripoli (crude)	short tons	124,482	r119,828	117,174	114,926	110,152
Value	thousands	r$843	r$844	$918	$975	$864
Special silica stone[1]	short tons	1,290	1,157	1,073	12,773	14,675
Value	thousands	$602	$515	$501	$957	$1,183
Garnet[2]	short tons	29,647	36,727	32,296	42,277	46,855
Value	thousands	$2,487	$2,973	$2,603	$4,350	$4,707
Emery	short tons	W	W	2,878	1,945	958
Value	thousands	W	W	W	W	W
Staurolite	short tons	W	W	W	W	W
Value	thousands	W	W	W	W	W
Manufactured abrasives[3 4]	short tons	531,264	478,897	482,860	486,442	612,483
Value[4]	thousands	$203,231	$171,974	$173,858	$182,039	$219,322
Foreign trade (natural and artificial abrasives):						
Exports (value)[5]	do.	$191,003	$191,272	$207,624	$238,522	$289,396
Reexports (value)[5]	do.	$27,248	$23,845	r$27,011	$21,192	$19,302
Imports for consumption (value)[5]	do.	$381,694	$382,877	r$406,572	$424,640	$501,707

r Revised. W Withheld to avoid disclosing company proprietary data.
[1] Includes grindstones, oilstones, whetstones, and deburring media. Excludes grinding pebbles and tube-mill liners.
[2] Primary garnet; denotes first marketable product.
[3] Includes Canadian production of crude silicon carbide and fused aluminum oxide and shipments of metallic abrasives by producers.
[4] Excludes United States and Canadian production and value of aluminum-zirconium oxide.
[5] Bureau of the Census.

value for the last 10 years was $237.9 million per year with the high of $300.9 million in 1988 and the low of $196.8 million in 1982. The last 3 years have each shown a significant increase in total value compared with the essentially level period of 1983–85.

The total value of abrasive materials imported was $501.7 million, an increase of 18% compared with the 1987 value. The average total value for the last 10 years was $347.1 million per year, with the high in 1988 of $501.7 million and the low of $245.0 million in 1982. Abrasive material imports have increased at a compounded rate of slightly less than 13% per year for the last 6 years.

The United States has shown a trade deficit in abrasive materials for 9 out of the last 10 years, 1979 being the exception. The trade deficit averaged $109.2 million per year for the last 10 years and averaged $173.8 million per year for the last 5 years. The deficit increased 23% to a record high of $200.8 million in 1988.

TABLE 2

U.S. EXPORTS OF ABRASIVE MATERIALS, BY KIND

(Thousands)

Kind		1987		1988	
		Quantity	Value	Quantity	Value
NATURAL					
Industrial diamond, natural or synthetic, powder or dust	carats	55,003	$88,710	72,093	$112,094
Industrial diamond, natural or synthetic, other	do.	1,004	12,164	1,830	15,063
Emery, natural corundum, pumice in blocks	pounds	3,092	1,069	3,303	4,065
MANUFACTURED					
Artificial corundum (fused aluminum oxide)	do.	28,017	22,298	34,091	25,796
Silicon carbide, crude or in grains	do.	10,505	7,819	9,256	7,763
Carbide abrasives, n.e.c.	do.	426	491	1,522	1,404
Other refined abrasives	do.	31,435	19,417	36,932	24,601
Grinding and polishing wheels and stones:					
Diamond	carats	489	5,793	531	6,641
Polishing stones, whetstones, oilstones, hones, similar stone	number	1,020	2,009	1,312	2,486
Wheels and stones, n.e.c.	pounds	5,640	25,876	7,142	29,471
Abrasive paper and cloth, coated with natural or artificial abrasive materials	do.	16,508	46,007	14,661	50,276
Grit and shot, including wire pellets	do.	15,967	6,869	26,181	9,736
Total		**XX**	**238,522**	**XX**	**289,396**

XX Not applicable.

Source: Bureau of Census.

TABLE 3

U.S. REEXPORTS OF ABRASIVE MATERIALS, BY KIND

(Thousands)

Kind		1987		1988	
		Quantity	Value	Quantity	Value
NATURAL					
Industrial diamond, natural or synthetic, powder or dust	carats	1,789	$4,148	2,440	$3,336
Industrial diamond, natural or synthetic, other	do.	1,538	15,428	1,164	14,279
Emery, natural corundum, pumice in blocks	pounds	258	156	178	193
MANUFACTURED					
Artificial corundum (fused aluminum oxide)	do.	181	135	126	90
Silicon carbide, crude or in grains	do.	2	6	172	82
Grinding and polishing wheels and stones:					
Diamond	carats	4	171	6	118
Polishing stones, whetstones, oilstones, hones, similar stone	number	3	10	12	10
Wheels and stones, n.e.c.	pounds	214	847	87	653
Abrasive paper and cloth, coated with natural or artificial abrasive materials	do.	133	291	169	541
Total		**XX**	**21,192**	**XX**	**19,302**

XX Not applicable.

Source: Bureau of the Census.

TRIPOLI

Fine-grained, porous silica materials are grouped together under the category of tripoli because they have similar properties and end uses.

Domestic Production

Processed tripoli, sold or used, decreased slightly in quantity, but because of an increase in the value per ton, the value of production increased about 3%. The quantity of crude tripoli produced decreased for the fifth consecutive year. The average production for the last 10 years was 116,347 tons per year with a high of 127,878 tons in 1979 and a low of 107,330 tons in 1981. Production in 1988 was 110,152 tons.

The six firms producing tripoli were Malvern Minerals Co., Garland County, AR, which produced crude and finished material; American Tri-

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF (NATURAL AND ARTIFICIAL) ABRASIVE MATERIALS, BY KIND

(Thousands)

Kind		1987		1988	
		Quantity	Value	Quantity	Value
Emery, flint, rottenstone, tripoli, crude or crushed	short tons	8	$451	24	$1,018
Silicon carbide, crude	do.	84	35,603	103	47,208
Aluminum oxide, crude	do.	142	58,541	141	55,197
Other crude artificial abrasives	do.	3	704	11	6,452
Abrasives, ground grains, pulverized or refined:					
Silicon carbide	do.	9	11,566	9	12,908
Aluminum oxide	do.	17	16,103	18	18,545
Emery, corundum, flint, garnet, other, including artificial abrasives	do.	4	9,471	5	10,786
Papers, cloths, other materials wholly or partly coated with natural or artificial abrasives		([1])	117,208	([1])	125,873
Hones, whetstones, oilstones, polishing stones	number	1,483	1,362	1,850	1,554
Abrasive wheels and millstones:					
Burrstones manufactured or bound up into millstones	short tons	1	129	([2])	61
Solid natural stone wheels	number	773	489	408	469
Diamond	do.	414	12,685	516	15,465
Abrasive wheels bonded with resins	pounds	11,147	21,711	11,861	24,677
Other		([1])	20,777	([1])	23,178
Articles not specifically provided for:					
Emery or garnet		([1])	708	([1])	739
Natural corundum or artificial abrasive materials		([1])	12,319	([1])	14,059
Other n.s.p.f		([1])	5,275	([1])	7,270
Grit and shot, including wire pellets	pounds	5,950	2,236	7,781	3,406
Diamond, natural and synthetic:					
Diamond dies	number	53	1,767	101	2,542
Crushing bort	carats	327	408	515	638
Natural industrial diamond stones	do.	3,322	34,771	6,326	61,204
Miners' diamond[3]	do.	551	3,166	563	2,965
Powder and dust, synthetic[4]	do.	32,000	43,901	50,748	54,901
Powder and dust, natural	do.	12,677	13,289	12,995	10,592
Total		**XX**	**424,640**	**XX**	**501,707**

XX Not applicable.
[1] Quantity not reported.
[2] Less than 1/2 unit.
[3] Includes 74,077 carats of synthetic miners' diamond in 1987 and 10,000 carats of synthetic miners' diamond in 1988.
[4] Includes 403,977 carats of synthetic diamond in 1987 and 676,413 carats of synthetic diamond in 1988.

Source: Bureau of the Census.

poli Co., which produced crude material in Ottawa County, OK, and finished material in Newton County, MO; Illinois Minerals Co. and Tammsco Inc., both in Alexander County, IL, which produced crude and finished amorphous (microcrystalline) silica; and Keystone Filler and Manufacturing Co. in Northumberland County, PA, which processed rottenstone, a decomposed fine grained siliceous shale produced by B. J. Ulrich & Sons, also in Northumberland County, PA.

Consumption

Because tripoli grains lack distinct edges and corners, they were used as mild abrasives in toothpaste and tooth-polishing compounds, industrial soaps, metal and jewelry polishing compounds, and as buffing and polishing compounds in lacquer finishing in the automobile industry. The mineral also was used as a filler and extender in paint, plastic, rubber, and enamel. The use of tripoli as an abrasive declined for the fifth consecutive year. Over this 5-year period, consumption declined about 29%. The average annual consumption of abrasive tripoli for the last 10 years was 37,715 tons, with a high of 53,600 tons in 1979 and a low of 29,057 tons in 1988. The 1988 consumption was the lowest since 1953, when only 25,000 tons were sold or used.

After 5 consecutive years of growth from 1982 to 1987, the amount of tripoli used as a filler in 1988 was essentially the same as in 1987. The average consumption of filler-grade tripoli for the last 10 years was 66,479 tons per year, with a high of 78,440 tons in 1987 and a low of 55,314 tons in 1982. Bureau of Mines multiyear data indicate that in the United States tripoli is being used less as an abrasive, more as a filler.

Prices

The average reported value of abrasive tripoli, sold or used, in the United States was $108.40 per ton. The average annual value reported for abrasive tri-

TABLE 5

PROCESSED TRIPOLI[1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[2]

Use		1984	1985	1986	1987	1988
Abrasives	short tons	40,812	40,022	36,584	29,362	29,057
Value	thousands	$3,738	$3,670	$3,590	$3,089	$3,151
Filler	short tons	65,941	68,800	73,908	78,440	78,200
Value	thousands	$6,989	$6,452	$8,588	$9,855	$10,216
Other	short tons	—	—	W	W	W
Value	thousands	—	—	W	W	W
Total	**short tons**	**106,753**	**108,822**	**110,492**	**107,802**	**107,257**
Total value	**thousands**	**$10,727**	**$10,122**	**$12,178**	**$12,944**	**$13,367**

W Withheld to avoid disclosing company proprietary data.
[1] Includes amorphous silica and Pennsylvania rottenstone.
[2] Partly estimated.

poli for the last 10 years was $81.60 per ton, with a high value reported in 1988 of $108.40 per ton and the low reported in 1979 of $46.00 per ton. The value of abrasive tripoli has increased over the last 10 years at an annual compounded rate of 10% per year. The increase has been continuous; however, the annual rates of increase from 1985 to the present were significantly lower than the annual rates of increase from 1979 through 1984.

The average reported value of filler tripoli, sold or used, in the United States was $130.60 per ton. The average annual value for the last 10 years was $95.30 per ton, with a high of $130.60 per ton in 1988 and a low of $61.10 per ton in 1979. The value increased at an annual compounded rate of 9% for the last 10 years.

The most recent prices quoted for tripoli, in the July 1988 issue of Engineering and Mining Journal were as follows:

Tripoli, paper bags, carload lots, f.o.b., in cents per pound:	
White, Elco, IL:	
Air floated through 200 mesh	3.55
Rose and cream, Seneca, MO., and Rogers, AR.	
Once ground	2.90
Double ground	2.90
Air float	3.15

SPECIAL SILICA STONE PRODUCTS

Special silica stone products include hones, whetstones, oilstones, stone files, grindstones, grinding pebbles, tube-mill liners, deburring media, and certain specialty products manufactured from novaculite, quartzite, or other microcrystalline quartz rock.

Domestic Production

Oilstones, hones, whetstones, and files were manufactured in Arkansas and Indiana, cuticle stones and coaster stones in Indiana, grindstones in Ohio, deburring media in Arkansas and Wisconsin, oilstones in New Hampshire, and grinding pebbles and mill liners in Minnesota. In all cases, except for the oilstones in New Hampshire, the crude material was quarried in the same State in which the products were manufactured. The novaculite for the New Hampshire oilstones was quarried in Arkansas.

The process for estimating the production of crude material was modified in 1981 and again in 1987. Because of the two changes in the way production was estimated, 10-year averages and other production trends would be of no practical use.

The production of oilstones, hones, whetstones, files, and grindstones decreased about 13% in quantity and 15% in value. The average annual production of the products for the last 10 years was 594 tons, with a high of 713 tons in 1982 and a low of 443 tons in 1985. The average value of annual production for the last 10 years was $5.0 million, with a high of $7.4 million in 1987 and a low of $3.7 million in 1979. In the last 10 years, two distinct and different trends in the value of production appeared. One was from 1979 through 1984, when the average value of production was $4.1 million per year. The other was 1985 through 1988, when the value of production was 56% greater at an average value of $6.4 million a year. During 1985–88, the average of annual production was less than the 10-year average, 583 tons per year versus 594 tons per year, but the average annual value of production was 28% greater than the 10-year average. The change in average annual value was the result of a significant increase in the value per ton of manufactured products, starting in 1985.

Four main grades of whetstone were manufactured, ranging from the high-quality Black Hard Arkansas Stone,

TABLE 6

SPECIAL SILICA STONE FINISHED PRODUCTS SOLD OR USED BY PRODUCERS IN THE UNITED STATES[1]

Year	Quantity (short tons)	Value (thousands)
1984	683	$3,975
1985	443	[r]5,371
1986	[r]510	[r]6,520
1987	[r]659	[r]7,367
1988	579	6,396

[r] Revised.
[1] Includes grindstones, oilstones, and whetstones. Excludes grinding pebbles, tube-mill liners, and deburring media.

with porosity of 0.07% and characterized by a waxy luster, down to the Washita Stone, with porosity of 16% and resembling unglazed porcelain. The four main types were as follows:

TRADE NAME	USE
Black Hard Arkansas Stone	Polishing the most perfect edge possible.
Hard Arkansas Stone	Polishing blades to a very fine edge.
Soft Arkansas Stone	General purpose.
Washita Stone	Rapid sharpening.

Arkansas accounted for 85% of the value and 75% of the total quantity of special silica stone products reported as sold or used by U.S. producers.

Consumption

The domestic consumption of special silica stone products resulted from a mixture of residential, industrial, leisure, and craft uses. The major residential uses were the sharpening of knives and other cutlery such as scissors, shears, and lawn and garden tools. Major industrial uses were the sharpening and honing of cutting surfaces, polishing of metal surfaces, and the deburring of metal and plastic castings. The stone files also are used in the manufacture, repair and modification of guns. The recreational uses were the sharpening of sports knives, arrowheads, spear points, fishhooks, and other recreational items. Craft applications included uses in wood carving, gun engraving, jewelry making, and other engraving work. Estimated apparent U.S. consumption was valued at $6.6 million.

Prices

The value per ton of crude novaculite suitable for cutting into finished products varied from $0.15 per pound for the Washita grade to as much as $1.25 per pound for Black Hard Arkansas grade. The material not suited for making oilstones, hones, or whetstones was used as deburring media or special-

TABLE 7

PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 1988

Company and location	Type of operation	Product
Arkansas Oilstone Co:		
Hot Springs, AR (inactive)	Stone cutting and finishing	Whetstones and oilstones.
Arkansas Whetstone Co., Inc:		
Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.
Baraboo Quartzite Co., Inc:		
Baraboo, WI	Crushing and sizing	Deburring media.
Do.	Quarry	Crude silica stone.
Buffalo Stone Corp:		
Hot Springs, AR	Tumbling and sizing novaculite	Metal finishing media and deburring media.
Cleveland Quarries Co.:		
Amherst, OH	Stone cutting and finishing	Grindstones.
Do.	Quarry	Crude silica stone.
Dans Whetstone Cutting Co., Inc:		
Royal, AR	Stone cutting and finishing	Whetstones and oilstones.
Do.	Quarry	Crude novaculite.
Halls Arkansas Oilstones, Inc.:		
Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Hindostan Whetstone Co.:		
Bedford, IN	do.	Cuticle stone.
Do.	Quarry	Crude silica stone.
Hiram A. Smith Whetstone Co., Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Do.	Quarry	Crude novaculite.
Norton Co. Oilstones, Norton Pike Div.:		
Hot Springs, AR	Quarry	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Pioneer Whetstone Co.:		
Hot Springs, AR	do.	Do.
Poor Boy Whetstones:		
Hot Springs, AR (inactive)	do.	Do.
Robert Lowery:		
Hot Springs, AR	do.	Do.
Taylor Made Crafts, Inc.:		
Lake Hamilton, AR	do.	Do.
Wallis Whetstone:		
Malvern, AR	do.	Do.
Wallis Whetstone:		
Malvern, AR	Quarry	Crude novaculite.
Washita Mountain Whetstone Co.:		
Lake Hamilton, AR	Stone cutting and finishing	Whetstones and oilstones.

purpose crushed stone and ranged in value from $39 per ton to more than $300 per ton. The average value in 1988 of oilstones, hones, whetstones, and grindstones sold or used by U.S. producers was $11,047 per ton or about $5.50 per pound. The average annual value of the same items for the last 10 years was $8,673 per ton, with a high of $12,784 per ton in 1986 and a low of $5,820 per ton in 1984.

The unit value of special silica stone products followed two distinct negative trends in the last 10 years. The first trend, a gradual decrease, occurred during the period 1979 to 1984. The value per ton averaged $6,599, with a high of $7,518 and a low of $5,820. The lowest value occurred in 1984. A second trend began in 1985 when the value per ton more than doubled from $5,820 to $12,124. The average annual value per ton for the period 1985 to 1988 was $11,784, with a high of $12,784 and a low of $11,047, in 1988. One possible explanation for the series of step-ramp trends is the introduction of new high-value products by a single manufacturer, only to encounter significant price competition from other producers in subsequent years. Because the special silica stone products industry is not based on high technology, new products can be duplicated by competitors, very quickly resulting in short-term price pressures.

Foreign Trade

Export value of all special silica stone products was $2.5 million, an increase of 24% compared with the value in 1987, the second-lowest year for exports in the last 10 years. The average annual value of exports for the last 10 years was $2.3 million, with a high of $2.6 million in 1983 and a low of $1.8 million in 1979. The annual value of exports over the last 10 years did not appear to have established a trend, but instead drifted between $2.0 million and $2.6 million with as many increases as decreases.

The value of imported products was $1.6 million, an increase of 14% compared with the 1987 value, but an 11% decrease compared with those of 1985 and 1986. The average annual value of imports for the last 10 years was $1.1 million, with a high of $1.8 million in 1985 and a low of $0.3 million in 1980. Overall, the trend of products imported to the United States has been generally upward with some occasional decreases. The United States continues to be a net exporter of special silica stone products. A portion of the finished products imported was manufactured from crude novaculite produced within the United States and exported for processing.

In 1988, the trade surplus in special silica stone products was $0.92 million, an increase of about 44%. During the last 10 years, the United States has enjoyed an average trade surplus of $1.2 million per year with a high of $2.0 million in 1981 and a low of $0.45 million in 1985. The trend for the last 10 years has been one of declining surpluses. The average annual surplus for the last 4 years has been only $0.68 million or about 57% of the 10-year average.

GARNET

High-quality industrial garnet, a mixture of almandine and pyrope which under pressure breaks into sharp chisel-edged plates, was used as an abrasive powder and to manufacture coated abrasives. Low-quality industrial garnet was used primarily as an airblasting or hydroblasting media and as a filtration media.

Domestic Production

The United States continued to be the largest garnet producer and consumer, accounting for about 45% of the world's production. Five domestic producers operated six plants, three in New York and one each in Idaho, Louisiana, and Maine. Barton Mines Corp., Warren County, NY, produced garnet for use in coated abrasives, glass grinding and polishing, and metal lapping. The NYCO Div. of Processed Minerals Inc.,Essex County, NY, recovered garnet as a byproduct from its wollastonite operation. It sold both crude garnet concentrate for additional refining and refined garnet for use as blasting and filtration media. International Garnet Abrasives Inc., Clinton County, NY, produced garnet for use as blasting and filtration media. The Clinton County plant began production in July. Emerald Creek Garnet Milling Co. continued to operate six mining operations, two jigging plants, and a single mill in Benewah County, ID. The garnet was used primarily as blasting and filtration media. International Garnet Abrasives began operations during March at its garnet reclaiming plant in Jefferson Parish, LA. The garnet was used chiefly by the petroleum industry as a blasting media. Industrial Garnet Extractive Inc., near Rangeley in Oxford County, ME, produced a range of garnet products, which were used mostly in sandblasting and water filtration, until the plant was closed and sold for salvage in April.

Production of crude garnet concentrates increased about 11% in quantity and 8% in value. The average annual production for the last 10 years was 31,847 tons, with a high of 46,855 in 1988 and a low of 21,240 in 1979. Over the last 10 years, production increased about 120%, or at an annual compounded rate of about 9% per year. The production trend for the last 10 years has been one of continued long-term growth with occasional downward adjustments.

Consumption

The quantity and value of garnet sold or used by producers increased about 17% and 44%, respectively, compared with those of 1987. The average annual quantity of garnet sold or used for the last 10 years was 30,675 tons, with a record high of 46,182 tons in 1988 and a low of 23,303 tons in 1979. The trend for the last 10 years

TABLE 8

GARNET SOLD OR USED BY PRODUCERS IN THE UNITED STATES

Year	Quantity (short tons)	Value (thousands)
1984	27,672	$5,677
1985	30,634	6,102
1986	31,856	6,748
1987	39,476	7,744
1988	46,182	11,144

was one of steady annual growth, with the exception of 4% decreases in both 1981 and 1984. The growth rate averaged about 8% compounded annually. Much of the growth in the use of garnet was the result of new regulations establishing new limits on leachable minerals and free silica content in hydroblasting and airblasting media. These changes made garnet the preferred blasting media in some work environments.

Prices

The average value per ton of all types of crude garnet concentrates was $100, a 3% decrease compared with the 1987 average. The average value for the last 10 years was $84 per ton, with a high of $103 in 1987 and a low of $71 per ton in 1980. During the last 10 years, the trend in value of crude concentrate was one of continued increases.

The average value per ton of all types of garnet sold or used was $241, an increase of 23% over the 1987 average. However, the 1987 value was the second lowest in 10 years. The average value for the last 10 years was $205 per ton, with a high of $241 in 1988 and a low of $186 per ton in 1980. Excluding the highest and two lowest values, the difference between the highest value and lowest value in the remaining 7 years was only 6.5%. The price trend of garnet sold or used during the last 10 years has been one of basically stable prices with very minor changes, except for the increase from 1987 to 1988.

Foreign Trade

Garnet exports, as reported by producers to the Bureau of Mines, were about 8,800 tons, an increase of about 60% compared with 1987. Export data on garnet were not available from the Bureau of the Census. Producers have reported exports to the Bureau of Mines for the last 2 years. Prior to 1987, export figures were estimated by the Bureau. Trend analysis beyond the last 2 years would be of limited value because of the large number of estimates included with the data. However, exports have increased, according to producers.

Mineral brokers and other garnet importers reported to the Bureau that about 5,000 tons of garnet was im-

FIGURE 1

GARNET SOLD OR USED IN THE UNITED STATES

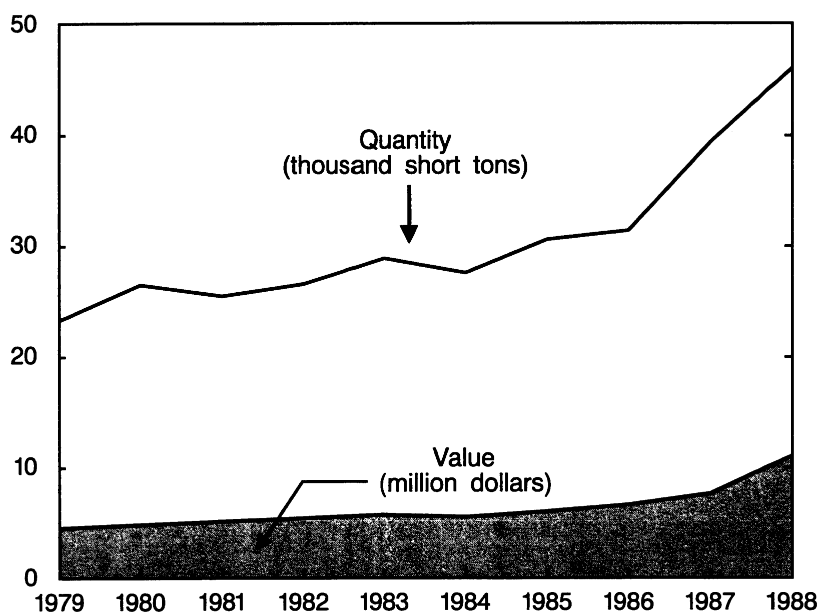


TABLE 9

WORLD GARNET ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Short tons)

Country	Capacity
North America:	
United States	70,000
Europe:	
Norway	8,000
Turkey	700
U.S.S.R.	1,000
Total	**9,700**
Asia:	
China	20,000
India	30,000
Sri Lanka	100
Total	**50,100**
Oceania:	
Australia	16,000
Others	1,000
World total	**146,800**

[1] Includes capacities of operating plants as well as plants on standby basis.

ported, an increase of about 67% compared with the 1987 value. Import data for garnet also were not available from the Bureau of the Census. Bureau of Mines data, which are available for only 3 years, showed a significant increase in garnet imports each year. The United States was a net exporter of garnet in 1988; exports exceeded imports by 76%.

World Review

Target Mines Ltd. continued to produce at near capacity from its Australian garnet sand operation. The company indicated a willingness to increase production if additional contracts were available. The Chinese mines continued to increase production of garnet for the export market. However, to date the quality of the garnet has not routinely met requirements for the U.S. market. Two beach-sand mining operations in India continued to produce garnet as a byproduct of mineral sands production. Samples of the garnet have been tested for applications in the United States, but, to date, the major market for the Indian garnet has been Japan. Norway, Turkey, and the U.S.S.R. primarily produce for local markets.

EMERY

Emery, an impure corundum containing magnesium-aluminum silicates, was used as an abrasive aggregate for nonskid, wear-resistant floors, pavements, and stair treads; as tumbling or deburring media; and in the manufacture of coated abrasives.

Domestic Production

One company, John Leardi Emery Mine, produced crude emery from a single mine near Peekskill in Westchester County, NY. In September, the mine was sold to Croton Dam Road Corp., Ossining, NY. The new owner operated the mine as a crushed stone producer and did not produce emery. Production for the year was less than 50% of 1987 production. The emery was processed by Washington Mills Abrasives Co., North Grafton, MA, and Emeri-Crete Inc., New Castle, NH.

Consumption

The U.S. consumption of emery was estimated to be approximately 12,000 tons. The majority of the material consumed was imported from Greece and Turkey. Three firms processed and distributed emery for domestic consumption: Washington Mills Abrasives Co.; Emeri-Crete Inc.; and General Abrasives Co.

Foreign Trade

The United States did not export emery in 1988, nor has it exported emery in the last 10 years. During the last 10 years, a small amount of emery may have been reexported, but emery reexports could not be determined because emery was reported by the Bureau of the Census in a mineral group category.

Emery imports were reported by the Bureau of the Census in a mineral group category; therefore, data on emery imports also were not available. The Bureau estimated Turkey exported approximately 10,500 tons of emery to the United States. Because of the high cost of the material, very little emery was exported from Greece, the second largest producer, to the United States.

World Review

Turkey, with production of approximately 21,000 tons, was the world's largest producer of emery. The second largest producer was Greece, with a total production of about 8,500 tons.

STAUROLITE

Staurolite is a naturally occurring, complex, hydrated aluminosilicate of iron having a variable composition. The mineral most commonly occurs as opaque, reddish-brown to black crystals with specific gravity ranging from 3.74 to 3.83 and Mohs' hardness of between 7 and 8.

Domestic Production

Mineral specimen staurolite crystals, in the cruciform twinned form commonly referred to as "fairy crosses," were produced from deposits in Georgia, North Carolina, and Virginia. Industrial staurolite was produced by E.I. du Pont de Nemours & Co. Inc. Production data are not published to avoid disclosing company proprietary data; however, production of industrial staurolite increased 19% in quantity compared with that of 1987.

Industrial staurolite was a byproduct of heavy-mineral concentrates recovered from a beach sand in Clay County, north-central Florida. The staurolite was removed by electrical and magnetic separation after the concentrates were scrubbed, washed with caustic, rinsed, and dried. The resulting material was composed of about 77% clean, rounded, and uniformly sized grains of staurolite, with minor amounts of tourmaline, ilmenite and other titanium minerals, kyanite, zircon, and quartz. The nominal composition of the material was 45% aluminum oxide (minimum), 18% ferric oxide (maximum), 5% silica (maximum), and 3% zirconium dioxide (maximum).

Consumption

Shipments of staurolite increased 13% in tonnage and 60% in value. Staurolite, marketed under the trade name Biasill, was used as molding material in nonferrous foundries because of its low thermal expansion, high thermal conductivity, and high melting point. Its low softening temperature tends to restrict its use to nonferrous casting. The major use of staurolite was as an abrasive for impact finishing of metals and sandblasting of buildings. The blasting media was marketed under the trade names Starblast (80 mesh) and Siasill (90 mesh). A coarse grade (55 mesh) was also used as an abrasive. A minor amount was used in some portland cement formulations. As regulations limiting the amount of free silica in airblasting media have become more stringent, the demand for staurolite increased.

Foreign Trade

Exports or imports of staurolite were not reported by the Bureau of the Census, staurolite producers, or staurolite consumers. Given the limited market and the relatively low price per ton, it is not expected that an international market for staurolite would develop in the near term.

World Review

India continued to produce small amounts of staurolite for local consumption. Other countries sometimes produce small amounts of staurolite as byproduct of mineral sands or gem stone production.

INDUSTRIAL DIAMOND

Industrial diamond is natural diamond that does not meet the standards of gem diamond because of its color, size, or some other imperfection, or a synthetic diamond that is tailor-made for industrial applications.

Legislation and Government Programs

The National Defense Stockpile for industrial diamonds, as of December 31, 1988, had a goal and an inventory of 22 million carats for crushing bort and a goal of 7.7 million carats for industrial stones and an inventory of 7.78 million carats. Approximately 1.8 million carats of industrial diamond stones in excess of the stockpile goal were sold during 1988. The inventory of small diamond dies was 25,473 pieces, compared with a goal of 60,000 pieces; however, no purchase authorization was issued.

Domestic Production

Three domestic firms produced synthetic industrial diamond in the United States: Du Pont Industrial Diamond Div., Gibbstown, NJ; General Electric Co., Superabrasives Department, Worthington, OH; and Megadiamond Industries Inc.,a subsidiary of Smith International Inc., Provo, UT. A fourth company, U.S. Synthetics Corp., Orem, UT, manufactured polycrystalline diamond from purchased synthetic diamond grit. U.S. Synthetics had the capability to manufacture synthetic industrial diamond grit, but chose not to for economic reasons. Production data are not published to avoid disclosing company proprietary data; however, domestic production increased significantly. The United States continued to be the largest single producer of synthetic industrial diamond, a role it has enjoyed since 1957. Production averaged about 67 million carats per year for the last 10 years. Over the same period, production increased at an average rate of 9% compounded annually.

The following seven firms were involved in U.S. secondary production of industrial diamond: Amplex Corp., Bloomfield, CT; Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston,TX; Kay Industrial Diamond Corp., Pompano Beach, FL; Keenkut Inc., Keene, NH; and National Research Co., Fraser, MI. The firms reclaimed a total of about 7.2 million carats from used drill bits, diamond tools, and wet and dry diamond-containing waste, an increase of 118% compared with that of 1987.

Consumption

The United States continued to be the largest single consumer of industrial diamond. The Bureau of Mines estimate of apparent consumption of industrial diamond was approximately 86 million carats, an increase of about 19% compared with 1987 consumption. Average annual consumption for the last 10 years was about 55.7 million carats. During this period, two consumption trends occurred. The average annual consumption for 1979-83 was about 37.5 million carats, whereas that for 1984-88 was 97% greater or about 73.9 million carats. The second trend was the result of the strong movement to industrial diamond in the U.S. manufacturing sectors because of the economic advantages in removing material and finishing surfaces using industrial diamond and diamond tools and wheels and the recovery from the 1982–83 recession.

Prices

The Bureau of Mines does not collect price data on industrial diamonds. However, the Bureau did track the average import value of various classifications of industrial diamonds. The average value of natural grit and powder, synthetic grit and powder, and industrial stones imported into the United States was $0.82 per carat, $1.08 per carat, and $9.31 per carat, respectively. The average annual value of imported natural grit and powder for the last 10 years was $1.64 a carat, with a high value of $2.86 in 1980 and a low of $0.82 a carat in 1988. The average value of natural grit and pow-

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND (EXCLUDING DIAMOND DIES)

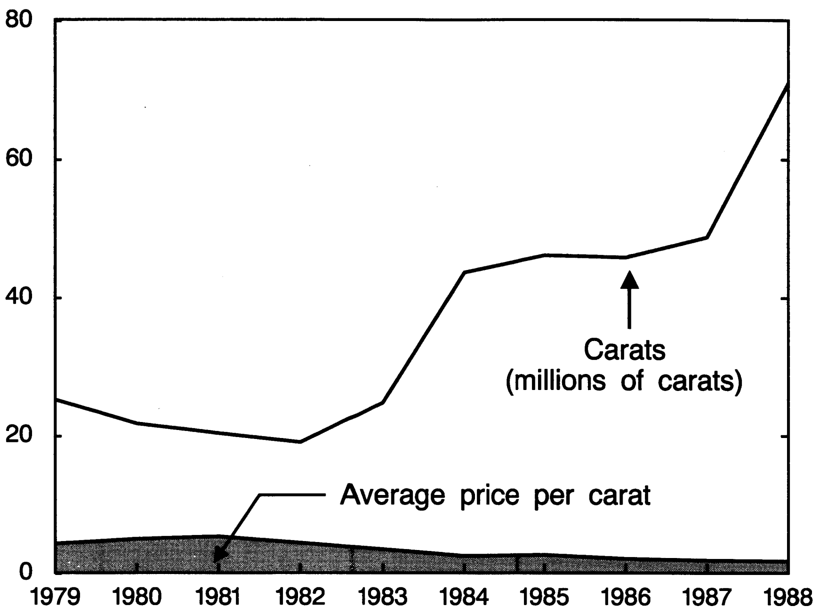
(Thousand carats and thousand dollars)

Year	Quantity	Value
1984	43,710	113,632
1985	46,222	127,191
1986	45,991	110,648
1987	48,877	95,559
1988	71,147	130,300

Source: Bureau of the Census.

FIGURE 2

INDUSTRIAL DIAMOND IMPORTED FOR U.S. CONSUMPTION



der, in current dollars, declined every year since 1980. The 1980 average value was 425% greater than that of 1988.

The average annual value of imported synthetic grit and powder for the last 10 years was $1.49 a carat, with a high value of $1.86 a carat in 1981 and a low of $1.08 in 1988. The average value of imported synthetic grit and powder decreased every year since 1981. The 1988 value declined 72% compared with 1981 while the decline from 1987 to 1988 was only about 7%. During the last 10 years, a major change occurred in the relationship of the average value of natural grit and powder to the average value of synthetic grit and powder. In 1979, natural grit and powder average value was 49% greater than the average value for the synthetics. In 1988, the average value for the synthetics was 32% greater than that for natural material. Natural grit and powder declined in value at a much greater rate than did synthetic grit and powder. This made the synthetic material more valuable.

The average annual value of imported industrial diamond stones for the last 10 years was $10.26 per carat, with a high value of $13.93 in 1981 and a low of $7.24 in 1986. The trend in the value of industrial stones has been mixed for the last 10 years but there has been an overall small, 7%, decrease in the average value. The period started with 3 years of increasing values, followed by 3 years of decreasing values. The final 4 years were mixed with alternating decreasing and increasing values. The 1988 average value was 4% less than the 1987 value, 50% less than the 1981 high, and 12% less than the 1979 value.

Foreign Trade

The United States was the largest exporter of industrial diamond grit and powder in the world. The United States exported and reexported a record 74.5 million carats of natural and synthetic grit and powder, valued at a record $115.4 million, and approximately 3.0 million carats of industrial stones, valued at $29.3 million.

Six countries received approximately 76% of the total U.S. exports of synthetic grit and powder. The countries and the percentage of exports they received were: Japan, 27%; Federal Republic of Germany, 21%; Ireland, 8%; Belgium, 7%; Italy, 7%; and Republic of Korea, 6%. The six countries that received about 74% of the total U.S. exports of industrial stones and the percentage of exports they received were: Belgium, 24%; Ireland, 21%; Canada, 10%; Japan, 9%; France, 8%; and Federal Republic of Germany, 6%.

The average annual exports plus reexports of natural and synthetic grit and powder for the last 10 years was 44.0 million carats, with an average value of $81.3 million. The highest level of exports plus reexports during the last 10 years was in 1988 when 74.5 million carats valued at $115.4 million were shipped, and the lowest was 27.8 million carats valued at $72.8 million in 1979. The trend of exports plus reexports for the last 10 years was one of continued growth with an increase of 168% over the period or an annual average compounded growth rate of 11.2%. However, the increase from 1987 to 1988 was about 31%, indicating very strong growth at nearly three times the 10-year average.

The average annual exports plus reexports of industrial stones for the last 10 years was 2.9 million carats a year and the average value was $33.3 million, with a high of 3.6 million carats in 1986 and a low of 1.9 million carats in 1982. The trend over the last 10 years was mixed. Exports plus reexports of about 3.0 million carats were 18% greater than in 1987 and about 9% higher than in 1979. However, 1987 exports plus reexports were 28% less in

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND, BY COUNTRY[1]

(Thousand carats and thousand dollars)

Country	Natural industrial diamond stones (including glazers' and engravers' diamond, unset) (520.2900)[4]				Miners' diamond[2] natural and synthetic[3] (529.1900 and 520.2340)[4]				Diamond powder and dust, synthetic (520.2000),[4] 5220.2020, 520.2040, 520.2060, and 520.2100)[4]				Diamond powder and dust, natural (520.2800)[4]			
	1987		1988		1987		1988		1987		1988		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Australia	9	114	45	597	—	—	—	—	—	—	—	—	4	47	1	85
Belgium-Luxembourg	553	4,653	648	5,890	33	423	8	27	459	763	174	764	703	833	462	412
Canada	2	166	31	90	([5])	4	8	18	70	59	119	75	208	89	256	82
China	([5])	13	—	—	—	—	—	—	23	42	—	—	6	326	—	—
Congo	2	58	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Finland	—	—	—	—	—	—	—	—	—	—	128	318	43	78	—	—
France	([5])	16	253	431	18	57	34	71	30	9	—	—	1	2	—	—
Germany, Federal Republic of	42	490	13	151	13	180	64	115	1,044	379	2,181	975	108	260	133	237
Ghana	156	1,826	240	4,785	—	—	2	39	—	—	14	90	794	889	26	109
Greece	—	—	—	—	—	—	—	—	525	240	256	115	—	—	—	—
Hong Kong	2	66	—	—	1	51	—	—	([5])	11	—	—	([5])	1	—	—
Iran	20	69	—	—	86	313	—	—	—	—	—	—	—	—	—	—
Ireland	201	924	257	966	154	1,011	348	2,259	22,751	37,925	37,642	46,111	4,038	3,253	4,748	5,310
Israel	6	303	3	232	—	—	—	—	45	84	([5])	33	([5])	24	80	26
Italy	—	—	—	—	—	—	—	—	361	226	679	307	25	51	—	—
Japan	14	614	353	1,589	—	—	—	—	4,694	3,000	5,583	3,463	1,405	620	1,941	1,312
Mexico	—	—	—	—	—	—	2	25	—	—	—	—	—	—	—	—
Netherlands	60	642	99	1,660	1	9	1	64	—	12	([5])	21	—	—	—	—
South Africa, Republic of	131	1,539	([5])	1	1	18	1	3	—	—	—	—	7	112	2	1
Switzerland	4	326	8	300	—	—	5	7	299	148	862	723	210	175	735	385
U.S.S.R.	1	68	—	—	—	—	—	—	391	102	430	114	1,206	372	3,265	1,294
United Kingdom	806	14,594	1,447	26,829	40	135	49	108	367	308	629	479	844	1,884	988	930
Venezuela	—	—	—	—	([5])	6	—	—	—	—	—	—	—	—	—	—
Zaire	1,203	7,581	2,736	10,249	134	702	6	22	7	31	31	50	2,664	3,828	216	321
Other Africa, n.e.c.	6	177	—	—	—	—	—	—	1	—	—	—	6	63	—	—
Other	104	532	193	7,434	106	257	35	207	938	585	2,020	1,263	405	382	142	88
Total[6]	**3,322**	**34,771**	**6,326**	**61,204**	**587**	**3,166**	**563**	**2,965**	**32,000**	**43,901**	**50,748**	**54,901**	**12,677**	**13,289**	**12,995**	**10,592**

[1] Excludes 390,400 carats of crushing bort from Belgium-Luxembourg, Canada, Japan, the Republic of South Africa, and the United Kingdom in 1987, and 251,600 carats from Belgium-Luxembourg, Japan, and the United Kingdom in 1988.

[2] Customs value.

[3] Includes 74,077 carats of synthetic miners' diamond in 1987 and 10,000 carats of synthetic miners' diamond in 1988.

[4] T.S.U.S. codes.

[5] Less than 1/2 unit.

[6] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

quantity than the 10-year high in 1986.

The average annual imports of natural diamond grit and powder was 6.6 million carats a year for the last 10 years, with a high of 13.0 million in 1988 and a low of 3.3 million in 1982. Imports as measured in carats were about 3% greater than 1987 and 147% greater than 1979. The trend in the quantity of natural grit and powder imported over the last 10 years was one of significant increases; however, during this period, the quantity of natural grit and powder decreased from 29% to 20% of all diamond grit and powder imported. During 1988, four countries supplied 85% of U.S. imports of natural grit and powder: Ireland, 37%; U.S.S.R., 25%; Japan, 15%; and the United Kingdom, 8%. Only the U.S.S.R. was a producer of natural diamonds.

The average annual imports of synthetic diamond grit and powder was 23.2 million carats a year for the last 10 years, with a high of 50.7 million carats in 1988 and a low of 10.9 million carats in 1981. Imports in 1988 were about 59% greater than in 1987 and 293% greater than in 1979. The trend of synthetic grit and powder imports over the last 10 years was one of an early decline of about 16% over 2 years followed by continued strong growth. The average annual compounded growth rate for the 10 years was about 16%; however, the average annual compounded rate of growth from the low in 1981 through 1988 was about 23%. The 59% increase in 1988 imports indicated that the growth trend has begun to increase at an even greater rate. Three countries furnished 89% of the synthetic diamond grit and powder imported into the United States in 1988: Ireland, 74%; Japan, 11%; and the Federal Republic of Germany, 4%.

The 10-year average for imports of industrial diamond stones was 6.7 million carats a year, with a high of 9.4 million in 1985 and a low of 3.9 million in 1987. The trend for the period was mixed, but the quantity imported in 1988 was about 3% less than the quantity imported in 1979. The 1988 imports were about 78% greater than 1987 imports, but 1987 imports were 57% below 1986 imports. Four countries accounted for about 81% of the diamond stones imported into the United States during 1988: Zaire, 40%; United Kingdom, 22%; Belgium, 10%; and Ireland, 9%.

The United States was a net exporter of diamond grit and powder, a net importer of industrial diamond stones, and overall a net exporter of industrial diamond for both quantity and total gross value. The excess trade balance in industrial diamonds was about 6.4 million carats and $14.4 million.

World Review

DeBeers Consolidated Mines Ltd.'s sales of uncut diamonds through its subsidiary Central Selling Organization, were reported to be a record high $4.17 billion, an increase of about 36% from the old record high of $3.07 billion in 1987. In March, DeBeers Industrial Diamond Div. announced an average price increase of 15% on synthetic diamond products. The price increase followed many years of static or falling prices, and the increase was reportedly due in part to the falling U.S. dollar, the currency in which all of the company's products are priced.

Australia.—Argyle Diamond Mines Pty. Ltd.'s annual diamond production increased by nearly 14% to a record 34,553,724 carats, all from the Argyle AK-1 pipe. Argyle provided about 37% of the annual world production of natural diamonds. The discovery of an additional deposit of alluvial diamonds in the lower reaches of the Smoke and Limestone Creeks that drain the AK-1 pipe added about 60 million carats to Argyle's resources. If the newly discovered alluvial diamonds are economical to recover, annual production is likely to increase by about 3.0 million carats.[2]

Freeport Bow River Properties Inc., the operator of the Freeport-McMoRan

TABLE 12

WORLD INDUSTRIAL DIAMOND ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

Rated capacity[1]
(Carats)

	Capacity	
	Natural	Synthetic
North America:		
United States	—	100,000,000
South America:		
Brazil	1,250,000	—
Guyana	10,000	—
Venezuela	600,000	—
Total	**1,860,000**	**—**
Africa:		
Angola	200,000	—
Botswana	5,000,000	—
Central African Republic	200,000	—
Ghana	750,000	—
Guinea	25,000	—
Liberia	200,000	—
Namibia	100,000	—
Sierra Leone	100,000	10,000
South Africa, Republic of	8,000,000	20,000,000
Tanzania	100,000	—
Zaire	30,000,000	—
Total	**44,675,000**	**20,010,000**
Europe:		
Czechoslovakia	—	5,000,000
France	—	4,000,000
Greece	—	1,000,000
Ireland	—	90,000,000
Romania	—	5,000,000
Sweden	—	25,000,000
U.S.S.R.	8,000,000	70,000,000
Yugoslavia	—	5,000,000
Total	**8,000,000**	**205,000,000**
Asia:		
China	800,000	15,000,000
India	5,000	—
Indonesia	30,000	—
Japan	—	30,000,000
Total	**835,000**	**45,000,000**
Oceania:		
Australia	25,000,000	—
Total world	**80,370,000**	**370,010,000**

[1] Includes capacity at operating plants as well as plants on standby basis. Rated capacity based on 340 days per year effective operation.

TABLE 13

DIAMOND: WORLD PRODUCTION, BY TYPE AND COUNTRY[1]

(Thousand carats)

Country	1984			1985			1986			1987[p]			1988[e]			Synthetic[3]
	Natural															
	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	
Angola	652	250	902	464	250	714	240	10	[e]250	180	10	[e]190	950	50	1,000	—
Australia	3,415	2,277	5,692	4,242	2,828	7,070	13,145	16,066	29,211	13,650	16,683	30,333	17,517	17,517	[4]35,034	—
Botswana	5,810	7,104	12,914	6,318	6,317	12,635	9,610	3,500	13,110	9,367	3,840	13,207	10,801	4,428	[4]15,229	—
Brazil	200	550	750	233	217	450	310	315	625	309	213	522	310	300	610	—
Central African Republic	236	101	337	190	87	277	259	99	358	304	108	412	[4]284	[4]59	[4]343	—
China[e]	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	15,000
Czechoslovakia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5,000
France	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4,000
Ghana	35	311	346	60	[r]576	[r]636	[r]83	[r]438	521	[r]65	[r]400	465	49	303	352	—
Greece	—	—	—	—	—	—	—	—	—	—	—	—	([5])	—	([5])	1,000
Guinea	44	3	47	123	9	132	190	14	204	163	12	175	136	10	146	—
Guyana[e]	6	8	14	4	7	11	3	6	[3]9	4	7	11	1	3	[4]4	—
India	13	2	15	14	2	16	13	[r]3	16	[r]16	[r]3	19	16	3	19	—
Indonesia[e]	5	22	27	5	22	27	5	22	27	5	25	30	5	25	30	—
Ireland	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	90,000
Ivory Coast[e 6]	20	5	25	15	5	20	10	4	14	15	[r]6	[r]21	15	5	20	—
Japan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25,000
Liberia	108	132	240	66	72	138	63	189	252	60	190	[e]250	67	100	[4]167	—
Namibia	884	46	930	865	45	910	970	40	1,010	[r]987	[r]50	1,037	901	37	[4]938	—
Romania	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5,000
Sierra Leone[6]	240	105	345	243	106	349	215	100	315	[r]150	[r]75	225	100	75	175	—
South Africa, Republic of:																
Finsch Mine	1,714	3,184	4,898	1,770	3,184	4,954	1,821	3,208	5,029	1,455	2,701	4,156	1,372	2,548	3,920	—
Premier Mine	765	1,785	2,550	820	1,864	2,684	882	1,977	2,859	772	1,713	2,485	696	1,543	2,239	—
Other DeBeers' properties[7]	1,452	593	2,045	1,500	569	2,069	1,428	529	1,957	1,427	546	1,973	1,388	531	1,919	—
Other	585	65	650	460	35	495	342	41	383	409	30	439	283	21	304	—
Total	**4,516**	**5,627**	**10,143**	**4,550**	**5,652**	**10,202**	**4,473**	**5,755**	**10,228**	**4,063**	**4,990**	**9,053**	**3,739**	**4,643**	**8,382**	**25,000**
Swaziland	7	10	17	9	12	21	17	23	[e]40	17	23	[e]40	60	90	150	—
Sweden	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25,000
Tanzania	193	84	277	165	71	236	133	57	190	[r]105	[r]45	[r e]150	105	45	150	—
U.S.S.R.[e]	4,300	6,400	10,700	4,400	6,400	10,800	4,400	6,400	10,800	[r]4,400	[r]6,400	[r]10,800	4,500	6,500	11,000	41,500
United States	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	W
Venezuela	40	232	272	35	180	215	45	189	234	50	200	[e]250	50	200	250	—
Yugoslavia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5,000
Zaire	5,169	13,290	18,459	4,032	16,127	20,159	4,661	18,643	23,304	[r]3,885	[r]15,540	19,425	3,800	15,200	19,000	—
Total	**26,093**	**37,359**	**63,452**	**[r]26,233**	**[r]39,785**	**[r]66,018**	**39,045**	**52,672**	**91,717**	**37,995**	**49,620**	**87,615**	**43,606**	**50,393**	**93,999**	**241,500**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Table includes data available through May 31, 1989. Total diamond output (gem plus industrial) for each country actually is reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1984-87), Botswana (1987), Brazil (1987), Central African Republic (1984-88), Guinea (1984-87), and Liberia (1984-86), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural, and for most countries, is based on the best available data at time of publication.

[2]Includes near-gem and cheap-gem qualities.

[3]Includes all synthetic diamond production.

[4]Reported figure.

[5]Less then 1/2 unit.

[6]Figures are estimates based on reported exports and do not include smuggled diamonds.

[7]Other DeBeers' Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

Australia Ltd. and Gem Exploration and Minerals Ltd. joint venture, started production from the Bow River alluvial diamond mine and produced an estimated 480,000 carats by yearend. The diamond production was estimated to be about 20% gem quality, 70% near-gem quality, and 10% industrial.

Botswana.—Debswana, the operator of the diamond mining joint venture between DeBeers Consolidated Mines Ltd. and the Botswana Government, announced plans to build a new diamond processing plant at the Jwaneng Mine. The plant will recover diamonds too small to be recovered by old methods. Production should increase 10% yearly from the 1988 production of about 7.6 million carats.[3]

China.—It was reported that the Mount Yimeng area in Shandong Province has an estimated 11.2 million carats of diamond reserves, the largest of any province in China. Two Government-owned mines operated, in the area, producing a total of 30,000 carats a year. Five of the largest diamonds discovered in China have come from this area.

Sierra Leone.—The Diamond Corp. West Africa Ltd. subsidiary of De Beers Consolidated Mines Ltd., reportedly closed down its operations in Sierra Leone, where it has been buying and exporting diamonds for over 30 years. No reason was given for closing the operations.

Technology

Ultra High Pressure Units, the industrial diamond manufacturing subsidiary of DeBeers Consolidated Mines Ltd., ordered five large-capacity hydraulic link presses. The presses are the new high-efficiency, high-production type for synthesizing industrial diamonds. The first press was delivered in September, and the fifth and last was to be delivered in early 1989.

A Japanese firm claims it can synthesis a 180-micrometer-thin diamond film in just 1 hour, using a jet nozzle to spray a high-density argon-hydrogen-methane plasma through a direct-current electric arc onto a substrate. The thin, strong film is reported to have a thermal conductivity ratio only 20% lower than natural diamond. The film could have major applications in the manufacture of circuits for computers. A major Japanese diamond tool manufacturer claims it can deposit a diamond film 5 micrometers thick within 1 hour on a tungsten tool tip, using an improved chemical vapor deposition method. To test the results of the diamond coating, the tool was used to dry-turn an aluminum alloy. After 100 minutes of continuous cutting, the tool's flank wear was only 1 micrometer. The tool was more than 50 times more abrasion resistant than the ordinary cemented-carbide tool.[4]

A U.S. firm in Ohio, using a high-energy ion beam process, can place a diamondlike film up to 1 micrometer thick on the surfaces of metallic, ceramic, plastic, and glass components. The film can be applied directly to three-dimensional components at temperatures that do not exceed 150° F. The film is uniform, transparent, nonporous, and bonded tightly to the surface to eliminate chipping and replicate the substrate surface finish.

A company in Menlo Park, CA, marketed a diamond-film-coated X-ray window for detectors used to analyze ores and other samples. The thin, uniform, and continuous diamond film was deposited using chemical vapor deposition. The coated X-ray windows last about 10 times longer than standard windows, according to a company spokesman.

MANUFACTURED ABRASIVES

Manufactured abrasives include silicon carbide, fused aluminum oxide, aluminia-zirconia oxide, metallic shot and grit, and cut wire shot and grit. Production data reported for silicon carbide, fused aluminum oxide, and alumina-zirconia oxide were for United States and Canada. Data for metallic and cut wire shot and grit were for only the United States.

Fused Aluminum Oxide

Legislation and Government Programs.—The National Defense Stockpile, as of December 31, 1988, contained 249,867 tons of crude fused aluminum oxide and 50,786 tons of abrasive-grain fused aluminum oxide. The crude and abrasive-grain fused aluminum oxide was being held as an offset against a goal of 379,253 tons of abrasive-grain bauxite.

Production.—At yearend, four firms were producing fused aluminum oxide at eight plants in the United States and Canada. Production of regular-grade fused aluminum oxide increased 30% to 189,770 tons, a 10-year high. The average annual production for the last 10 years was 152,320 tons, with a low of 116,727 tons in 1982. The production trend for the last 10 years was one of sharp decline, 35% in three years, followed by up and down years to full recovery, so that 1988 production was 6% greater than 1979 production.

Production of high-purity fused aluminum oxide increased 82% to 36,197 tons, a 6-year high. The average annual production for the last 10 years was 25,511 tons, with a high of 45,560 tons in 1979 and a low of 14,846 tons in 1982. The production trend for the last 10 years started with a very sharp decline, 67% between 1979 and 1982, followed by years of increases and decreases that saw production swing between about 15,000 and 20,000 tons until the major increase of 82% in 1988. The 10-year period ended with production 21% below the 1979 level. Total 1988 production of 225,967 tons was 36% greater than 1987 production and 72% higher than the low of 131,573 tons in 1982, but essentially

TABLE 14

CRUDE MANUFACTURED ABRASIVES PRODUCED IN THE UNITED STATES AND CANADA, BY KIND

Kind		1984	1985	1986	1987	1988
Silicon carbide[1]	short tons	137	113	124	125	130
Value	thousands	$57,125	$42,563	$48,064	$48,790	$50,559
Aluminum oxide (abrasive grade)[1]	short tons	177	169	151	144	226
Value	thousands	$63,818	$54,061	$50,584	$56,393	$71,325
Aluminum-zirconium oxide	short tons	W	W	W	W	W
Value	thousands	W	W	W	W	W
Metallic abrasives[2]	short tons	217	197	208	217	245
Value	thousands	$82,288	$75,349	$75,210	$76,856	$88,114
Total	**short tons**	**[3]531**	**[3]479**	**[3]483**	**[3]486**	**601**
Total value	**thousands**	**[3]$203,231**	**[3 4]$171,974**	**[3]$173,858**	**[3]$182,039**	**$209,998**

W Withheld to avoid disclosing company proprietary data.
[1] Figures include material used for refractories and other nonabrasive purposes.
[2] Shipments for U.S. plants only.
[3] Excludes United States and Canadian production and value of aluminum-zirconium oxide.
[4] Data do not add to total shown because of independent rounding.

unchanged from 1979 production of 224,951 tons.

Prices.—The Bureau did not collect data on the prices of various grades of fused aluminum oxide. It did, however, collect data on the value of fused aluminum oxide production. The average value of regular-grade fused aluminum oxide, as reported by producers, was a 10-year low of approximately $294 a ton. The average annual value for the last 10 years was $323 a ton, with a high of $351 in 1983. In 1988, the average value of high-purity fused aluminum oxide was a 10-year low at $432 a ton. The average annual value of the last 10 years was $478 a ton, with a high of $571 a ton in 1982. The average value of all grades of fused aluminum oxide in 1988 was a 10-year low at $316 a ton. The average annual value for the last 10 years was $343 a ton, with a high of $369 in 1983. The trend of fused aluminum oxide values for the last 10 years was mixed, with a general upward trend from 1979 to 1983 and a general downward trend from 1983 to 1988. The 1988 average value declined about 5% from that of 1979.

Foreign Trade.—The quantity of exports plus reexports of fused aluminum oxide increased 21% to 17,109 tons; the value of exports plus reexports increased 16% to $25.9 million. However, the average value of a ton of fused aluminum oxide exported or reexported decreased 5% to $1,514. During the last 10 years exports plus reexports have averaged 16,306 tons a year with an average annual value of $18.5 million and an average value per ton of $1,216. The largest quantity of material exported in a single year in the last 10 years was 29,364 tons in 1982, and the smallest amount was 10,930 tons in 1986. Over the last 10 years no trend developed in the export and reexport of fused aluminum oxide. Quantities increased and decreased randomly, and the period ended in 1988 with exports about 14% below those of 1979.

Imports were constant for the last 3 years at 159,000 tons, but the value of imports decreased slightly from $74.6 million in 1987 to $73.7 million in 1988. Average annual imports for the last 10 years were 171,500 tons, with a high of 219,000 tons in 1979 and a low of 125,000 tons in 1982. The trend of fused aluminum oxide imports for the last 10 years was one of general decline and then stabilizing for the last 3 years at about 73% of the 1979 level.

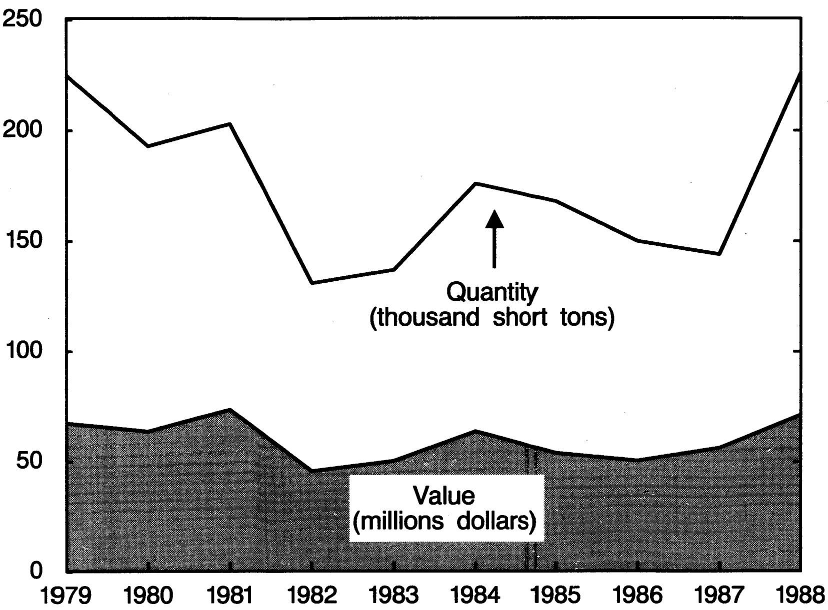
Silicon Carbide

Legislation and Government Programs.—The National Defense Stockpile, as of December 31, 1988, contained 71,690 tons of silicon carbide and the goal was 29,000 tons. During the year, 1,260 tons of silicon carbide was disposed of from the stockpile; existing legislation authorizes disposal of an additional 40,740 tons in the future. The disposal was in support of the ferroalloys upgrading project.

Production.—Four firms produced silicon carbide at six plants in the United States and Canada in 1988. Production of abrasive-grade material increased slightly to 56,440 tons. Average annual production for the last 10 years of abrasive silicon carbide was

FIGURE 3

PRODUCTION OF CRUDE FUSED ALUMINUM OXIDE



51,525 tons, with a high of 68,600 tons in 1979 and a low of 39,896 tons in 1983. Production of metallurgical-grade silicon carbide increased about 4% to 71,648 tons. Average annual production of metallurgical-grade silicon carbide for the last 10 years was 63,210 tons, with a high of 78,275 tons in 1980 and a low of 42,300 tons in 1983. Production of refractory and other grades of silicon carbide increased 59% to 2,068 tons, but was still only 15% of 1986 production and only about 5% of 1980 production. The average annual production of refractory and other grades of silicon carbide for the last 10 years was 17,000 tons, with a high of 38,174 tons in 1980 and a low of 1,302 tons in 1987. Total production of silicon carbide increased about 4% in 1988 to 130,156 tons, compared with a 10-year average annual production of 137,156 tons, a high of 196,000 tons in 1979, and a low of 109,099 tons in 1983. The 10-year production trend for all grades of silicon carbide was one of sharp decline, 44% in 4 years, and then slow growth and recovery to 66% of the 1979 production level by 1988.

TABLE 15

CRUDE ARTIFICIAL ABRASIVES MANUFACTURERS IN 1988

Company	Location	Product
Electro Minerals (Canada) Ltd.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Electro Minerals (US) Inc.	Niagara Falls, NY	Fused aluminum oxide (high-purity).
The Exolon-Esk Co.	Hennepin, IL	Silicon carbide.
Do.	Thorold, Ontario, Canada	Fused aluminum oxide (regular) and silicon carbide.
General Abrasives, a division of Dresser Industries Inc.	Niagara Falls, NY	Fused aluminum oxide (regular and high-purity).
Do.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular) and silicon carbide.
Norton Co.	Huntsville, AL	Fused aluminum oxide (high-purity) and aluminum-zirconium oxide.
Do.	Worcester, MA	General abrasive processing.
Do.	Cap-de-la-Madeleine, Quebec, Canada	Silicon carbide.
Do.	Chippawa, Ontario, Canada	Fused aluminum oxide (regular and high-purity) and aluminum-zirconium oxide.
Do.	Shawinigan, Quebec, Canada	Silicon carbide.
Superior Graphite Co.	Hopkinsville, KY	Do.
Washington Mills Abrasives Co.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).

FIGURE 4

PRODUCTION OF CRUDE SILICON CARBIDE

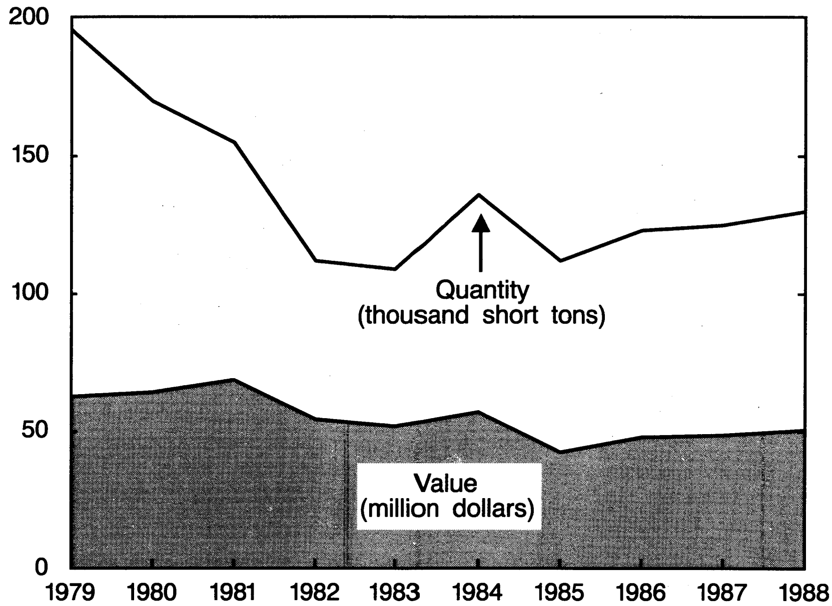


TABLE 16

WORLD FUSED ALUMINUM OXIDE ANNUAL PRODUCTION RATED CAPACITY,[1] DECEMBER 31, 1988

(Short tons)

Country	Capacity
North America:	
United States and Canada	255,600
South America:	
Brazil	106,000
Europe:	
Austria	65,000
France	50,000
Germany, Federal Republic of	95,000
Italy	20,000
Spain	15,300
United Kingdom	70,000
Total	**315,300**
Eastern Europe:	
Hungary, Poland, U.S.S.R., Yugoslavia	315,000
Asia:	
China	150,000
India	5,000
Japan	60,000
Total	**215,000**
World total	**1,206,900**

[1] Includes capacities of operating plants as well as plants on standby basis.

In July, Dresser Industries agreed to sell its Bay States and General Abrasives Divisions to Sterling Abrasive Products Co., Clearwater, FL. The Dresser divisions were manufacturers of silicon carbide and fused aluminum oxide crude and grain abrasives, with plants in both the United States and Canada.

Prices.—The Bureau did not collect price data on the various grades of silicon carbide. However, data were available on the value of production of the various grades. The average value per ton of abrasive-grade silicon carbide, as reported by producers, was \$424; metallurgical-grade averaged \$355; refractory and other grade material averaged \$585; and the average value of all grades was \$388. The average value per ton of abrasive-grade material for the last 10 years was \$449, with a high of \$568 in 1982 and a low of \$376 in 1980. Metallurgical-grade silicon carbide averaged \$378, with a high of \$423 in 1983 and a low of \$353 in 1980. Refractory grade was \$478, with a high of \$547 in 1981 and a low of \$401 in 1986. For all grades the average was \$407, with a high of \$486 in 1982 and a low of \$320 in 1979. The trend of the value of all grades of silicon carbide for the last 10 years was one of fairly sharp increases, 52% in 3 years, followed by a general decrease and then stabilization with 3 years essentially unchanged at 121% of the 1979 value.

Foreign Trade.—Exports plus reexports of silicon carbide decreased 10% to 4,714 tons. While the total value of silicon carbide exported plus reexported remained unchanged at \$7.8 million, the value per ton increased 12% to \$1,664 and was within 2% of the 10-year high of \$1,692 in 1986. The average annual exports plus reexports for the last 10 years was 7,338 tons, with a high of 13,661 tons in 1980 and a low of 4,254 tons in 1986. The average annual value per ton of exports plus reexports for the last 10 years was \$1,306, with a high of \$1,692 in 1986 and a low of \$922 in 1979. The value of exports plus reexports decreased 54% during the last 10 years.

Imports of silicon carbide in 1988 increased 20% in quantity to 112,000 tons, 27% in total value to \$60.1 million, and 6% in average value per ton to \$537. The quantity and total value were 10-year highs. The average annual imports for the last 10 years was 84,300 tons, with a high of 112,000 tons in 1988 and a low of 62,000 tons in 1985.

TABLE 17

WORLD SILICON CARBIDE ANNUAL PRODUCTION RATED CAPACITY,[1] DECEMBER 31, 1988

(Short tons)

	Capacity
North America:	
United States and Canada	139,500
Mexico	25,000
Total	**164,500**
South America:	
Brazil	14,000
Europe:	
France	18,000
Germany, Federal Republic of	40,000
Italy	40,000
Netherlands	50,000
Norway	81,500
Spain	20,000
Total	**249,500**
Eastern Europe:	
Czechoslovakia, Poland, U.S.S.R., Yugoslavia	175,000
Asia:	
China	160,000
India	15,000
Japan	95,000
Total	**270,000**
World total	**873,000**

[1] Includes capacities of operating plants as well as plants on standby basis.

The average value per ton for the period was $500, with a high of $565 in 1983 and a low of $365 in 1979. The trend of silicon carbide imports for the last 10 years was one that generally decreased to a low in 1985, followed by continuing increases until 1988 imports exceeded 1979 imports by about 9%.

Alumina-Zirconia Oxide

One firm produced fused alumina-zirconia oxide in two plants, one each in the United States and Canada. All production was used for abrasive applications. Output increased in both tonnage and value compared with 1987. Production data were not published to prevent disclosure of company proprietary data. Export and import data were not available.

Metallic Abrasives

Domestic Production.—Metallic abrasives were produced by 11 firms in 12 plants in the United States. At yearend, a firm purchased a closed plant and announced plans to put the plant into operation in 1989. Production of steel shot and grit increased 12% to 225,142 tons, 37% in value to $77.3 million, and 22% in average value per ton to $344. The average annual production for the last 10 years was 194,046 tons, with a high of 232,475 tons in 1979 and a low of 149,741 tons in 1982. The average value per ton during the period was $316, with a high of $364 in 1982 and a low at $282 in both 1979 and 1987. The trend of steel shot and grit production for the last 10 years was one of decline to the low in 1982 and then general continued recovery until 1988 production was equal to about 96% of the 1979 production level. Michigan, Ohio, Pennsylvania, Virginia, Maryland, and Indiana, in decreasing order of quantity, supplied all of the production of steel shot and grit.

Chilled and annealed iron shot and grit was produced by two companies, one each in Indiana and Ohio. Cut wire shot production was reported by two firms, one in Michigan and one in New York. Production of chilled and annealed iron and cut wire shot and grit increased 5% in quantity to 19,383 tons and 78% in total value to $10.8 million. The average value per ton increased 70% to a 10-year high of $556. The average annual production of these types of shot and grit for the last 10 years was 20,560 tons, with a high of 30,745 tons in 1980 and a low of 14,718 tons in 1986. The average value per ton

TABLE 18

END USES OF CRUDE SILICON CARBIDE AND ALUMINUM OXIDE (ABRASIVE GRADE) IN THE UNITED STATES AND CANADA, AS REPORTED BY PRODUCERS

Use	1987			1988		
	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)
SILICON CARBIDE						
Abrasives	54,599	$23,128	9,127	56,440	$23,907	2,071
Metallurgical	69,109	25,049	4,298	71,648	25,443	2,034
Refractories and other	1,302	613	219	2,068	1,209	61
Total	**125,010**	**48,790**	**13,644**	**130,156**	**50,559**	**4,166**
ALUMINUM OXIDE						
Regular: Abrasives plus refractories[1]	124,174	47,354	5,560	189,770	55,705	9,536
High purity	19,946	9,039	262	36,197	15,620	1,512
Total	**144,120**	**56,393**	**5,822**	**225,967**	**71,325**	**11,048**

[1] Abrasives combined with refractories to avoid disclosing company proprietary data.

for the last 10 years was $375, with a high of $556 in 1988 and a low of $279 in 1980.

Consumption.—The quantity of steel shot and grit sold or used increased 19% to 236,762 tons, the total value increased 25% to $86.0 million, and the average value per ton increased about 5% to $363. The average annual quantity of steel shot and grit sold or used for the last 10 years was 196,182 tons, with a high of 238,190 tons in 1979 and a low of 146,910 tons in 1982. The trend of sold or used steel shot and grit for the last 10 years was one of fluctuating decreases and increases, the 1988 sold-and-used value was essentially the same as in 1979.

The quantity of chilled and annealed iron and cut wire shot and grit sold or used increased 6% to 19,598 tons, increased 44% in total value to $11.4 million, and increased 36% in average value per ton to $584. The average annual quantity of these shot and grit sold or used for the last 10 years was 19,883 tons, with a high of 31,635 tons in 1980 and a low of 10,088 tons in 1985. The trend of the sold and used value for the last 10 years was one of large individual increases and decreases, as much as 50% in a year, resulting in a low in 1985. Since then, continued growth resulted in the 1988 value equaling 76% of the 1979 level.

The estimated apparent consumption of all types of metallic shot and grit increased 16% in quantity to 247,160 tons, 26% in total value to $91.1 million, and 9% in average value per ton to $369. Estimated apparent consumption is calculated as U.S. production plus imports minus exports. The average annual estimated apparent consumption of metallic shot and grit for the last 10 years was 207,575 tons, with a high of 247,160 tons in 1988 and a low of 159,820 in 1982. The average value per ton for the same period was $351, with a high of $374 in 1985 and a low of $316 in 1979. The trend of apparent consumption for the last 10

TABLE 19

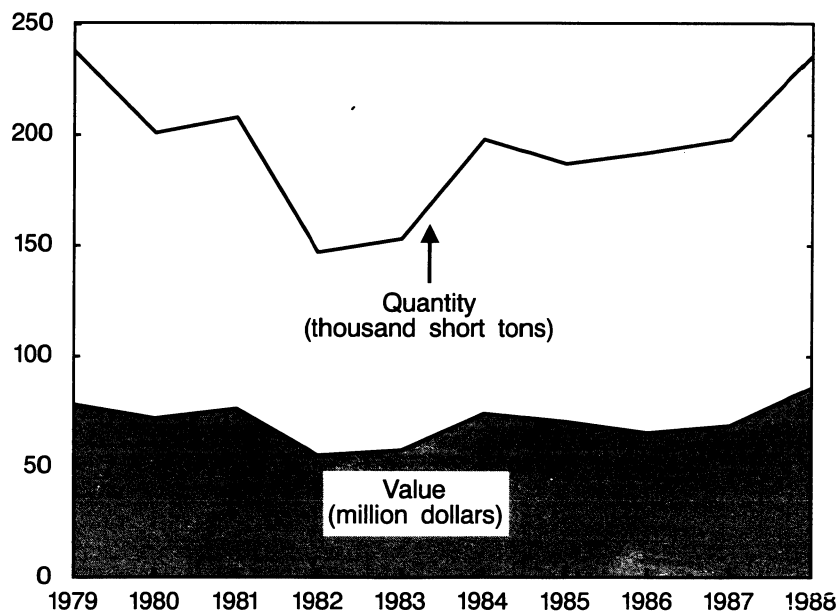
PRODUCERS[1] OF METALLIC ABRASIVES IN 1988

Company	Location	Product (shot and/or grit)
Abrasive Materials Inc.	Hillsdale, MI	Cut wire, steel.
Chesapeake Specialty Products	Baltimore, MD	Steel.
Durasteel Co.	Pittsburgh, PA	Do.
Ervin Industries Inc.	Adrian, MI	Do.
Do.	Butler, PA	Do.
Globe Steel Abrasives Co.	Mansfield, OH	Do.
Metaltec Steel Abrasives Co.	Canton, MI	Do.
National Metal Abrasives Co.	Wadsworth, OH	Do.
Pellets Inc.	Tonawanda, NY	Cut wire.
Steel Abrasives Inc.	Fairfield, OH	Chilled iron.
U.S. Abrasives, Inc.	Tippecanoe, IN	Chilled and annealed iron and steel.
Wheelabrator-Frye Inc.	Bedford, VA	Steel.

[1] Excludes secondary (salvage) producers.

FIGURE 5

SOLD OR USED STEEL SHOT AND GRIT



years was one of decline to a low in 1985, followed by general growth until 1988 consumption was slightly greater than that of 1979.

Foreign Trade.—U.S. exports of metallic shot and grit increased 64% to 13,091 tons. The total value of exports increased 42% to $9.7 million, and the average value per ton decreased 13% to $744. The average annual tonnage of metallic shot and grit exports for the last 10 years was 11,588 tons, with a high of 22,198 tons in 1979 and a low of 7,109 tons in 1983. The average value per ton for the last 10 years was $653, with a high of $860 in 1987 and a low of $382 in 1979. The trend of metallic abrasive exports for the last 10 years was one of general decline from 1979 through 1983, followed by fluctuating increases and decreases. The significant increase in 1988 possibly signaled the start of a real recovery, but exports were still 41% below the level of 1979 exports.

U.S. imports of metallic abrasives increased 31% in quantity to 3,891 tons, 52% in total value to $3.4 million, and 16% in value per ton to $875. The average annual imports for the last 7 years was 4,627 tons, with a high of 9,380 tons in 1984 and a low of 2,975 tons in 1987. The average value per ton for the period was $533, with a high of $875 in 1988 and a low of $254 in 1984. The trend in the quantity of imports for the last 7 years was one of up-and-down fluctuations resulting in a general decline; 1988 imports were only about 79% of those of 1979.

The United States was a net exporter of metallic abrasives in 1988, a position it has enjoyed by about a 2.5-to-1 ratio for the last 10 years.

[1] Physical scientist, Branch of Industrial Minerals.

[2] Australian Minerals Industry Annual Review Preliminary Summary 1988, Gemstones. Bureau of Resources, Geology and Geophysics.

[3] Jewelers' Circular-Keystone. V. 157, No. 11, Nov. 1988, p. G.

[4] McCullock, R. Japanese Diamond Developments. Materials Edge. pp. 47-51.

FIGURE 6

SOLD OR USED OTHER METALLIC SHOT AND GRIT

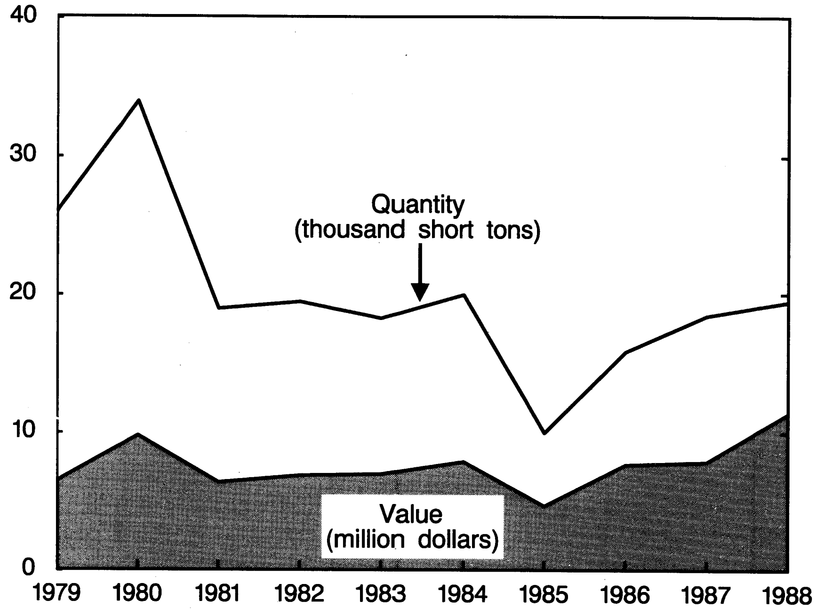


TABLE 20

PRODUCTION, SHIPMENTS, AND ANNUAL CAPACITIES OF METALLIC ABRASIVES IN THE UNITED STATES, BY PRODUCT[1]

Product	Production		Shipments		Annual capacity[2] (short tons)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1987:					
Chilled iron shot and grit	W	W	W	W	W
Annealed iron shot and grit	W	W	W	W	W
Steel shot and grit	200,255	$56,371	198,743	$68,885	253,800
Other[3]	18,470	r6,039	18,569	7,971	XX
Total	**218,725**	**r62,410**	**217,312**	**76,856**	**XX**
1988:					
Chilled iron shot and grit	W	W	W	W	W
Annealed iron shot and grit	W	W	W	W	W
Steel shot and grit	225,142	77,344	236,762	85,995	253,800
Other[3]	19,383	10,770	19,598	11,443	XX
Total	**244,525**	**88,114**	**256,360**	**97,438**	**XX**

W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
[1] Excludes secondary (recycle) producers.
[2] Total quantity of the various types of metallic abrasives that a plant could have produced during the year, working three 8-hour shifts per day, 7 days per week, allowing for usual interruptions, and assuming adequate fuel, labor, and transportation.
[3] Includes cut wire, aluminum, stainless steel shot, and items indicated by symbol W.

ALUMINUM

By Patricia A. Plunkert[1]

The domestic aluminum industry continued to improve in 1988. Strong demand for aluminum and low inventories contributed to increased production of both primary and secondary aluminum metal. By yearend, the vast majority of primary aluminum smelters were operating virtually at full capacity. A record 42.5 billion aluminum used beverage cans (UBC) were recycled in 1988, equivalent to more than 54% of aluminum can shipments for the year. Although domestic stocks increased slightly by yearend, they remained at historically low levels. Strong demand, tight supply, and low inventory levels in the domestic and world markets contributed to a rapid rise in aluminum ingot prices, both domestically and overseas. Despite the fact that world primary aluminum production reached a record high in 1988, the export market for U.S. products continued to increase.

DOMESTIC DATA COVERAGE

Domestic production data for aluminum are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Aluminum" survey. Of the 12 companies to which monthly survey requests were sent, all responded, representing 100% of the total domestic primary aluminum production shown in tables 1, 6, and 15.

LEGISLATION AND GOVERNMENT PROGRAMS

In August, the U.S. Court of Appeals for the District of Columbia Circuit ordered the Environmental Protection Agency (EPA) to relist as hazardous six smelter wastes that previously had been excluded from regulation under the Bevill Amendment to the Resource Conservation and Recovery Act (RCRA). In September, the EPA reinstated the hazardous waste listing for these six wastes, which included spent potliners from primary aluminum reduction plants. The result of this action, which is to become effective March 13, 1989, was to subject these wastes to the hazardous waste management requirements of subtitle C of RCRA.[2]

The Bureau of Mines released a study that examined the impact of five proposed acid rain control bills on electric utility costs for coal-burning utilities servicing the domestic primary aluminum smelting industry and, subsequently, on the costs of production for the affected aluminum smelters. The increases in utility rates were estimated to range from 0 to 10.4 mills per kilowatt hour (mills/kW•h), depending on the bill and on the particular utility affected. The annual cost of the resulting rate increases to the 10 affected aluminum smelters was estimated at $94 million to $150 million.[3]

The U.S. Department of Commerce issued a final determination that certain electrical conductor aluminum redraw rod from Venezuela was being sold in the United States at less than fair market value, and that such imports threatened material injury to a U.S. industry. Effective August 17, 1988, a countervailing duty of 38.4% ad valorem and a dumping duty margin of 5.8% were imposed on redraw rod imports from Venezuela.[4]

DOMESTIC PRODUCTION

Primary

Domestic primary aluminum production increased to more than 3.9 million metric tons, the highest annual production level since 1984. By yearend 1988, the operating capacity of U.S. primary smelters was over 99% with only 36,000 tons of the 3.96 million tons of annual capacity shut down. At

TABLE 1

SALIENT ALUMINUM STATISTICS

(Thousand metric tons and thousand dollars unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Primary production	4,099	3,500	3,037	3,343	3,944
Value	$7,139,844	$6,249,614	$5,422,993	$5,328,300	$9,572,066
Price: Average cents per pound:					
U.S. producer list	81.0	81.0	[1]81.0	NA	NA
U.S. market (spot)	61.1	48.8	55.9	72.3	110.1
Secondary recovery[2]	1,760	1,762	1,773	1,986	2,122
Exports (crude and semicrude)	734	908	753	r917	1,247
Imports for consumption (crude and semicrude)	1,477	1,420	1,967	r1,850	1,620
Aluminum industry shipments[3]	6,552	6,382	6,545	6,813	6,633
Consumption, apparent	5,279	5,174	5,143	5,469	5,352
World: Production	r15,705	r15,398	15,354	p16,378	e17,304

e Estimated. p Preliminary. r Revised. NA Not available.

[1] Based on 7 months in 1986.

[2] Beginning with 1984, metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage. Prior to 1984, aluminum recovered from all types of purchased scrap not expanded for full industry coverage.

[3] To domestic industry.

yearend, 2 smelters were operating at reduced capacity and 21 were operating at full-capacity levels.

In October, MAXXAM Group Inc., Los Angeles, CA, announced the purchase of KaiserTech Ltd., parent company of Kaiser Aluminum & Chemical Corp. The $708 million purchase made holding company KaiserTech a wholly owned subsidiary of MAXXAM.

AMAX Inc. reported the sale of a 25% interest in each of its smelters in Ferndale, WA, and Frederick, MD, to a Japanese consortium for $210 million. The consortium included Mitsui & Co., a trading company, and Toyo Sash Co. and Yoshida Kogya K.K., manufacturers of aluminum building products. The 25% interests represented a combined annual capacity of about 106,000 tons.

Kaiser Aluminum & Chemical announced that it had reached an agreement to sell its primary aluminum smelter and rolling mill at Ravenswood, WV; aluminum can recycling plant at Bedford, IN; and regional data center at Columbus, OH, to a new corporation formed by Stanwich Partners Inc., an investment company headquartered in Stamford, CT. Kaiser Aluminum & Chemical also agreed to sell alumina to the new corporation, Ravenswood Aluminum Corp., under a 3-year supply agreement and to provide certain technical services for a similar period.

Shell Mining Co. announced that it had entered into a tolling arrangement with Columbia Falls Aluminum Co. that would give Billiton Metals Inc., a subsidiary of Shell Mining, 40% of the metal produced at the Columbia Falls, MT, aluminum smelter from June 1988 through yearend 1995. The new arrangements would give Billiton 40% of the production; The Broken Hill Pty. Co. Ltd. (BHP), 40%; and Hydro Aluminum A/S, 20% until the BHP contract lapses in July 1989, at which point Hydro will receive 60% and Billiton, 40%.

Members of the United Steelworkers of America (USWA), at 11 Kaiser Aluminum & Chemical plants, voted to approve a new 30-month labor contract that reportedly increased base pay and provided a cash-bonus plan that tied payouts to the Metals Week U.S. transaction price for primary aluminum ingot. Hourly workers would receive a base pay increase of 50 cents per hour, a $1,000 per worker signing bonus, and a maximum cash bonus of $2 an hour based on the price of aluminum ingot. When the ingot price drops below 83 cents per pound, the bonus decreases. No bonus would be paid if the ingot price dropped to 53 cents per pound or lower. The new contract, which covered about 5,400 employees, was scheduled to expire on October 31, 1990.

The Aluminum Co. of America (Alcoa) and Reynolds Metals Co. reached a new 43-month labor agreement with members of the USWA and the Aluminum, Brick, and Glass Workers International Union. The contract, which covered more than 22,000 workers at 32 plants, was retroactive to November 1, 1988, and superseded the previous contract, which was to expire on May 31, 1989. The new contract reportedly included a profit-sharing plan for calendar years 1988–91, a cash signing bonus of $1,000 per worker in 1988, two lump-sum bonuses of $500 in 1990 and 1991, and a 50 cents per hour increase in base wage rates beginning in the second year of the contract. The new contract was scheduled to expire on May 31, 1992.

The Kentucky State circuit court ruled that the variable rate for power supplied by Big Rivers Electric Corp. to two primary aluminum smelters, Alcan Aluminum Corp.'s Sebree, KY, plant and National Southwire Aluminum Co.'s Hawesville, KY, smelter, would remain in effect. The aluminum producers had sued to overturn a September 1987 order by the Kentucky Public Service Commission that instituted the variable rate, which linked energy charges to aluminum ingot prices and resulted in a significant rate increase. Big Rivers sued to overturn the order on the grounds that it needed an even greater rate hike. The judge denied both arguments.

Reynolds Metals announced plans to construct a $125 million state-of-the-art cast house at its aluminum fabricating facility in Listerhill, AL. Construction was scheduled to begin in the first quarter of 1989 with completion set for late 1991. The new facility, which will cast aluminum ingot as feedstock for the plant's rolling mills, will utilize the latest technology available, which reportedly will improve the plant's productivity and material quality, usage, and handling. The plant's annual capacity to cast sheet ingot will be increased from about 800 million pounds to more than 1 billion pounds.

In line with Reynolds Metals announced objective to expand its consumer products business, the company acquired two producers of plastic products, Presto Products Inc. and Mount Vernon Plastics Corp., adding several types of plastic bags and food wraps and a broad line of other plastic products to Reynolds Metals line of consumer products.

Reynolds Metals also announced plans to close its Grand Rapids, MI, aluminum extrusion plant. The company cited the age of the plant, built by the Federal Government during World War II, and high production costs as the reasons for the closure. The plant produced a variety of extruded aluminum shapes, including components for automobile bumpers.

Alcan Rolled Products Co. announced plans to invest more than $60 million to modernize its aluminum foil rolling plant in Terre Haute, IN. The major part of the modernization would be a new mill capable of rolling foil up to 82 inches wide at a speed of 6,000 feet per minute. Construction, scheduled to begin in January 1989, was expected to be completed in 1990.

KaiserTech reported the signing of a letter of intent to sell its foil rolling operations at Permanente, CA, and its foil laminating facility at Belpre, OH,

TABLE 2

PRIMARY ANNUAL ALUMINUM PRODUCTION CAPACITY IN THE UNITED STATES, BY COMPANY

Company	Yearend capacity (thousand metric tons) 1987	1988	1988 ownership (percent)
Alcan Aluminum Corp.:			
Sebree, KY	163	163	Alcan Aluminium Ltd., 100%.
Alumax Inc.:			
Ferndale, WA (Intalco)	254	254	AMAX Inc., 75%; Mitsui & Co., 11%; Toyo Sash, 7%; Yoshida Kogya K.K., 7%.
Frederick, MD (Eastalco)	160	160	Do.
Mount Holly, SC	181	181	AMAX, 73%; Clarendon Ltd., 27%.
Total	**595**	**595**	
Aluminum Co. of America:			
Alcoa, TN	160	200	Aluminum Co. of America, 100%.
Badin, NC	115	115	Do.
Evansville, IN (Warrick)	270	270	Do.
Massena, NY	127	127	Do.
Rockdale, TX	205	310	Do.
Wenatchee, WA	205	205	Do.
Total	**1,082**	**1,227**	
Columbia Aluminum Corp.:[1]			
Goldendale, WA	168	168	Columbia Aluminum Corp., 70%; employees, 30%.
Columbia Falls Aluminum Co.:			
Columbia Falls, MT	163	163	Montana Aluminum Investors Corp., 100%.
Kaiser Aluminum & Chemical Corp.:			
Mead, WA (Spokane)	200	200	MAXXAM Inc., 100%.
Ravenswood, WV[2]	110	—	Do.
Tacoma, WA	73	73	Do.
Total	**383**	**273**	
National-Southwire Aluminum Co.:			
Hawesville, KY	172	172	National Steel Corp., 50%; Southwire Co., 50%.
Noranda Aluminum Inc.:			
New Madrid, MO	204	204	Noranda Mines Ltd., 100%.
Northwest Aluminum Corp.:[3]			
The Dalles, OR	82	82	Martin Marietta Corp., 87.2%; private interests, 12.8%.
Ormet Corp.:			
Hannibal, OH	245	245	Ohio River Associates Inc., 100%.
Ravenswood Aluminum Corp.:[4]			
Ravenswood, WV	—	110	Stanwich Partners, Inc., 100%.
Revere Copper and Brass Inc.:[5]			
Scottsboro, AL	105	—	Revere Copper and Brass Inc., 100%.
Reynolds Metals Co.:			
Longview, WA	191	204	Reynolds Metals Co., 100%.
Massena, NY	114	123	Do.
Troutdale, OR	118	121	Do.
Total	**423**	**448**	
Vanalco Inc.:[6]			
Vancouver, WA	110	110	Vanalco Inc., 100%.
Grand total	**3,895**	**3,960**	

[1] Purchased from Comalco Pty. Ltd. in Aug. 1987.
[2] Sold to Ravenswood Aluminum Corp. in Dec. 1988.
[3] Northwest Aluminum Corp. signed a lease-purchase agreement for The Dalles smelter with Martin Marietta Corp. in 1986.
[4] Purchased from MAXXAM Inc. in Dec. 1988.
[5] Revere Copper and Brass Inc. filed for bankruptcy in 1982.
[6] Purchased from Aluminum Co. of America in June 1987.

to TXL Corp., a San Francisco-based private investment firm. TXL announced that it also had agreed to purchase three aluminum extrusion plants in California. These plants included two Indal Ltd. facilities that specialized in aluminum extrusions for truck-trailer and cargo-container manufacturers and the Pacific Aluminum Corp. plant in Modesto, CA.

KaiserTech reported the sale of its Halethorpe, MD, hard-alloy aluminum extrusion plant to a group of investors led by the Townsend Co. of Towson, MD. The plant, which had been closed since November 1987, had two 11,000-ton aluminum extrusion presses and one 4,400-ton press from which it produced specialty extrusions.

Kaiser Aluminum & Chemical reported the startup of a 6.5-million-pound-per-month remelt and billet-casting facility at its Sherman, TX, extrusion plant. Major markets served by the plant, either directly or through distributors, included transportation, consumer durables, architectural products, machinery, and electrical equipment.

Kaiser Aluminum & Chemical also announced completion of the construction and installation of an $8.5 million ingot scalper at its Trentwood, WA, rolling mill. The scalper has the capability to face-scalp a rolling ingot's horizontal surface while simultaneously edge-scalping the sides. This improved technology was expected to increase the plant's capacity, productivity, recovery, and cost performance for all items in its product mix, including can body, lid, and tab stock.

Fuso Light Alloys Co. of Japan announced plans to begin construction of an aluminum diecasting plant in Wilmington, OH. The plant, to be equipped with five diecasting machines, was expected to have a monthly capacity of 400 tons. Scheduled for completion in 1989, the plant would manufacture aluminum components and parts for the automotive industry, as well as parts for electric, farming, and other industrial equipment.

TABLE 3

U.S. CONSUMPTION OF AND RECOVERY FROM PURCHASED NEW AND OLD ALUMINUM SCRAP,[1] BY CLASS

(Metric tons)

Class	Consumption	Calculated recovery	
		Aluminum	Metallic
1987			
Secondary smelters	803,188	663,180	714,451
Primary producers	964,072	815,805	873,637
Fabricators	221,878	193,510	207,017
Foundries	79,067	65,927	70,930
Chemical producers	27,866	22,572	22,720
Total	**2,096,071**	**1,760,994**	**1,888,755**
Estimated full industry coverage	2,204,000	1,851,000	1,986,000
1988			
Secondary smelters	871,484	725,881	781,813
Primary producers	1,025,107	860,494	921,725
Fabricators	229,868	200,978	214,988
Foundries	71,499	59,297	63,755
Chemical producers	36,854	36,854	36,854
Total	**2,234,812**	**1,883,504**	**2,019,135**
Estimated full industry coverage	2,348,000	1,979,000	2,122,000

[1] Excludes recovery from other than aluminum-base scrap.

Secondary

According to a survey conducted by the Aluminum Association, the Institute of Scrap Recycling Industries, and the Can Manufacturers Institute, a record 42.5 billion aluminum UBC's were recycled in 1988, surpassing by almost 6 billion the number of UBC's recovered in 1987. The percentage of aluminum cans recycled in the United States increased from slightly more than 50% of the aluminum cans shipped in 1987 to 54.6% of can shipments in 1988.

International Mill Service Inc., a waste recycler and industrial services firm, announced plans to construct a $10 million aluminum can recycling plant in Hauser, ID. The new plant, scheduled for completion in 1989, was expected to process 80 million pounds of UBC's annually for shipment to Kaiser Aluminum & Chemical's rolling mill in nearby Trentwood, WA.

Imco Recycling Inc. announced plans to construct an $8 million aluminum recycling plant in Morgantown, KY. The plant, with an annual capacity of about 60,000 tons, was expected to convert byproducts of can manufacturing and UBC's into molten metal and remelt ingot. Construction was scheduled to begin in 1989.

Consolidated Aluminum Corp. announced that its new 100-million-pound-per-year aluminum scrap recycling facility in West Virginia was expected to begin operations in late 1989. The $15 million plant would be located near the company's large aluminum rolling mill in Hannibal, OH.

Southern Alloys Co. reported that construction had begun on a new 6-million-pound-per-month secondary aluminum smelter in Shelbyville, TN. The company plans to sell the secondary ingot and molten metal produced at the facility to diecasting operations servicing the automobile and electronics industries in and around the State.

American Technology Systems announced plans to purchase Alumet Smelting Corp.'s secondary aluminum plant in Newark, NJ, which has been idle since 1987. The facility was expected to process drosses on a tolling basis.

CONSUMPTION

Apparent consumption of aluminum metal remained relatively stable in 1988 compared with that of the previous year. Shipments of aluminum to domestic end-use markets decreased in 1988; however, the container and packaging industry remained the largest domestic consumer of aluminum products.

The French-based company, Pechiney, announced plans to purchase Triangle Industries Inc., a major domestic producer of aluminum beverage cans and other packaging products, for $1.26 billion. Triangle owned American National Can Co., which was reported to be the world's largest producer of aluminum beer and soda cans. It was estimated that Triangle supplied about one-fourth of the aluminum cans used by the domestic beverage market.

According to company officials at Siligan Container, the company planned to have 25% of its output in aluminum by the end of the year. Siligan produces about 3 billion food cans per year. Most of Siligan's aluminum can output consisted of cat and dog food containers. Alcoa supplied alloy 5,042 can sheet to Siligan.

ARCO Aluminum Corp., a subsidiary of Atlantic Richfield Co., reported the production of 5182 alloy end stock for beer and soda cans to a gauge tolerance of plus/minus 0.0002 inch. This was one-third better than the 0.0003-inch gauge tolerance reportedly possible at the best of the can stock facilities operated by domestic and foreign competitors. Company officials claimed that

TABLE 4

U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP[1] AND SWEATED PIG IN 1988

(Metric tons)

Class of consumer and type of scrap	Stocks, Jan. 1[r]	Net receipts[2]	Consumption	Stocks, Dec. 31
Secondary smelters:				
New scrap:				
Solids	8,178	222,118	193,740	36,556
Borings and turnings	4,284	110,030	109,763	4,551
Dross and skimmings	3,361	20,391	21,356	2,396
Other[3]	4,474	86,062	85,189	5,347
Total	**20,297**	**438,601**	**410,048**	**48,850**
Old scrap:				
Castings, sheet, clippings	14,095	267,648	266,293	15,450
Aluminum-copper radiators	918	13,387	13,222	1,083
Aluminum cans	1,246	[4]125,575	[4]122,924	3,897
Other[5]	1,085	17,332	17,332	1,085
Total	**17,344**	**423,942**	**419,771**	**21,515**
Sweated pig	2,523	42,394	41,665	3,252
Total secondary smelters	**40,164**	**904,937**	**871,484**	**73,617**
Primary producers, foundries, fabricators, chemical plants:				
New scrap:				
Solids	14,549	509,443	508,860	15,132
Borings and turnings	120	21,488	21,404	204
Dross and skimmings	424	10,995	10,407	1,012
Other[3]	3,188	145,115	144,708	3,595
Total	**18,281**	**687,041**	**685,379**	**19,943**
Old scrap:				
Castings, sheet, clippings	1,480	118,183	118,367	1,296
Aluminum-copper radiators	33	958	952	39
Aluminum cans	10,174	526,355	518,347	18,182
Other[5]	1,474	15,480	15,480	1,474
Total	**13,161**	**660,976**	**653,146**	**20,991**
Sweated pig	2,252	23,705	24,803	1,154
Total primary producers, etc.	**33,694**	**1,371,722**	**1,363,328**	**42,088**
All scrap consumed:				
New scrap:				
Solids	22,727	731,561	702,600	51,688
Borings and turnings	4,404	131,518	131,167	4,755
Dross and skimmings	3,785	31,386	31,763	3,408
Other	7,662	231,177	229,897	8,942
Total new scrap	**38,578**	**1,125,642**	**1,095,427**	**68,793**
Old scrap:				
Castings, sheet, clippings	15,575	385,831	384,660	16,746
Aluminum-copper radiators	951	14,345	14,174	1,122
Aluminum cans	11,420	651,930	641,271	22,079
Other	2,559	32,812	32,812	2,559
Total old scrap	**30,505**	**1,084,918**	**1,072,917**	**42,506**
Sweated pig	4,775	66,099	66,468	4,406
Total of all scrap consumed	**73,858**	**2,276,659**	**2,234,812**	**115,705**

[r] Revised.

[1] Includes imported scrap. According to reporting companies, 5.94% of total receipts of aluminum-base scrap, or 135,046 metric tons, was received on toll arrangements.

[2] Includes inventory adjustment.

[3] Includes data on foil, can stock clippings, and other miscellaneous.

[4] Used beverage cans toll treated for primary producers are included in secondary smelter tabulation.

[5] Includes municipal wastes (includes litter) and fragmentized scrap (auto shredder).

TABLE 5

PRODUCTION AND SHIPMENTS OF SECONDARY ALUMINUM ALLOYS BY INDEPENDENT SMELTERS IN THE UNITED STATES

(Metric tons)

	1987		1988	
	Production	Net shipment[1]	Production	Net shipment[1]
Die-cast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	108,807	108,864	107,626	108,475
380 and variations	255,405	257,546	326,011	323,698
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	27,768	27,839	19,063	18,849
No. 12 and variations	W	W	W	W
No. 319 and variations	54,350	54,994	53,971	53,921
F–132 alloy and variations	9,661	9,471	6,945	6,781
Al-Mg alloys	216	235	224	222
Al-Zn alloys	3,835	4,599	2,390	2,296
Al-Si alloys (0.6% to 2.0% Cu)	5,986	6,012	6,933	6,737
Al-Cu alloys (1.5% Si, maximum)	1,198	1,216	1,189	1,176
Al-Si-Cu-Ni alloys	1,016	1,011	933	943
Other	3,272	3,288	3,672	3,626
Wrought alloys: Extrusion billets	147,253	146,644	108,052	108,052
Miscellaneous:				
Steel deoxidation	22,311	23,101	8,605	8,903
Pure (97.0% Al)	140	156	—	—
Aluminum-base hardeners	1,727	1,638	1,904	1,933
Other[2]	20,853	19,434	44,307	43,318
Total	**663,798**	**666,048**	**691,825**	**688,930**
Less consumption of materials other than scrap:				
Primary aluminum	42,740	—	46,939	—
Primary silicon	31,122	—	38,344	—
Other	3,263	—	5,405	—
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[3]	586,673	XX	601,137	XX

W Withheld to avoid disclosing company proprietary data; included with "Sand and permanent mold: Other." XX Not applicable.
[1] Includes inventory adjustment.
[2] Includes other die-cast alloys and other miscellaneous.
[3] No allowance made for melt-loss of primary aluminum and alloying ingredients.

the use of this thinner starting material would reduce cost and lower the overall weight of the can.

Noranda Aluminum Inc. announced the purchase of the American Racing Group, a California-based, privately owned manufacturer of aluminum and custom steel automotive wheels. According to Noranda, American Racing ranked third in size in its field and had three plants in southern California and one in Mexico.

Alcoa announced the introduction of two new aluminum alloys aimed at the automotive market. Alloy 5552 was developed for automobile trim applications, and alloy 2008 was formulated for structural body sheet applications.

KaiserTech announced the sale of its drainage product business, which included aluminum culvert and structural plate, to Contech Construction Products Inc. of Middletown, OH. The facilities included plants in Vancouver, WA; Sacramento, CA; Mitchell, IN; New Castle, DE; Anderson, SC; and Eunice, LA.

STOCKS

Inventories of aluminum ingot, mill products, and scrap at reduction and other processing plants, as reported by the U.S. Department of Commerce, increased slightly from about 1.89 million tons at yearend 1987 to about 1.90 million tons at yearend 1988.

PRICES

The monthly average U.S. market price for primary aluminum ingot continued to be strong during the year. The monthly average price increased rapidly during the first half of 1988 and reached a high for the year of $1.26 per pound in June. The price began to soften during the latter half of the year, as the aluminum supply slowly began to close the gap between supply and demand, which began to appear in early 1987. Strong demand, tight supply, and continuing low inventory levels—in the domestic and world markets—contributed to the rapid rise in aluminum ingot prices during 1988.

The London Metal Exchange (LME) and New York Commodity Exchange (COMEX) prices for aluminum futures followed the same general trend as the U.S. market price. The increase in the LME cash price during the first half of the year was even more dramatic than the U.S. market price increase. The monthly average LME cash price

TABLE 6

U.S. APPARENT ALUMINUM SUPPLY AND CONSUMPTION

(Thousand metric tons)

	1984	1985	1986	1987	1988
Primary production	4,099	3,500	3,037	3,343	3,944
Change in stocks:[1] Aluminum industry	-388	+312	+108	+341	-10
Imports	1,477	1,420	1,967	r1,850	1,620
Secondary recovery:[2]					
New scrap	935	912	989	1,134	1,077
Old scrap	825	850	784	852	1,045
Total supply	**6,948**	**6,994**	**6,885**	**r7,520**	**7,676**
Less total exports	734	908	753	r917	1,247
Apparent aluminum supply available for domestic manufacturing	6,214	6,086	6,132	6,603	6,429
Apparent consumption[3]	5,279	5,174	5,143	5,469	5,352

r Revised.
[1] Positive figure indicates a decrease in stocks; negative figure indicates an increase in stocks.
[2] Metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage.
[3] Apparent aluminum supply available for domestic manufacturing less recovery from purchased new scrap (a measure of consumption in manufactured end products).

TABLE 7

DISTRIBUTION OF END-USE SHIPMENTS OF ALUMINUM PRODUCTS IN THE UNITED STATES, BY INDUSTRY

Industry	1986		1987		1988p	
	Quantity (thousand metric tons)	Percent of grand total	Quantity (thousand metric tons)	Percent of grand total	Quantity (thousand metric tons)	Percent of grand total
Containers and packaging	1,926	27.7	2,052	27.8	2,036	27.4
Building and construction	1,432	20.6	1,441	19.5	1,318	17.8
Transportation	1,372	19.7	1,500	20.3	1,568	21.1
Electrical	626	9.0	620	8.4	673	9.1
Consumer durables	540	7.8	576	7.8	594	8.0
Machinery and equipment	383	5.5	401	5.4	441	5.9
Other markets	252	3.6	223	3.1	3	0.1
Statistical adjustment [1]	+14	+.2	—	—	—	—
Total to domestic users	**6,545**	**94.1**	**6,813**	**92.3**	**6,633**	**89.4**
Exports	413	5.9	569	7.7	787	10.6
Grand total	**6,958**	**100.0**	**7,382**	**100.0**	**7,420**	**100.0**

p Preliminary.
[1] Included in other markets for 1987 and 1988.

Source: The Aluminum Association Inc.

TABLE 8

U.S. NET SHIPMENTS[1] OF ALUMINUM WROUGHT AND CAST PRODUCTS, BY PRODUCERS

(Metric tons)

	1987	1988p
Wrought products:		
Sheet, plate, foil	3,739,865	3,774,646
Rod, bar, pipe, tube, and shapes	1,350,615	1,348,189
Rod, wire, cable	346,040	350,349
Forgings (including impacts)	70,886	75,436
Powder, flake, paste	41,792	38,064
Total	**5,549,198**	**5,586,684**
Castings:		
Sand	112,738	NA
Permanent mold	180,822	NA
Die	684,730	NA
Other	34,193	NA
Total	**1,012,483**	**1,102,254**
Grand total	**6,561,681**	**6,688,938**

p Preliminary. NA Not available.
[1] Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipments of that shape.

Source: U.S. Department of Commerce.

TABLE 9

DISTRIBUTION OF WROUGHT PRODUCTS IN THE UNITED STATES

(Percent)

	1987	1988
Sheet, plate, foil:		
Nonheat-treatable	56.7	56.1
Heat-treatable	3.6	4.0
Foil	7.0	7.3
Rod, bar, pipe, tube, shapes:		
Rod and bar (rolled and extruded)	1.8	1.4
Pipe and tube (extruded and drawn)	2.2	2.3
Extruded shapes	20.2	20.2
Rod, wire, cable:		
Rod and bar wire	1.1	1.0
Cable and insulated wire	5.1	5.4
Forgings (including impacts)	1.3	1.3
Powder, flake, paste	1.0	1.0
Total	**100.0**	**100.0**

Source: U.S. Department of Commerce.

reached a high of $1.62 per pound in June. The "backwardation" of COMEX prices, a term used to describe situations where near-term delivery prices were at a premium over distant contracts, reflected the tightness of aluminum supply prevalent during most of the year.

The following table summarizes various average monthly and annual aluminum prices during the year, in cents per pound:

UBC scrap, processed and delivered to producers, was bought at the range of 60 to 63 cents per pound at the beginning of 1988. The UBC purchase price range increased 71 to 74 cents per pound in mid-February and remained at this level through mid-August before beginning a downward trend, which reversed itself in the latter half of December. At yearend, the UBC purchase price range was 68 to 71 cents per pound.

	COMEX 1[1]	COMEX 2[1]	COMEX 3[1]	LME (cash)	U.S. market	U.S. transaction
1987: Annual average	71.24	69.89	65.30	70.84	72.30	73.26
1988:						
January	87.93	86.93	78.59	90.83	89.72	90.84
February	96.01	92.35	77.11	96.98	96.28	97.86
March	109.30	103.96	82.11	114.60	107.09	109.24
April	113.77	104.26	82.77	113.78	107.12	109.58
May	120.95	110.04	83.81	135.54	114.48	118.79
June	130.53	121.36	88.02	162.29	126.27	129.43
July	124.08	120.99	89.65	117.12	122.25	124.68
August	127.28	119.38	92.87	122.52	124.39	126.29
September	114.11	110.21	91.22	108.28	111.38	113.68
October	102.80	102.91	94.21	104.76	104.73	106.36
November	103.45	102.55	99.65	108.04	107.35	108.85
December	103.39	103.93	97.52	NA	110.00	111.23
Annual average	111.13	106.57	88.13	[2]115.88	110.09	112.24

NA Not available.
[1] COMEX delivery positions: 1—within 1 month; 2—within 3 months; and 3—within 12 months.
[2] Average for 11 months.
Source: Metals Week.

Purchase prices for aluminum scrap, as quoted by American Metal Market, remained strong during the year. The purchase prices of old sheet and cast aluminum were in the mid- to high-60-cent-per-pound range, and the price for low-copper-content aluminum clips were at the mid- to high-70-cent-per-pound level during most of the year. High aluminum scrap prices and reported shortages of available scrap were seen as contributing factors to numerous reports of thefts of aluminum products such as highway guard rails and aluminum siding and gutters for resale on the scrap market.

Secondary aluminum ingot prices, as quoted by American Metal Market, followed the trend of primary aluminum ingot prices, increasing to their high price ranges in June before slowly declining during the last 6 months of the year. The yearend price ranges for selected secondary aluminum ingots were as follows: alloy 380 (1% zinc content), $1.00 to $1.01 per pound; alloy 360 (0.6% copper content), $1.06 to $1.07 per pound; alloy 413 (0.6% copper content), $1.06 to $1.08 per pound; and alloy 319, $1.03 to $1.04 per pound.

FOREIGN TRADE

For the second consecutive year, exports of all forms of aluminum from the United States increased substantially from those of the previous year. Total exports in 1988 were about one-third greater than those of 1987. Japan and Canada continued to be the major recipients of U.S. aluminum materials in 1988. Exports of UBC's, which were included in the scrap category, totaled 3,885 tons in 1988, an increase of 44% compared with those of 1987. Japan was the principal destination of UBC exports, accounting for more than 40% of the total UBC exports in 1988.

Imports for consumption of aluminum decreased slightly compared with those of 1987. Canada remained the major shipping country to the United States, supplying 65% of the total U.S. imports in 1988.

U.S. tariff rates in effect in 1988 for aluminum products from countries with most-favored-nation status were as follows:

Item	TSUS No.	Import duty
Unwrought metal (in coils).	618.01	2.6% ad valorem.
Unwrought (other than Si-Al alloys).	618.02	Free.
Wrought (bars, plates, sheets, strip).	618.25	3% ad valorem.
Waste and scrap	618.10	2% ad valorem.

WORLD CAPACITY

The data in table 14 are rated annual capacity for plants producing primary aluminum metal as of December 31 for the years shown. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

World primary aluminum production capacity increased slightly from that of 1987. The shifting of capacity to areas of the world with lower labor and energy costs, principally hydroelectric power, continued. During the year, several companies announced greenfield smelter expansion plans for Canada, France, the Persian Gulf area, and Venezuela.

WORLD REVIEW

For the first time ever, world primary aluminum production exceeded 17 million tons. Because of the strength in worldwide aluminum demand and the low level of world inventories, smelter operating capacity continued to increase during the year. Many of the world's producers of aluminum indicated that their primary smelters were operating at or near their rated capacity levels.

Primary aluminum inventories held by members of the International Primary Aluminium Institute (IPAI), which represent the bulk of stocks held outside the centrally planned economy countries, increased slightly from 1.390 million tons at yearend 1987 to 1.482 million tons at yearend 1988. IPAI reported that total metal inventories, including secondary aluminum, increased from 3.050 million tons at yearend 1987 to 3.085 million tons at yearend 1988. Despite the slight upturn in world inventories, stocks remained at historically low levels.

Australia

Alcoa of Australia Pty. Ltd. announced the startup of a second 150,000-ton-per-year potline at its Portland aluminum smelter. The additional potline increased the annual capacity of the smelter to 300,000 tons.

Pechiney reportedly was awarded the contract for a feasibility study of a proposed aluminum smelter and associated powerplant in Western Australia. The study was expected to examine a phased operation consisting of two potlines, each with a planned capacity of 185,000 tons per year.

Comalco Ltd. announced that an aluminum wheel casting plant would be constructed adjacent to its primary aluminum smelter at Bell Bay, Tasmania. The partners in the new venture, to be called Southern Aluminium Pty. Ltd., were Comalco, 51%; the Australian Industry Development Corp., 19%; Enshu Keigokin K.K., 15%; and Mitsubishi Corp. 15%. The plant, expected to be operational in 1989, was designed to produce 600,000 automotive wheels per year, mainly for export to Europe, Japan, and the United States.

Bahrain

Aluminium Bahrain Ltd. (Alba) announced that a $40 million contract was awarded to Northern Engineering Industries of the United Kingdom for the construction of a 60-megawatt powerplant. Scheduled for completion by April 1990, the powerplant was part of a modernization and expansion program, which aimed to increase capacity at Alba's primary aluminum smelter from 180,000 tons per year to 225,000 tons per year by 1991.

Brazil

Alcoa Alumínio do Nordeste announced a $50 million expansion plan to increase annual output by 12,000 tons at its aluminum fabricating plant in northeast Pernambuco. Currently, the plant reports an output of 24,000 tons per year of aluminum rolled products and 18,000 tons per year of aluminum extrusion products. The expansion project was expected to be completed by 1992.

Canada

The four owners of Aluminium Bé-

TABLE 10

U.S. EXPORTS OF ALUMINUM, BY CLASS

Class	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	r281,816	r$415,013	400,057	$925,572
Scrap	r368,510	r409,712	486,615	774,277
Plates, sheets, bars, etc.	251,572	647,890	334,395	995,767
Castings and forgings	6,902	65,504	16,964	111,168
Semifabricated forms, n.e.c.	7,874	41,405	9,306	50,669
Total	**r916,674**	**r1,579,524**	**1,247,337**	**2,857,453**
Manufactures:				
Foil and leaf	55,834	59,917	52,307	78,912
Powders and flakes	2,420	9,694	4,445	19,472
Wire and cable	4,449	15,856	4,160	15,823
Total	**62,703**	**85,467**	**60,912**	**114,207**
Grand total	**r979,377**	**r1,664,991**	**1,308,249**	**2,971,660**

r Revised.

Source: Bureau of the Census.

TABLE 11

U.S. EXPORTS OF ALUMINUM, BY COUNTRY

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1987:								
Belgium-Luxembourg[2]	11	$18	883	$4,366	1,253	$2,861	2,147	$7,245
Brazil	102	359	1,093	5,699	1,974	1,794	3,169	7,852
Canada	25,815	52,319	163,379	417,008	20,995	22,272	210,189	491,599
France	24	192	1,028	9,986	2,227	2,391	3,279	12,569
Germany, Federal Republic of	89	1,601	2,240	11,372	3,097	3,395	5,426	16,368
Hong Kong	3,437	4,796	6,843	14,609	759	707	11,039	20,112
Italy	256	518	3,493	20,395	3,362	2,807	7,111	23,720
Japan	226,884	310,618	13,936	45,451	[r]263,314	[r]300,884	[r]504,134	[r]656,953
Korea, Republic of	3,145	4,704	9,318	24,364	6,312	7,886	18,775	36,954
Mexico	[r]6,779	[r]11,402	26,806	68,233	21,672	23,314	[r]55,257	[r]102,949
Netherlands	561	892	1,955	10,965	4,869	5,381	7,385	17,238
Panama	667	1,163	171	474	210	229	1,048	1,866
Peru	129	167	218	843	12	24	359	1,034
Singapore	3,283	5,896	387	3,396	155	165	3,825	9,457
Spain	5	21	918	3,219	642	434	1,565	3,674
Taiwan	[r]5,542	[r]7,155	3,538	9,589	34,258	30,698	[r]43,338	[r]47,442
United Kingdom	548	2,001	5,489	25,380	946	1,053	6,983	28,434
Other	4,539	11,191	24,653	79,450	2,453	3,417	31,645	94,058
Total	**[r]281,816**	**[r]415,013**	**266,348**	**754,799**	**[r]368,510**	**[r]409,712**	**[r]916,674**	**[r]1,579,524**
1988:								
Belgium[2]	5,243	13,541	809	4,253	4,094	7,332	10,146	25,126
Brazil	252	573	1,884	11,958	746	924	2,882	13,455
Canada	29,756	83,720	210,524	607,678	30,689	33,306	270,969	724,704
France	176	707	1,923	16,059	12,814	22,628	14,913	39,394
Germany, Federal Republic of	1,227	5,087	4,437	23,923	4,280	6,360	9,944	35,370
Hong Kong	1,023	2,078	11,513	31,940	922	1,496	13,458	35,514
Italy	77	281	2,611	18,470	8,575	11,711	11,263	30,462
Japan	303,120	673,326	15,281	62,234	268,846	441,645	587,247	1,177,205
Korea, Republic of	10,108	25,197	17,532	57,582	35,663	75,627	63,303	158,406
Mexico	13,966	32,038	31,176	86,608	29,859	37,703	75,001	156,349
Netherlands	10,434	26,966	2,957	13,801	13,150	26,980	26,541	67,747
Panama	82	836	605	1,756	193	439	880	3,031
Peru	418	942	141	541	50	113	609	1,596
Singapore	10,328	25,175	642	9,829	1,705	3,718	12,675	38,722
Spain	24	78	1,170	6,040	330	482	1,524	6,600
Taiwan	7,054	16,762	8,903	28,006	65,823	87,946	81,780	132,714
United Kingdom	1,391	3,328	8,027	45,339	1,993	3,610	11,411	52,277
Other	5,378	14,937	40,530	131,587	6,883	12,257	52,791	158,781
Total	**400,057**	**925,572**	**360,665**	**1,157,604**	**486,615**	**774,277**	**1,247,337**	**2,857,453**

[r] Revised.

[1] Includes castings, forgings, and unclassified semifabricated forms.

[2] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

cancour Inc. (ABI), Reynolds Metals, Pechiney, Alumax, and Société Générale de Financement du Quebec, announced plans to construct a third 120,000-ton-per-year potline at their primary aluminum smelter in Quebec. The new potline, using Pechiney technology and costing about $420 million, would increase the smelter's capacity to 360,000 tons per year. Construction of the potline was scheduled to begin in 1989 and to be completed in early 1991. In addition, the owners of ABI reported that a new power contract, effective January 1, 1989, was signed with Hydro Quebec that linked power rates to the prevailing price of aluminum ingot.

Alcan Aluminium Ltd. disclosed plans to speed up the construction timetable for its Laterrière, Quebec, primary aluminum smelter project. The 200,000-ton-per-year project would be constructed in four phases of 50,000 tons each. The scheduled completion dates were as follows: phase 1, December 1989; phase 2, March 1990; phase 3, October 1990; and phase 4, March 1991. This new construction schedule advanced the original completion date by 20 months. The new capacity at Laterrière was expected to replace the older, less efficient, Soderberg potlines at Alcan Aluminium's Arvida smelter.

Labor contracts at several of Alcan Aluminium's Quebec primary aluminum smelters, which had expired on August 31, 1987, were renegotiated in 1988. Alcan Aluminium and members of the Federation des Syndicats du Secteur Aluminium signed a new 3-year labor contract on March 7. The new contract, scheduled to expire on March 5, 1991, covered workers at the Arvida, Beauharnois, Grand Baie, and Isle Maligne smelters. The contract reportedly included a $750 per worker signing bonus and an 11% pay increase to be spread out over the life of the contract.

Unlike the other Quebec smelters, operations at Alcan Aluminium's Shawinigan smelter were halted during contract negotiations. Members of the Confederation of National Trade Unions, which represented workers at the Shawinigan smelter, also ratified a new 3-year labor contract similar to that covering the workers at Alcan Aluminium's other Quebec smelters. Workers at Shawinigan reportedly received a signing bonus of $216 and a pay increase of 11% spread over the life of the contract. The new contract at Shawinigan was also scheduled to expire on March 5, 1991.

The labor contract between Alcan Aluminium and the Canadian Association of Smelter and Allied Workers, representing hourly employees at the Kitimat smelter, expired on July 23, 1988. A new 2-year contract, retroactive to July 24, was ratified in early September 1988. This new contract reportedly contained a lump sum signing bonus of about $1,000 per worker, a 5.5% pay increase the first year, and a 72-cent-per-hour pay increase during the second year. The new contract was scheduled to expire on July 24, 1990.

Alcan Aluminium announced plans to build a 540-megawatt extension to its 896-megawatt Kemano hydroelectric powerplant in British Columbia. This powerplant supplies electricity to the company's Kitimat aluminum smelter. Alcan Aluminium reported that the company had no immediate plans to build new smelting capacity in the area, and until it did, available surplus power would be sold to British Columbia Hydro and Power Authority, the provincially owned utility company. The project, expected to cost $480 million, was scheduled for completion in 1994.

China

Sumitomo Metal Industries of Japan reportedly sold its previously idled 100,000-ton-per-year Sakata primary

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY CLASS

Class	1987[r] Quantity (metric tons)	1987[r] Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	1,245,638	$1,852,304	1,027,246	$2,197,785
Circles and disks	16,068	34,293	14,394	40,046
Plates, sheets, etc., n.e.c.	339,547	695,451	327,114	858,340
Rods and bars	55,418	92,372	47,113	111,622
Pipes, tubes, etc.	4,178	18,293	3,838	18,205
Scrap	188,667	202,333	200,517	318,015
Total	**1,849,516**	**2,895,046**	**1,620,222**	**3,544,013**
Manufactures:				
Foil	29,145	63,098	33,058	144,643
Leaf	([1])	220	([1])	299
Flakes and powders	3,678	5,885	2,869	6,799
Wire	3,512	10,493	5,452	18,331
Total	**36,335**	**79,696**	**41,379**	**170,072**
Grand total	**1,885,851**	**2,974,742**	**1,661,601**	**3,714,085**

[r] Revised.

[1] 1987—aluminum leaf not over 30.25 square inches in area, 3,618,270 leaves, and aluminum leaf over 30.25 square inches in area, 834,506,782 square inches; and 1988—aluminum leaf not over 30.25 square inches in area 5,235,781 leaves, and aluminum leaf over 30.25 square inches in area, 771,966,360 square inches.

Source: Bureau of the Census.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY COUNTRY

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1987:								
Argentina	16,201	$23,331	4,545	$8,624	204	$328	20,950	$32,283
Australia	r12,584	r17,689	7,296	13,861	1,404	1,282	r21,284	r32,832
Belgium-Luxembourg[2]	271	475	28,472	53,452	15	95	28,758	54,022
Brazil	67,596	101,029	6,314	11,033	215	295	74,125	112,357
Canada	918,884	1,351,269	91,537	167,888	125,369	140,657	1,135,790	1,659,814
France	859	1,418	23,382	55,024	589	376	24,830	56,818
Germany, Federal Republic of	7,379	14,199	10,624	30,727	346	703	18,349	45,629
Ghana	92,192	157,365	—	—	—	—	92,192	157,365
Israel	71	89	1,943	6,712	339	434	2,353	7,235
Japan	541	2,061	99,852	221,200	8	32	100,401	223,293
Mexico	1,473	2,111	3,658	6,660	15,295	12,415	20,426	21,186
Netherlands	1,872	2,283	7,717	30,967	1,116	1,444	10,705	34,694
Norway	2,492	4,585	3,222	5,894	—	—	5,714	10,479
Romania	17,325	24,834	9,217	14,380	—	—	26,542	39,214
South Africa, Republic of	5,526	6,957	4,119	7,000	—	—	9,645	13,957
U.S.S.R.	2,016	2,322	—	—	24,399	24,364	26,415	26,686
United Kingdom	544	1,091	6,921	24,867	1,393	1,755	8,858	27,713
Venezuela	42,909	61,645	43,012	64,374	r11,599	r11,637	r97,520	r137,656
Other r	54,903	77,551	63,380	117,746	6,376	6,516	124,659	201,813
Total	**r1,245,638**	**r1,852,304**	**415,211**	**840,409**	**r188,667**	**r202,333**	**r1,849,516**	**r2,895,046**
1988:								
Argentina	25,088	39,581	9,763	23,231	—	—	34,851	62,812
Australia	13,358	28,440	5,182	10,996	662	1,281	19,202	40,717
Belgium[2]	89	504	33,616	86,617	231	233	33,936	87,354
Brazil	43,890	92,302	14,403	35,324	52	57	58,345	127,683
Canada	794,786	1,704,106	117,984	286,102	135,061	219,793	1,047,831	2,210,001
France	130	657	25,926	78,609	422	660	26,478	79,926
Germany, Federal Republic of	1,229	6,908	11,814	40,428	3,474	4,462	16,517	51,798
Ghana	50,543	126,417	723	1,596	—	—	51,266	128,013
Israel	9	37	1,165	5,064	76	109	1,250	5,210
Japan	558	2,782	40,062	108,508	234	642	40,854	111,932
Mexico	7,085	15,538	5,882	17,164	17,180	21,148	30,147	53,850
Netherlands	2,167	3,581	8,978	40,750	3,224	4,332	14,369	48,663
Norway	503	1,213	3,091	7,742	—	—	3,594	8,955
Romania	150	261	3,135	6,368	—	—	3,285	6,629
South Africa, Republic of	1,418	3,159	8,671	18,941	—	—	10,089	22,100
U.S.S.R.	267	485	—	—	16,877	29,118	17,144	29,603
United Kingdom	2,000	5,524	7,063	29,739	3,955	6,284	13,018	41,547
Venezuela	52,829	106,448	36,641	81,206	8,644	15,865	98,114	203,519
Other	31,147	59,842	58,360	149,828	10,425	14,031	99,932	223,701
Total	**1,027,246**	**2,197,785**	**392,459**	**1,028,213**	**200,517**	**318,015**	**1,620,222**	**3,544,013**

r Revised.

[1] Includes circles, disks, rods, pipes, tubes, etc.

[2] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

aluminum smelter to the Taihang Aluminium Co. The dismantling and shipping of the smelter to Handan, China, were estimated to take 15 months. Shipments of the plant equipment were scheduled to begin in 1989.

Several agreements were apparently signed in 1988 to increase capacity for semifabricated aluminum products. A consortium of three Japanese companies reportedly signed an agreement with China to improve the operating efficiency at the Southwest Aluminum Fabrication Plant in central China's Sichuan Province. Ishikawajima-Harima Heavy Industries Co. would supply machinery, and Mitsubishi Electric Co. would provide electrical parts for the renovation. The third company, Toyo Menda Shaisha Ltd., acted as a go-between in the negotiations. When renovations are completed in about 2 years, the plant's hot-rolled aluminum production capacity was expected to increase from 50,000 tons per year to about 200,000 tons per year.

The China International Trust & Investment Corp. (CITIC) announced that an agreement had been signed with Davy McKee Corp. of the United Kingdom for a new aluminum rolling facility for Bohai Aluminium Industries. Davy McKee reportedly would supply four rolling mills—one cold mill and three foil mills. The Bohai plant at Qinhuangdao, Hebei Province, was expected to have an annual capacity of 75,000 tons.

France

Pechiney announced plans to build a 200,000-ton-per-year primary aluminum smelter at Dunkirk on the North Sea coast of France. The new plant was expected to replace the capacity at the company's aging Nogueres and Rioux-peroux smelters, which were scheduled to close by 1991. Pechiney would own 51% of the new smelter and the state-owned utility, Électricité de France (EdF) would take the remainder. EdF reportedly would provide power for the smelter at the estimated rate of 10 mills/kW•h. The Dunkirk smelter, hav-

TABLE 14

ALUMINUM: WORLD ANNUAL PRIMARY PRODUCTION CAPACITY, BY CONTINENT AND COUNTRY[1]

(Thousand metric tons)

Continent and country	1986	1987	1988[p]
North America:			
Canada	1,462	1,577	1,594
Mexico	45	66	66
United States	4,038	3,895	3,960
South America:			
Argentina	150	150	160
Brazil	869	869	869
Suriname	60	30	30
Venezuela	430	430	460
Europe:			
Austria	92	92	92
Czechoslovakia	60	60	60
France	394	346	346
German Democratic Republic	85	85	85
Germany, Federal Republic of	777	733	733
Greece	145	145	145
Hungary	76	76	76
Iceland	86	86	86
Italy	276	276	276
Netherlands	266	266	266
Norway	770	834	843
Poland	110	110	110
Romania	250	250	250
Spain	344	344	344
Sweden	82	91	91
Switzerland	72	72	72
U.S.S.R.	2,540	2,590	2,590
United Kingdom	287	287	287
Yugoslavia	357	357	367
Africa:			
Cameroon	80	80	80
Egypt	170	170	170
Ghana	200	200	200
South Africa, Republic of	172	172	172
Asia:			
Bahrain	180	180	180
China	[r]455	685	875
India	363	472	472
Indonesia	225	225	225
Iran	50	50	50
Japan	284	64	64
Korea, North	20	20	20

See footnote at end of table.

TABLE 14—Continued

ALUMINUM: WORLD ANNUAL PRIMARY PRODUCTION CAPACITY, BY CONTINENT AND COUNTRY[1]

(Thousand metric tons)

Continent and country	1986	1987	1988[p]
Korea, Republic of	18	18	18
Taiwan	50	50	50
Turkey	60	60	60
United Arab Emirates: Dubai	149	149	159
Oceania:			
Australia	1,012	1,012	1,177
New Zealand	244	244	250
Total	**[r]17,855**	**17,968**	**18,480**

[p] Preliminary. [r] Revised.

[1] Detailed information on the individual aluminum reduction plants is available in a 2-part report that can be purchased from Chief, Division of Finance, Bureau of Mines, Bldg. 20, Federal Center, Denver, CO 80225. Part 1 of "Primary Aluminum Plants, Worldwide" details location, ownership, and production capacity for 1985–92 and sources of energy and aluminum raw materials for foreign and domestic primary aluminum plants, including those in centrally planned economies. Part 2 summarizes production capacities for 1985–92 by smelter and country.

ing an estimated cost of about $850 million, was scheduled to be completed in 1991.

India

KaiserTech announced the sale of its 26.7% interest in Hindustan Aluminium Corp. Ltd. (Hindalco) for $8.6 million. The sale involved a share offering to Hindalco shareholders and employees.

Indonesia

A disagreement between the Government of Indonesia and Nippon Asahan Aluminium Co. Ltd., joint owners of the Indonesia Asahan Aluminum primary aluminum smelter in Sumatra, led to a temporary suspension of shipments of aluminum ingots to Japan. The Government wants to increase its share of the smelter's output to meet the growing domestic demand for aluminum. Meetings between the two parties were held in Japan and Jakarta, and a final resolution to this problem was expected in 1989.

Italy

Swiss Aluminium Ltd. (Alusuisse) sold its 50% holding in Aluminio Veneto S.p.A. (SAVA) to Italy's Government-owned MCS Aluminia S.p.A., making MCS Aluminia the sole owner of SAVA. The sale included two primary aluminum smelters, Fusina and Porto Marghera, and several processing plants in Italy.

Japan

Aluminum can makers in Japan announced major expansion plans to meet the increasing demand for aluminum cans in the domestic beverage container market. Mitsubishi Metal announced plans to build a 300-million-can-per-year plant in Yuki, Ibaraki Prefecture, scheduled for completion in 1990. Showa Aluminium Can Corp. held a ground-breaking ceremony for a 500-million-can-per-year plant at its Hikone can mill.

The LME announced that a final agreement had been reached with the Government of Japan on the opening of LME warehouses in Japan. In late December, the LME announced the names and locations of 36 warehouses in Japan that would begin storing 99.7%-pure aluminum beginning July 19, 1989.

Norway

Elkem A/S announced that the company had increased its stake in Alcoa Nederland BV, an aluminum fabricating company, from 25% to 50%. In exchange, Alcoa increased its interest in Mosal Aluminium A/S from 45% to 50%, and took over Elkem's 11% interest in Alcoa Manufacturing Ltd. in the United Kingdom.

Norsk Hydro A/S announced the completion of its purchase of the remaining 30% of Hydro Aluminium A/S from the Government of Norway, thereby becoming the sole owner of Hydro Aluminium. However, the Norwegian Government maintained its 51% stake in Norsk Hydro.

Qatar

Qatar reported the signing of a memorandum of understanding with an international consortium to build a 240,000-ton-per-year primary aluminum smelter at the village of Umm Said. The ownership of the newly formed company, Doha Aluminium Co. Ltd., was reported to be as follows: United Aluminum Fabricators, a group of U.S.-based fabricators, 30%; International Engineering Consultants, 30%; Amari Plc, 15%; private Arab interests, 15%; and China National Metals & Minerals Import & Export Corp., 10%. Plans called for construction to begin in mid-1991.

Spain

Alcan Aluminium announced plans to sell its 24% interest in Indústria Espanõla de Alúminio (Inespal). By yearend, a replacement for Alcan's interest in Inespal had yet to be found.

Suriname

Alcoa announced plans to restart 30,000 tons per year of capacity at its primary aluminum smelter in Paranam. The plant was forced to close in March 1987 following an attack by anti-Government insurgents that destroyed powerlines from the plant's hydroelectric generating station.

TABLE 15

ALUMINUM, PRIMARY: WORLD PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina	[r]134	[r]136	148	156	160
Australia	758	851	882	1,004	[2]1,150
Austria	96	94	93	93	96
Bahrain	177	[r]176	178	180	182
Brazil	455	549	757	843	874
Cameroon	73	90	84	72	72
Canada	[r]1,222	1,282	1,355	1,540	[2]1,535
China[e]	400	410	410	[r]615	800
Czechoslovakia	32	[e]32	33	32	26
Egypt	170	209	175	179	179
France	342	293	322	323	322
German Democratic Republic[e]	58	60	[r]61	[r]62	65
Germany, Federal Republic of	777	745	765	738	744
Ghana	—	49	125	150	[2]118
Greece[3]	136	125	126	127	127
Hungary	74	74	74	76	75
Iceland	80	73	76	85	85
India[3]	269	260	257	245	298
Indonesia[3]	199	217	219	216	180
Iran[e]	42	43	40	40	40
Italy	230	[r]224	243	233	227
Japan[4]	287	227	140	41	[2]35
Korea, North[e]	10	10	10	10	10
Korea, Republic of[3]	18	18	19	22	20
Mexico[3]	44	43	40	63	65
Netherlands	249	251	266	276	[2]278
New Zealand	243	241	173	249	200
Norway	765	[r]743	726	806	840
Poland[5]	46	47	48	48	48
Romania[6]	244	247	269	260	260
South Africa, Republic of	167	165	170	171	[2]172
Spain	381	370	350	341	[2]323
Suriname[7]	29	[e]29	30	9	5
Sweden	83	84	77	82	98
Switzerland	79	73	80	73	72
Turkey	38	54	60	42	[2]57
U.S.S.R.[e]	2,100	2,200	2,300	2,400	2,400
United Arab Emirates: Dubai	155	153	155	155	155
United Kingdom	288	275	276	294	[2]300
United States	4,099	3,500	3,037	3,343	[2]3,944
Venezuela	386	396	423	440	417
Yugoslavia[e] [3]	270	280	282	244	250
Total	**[r]15,705**	**[r]15,398**	**15,354**	**16,378**	**17,304**

[e]Estimated. [p]Preliminary. [r]Revised.

[1]The Bureau of Mines defines primary aluminum as "The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well as that of any metal produced from either returned scrap or remelted materials." International reporting practices vary from country to country, some nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through May 31, 1989.

[2]Reported figure.

[3]Primary ingot.

[4]Excludes high-purity aluminum containing 99.995% or more as follows, in metric tons: 1984—4,358; 1985—4,783; 1986—8,140; 1987—12,099; and 1988—13,628.

[5]Primary unalloyed ingot plus secondary unalloyed ingot.

[6]Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.

[7]Data represent exports of ingot aluminum, presumably all primary.

Switzerland

Reynolds Metals reported plans to reorganize its European operations under a new unit, Reynolds Europe Ltd., to be headquartered in Lausanne. Reynolds Europe was expected to better coordinate the company's sales and marketing operations in Europe. Reynolds Metals European operations included facilities in Belgium, the Federal Republic of Germany, France, Italy, and the Netherlands.

Thailand

Alcan Aluminium reported the sale of 34% of its interest in Alcan Thai Co. Ltd., a manufacturer of aluminum extrusions, to Nippon Light Metals Co. (NLM). Following the sale, Alcan Aluminium's share was 51% and NLM's share, 34%. The remaining 15% was owned by Siam Commercial Bank Group of Thailand.

U.S.S.R.

Pechiney announced the signing of a joint venture with the U.S.S.R. to modernize an aluminum packaging plant in Armenia. The upgrading, which included new equipment and technical assistance by Pechiney, was expected to triple the plant's output to 23,000 tons in about 3 years.

United Kingdom

Trent Alloys Ltd., a wholly owned subsidiary of the Cookson Group, announced plans to build a secondary smelter at North Cave on Humberside. According to company officials, the plant was expected to be operational in late 1989.

Five companies, Alcan Aluminium, Alcoa, Pechiney, Reynolds Metals, and Vereinigte Aluminium-Werke, announced the formation of the Aluminium Can Recycling Association (Alucan). The new association was expected to promote the collecting and recycling of aluminum cans in the United Kingdom.

Venezuela

Industria Venezolana de Aluminio

C.A. (VENALUM) reported the purchase of a 20% stake in a U.S. aluminum extruder, Wells Aluminum. As part of the agreement, VENALUM was expected to supply 40% to 60% of the metal needs of Wells in coming years.

TECHNOLOGY

Martin Marietta Energy Systems Inc. reported the licensing of a process to make a new nickel-aluminide to specialty steelmaker Armco Inc. The alloy reportedly had the characteristics of both a metal and a ceramic. It was nonbrittle and resistant to heat and corrosion. Some potential applications for the new alloy included jet engine parts, heat exchangers in nuclear and coal-fired steam plants, and dies and molds for forging, forming, and casting at high temperatures.

Alcan Aluminium announced that construction had begun on its first commercial aluminum metal matrix composite plant in Jonquière, Quebec, Canada. Capacity at the plant, scheduled to be in full operation by 1989, was expected to be 25 million pounds of composite. The aluminum composite, commercial name Dural, was targeted for the aerospace, automotive, and sporting goods markets.

The National Aeronautics and Space Administration reportedly was evaluating aluminum space suits for use on future space stations. The suits could be pressurized up to 1 atmosphere and were designed to shield against radiation, micrometeoroids, and "space junk" in Earth orbit.[5]

Showa Aluminium K.K. reported the development of a high-capacity, titanium-coated aluminum cathode foil. The titanium coating was applied by a vacuum deposition process. Company officials noted that the development made it possible to produce electrolytic capacitors and other electronic components in much smaller sizes, opening an entirely new market for aluminum foil.[6]

Ogden Environmental Services Inc. reported the completion of a program to develop circulating-bed combustion techniques for the treatment of spent potliners. After treatment in this process, the resultant spent potliner ash reportedly met all requirements for placement in nonhazardous, solid waste landfills. In this report, Ogden described the company's 10,000-ton-per-year circulating-bed combustion system that was designed to be transported to individual smelter locations to treat spent potliners on-site.[7]

On November 17, the President signed Public Law 100-680, the Steel and Aluminum Energy Conservation and Technology Competitiveness Act of 1988. The law provided for the establishment of public-private sector partnerships to undertake scientific research and development of technology of significance to the steel and aluminum industries, utilizing the expertise of industry scientists and scientists from Federal laboratories, universities, and other organizations.

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Federal Register. Hazardous Waste Management System; Identification and Listing of Hazardous Waste; and Designation, Reportable Quantities, and Notification. V. 53, No. 177, Sept. 13, 1988, pp. 35412-35421.

[3] Bennett, J. B. The Potential Impact of Acid Rain Legislation on the Domestic Aluminum Smelting Industry. BuMines OFR 58-88, 1988, 14 pp.

[4] Federal Register. Antidumping Duty Order: Certain Electrical Conductor Aluminum Redraw Rod From Venezuela. V. 53, No. 162, Aug. 22, 1988, pp. 31903-31904.

——. Countervailing Duty Order: Certain Electrical Conductor Aluminum Redraw Rod From Venezuela. V. 53, No. 162, Aug. 22, 1988, pp. 31904-31905.

[5] American Metal Market. NASA Evaluating Aluminum Suits For Use by Crew of Space Station. V. 96, No. 124, June 27, 1988, p. 5.

[6] Furukawa, T. Showa, Matsushita Develop TitaniumCoated Aluminum Foil. Am. Met. Mark., v. 96, No. 15, Jan. 22, 1988, p. 4.

[7] Rickman, W. S. Circulating Bed Combustion of Spent Potliners. Paper in Light Metals 1988, ed. by L. G. Boxall, Metall. Soc. AIME, Warrendale, PA, pp. 735-743.

ANTIMONY

By Thomas O. Llewellyn[1]

Production of primary antimony products remained at the same level as the previous year, despite the closure during 1988 of two antimony refining facilities. Total imports of antimony materials increased considerably over those of 1987. Increased reported industrial consumption was due mainly to the continued improved market for antimony trioxide in flame-retardant applications. The development of high-technology applications for antimony continued in 1988. Researchers developed a unique manufacturing process that forms liquid compounds from certain metals such as antimony and zinc by using special organic chemicals.

DOMESTIC DATA COVERAGE

Domestic production data for antimony are developed by the Bureau of Mines from two voluntary surveys of U.S. operations. Typical of these surveys is the "Primary Antimony" survey. Of the seven operations to which a survey request was sent, all responded, representing 100% of the primary smelter production shown in table 1 and 100% of the total antimony content of primary antimony production by class shown in table 3.

LEGISLATION AND GOVERNMENT PROGRAMS

On February 25, 1988, the President signed Executive Order 12626, designating the Secretary of Defense to be the manager of the National Defense Stockpile (NDS).[2] The Secretary delegated operational management functions of the NDS to the Defense Logistics Agency. Previously, the NDS responsibilities were distributed among the U.S. Department of Defense, the Federal Emergency Management Agency, and the General Services Administration.

The NDS goal for antimony metal remained at 36,000 short tons. No inventory acquisitions or sales were made during the year, and as of December 31, 1988, the stockpile inventory was 35,999 tons of antimony metal.

DOMESTIC PRODUCTION

Mine Production

During the second quarter of 1988, Sunshine Mining Co. resumed antimony production as a byproduct of the treatment of tetrahedrite, a complex silver-copper-antimony sulfide ore, from the Coeur d'Alene District of Idaho. Mine production was withheld to avoid disclosing company proprietary data.

Smelter Production

Primary.—In February, Anzon America Inc., a U.S. subsidiary of the London-based Cookson Group, completed the purchase of an antimony oxide plant in Cleveland, OH, owned by McGean-Rohco Inc., and McGean's interest in an antimony smelter in the Republic of South Africa. The equipment from Cleveland was reportedly shipped to Anzon America's smelter at Laredo, TX, where it was reinstalled to increase refinery capacity needed to process the recent increase of antimony concentrates from the new owner's mine in Mexico. The closure of the Cleveland plant was not expected to have any significant impact on U.S. antimony refinery capacity.

In June, M&T Chemicals Inc. of Baltimore, MD, and Laurel Industries Inc. of Cleveland, OH, announced an agreement to consolidate their antimony oxide production. Antimony oxide will be manufactured at the Laurel plant in La Porte, TX. M&T Chemicals will continue manufacturing other specialty antimony products, such as sodium antimonate, at its Baltimore plant. Each company will remain responsible for marketing its own products.

Production was restarted at Sunshine's

TABLE 1

SALIENT ANTIMONY STATISTICS

(Short tons of antimony content unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Production:					
Primary:					
Mine (recoverable antimony)	557	W	W	—	W
Smelter	17,639	16,449	17,978	r20,719	20,604
Secondary	14,823	15,030	15,522	r17,453	17,827
Exports of metal, alloys, waste and scrap	511	362	595	876	688
Exports of antimony oxide	480	885	580	777	1,352
Imports for consumption	23,089	20,694	25,401	26,729	33,099
Reported industrial consumption, primary antimony	12,465	11,697	10,952	r11,435	13,294
Stocks: Primary antimony, all classes, Dec. 31	6,895	6,040	6,131	r6,784	7,315
Price: Average, cents per pound[1]	151.2	131.1	121.9	110.6	103.9
World: Mine production	r60,293	r61,984	63,331	p76,112	e78,196

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.
[1] New York dealer price for 99.5% to 99.6% metal, c.i.f. U.S. ports.

TABLE 2

PRIMARY ANTIMONY PRODUCED OR GENERATED IN THE UNITED STATES

(Short tons of antimony content)

Year	Class of material produced or generated			
	Metal	Oxide	Resi-dues	Total
1984	1,113	16,379	147	17,639
1985	943	15,398	108	16,449
1986	378	17,525	75	17,978
1987	W	20,677	r42	r20,719
1988	W	20,091	513	20,604

r Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

antimony smelter at Kellogg, ID, during the second quarter. The smelter had been closed since 1986. Antimony metal was a byproduct of the treatment of tetrahedrite ore at Sunshine's refinery in Kellogg.

In January, Chemet Co. announced that it had closed its antimony trioxide plant in Moscow, TN, and that the plant would remain closed until the facility could be operated on a profitable basis.

The producers of primary antimony metal and oxide products were ASARCO Incorporated, Omaha, NE; Amspec Chemical Corp., Gloucester City, NJ; Anzon America, Laredo, TX; Laurel Industries, La Porte, TX; M&T Chemicals, Baltimore, MD; Sunshine Mining, Kellogg, ID; and U.S. Antimony Corp., Thompson Falls, MT.

Secondary.—Old scrap, predominantly lead battery plates, was the source of most of the secondary antimony output. New scrap, mostly in the form of drosses and residues from various sources, supplied the remainder. The antimony content of scrap was usually recovered and consumed as antimonial lead.

TABLE 3

SECONDARY ANTIMONY PRODUCED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Short tons of antimony content unless otherwise specified)

	1987r	1988
KIND OF SCRAP		
New scrap: Lead- and tin-base	1,424	1,229
Old scrap: Lead- and tin-base	16,029	16,598
Total	**17,453**	**17,827**
FORM OF RECOVERY		
In antimonial lead	16,743	17,233
In other lead- and tin-base alloys	710	594
Total	**17,453**	**17,827**
Value (millions)	$46	$47

r Revised.

CONSUMPTION AND USES

Reported domestic consumption of primary antimony increased compared with that of 1987 and reached the highest level since 1977. Lead-antimony alloys were used in starting-lighting-ignition (SLI) batteries, ammunition, corrosion resistant pumps and pipes, tank linings, roofing sheets, solder, cable sheaths, and antifriction bearings. In 1988, the Battery Council International reported a 6% increase in the total shipments of replacement and original equipment automotive SLI batteries in the United States compared with those of 1987.

Antimony compounds were used in plastics both as stabilizers and as flame retardants. Antimony trioxide in an organic solvent was used to make textiles and plastics flame retardant. Antimony was used as a decolorizing and refining agent in some forms of glass, such as special optical glass. The largest end use for antimony compounds was in flame retardants.

PRICES

The New York dealer price range for antimony metal, published by Metals Week, was $1.12 to $1.16 per pound at the beginning of the year. A slight upturn in price occurred during the month of February; however, during March the price began a decrease that continued throughout the remainder of the year. By yearend, the price range was $0.96 to $1.01 per pound.

Asarco's published price for high-tint antimony trioxide in lots of 40,000 pounds was $1.35 per pound at the beginning of the year. This price was increased to $1.43 at the end of May and remained constant for the rest of 1988. Other domestic producers ad-

TABLE 4

REPORTED INDUSTRIAL CONSUMPTION OF PRIMARY ANTIMONY IN THE UNITED STATES

(Short tons of antimony content)

Year	Class of material consumed				
	Metal	Oxide	Sulfide	Residues	Total
1984	1,543	10,747	28	147	12,465
1985	1,503	10,053	33	108	11,697
1986	2,437	8,410	30	75	10,952
1987r	2,478	8,872	43	42	11,435
1988	2,338	10,397	46	513	13,294

r Revised.

TABLE 5

REPORTED INDUSTRIAL CONSUMPTION OF PRIMARY ANTIMONY IN THE UNITED STATES, BY PRODUCT

(Short tons of antimony content)

Product	1984	1985	1986	1987[r]	1988
Metal products:					
Ammunition	W	410	W	W	W
Antimonial lead	845	568	607	1,215	1,694
Bearing metal and bearings	182	177	153	206	196
Cable covering	W	W	68	W	W
Castings	11	11	12	9	14
Collapsible tubes and foil	W	W	W	W	—
Sheet and pipe	80	W	40	84	200
Solder	232	336	278	383	282
Type metal	31	31	9	9	7
Other	337	105	418	644	665
Total	**1,718**	**1,638**	**1,585**	**2,550**	**3,058**
Nonmetal products:					
Ammunition primers	21	27	23	35	38
Ceramics and glass	1,292	1,187	1,027	1,237	1,346
Fireworks	7	4	4	3	5
Pigments	178	147	250	307	197
Plastics	1,108	998	975	827	1,009
Rubber products	21	25	41	W	32
Other	161	141	162	220	163
Total	**2,788**	**2,529**	**2,482**	**2,629**	**2,790**
Flame-retardant:					
Adhesives	343	310	170	347	276
Paper	159	111	1	W	W
Pigments	8	8	14	33	115
Plastics	5,858	5,529	4,979	4,562	6,028
Rubber	342	315	439	426	311
Textiles	1,249	1,257	1,282	882	708
Other	—	—	—	6	8
Total	**7,959**	**7,530**	**6,885**	**6,256**	**7,446**
Grand total	**12,465**	**11,697**	**10,952**	**11,435**	**13,294**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

TABLE 6

INDUSTRY STOCKS OF PRIMARY ANTIMONY IN THE UNITED STATES, DECEMBER 31

(Short tons of antimony content)

Stocks	1984	1985	1986	1987[r]	1988
Metal	582	807	957	906	2,602
Ore and concentrate	1,304	1,164	1,030	1,265	W
Oxide	4,926	3,954	4,019	4,496	4,384
Residues and slags	69	99	106	92	303
Sulfide	14	16	19	25	26
Total	**6,895**	**6,040**	**6,131**	**6,784**	**7,315**

[r] Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

TABLE 7

ANTIMONY PRICE RANGES IN 1988, BY TYPE

Type	Price per pound
Domestic metal[1]	$2.00
Foreign metal[2]	$1.01– 1.16
Antimony trioxide[3]	1.35– 1.43

[1] Based on antimony in alloy.
[2] Duty-paid delivery, New York.
[3] Producer price, published by ASARCO Incorporated, for high-tint antimony trioxide.

justed their prices to remain competitive, so that by yearend, the published price for antimony trioxide ranged from $1.43 to $1.71 per pound. European price quotations for antimony ore and concentrates, as published by Metal Bulletin (London), increased by mid-January, held steady for 8 months, and then decreased to levels lower than those quoted on January 1. At yearend, the price ranges published by Metal Bulletin were as follows: clean sulfide concentrates, 60% antimony content, $19.00 to $20.50 per metric ton unit (equivalent to $17.30 to $18.60 per short ton unit); and lump sulfide ore, 60% antimony content, $20.00 to $21.50 per metric ton unit (equivalent to $18.20 to $19.60 per short ton unit).

FOREIGN TRADE

Exports of antimony oxide increased significantly in 1988 and reached their highest level since the Bureau of Mines began reporting this data 21 years ago. In addition to exports of antimony oxide, the United States also exported 972 tons (gross weight) of other antimony compounds with a value of $2.8 million. Canada, the Federal Republic of Germany, the Republic of Korea, Mexico, and the United Kingdom were the recipients of approximately 65% of other antimony compounds, and the remainder was distributed among 24

TABLE 8

U.S. EXPORTS OF ANTIMONY METAL, ALLOYS, WASTE AND SCRAP, BY COUNTRY

Country	1987 Gross weight (short tons)	1987 Value (thousands)	1988 Gross weight (short tons)	1988 Value (thousands)
Belgium-Luxembourg[1]	45	$390	106	$513
Canada	199	863	90	206
Dominican Republic	16	39	50	14
Germany, Federal Republic of	46	117	10	49
Israel	—	—	18	117
Italy	1	6	—	—
Japan	43	68	17	17
Korea, Republic of	4	6	38	59
Mexico	61	109	146	248
Netherlands	52	390	62	91
Spain	110	90	—	—
Taiwan	([2])	9	2	31
United Kingdom	81	154	12	21
Venezuela	124	224	83	274
Other	94	352	54	153
Total	**876**	**2,817**	**688**	**1,793**

[1] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data Belgium only.
[2] Less than 1/2 unit.

Source: Bureau of the Census.

other countries.

Total imports of antimony materials increased approximately 24% from those of 1987.

WORLD CAPACITY

The data in table 12 represent rated annual production capacity for mines and refineries on December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

The rated capacity of antimony mines and refineries was estimated based on discussions with officials from private industry, past and present production rate, the author's knowledge of the type of facility, and published capacity data.

WORLD REVIEW

Canada

Dominion Explorers, formerly Durham Resources Inc., deepened its Durham mine shaft to the 1,275-foot level in 1987. The opening of the new level gave access to additional minable antimony ore, which the company reportedly began processing in 1988.

France

The Government-owned Bureau de Recherches Géologiques et Minières and Société Gangneraud Pere et Fils, a private French company dealing in public works and mining, developed an antimony deposit in the western part of the country in Las Brouzils, Vendee County, and planned to produce 2,000 tons per year of concentrates averaging more than 60% antimony content.

Japan

Antimony trioxide production, using mainly imported materials as feedstock, was 10,661 tons, an increase of 9% compared with 1987 production. Antimony metal production decreased from 196 tons in 1987 to 185 tons in 1988.[3]

Mexico

Antimony Products of Mexico (Apomex), a subsidiary of Amspec Chemical, Gloucester City, NJ, completed construction of a new antimony refinery plant at Ciudad Miguel Alemán. The plant, with an annual production capacity of 3,500 tons of antimony oxide, was designed to treat domestic and imported raw materials. The company expected to begin operating by early 1989.

TECHNOLOGY

Researchers at Atochem Japan, a subsidiary of Paris-based Atochem, developed a unique manufacturing process that forms liquid compounds from certain metals such as antimony and zinc by using special organic chemicals. This facilitates a wide range of applications, such as the production of catalysts and electrical conductors. In addition, the process for manufacturing polyester resin can be made safer by using a liquid antimony compound to catalyze the polymerization instead of using antimony oxide. The company has successfully synthesized four types of such compounds utilizing antimony, copper, phosphorus, and zinc. Specific details of the process to produce the liquid metal compounds were not revealed as they are company proprietary data.[4]

[1] Physical scientist, Branch of Nonferrous Metals.

[2] Federal Register. National Defense Stockpile Manager. V. 53, No. 39, Feb. 29, 1988, p. 6114.

[3] Japan Metal Journal. V. 19, No. 11, Mar. 13, 1989, pp. 7-8.

[4] Japan Chemical Week. Atochem Japan Develops New Process To Liquefy Metals. V. 29, No. 148, Sept. 1, 1988, p. 5.

TABLE 9

U.S. EXPORTS OF ANTIMONY OXIDE, BY COUNTRY

Country	1987			1988		
	Gross weight (short tons)	Antimony content[1] (short tons)	Value (thousands)	Gross weight (short tons)	Antimony content[1] (short tons)	Value (thousands)
Australia	—	—	—	21	17	$64
Belgium-Luxembourg[2]	22	18	$76	13	11	41
Brazil	16	13	62	—	—	—
Canada	395	328	1,141	536	447	1,553
China	—	—	—	10	8	41
Costa Rica	23	19	34	31	26	57
Germany, Federal Republic of	52	43	165	133	110	422
Hong Kong	—	—	—	65	54	85
India	15	12	50	4	3	16
Ireland	—	—	—	26	22	74
Israel	11	9	21	—	—	—
Italy	99	82	360	163	135	559
Japan	53	44	167	56	46	211
Korea, Republic of	31	26	90	100	83	236
Mexico	48	40	82	19	16	58
Netherlands	—	—	—	20	17	57
Singapore	28	23	79	24	20	76
Spain	—	—	—	35	29	88
Switzerland	—	—	—	23	19	78
Taiwan	23	19	63	281	233	677
Turkey	55	46	169	—	—	—
United Kingdom	35	29	83	33	27	126
Venezuela	8	7	39	15	12	52
Other	22	19	71	21	17	92
Total	**936**	**777**	**2,752**	**1,629**	**1,352**	**4,663**

[1] Estimated by the Bureau of Mines.

[2] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data Belgium only.

Source: Bureau of the Census.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY, BY CLASS AND COUNTRY

Country	1987 Gross weight (short tons)	1987 Antimony content[1] (short tons)	1987 Value (thousands)	1988 Gross weight (short tons)	1988 Antimony content[1] (short tons)	1988 Value (thousands)
Antimony ore and concentrate:						
Bangladesh	66	43	$61	—	—	—
Belgium	—	—	—	103	59	$97
Bolivia	1,329	825	1,182	1,280	748	1,158
Chile	66	43	60	61	27	29
China	2,167	1,269	1,558	1,389	753	1,471
Guatemala	2,436	1,379	718	846	508	255
Honduras	100	45	34	—	—	—
Hong Kong	513	302	362	79	50	130
Mexico	3,772	1,308	1,312	4,186	1,491	1,735
Peru	120	69	75	—	—	—
South Africa, Republic of	—	—	—	297	178	231
Thailand	745	307	343	626	295	437
Trinidad	22	12	12	—	—	—
United Kingdom	53	32	15	—	—	—
Total	**11,389**	**5,634**	**5,732**	**8,867**	**4,109**	**5,543**
Antimony oxide:						
Belgium-Luxembourg[2]	807	670	1,853	869	722	2,327
Bolivia	546	453	918	602	500	1,060
Canada	—	—	—	1	1	4
Chile	—	—	—	93	77	173
China	3,404	2,825	6,653	4,075	3,382	7,770
France	883	733	2,206	942	782	2,381
Germany, Federal Republic of	96	80	731	187	155	1,238
Guatemala	75	62	70	—	—	—
Hong Kong	1,103	915	2,321	551	457	1,146
Japan	3	2	37	2	2	26
Mexico	460	382	408	523	434	508
Netherlands	—	—	—	39	32	113
South Africa, Republic of	4,332	3,596	2,986	4,333	3,596	2,823
Taiwan	187	155	372	—	—	—
United Kingdom	159	132	411	108	90	437
Yugoslavia	1,590	1,320	1,058	406	337	158
Total	**13,645**	**11,325**	**20,024**	**12,731**	**10,567**	**20,164**
Antimony sulfide:[3]						
Austria	7	5	24	29	19	128
Belgium-Luxembourg[2]	9	6	18	—	—	—
China	86	58	70	115	77	147
Germany, Federal Republic of	—	—	—	22	15	93
United Kingdom	—	—	—	13	9	64
Total	**102**	**69**	**112**	**179**	**120**	**432**

[1] Antimony ore and concentrate content reported by Bureau of the Census. Antimony oxide and antimony sulfide content estimated by the Bureau of Mines.
[2] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
[3] Includes needle or liquated.

Source: Bureau of the Census.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY METAL, BY COUNTRY

Country	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Belgium-Luxembourg [1]	5	$4	17	19
Bolivia	43	83	—	—
Canada	1	171	2	131
Chile	106	202	84	151
China	6,883	13,416	14,810	29,123
Germany, Federal Republic of	3	88	1	159
Hong Kong	1,184	2,268	1,614	3,230
Indonesia	66	409	—	—
Korea, Republic of	168	356	—	—
Mexico	990	669	1,145	842
Netherlands	([2])	9	220	429
Taiwan	19	30	—	—
Thailand	—	—	303	569
U.S.S.R.	189	383	—	—
United Kingdom	44	83	106	181
Other	—	—	1	3
Total [3]	**9,701**	**18,171**	**18,303**	**34,837**

[1] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data Belgium only.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 12

WORLD ANNUAL ANTIMONY PRODUCTION CAPACITY, DECEMBER 31, 1988

(Short tons, antimony content)

	Mine	Smelter [1]
North and Central America:		
United States	3,000	29,200
Other	15,100	4,500
Total	**18,100**	**33,700**
South America	20,800	12,500
Europe [2]	20,500	30,800
Africa	22,500	7,000
Asia [3]	42,400	38,300
Oceania: Australia	4,000	—
World total	**128,300**	**122,300**

[1] Includes antimony oxide plants.
[2] Includes estimates for the U.S.S.R. and other centrally planned economies.
[3] Includes estimates for China.

TABLE 13

ANTIMONY: WORLD MINE PRODUCTION (CONTENT OF ORE UNLESS OTHERWISE SPECIFIED), BY COUNTRY[1]

(Short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Australia[2]	1,267	[r]1,607	1,247	1,357	1,300
Austria	577	526	566	[r e]360	330
Bolivia	10,231	9,838	11,291	11,723	[3]10,960
Canada[4]	610	1,185	4,194	4,085	[3]3,282
China[e]	16,500	16,500	16,500	[r]30,000	35,000
Czechoslovakia[e]	[3]1,100	[r]990	1,000	1,100	1,100
Guatemala	82	[r]1,806	1,687	1,736	[3]1,472
Honduras	122	96	[r e]55	31	[3]21
Italy	269	546	325	([5])	390
Malaysia (Sarawak)	19	13	—	142	—
Mexico[6]	3,377	4,702	3,678	3,129	[3]2,540
Morocco (content of concentrates)	1,071	[e]830	680	489	485
Pakistan	1	4	—	8	9
Peru (recoverable)	741	655	[e]740	650	550
South Africa, Republic of (content of concentrates)	8,201	8,150	7,513	[e]7,500	7,600
Spain	643	273	50	22	22
Thailand	2,172	1,367	1,123	451	550
Turkey	1,121	1,082	1,039	1,640	1,100
U.S.S.R.[e]	10,300	10,400	10,500	10,600	10,600
United States[7]	557	W	W	—	W
Yugoslavia[e]	1,050	[r]1,200	[r]950	[r]920	720
Zimbabwe (content of concentrates)	282	214	193	169	165
Total	**[r]60,293**	**[r]61,984**	**63,331**	**76,112**	**78,196**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through May 23, 1989.
[2]Antimony content of antimony ore and concentrates, lead concentrates, and lead-zinc concentrates.
[3]Reported figure.
[4]Partly estimated on the basis of reported value of total production.
[5]Revised to zero.
[6]Antimony content of ores for export plus antimony content of antimonial lead and other smelter products produced.
[7]Production from antimony mines; excludes amount produced as a byproduct of domestic lead ores.

ASBESTOS

By Robert L. Virta[1]

Asbestos-related health risk was the major issue affecting the domestic asbestos industry as the Environmental Protection Agency (EPA) continued to review its proposed ban/phaseout of asbestos and asbestos-containing products. In the United States, production, imports, exports, and apparent consumption of asbestos declined in 1988, continuing a 15-year downward trend.

DOMESTIC DATA COVERAGE

Domestic production data for asbestos are developed by the Bureau of Mines by means of a voluntary industry survey. Of the two canvassed operations to which a survey request was sent, both responded, representing 100% of the total production data shown in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

EPA completed a regulatory impact analysis of its proposed ban and/or phaseout of asbestos and asbestos-containing products and submitted its recommendations concerning the proposal to the Office of Management and Budget for review.[2]

The Occupational Safety and Health Administration (OSHA) amended its ruling covering occupational exposure to asbestos, tremolite, anthophyllite, and actinolite (29 CFR Parts 1910 and 1926) to include an exposure limit of 1 fiber per cubic centimeter of air averaged over a 30-minute time period.[3]

On February 16, 1988, the EPA issued a final ruling that contained the toxic chemical release inventory reporting form as required by Section 313 of the Superfund Amendments and Reauthorization Act of 1986 (SARA). SARA requires the owners and operators of facilities that manufacture, import, process, or use certain toxic chemicals to report annually any releases of those chemicals to the environment. The ruling also requires suppliers to notify purchasers of compounds and trade name products of the presence of those toxic chemicals. Friable asbestos was included under the ruling.[4]

OSHA extended through July 21, 1989, an administrative stay on its 1986 regulation governing worker exposure to the nonasbestiform varieties of tremolite, actinolite, and anthophyllite. During the stay, OSHA continued to analyze the impact of using the asbestos standard to regulate the nonasbestiform varieties of the minerals.[5]

ENVIRONMENTAL IMPACT

EPA released a report on asbestos-containing materials in public buildings. In this report, EPA recommended improved training for inspection and abatement professionals, planned

TABLE 1

SALIENT ASBESTOS STATISTICS

		1984	1985	1986	1987	1988
United States:						
Production (sales):						
Quantity	metric tons	57,422	57,457	51,437	50,600	18,233
Value[1]	thousands	$24,238	$20,485	$17,367	$17,198	W
Exports and reexports (unmanufactured):						
Quantity	metric tons	39,919	45,656	47,281	60,084	31,544
Value	thousands	$18,346	$16,489	$14,520	$16,149	$8,468
Exports and reexports of asbestos products:						
Value	do.	$163,347	$193,765	$163,896	$180,602	$194,858
Imports for consumption (unmanufactured):						
Quantity	metric tons	209,963	142,431	108,352	93,763	85,326
Value	thousands	$64,749	$44,093	$26,537	$22,022	$21,528
Consumption, apparent[2]	metric tons	226,000	162,000	119,627	84,279	71,354
World: Production	do.	r4,311,842	r4,271,488	4,053,585	p4,253,194	e4,357,742

e Estimated. p Preliminary. r Revised. W Withheld to avoid disclosing company proprietary data.
1 F.o.b. mine.
2 Production, plus imports, minus exports, plus adjustments in Government and industry stocks.

management programs for asbestos abatement activities, increased attention to thermal insulation applications, and assessment of the effectiveness of the Asbestos Hazard Emergency Response Act prior to establishing any new programs for asbestos control.[6]

TABLE 2

STOCKPILE GOALS AND GOVERNMENT INVENTORIES FOR ASBESTOS, DECEMBER 31

(Metric tons)

	Stockpile goals	Total inventories		
		1986	1987	1988
Amosite	15,422	30,853	30,849	30,849
Chrysotile	2,722	9,711	9,709	9,710
Crocidolite	—	33	33	33
Total	**18,144**	**40,597**	**40,591**	**40,592**

Source: Department of Defense.

TABLE 3

U.S. ASBESTOS CONSUMPTION, BY END USE, GRADE, AND TYPE

(Thousand metric tons)

End use	Chrysotile[1]						Crocidolite	Other[3]	Total asbestos[2,4]
	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Total[2]			
1987	1.0	7.8	6.5	7.3	56.8	79.3	1.1	3.8	80.4
1988:									
Asbestos-cement pipe	—	6.9	1.4	2.2	—	10.4	1.3	—	11.6
Asbestos-cement sheet	—	—	—	2.0	2.0	4.0	—	—	4.0
Coatings and compounds	(5)	(5)	—	—	3.7	3.7	—	—	3.7
Flooring products	—	—	.1	—	.2	.3	—	—	.3
Friction products	(5)	(5)	2.0	.8	11.9	14.8	—	—	14.8
Insulation:									
Electrical	—	—	(5)	—	—	(5)	—	—	(5)
Thermal	—	—	(5)	(5)	(5)	(5)	—	—	(5)
Packing and gaskets	—	.5	1.5	(5)	7.4	9.5	—	—	9.5
Paper	—	—	—	—	1.2	1.2	—	—	1.2
Plastics	—	(5)	—	—	.3	.3	—	—	.3
Roofing products	—	(5)	(5)	.2	19.6	19.9	—	—	19.9
Textiles	.4	—	—	—	—	.4	—	—	.4
Other	(5)	.1	(5)	—	.2	.4	—	—	.4
Total[2]	**.4**	**7.6**	**5.1**	**5.4**	**46.4**	**65.0**	**1.3**	**5.1**	**66.2**

[1] Estimated distribution based upon data provided by the Asbestos Institute, Montreal, Canada, and the Bureau of Mines asbestos producer survey.
[2] Data may not add to totals shown because of independent rounding.
[3] Source: Bureau of the Census. "Other" category contains unspecified fiber type and end use.
[4] Does not include "Other" category in total.
[5] Less than 1/10 unit.

The International Labor Organization (ILO) provision that supports the controlled use of asbestos was ratified by the Canadian Government on June 16. With its ratification by Canada, the ILO provision will become part of the International Labor Code on June 16, 1989.[7]

Stockpile goals for asbestos were unchanged from those of 1987.

DOMESTIC PRODUCTION

The producers of asbestos were KCAC Inc., San Benito County, CA, and Vermont Asbestos Group Inc., Orleans County, VT. Domestic production decreased significantly in 1988 with the closing of Calaveras Asbestos Corp. in 1987. Vermont Asbestos Group announced plans to apply for permits to open a landfill for asbestos-containing wastes on its property in Eden. The company would use an abandoned open pit for the disposal of wastes generated from asbestos abatement programs.[8]

CONSUMPTION AND USES

Total U.S. asbestos consumption decreased 15% in 1988. Approximately 91% of the asbestos consumed was chrysotile, 2% was crocidolite, and 7% was an unspecified fiber type. Chrysotile grade 7 was most commonly used, followed by grades 4, 6, 5, and 3. Asbestos-cement pipe, friction products, packing and gaskets, and roofing products accounted for 84% of the asbestos consumption.

PRICES

The average unit value of domestically produced asbestos increased in 1988. Unit values for imported asbestos ranged from $115 per ton to $2,849 per ton and averaged $252 per ton. Unit values for exported asbestos ranged from $163 per ton to $3,906 per ton and averaged $268 per ton.

FOREIGN TRADE

There was a 3% increase in the total value of asbestos fibers and asbestos products exported from the United States. Exports and reexports of asbestos fiber decreased 48% in quantity and value. The value of exported and reexported manufactured products increased 8%. Exports and reexports of brake linings and disc pads accounted for 72% of the value of all manufactured asbestos products. Canada remained the largest importer of unmanufactured fibers and manufactured asbestos products, followed by Japan, Mexico, Brazil, and Australia.

Canada provided 93% of the asbestos imported into the United States, and the Republic of South Africa provided 5%. Several other countries provided minor amounts. Chrysotile accounted for approximately 93% of asbestos fiber imports.

Imports of asbestos-containing pipes, tubes, and fittings increased from 2,152 tons in 1987 to 7,757 tons in 1988 according to the Bureau of the Census. Imports of other asbestos-containing products decreased from 5,100 tons in 1987 to 2,756 tons in 1988.

WORLD CAPACITY

The data in table 8 are rated annual capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

TABLE 4

CUSTOMS UNIT VALUES OF IMPORTED ASBESTOS

(Dollars per metric ton)

	1984	1985	1986	1987	1988
Canada:					
Chrysotile:					
Cement	284	—	—	—	—
Crude	1,084	576	547	610	635
Spinning	699	731	507	598	756
Other	431	283	229	218	227
South Africa, Republic of:					
Amosite	869	830	—	—	—
Crocidolite	705	569	582	572	609

Source: Bureau of the Census.

TABLE 5

COUNTRIES IMPORTING U.S. ASBESTOS FIBERS AND PRODUCTS

(Thousand dollars)

Country	1987			1988		
	Unmanufactured fibers	Manufactured products	Total[1]	Unmanufactured fibers	Manufactured products	Total[1]
Australia	24	1,513	1,537	9	2,285	2,294
Brazil	401	4,642	5,043	656	4,662	5,317
Canada	673	136,828	137,501	694	144,305	144,999
Germany, Federal Republic of	673	1,975	2,648	228	2,316	2,544
Japan	3,604	5,931	9,535	3,312	8,538	11,850
Korea, Republic of	1,579	991	2,569	182	1,266	1,448
Kuwait	—	132	132	—	456	456
Mexico	2,893	6,720	9,613	1,636	7,677	9,313
Saudi Arabia	—	1,329	1,329	—	1,814	1,814
Thailand	3,028	397	3,425	150	757	908
Turkey	—	279	279	—	706	706
United Kingdom	359	1,949	2,307	97	2,127	2,224
Venezuela	257	2,314	2,571	106	1,805	1,912
Other	2,659	15,602	18,261	1,399	16,143	17,542
Total[1]	**16,149**	**180,602**	**196,751**	**8,468**	**194,858**	**203,326**

[1] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 6

U.S. EXPORTS AND REEXPORTS OF ASBESTOS AND ASBESTOS PRODUCTS

Products		1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)
			EXPORTS				
Unmanufactured:							
Crudes, fibers, stucco	metric tons	30,252	$9,728	39,720	$11,151	26,146	$6,727
Sand and refuse	do.	16,645	4,673	19,416	4,666	5,188	1,683
Total[1]	**do.**	**46,897**	**14,401**	**59,136**	**15,818**	**31,334**	**8,410**
Manufactured:							
Asbestos fibers	do.	723	3,902	1,078	4,761	1,388	5,377
Brake linings and disk brake pads	do.	NA	123,515	NA	133,733	NA	139,217
Clutch facings and linings	number	NA	16,187	NA	19,982	NA	26,361
Gaskets	metric tons	266	1,285	471	1,857	530	2,225
Insulation	do.	NA	1,889	NA	3,700	NA	4,553
Packing and seals	do.	820	6,373	659	5,710	638	5,781
Shingles and clapboard	do.	880	805	1,225	605	1,095	662
Other articles of asbestos	do.	1,614	1,553	1,632	2,132	1,591	2,056
Other articles, n.s.p.f.	do.	NA	7,342	NA	6,473	NA	6,613
Total[1]		**XX**	**162,851**	**XX**	**178,953**	**XX**	**192,846**
			REEXPORTS				
Unmanufactured:							
Crudes and fibers	do.	329	98	904	316	210	58
Sand and refuse	do.	54	20	44	15	—	—
Total[1]	**do.**	**384**	**119**	**948**	**331**	**210**	**58**
Manufactured:							
Asbestos fibers	do.	—	—	27	65	6	54
Brake linings and disk brake pads	do.	NA	222	NA	333	NA	969
Clutch facings and linings	number	NA	604	NA	845	NA	733
Gaskets	metric tons	6	65	—	—	6	19
Insulation	do.	NA	23	—	—	NA	5
Packing and seals	do.	([2])	50	([2])	3	3	12
Other articles of asbestos	do.	NA	3	3	143	18	77
Other articles, n.s.p.f.	do.	NA	78	NA	260	NA	144
Total[1]		**XX**	**1,045**	**XX**	**1,649**	**XX**	**2,012**

NA Not available. XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.
Source: Bureau of the Census.

WORLD REVIEW

Canada continued to be the largest market economy producer of asbestos, followed by Brazil, the Republic of South Africa, and Italy. The U.S.S.R. was the world's largest producer of asbestos. Canada and the U.S.S.R. accounted for approximately 76% of the world production.

Brazil

SA Mineracao de Amianto announced plans to begin operation of a 250,000-ton-capacity mill at the Cana Brava Mine. The company produces asbestos grades 4 to 6. The ore contains 7% to 8% chrysotile asbestos.[9]

Canada

Canadian production increased in 1988 to an estimated 705,000 tons, a 6% increase over 1987. Prices for asbestos fiber also increased slightly in 1988 as demand for Canadian asbestos remained strong. Developing countries, particularly in Asia, were major markets for Canadian asbestos, accounting for approximately 42% of Canadian asbestos sales.[10]

Cassiar Mining Corp. began an underground development program at its McDame Mine in British Columbia. The ore in the currently operating surface mine is expected to be exhausted by the early 1990's. Production from the underground mine is expected to begin in 1991 at an annual production rate of 90,000 tons per year. The company will continue to produce asbestos grades 3 to 6 although approximately 70% of the asbestos produced from the mine will be grade 4.[11]

Baie Verte Mines Inc. received additional funding from the Newfoundland Government and Minerals Commodities Ltd. and began finalizing a program for expansion of its open pit mine in Newfoundland. The expansion will permit access to an additional 5 years of minable reserves at current production rates. The company also began planning for the installation of a 20,000-ton-per-year wet-processing plant. The plant will produce a grade 5 product in pellet form.[12]

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Asbestos Information Association News & Notes. EPA Forwards Draft Final Rule to OMB for Review. Dec. 30, 1988, p. 1.

[3] Federal Register. Occupational Safety and Health Administration. Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite. V. 53, No. 178, Sept. 14, 1988, pp. 35610–35629.

[4] ———. Environmental Protection Agency. Toxic Chemical Release Reporting; Community Right-to-know. V. 53, No. 30, Feb. 16, 1988, pp. 4500–4554.

[5] ———. Occupational Safety and Health Administration. Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite. V. 53, No. 139, July 20, 1988, pp. 27345–27346.

[6] Environmental Protection Agency. EPA Study of Asbestos-containing Materials in Public Buildings, A Report to Congress, Feb. 1988. U.S. EPA, Washington, DC, 1988, 115 pp.

[7] Asbestos Information Association News & Notes. Canada Ratifies ILO Agreement on Controlled Use of Asbestos. June 30, 1988, p. 4.

[8] Crowe, N. Asbestos Landfill Planned. Burlington Free Press, Aug. 12, 1988.

[9] Asbestos. Brazilian Mine Living Up to Safe Use. V. 3, No. 1, 1988, p. 4.

[10] Freeman, A. Canadian Asbestos Mining Enjoys a Modest Recovery. Wall St. J., Mar. 10, 1989, p. B2.

[11] Industrial Minerals (London). Cassiar Asbestos Development. No. 245, Feb. 1988, p. 8.

[12] ———. Baie Verte Asbestos Developments. No. 247, Apr. 1988, p. 17.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF ASBESTOS FIBERS, BY TYPE, ORIGIN, AND VALUE

Type	Canada		South Africa, Republic of		Other		Total[1]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	103,517	$23,814	4,455	$2,506	380	$217	108,352	$26,537
1987:								
Chrysotile:								
Crude	19	12	10	11	15	17	44	40
Spinning fibers	589	352	—	—	15	45	604	397
All other	88,107	19,207	44	57	22	5	88,173	19,269
Crocidolite (blue)	—	—	1,113	637	—	—	1,113	637
Other (unspecified asbestos type)	1,509	526	2,079	1,083	241	70	3,829	1,679
Total[1]	**90,224**	**20,096**	**3,246**	**1,788**	**293**	**137**	**93,763**	**22,022**
1988:								
Chrysotile:								
Crude	20	2	—	—	17	21	37	23
Spinning fibers	526	358	—	—	75	97	601	455
All other	77,779	17,421	488	273	61	73	78,328	17,767
Crocidolite (blue)	—	—	1,252	763	—	—	1,252	763
Other (unspecified asbestos type)	1,365	555	2,548	1,480	1,195	484	5,108	2,520
Total[1]	**79,690**	**18,336**	**4,288**	**2,516**	**1,348**	**676**	**85,326**	**21,528**

[1] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 8

WORLD ASBESTOS ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

	Rated capacity[1] (Thousand metric tons)
Chrysotile:	
North America:	
Canada	780
United States	30
Total	**810**
South America:	
Brazil	250
Colombia	20
Other	1
Total	**271**
Europe:	
Greece	100
Italy	150
U.S.S.R.	2,800
Yugoslavia	20
Total	**3,070**
Africa:	
South Africa, Republic of	150
Swaziland	30
Zimbabwe	250
Total	**430**
Asia:	
China	170
Cyprus	35
India	30
Japan	4
Korea, Republic of	5
Turkey	6
Other	([2])
Total	**250**
World chrysotile total	**4,831**
Crocidolite: South Africa, Republic of	210
Amosite: South Africa, Republic of	110

[1] Includes capacity at operating plants as well as at plants on standby basis.
[2] Less than 1/2 unit.

TABLE 9

ASBESTOS: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina	1,093	1,244	1,697	1,200	1,200
Brazil[3]	134,788	165,446	204,460	212,807	230,000
Bulgaria	500	400	300	400	400
Canada (shipments)	[r]836,654	[r]750,190	662,381	664,546	[4]704,989
China[e]	135,000	150,000	150,000	150,000	150,000
Colombia	9,982	12,435	[e]13,000	[e]13,000	10,000
Cyprus	[r]11,298	16,360	13,011	18,070	13,000
Egypt	389	229	476	209	215
Greece	45,376	46,811	51,355	63,000	80,000
India	25,450	30,183	25,236	27,019	25,000
Indonesia[e]	25,000	25,000	25,000	25,000	25,000
Italy	147,272	136,006	115,208	100,834	120,000
Japan	3,140	2,971	3,593	3,143	3,200
Korea, Republic of	8,062	4,703	2,983	2,518	2,500
Mozambique	[e]400	55	—	—	—
South Africa, Republic of	167,389	164,247	138,862	135,074	[4]145,405
Swaziland	25,832	25,130	20,908	25,925	23,000
Taiwan	1,355	625	—	—	—
Turkey	1,499	[e]1,500	1,098	360	100
U.S.S.R.[e]	2,500,000	2,500,000	2,400,000	[4]2,554,600	2,600,000
United States (sold or used by producers)	57,422	57,457	51,437	50,600	[4]18,233
Yugoslavia	8,556	6,916	8,596	10,964	15,500
Zimbabwe	165,385	173,580	163,984	193,925	190,000
Total	**[r]4,311,842**	**[r]4,271,488**	**4,053,585**	**4,253,194**	**4,357,742**

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through Apr. 26, 1989.

[2] In addition to the countries listed, Afghanistan, Czechoslovakia, North Korea, and Romania also produce asbestos, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

[3] Excludes direct sales of run-of-mine material, in metric tons, of: 1984—141; 1985—887; 1986—2,060; 1987—2,000 (estimated); and 1988—2,000 (estimated).

[4] Reported figure.

BARITE

By Sarkis G. Ampian[1]

Domestic production of barite was relatively unchanged, continuing to reverse the downtrend that started in 1982 and persisted until 1986. Production from Nevada, the leading producing State, increased about 50%. Imports for consumption of crude barite increased more than 50%, while ground barite imports increased nearly 35%. Imports of barite exceeded domestic production for the seventh consecutive year, but the import figure of 1.25 million short tons for 1988 was about 1 million tons below the record-high tonnage of 1982. Ground barite imports, except for the drilling boom years of the late 1970's and early 1980's, have been negligible. The principal use for barite, as a weighting agent in oil- and gas-well-drilling fluids (muds), accounted for about 90% of U.S. consumption. Chemical, glass, and filler and/or extender uses accounted for the remaining 10%.

Strong demand for barite, by the oil- and gas-well-drilling industry, carried over to the third quarter of the year, owing to the firming of oil prices and improvements in the overall economy. Spot shortages were commonplace. The upturn in demand also has been in large part due to the increase in offshore drilling, which tends to have deeper wells that consume more barite than the shallower wells. Two big factors in the offshore-drilling upturn were the backlog of undrilled expiring leases and new development spurred by a view that gas demand and prices were firming. Overproduction by major oil-producing countries during the last quarter caused crude oil prices to decline, which in turn depressed the demand for barite drilling muds. U.S. mine production of barite continued, although still depressed, producer's were encouraged by spot shortages, strong regional sales and declining rail rates, which increased the competitiveness of domestic ores in the gulf coast and midcontinent areas. Barite grinding capacity, despite numerous closures, mergers, and acquisitions, remained sufficient to meet present and future requirements.

DOMESTIC DATA COVERAGE

Domestic production data for barite are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 63 operations to which a survey request was sent, all responded, representing 100% of the total crushed and ground production sold or used shown in table 1.

DOMESTIC PRODUCTION

The term "primary barite" denotes the first marketable product and includes crude run-of-mine barite, flotation concentrates, and material concentrated by other beneficiation processes such as washing, jigging, or magnetic separation. Run-of-mine barite, the lowest cost primary barite sold or used by producers, represented 43% of total production, compared with 54% in 1987; the remaining 57% was flotation concentrate and other beneficiated material. The lower cost crude barite and jigged beneficiated materials were used chiefly in drilling muds; the higher valued floated and other beneficiated material was used mostly in chemical and glass manufacturing and in filler applications.

Reported primary production was relatively unchanged. Nevada and Georgia remained the two leading barite-producing States. Other producing States, in descending order, were Missouri, California, and Montana. All domestic barite production is a primary product.

The leading domestic barite producers were M–I Drilling Fluids Co., a Dresser-Halliburton Co.; Milpark Drilling Flu-

TABLE 1

SALIENT BARITE AND BARIUM CHEMICAL STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Barite, primary:					
Sold or used by producers	775	739	297	448	445
Value	$25,445	$21,501	$12,326	$15,810	$15,512
Exports	1	6	7	9	(1)
Value	$574	$692	$1,021	$716	$353
Imports for consumption (crude)	1,731	2,056	745	825	1,248
Consumption, apparent[2]	2,505	2,789	1,035	1,264	1,693
Crushed and ground (sold or used by processors)[3]	2,883	2,184	1,216	1,434	1,777
Value	$220,806	$154,463	$75,965	$108,759	$127,373
Barium chemicals (sold or used by processors)	26	24	25	28	27
Value	$17,105	$16,036	$16,871	$16,466	$15,284
World: Production	6,404	r6,679	5,183	p5,197	e5,844

e Estimated. p Preliminary. r Revised.
1 Less than 1/2 unit.
2 Sold or used plus imports minus exports.
3 Includes imports.

ids, a Baker Hughes Inc. company with mines in Nevada; and NL Baroid, a division of NL Petroleum Services Inc., with mines in Missouri and Nevada.

The recovery of the domestic barite industry that began in mid-1987 continued until the last quarter of 1988, when overproduction by oil- producing countries caused crude oil prices to decline. During this recovery period, steadily rising oil prices increased drilling activity. The strength of the growing overall economy added to the recovery. The yearend oil glut depressed barite demand by the exploration and development segments of the industry. The constant production rates in 1987–88 reversed the trend of declining barite output that had begun after 1981, the high production year (2.8 million tons). Production data indicate that competitive rail rates to the gulf coast and midcontinent areas, based on unit trains and guaranteed-tonnage contracts, combined with a tight barite supply early in the year, permitted modest domestic mining campaigns.

Nevertheless, the persistent oil glut, exacerbated primarily over production, caused price volatility, lowered energy rates and continued to temper or limit any major upturn in drilling activity. Another factor depressing the domestic marketplace was the over capacity of the drilling-fluids producers. The slowly recovering domestic barite industry, the world's largest, continued to be threatened by imports of crude and ground barite. Rising ocean freight rates, in part due to higher bunker fuel costs and limited availability of bottoms, helped reduce competition by foreign ores.

Most mining and grinding operations continued to be either suspended or operated on minimal production schedules to address the industry's over-capacity. Many of the additions to mining, milling, and grinding capacity were largely to reduce operating costs in order to remain competitive in a firming but volatile market situation. Many ongoing and planned projects, including exploration programs, were indefinitely deferred.

The International Trade Commission/Import Administration, U.S. Department of Commerce revised a notice of final results of an antidumping-duty administrative review and revocation for barium carbonate imported from the Federal Republic of Germany.[2] The review covered one manufacturer-exporter, Kali-Chemie AG, for barium carbonate exported to the United States between July 1, 1986, and April 3, 1987. The review also indicated the existence of a de minimis dumping margin for the firm during this period. The Department of Commerce, satisfied that it was not likely that Kali-Chemie would resume sales at less than fair market value, partly revoked the antidumping duty issued earlier. The revocation applies to all unliquidated entries of barium carbonate from the company, either entered or withdrawn, from warehouse, for consumption on or after April 3, 1987. The notice of preliminary results of another antidumping duty administrative review on barium chloride from China indicated the existence of dumping margins during the periods April 6, 1984, through September 30, 1984 (27.21%), and October 1, 1984, through September 30, 1986 (59.99%).[3] The review covered only the China National Chemicals Import and Export Corp. (Sinochem) and determined preliminarily to assess antidumping duties equal to the calculated percentage differences between the United States price and the foreign market value.

The Occupational Safety and Health Administration (OSHA), on June 7, 1988, proposed to amend its existing air contaminants standards for barium sulfate.[4] In recognition that barium sulfate is an insoluble and inert dust, OSHA set no limit for it other than that for nuisance dust. The American Conference of Governmental Industrial Hygienists recommended a threshold limit value of 10 milligrams per cubic meter of total dust. The Environmental Protection Agency, under the authority of the Clean Water Act, requested comments by December 5, 1988, on effluent limitations for the offshore discharge of drilling fluids and produced wastewater streams.[5] The agency was seeking to employ the best available technology in its control of offshore discharges.

CONSUMPTION AND USES

Consumption of crushed and ground barite increased nearly 29%, from 1.4 million tons in 1987 to 1.8 million tons in 1988. This second consecutive year of increased consumption reverses the decline in total barite consumption prevalent since 1981, when the record high of 4.7 million tons of crushed and ground barite was set. The increase reflects an upturn not only in barite requirements for oil well drilling, which still accounts for about 90% of total sales, but also in the overall economy. The oil- and gas-well-drilling industry completed nearly 25,000 wells and drilled about 124 million feet of hole;[6] these figures were 4% and 1% lower, respectively, than in 1987.

Total drilling footage exceeded 8 million feet in four States: Texas, 46.8 million feet; Oklahoma, 14.9 million; Louisiana, 13.2 million; and Kansas, 8.1 million. Generally, the deeper a hole is drilled, the more barite is used per foot of drilling. Among the four leading States, Louisiana had the highest average well depth, over 7,500 feet, and Kansas the shallowest, about 3,300 feet. Wyoming, absent from the top States this year in well footage drilled, again had the highest average well depth: nearly 7,600 feet. The U.S. average increased to nearly 5,100 feet. Barite consumption increased despite the 4% reduction in the number of wells drilled because of the upturn in operating offshore rigs in the Gulf of Mexico and California at the expense of shallower drilling, onshore varieties

TABLE 2

U.S. PRIMARY BARITE SOLD OR USED BY PRODUCERS, BY STATE

State	Number of operations	Run of mine: Quantity (thousand short tons)	Run of mine: Value (thousands)	Flotation concentrates: Quantity (thousand short tons)	Flotation concentrates: Value (thousands)	Beneficiated material: Quantity (thousand short tons)	Beneficiated material: Value (thousands)	Total: Quantity (thousand short tons)	Total: Value (thousands)
1987:									
California	1	W	W	—	—	—	—	W	W
Georgia	2	—	—	W	W	W	W	W	W
Missouri	3	—	—	—	—	W	W	W	W
Montana	1	W	W	—	—	—	—	W	W
Nevada	7	214	$3,249	W	W	W	W	214	$3,249
Tennessee	1	W	W	—	—	—	—	W	W
Total[1]	**15**	**244**	**7,515**	**61**	**$5,238**	**142**	**$6,300**	**448**	**15,810**
1988:									
California	2	W	W	—	—	—	—	W	W
Georgia	2	—	—	W	W	W	W	W	W
Missouri	3	W	W	—	—	W	W	W	W
Nevada	5	156	2,163	W	W	164	2,782	320	5,053
Tennessee	1	W	W	—	—	—	—	W	W
Total[1]	**13**	**192**	**3,621**	**17**	**1,908**	**238**	**9,983**	**445**	**15,512**

W Withheld to avoid disclosing company proprietary data.
[1] Data may not add to totals shown because of independent rounding.

elsewhere. Most of the onshore wells were in the Overthrust Belt in Wyoming and Anadarko Basin in Oklahoma, both deep drilling areas. There was a 27% increase in the amount of barite used per foot of drilling, from 49.5 pounds in 1987 to 63.02 pounds in 1988.

Another barometer of drilling activity, the Baker Hughes rig count, showed the average number of operating domestic rigs in 1987 and 1988 remained relatively unchanged at 936.[7] This constancy in rigs reversed a downward trend that, except for 1984, has seen the number of rigs fall from the 1981 record high of 3,974. The 1988 average rig count of 936 is the third time since 1971 (976 rigs) that the count was below 1,000. The estimated rig count during the year ranged from 880 to 1,121. The low count of 880, recorded the week of May 1, was the second lowest since World War II. The high, 1,121 rigs, was registered the week of January 2.

PRICES

Price quotations in trade publications for barite remained unchanged. These prices may serve as a general guide but do not reflect actual transactions.

The reported average value per ton of domestic barite, based on reported value or direct-ship, beneficiated, and floated material, decreased slightly, f.o.b. plant, from $35.29 per ton in 1987 to $34.80. This decline in value for domestic concentrate is attributed to a greater percentage of lower valued drilling-mud-grade material in the total. The average reported value per ton of ground drilling-mud-grade barite from Louisiana and Texas was $66.90; the average value of that from California, Nevada, and Utah was $53.28. The value of the Louisiana and Texas ground material, in direct response to steadily improving market conditions, rose about 24%. Material from the other major grinding States, supplied largely by domestic mines, declined slightly. The average customs value of barite exported to Canada and Mexico was about $400 per ton; the customs value of material exported to Latin America was about $200 per ton.

FOREIGN TRADE

Exports of natural barium sulfate or barite decreased from about 9,000 tons to 225 tons. This decline ends the modest rebound in barite exports for the previous 3 years, 5,800 to 9,100 tons, and resumes the downward pattern that saw exports plummet from the record high of 109,000 tons in 1979. Export and import data provided by the Bureau of the Census did not indicate the grades of barite traded; however, based only on the value of individual ship-

TABLE 3

PRODUCERS OF BARIUM MATERIALS IN 1988

Company	Plant location	Material
BARITE MATERIALS		
American Minerals Inc.	Camden, NJ	Well drilling and filler.
Do.	El Paso, TX	Do.
Do.	Rosiclare, IL	Do.
Circle A Construction Co. Inc.	Wells, NV	Primary and filler.
Clark Minerals Inc.	South Plainfield, NJ	Filler.
Custom Milling & Supply Co.	Salt Lake City, UT	Well drilling.
Cyprus Industrial Minerals Co.	Cartersville, GA	Primary and ground.
De Soto Mining Co. Inc.	Richwoods, MO	Primary.
Dyna Material Inc.	Pecos, TX	Well drilling.
Extender Products Ltd.	Mineral Point, MO	Filler.
General Barite Co.	Washington, MO	Primary.
GEO International Inc.	Nevada City, CA	Do.
Industrial Minerals Co.	Florin, CA	Filler.
International Drilling Fluids	Amelia, TX	Well drilling.
M-I Drilling Fluids	Battle Mountain, NV	Do.
Do.	Brownsville, TX	Well drilling and filler.
Do.	Galveston, TX	Well drilling.
Do.	Houma, LA	Do.
Do.	Houston, TX	Do.
Do.	Lander, NV	Primary and ground.
Do.	New Orleans, LA	Well drilling.
Do.	West Lake Charles, LA	Well drilling and filler.
Milpark Drilling Fluids	Argenta, NV	Primary and ground.
Do.	Clinton, OK	Well drilling.
Do.	Corpus Christi, TX	Do.
Do.	Galveston, TX	Do.
Do.	New Orleans, LA	Do.
The Milwhite Co. Inc.	Brownsville, TX	Well drilling and filler.
Do.	Bryant, AK	Do.
Do.	Chatworth, GA	Ground.
Do.	Houston, TX	Well drilling and filler.
Do.	Morgan City, LA	Well drilling.
Minerals, Pigments and Metals Div., Pfizer Inc.	East St. Louis, IL	Filler.
Mountain Minerals Co. Ltd.	Missoula, MT	Primary and ground.
New Riverside Ochre Co.	Cartersville, GA	Primary.
NL Baroid	Battle Mountain, NV	Do.
Do.	Dunphy, NV	Well drilling.
Do.	Fountain Farm, MO	Do.
Do.	Lake Charles, LA	Do.
Do.	New Orleans, LA	Do.
Do.	Potosi, MO	Primary.
Old Soldiers Minerals Ltd.	Abbeville, LA	Well drilling.
Do.	Elk City, OK	Do.
Ozark-Mahoning Co.	Rosiclare, IL	Primary.
A. J. Smith Co. Inc.	Sweetwater, TN	Primary and ground.
Standard Industrial Minerals	Laws, CA	Filler.
Standard Slag Co.	Churchill, NV	Primary.
Do.	Nye, NV	Do.
BARIUM COMPOUNDS		
J. T. Baker Chemical Co.	Phillipsburg, NJ	Chemicals.
Chemical Products Corp.	Cartersville, GA	Do.
Mallinckrodt Inc., a subsidiary of IMC Corp.	St. Louis, MO	Do.

ments, from more than $400 to $4,000 per ton, only pharmaceutical, chemical, filler, or glass-grade was exported. Historically, barite exports were predominantly ground drilling-mud grade material with less than 5% of the tonnage specialty ground barites. Minor amounts of witherite (natural barium carbonate), precipitated barium carbonate, and barium sulfate also were exported. Crude barite was not exported. Canada and Mexico, traditionally either first or second among export recipients of U.S. ground barite, were replaced by Venezuela and Nigeria, in decreasing order. These two countries were the leading buyers of U.S. ground barite and accounted for about 89% of the total exports. They consumed about 65% of the total exports. Exports to Canada and Mexico, major oil-producing countries, declined to only 50 tons from a high of 18,000 tons in 1983. Both Canada and Mexico continued to rely more on domestic production. During the year, the weakening U.S. dollar had little effect on trade because of continuing Canadian and Mexican financial or economic problems.

Imports for consumption of crude barite increased more than 50%, from 825,000 tons in 1987 to nearly 1.25 million tons. The 1988 barite import figure was nearly 55% below the record high of 2.32 million tons set in 1982. The c.i.f.[8] value of this material rose 9% to $34.81 per ton, after 8 consecutive years of decline, indicating that prices of foreign ores increased in response to undersupply and higher ocean shipping rates. Earlier cutbacks in foreign production, notably in China and India, due to an absence of forward commitments, saw a firming of both crude barite prices and shipping rates. Crude prices advanced in part because of shortages of miners and rising rail and trucking rates from the mines to the plants. Ocean freight rates were influenced, in part, by the yearend upturn in rates for more profitable competing foodstuff cargoes, such as wheat. Domestic producers and con-

TABLE 4

CRUSHED AND GROUND BARITE[1] SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY STATE

State	1987 Number of plants	1987 Quantity (thousand short tons)	1987 Value (thousands)	1988 Number of plants	1988 Quantity (thousand short tons)	1988 Value (thousands)
Louisiana	8	721	$47,133	8	936	$58,916
Missouri	2	W	W	1	W	W
Nevada	3	236	14,939	4	243	12,666
Oklahoma	2	W	W	2	W	W
Texas	8	301	22,230	8	427	32,259
Other[2]	16	179	24,457	12	171	23,532
Total	**39**	**[3]1,434**	**108,759**	**35**	**1,777**	**127,373**

W Withheld to avoid disclosing company proprietary data; included with "Other".
[1] Includes imports.
[2] Includes Arkansas, California, Georgia, Illinois, New Jersey, New York, Tennessee, and Utah.
[3] Data do not add to total shown because of independent rounding.

sumers in the gulf coast area, still faced with relatively high rail rates from domestic drilling-quality barite mines in Nevada, continued to take advantage of the lower priced foreign ores to meet their demands. Based on average value per ton of material shipped, the principal source countries, in descending order, were: Morocco, $40.70; India, $35.45; Mexico, $35.06; China, $33.97 and Chile, $29.91. The high-priced Mexican material was chiefly crude filler and extender-quality barite. The high-quality barite, generally material with a specific gravity greater than 4.2, is usually blended during grinding with lower grade ore, foreign or domestic, to meet American Petroleum Institute specifications for 4.2 drilling-mud-grade barite. Most of the crude barite, entered through customs districts along the gulf coast for delivery to grinding plants in the area. The import distribution by customs districts in 1988 (1987) was New Orleans, LA, 74% (68%); Houston, TX, 23% (21%); and Laredo, TX (Port of Brownsville, TX), 13% (11%). Small amounts were also received, in decreasing order, in Philadelphia, PA, and St. Albans, VT.

Imports of ground barite increased about 35% to more than 15,000 tons from about 11,000 tons in 1987; of this Canada and Mexico supplied about 90%. Prior to 1984, ground barite imports had been limited to premium-quality pharmaceutical grades, which were unavailable domestically. In recent years, this market has been dwindling because certain medical X-ray diagnostic procedures employing barium compounds have been largely replaced with computer-assisted tomography (CAT) scanners or imaging techniques. Sources of medical-grade barite were Belgium-Luxembourg, Canada, France, the Federal Republic of Germany, and the Netherlands. The average c.i.f. value of imports from Canada, China, and Mexico, about $175 per ton, suggests that this ground barite is probably destined for the domestic filler and/or extender markets that usually are supplied by U.S. producers. The continued imports of ground filler and extender-grade barite into this mature market will probably cause concern among domestic producers. The value of imports from other countries, $400 per ton, indicate that these ground materials were either an ultrahigh-purity filler or a competitively priced pharmaceutical-grade material.

Imports for consumption of barium chemicals and unwrought and/or waste and scrap barium metal, for the most part, increased in quantity and value.

TABLE 5

CRUSHED AND GROUND BARITE[1] SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY USE

(Thousand short tons and thousand dollars)

Use	1987 Quantity	1987 Value	1988 Quantity	1988 Value
Barium chemicals, filler and/or extender, glass	141	22,419	233	24,346
Well drilling	1,294	86,340	1,544	103,027
Total	**[2]1,434**	**108,759**	**1,777**	**127,373**

[1] Includes imports.
[2] Data do not add to total shown because of independent rounding.

TABLE 6

U.S. BARIUM CHEMICALS[1] PRODUCED AND SOLD OR USED BY PROCESSORS

Barium chemical	1987 Plants[2]	1987 Production (short tons)	1987 Sold or used by processors: Quantity (short tons)	1987 Sold or used by processors: Value (thousands)	1988 Plants[2]	1988 Production (short tons)	1988 Sold or used by processors: Quantity (short tons)	1988 Sold or used by processors: Value (thousands)
Barium acetate	1	W	W	W	1	W	W	W
Barium carbonate	2	W	W	W	2	W	W	W
Barium chloride	2	W	W	W	2	W	W	W
Barium nitrate	1	W	W	W	—	—	—	—
Barium sulfide, gray	1	W	W	W	1	W	W	W
Black ash	1	W	W	W	1	W	W	W
Blanc fixe	1	W	W	W	1	W	W	W
Total	**3**	**28,447**	**28,008**	**$16,466**	**3**	**27,421**	**27,279**	**$15,284**

W Withheld to avoid disclosing company proprietary data.
[1] Data reported by plants that consume either barite or precursors are included.
[2] A plant producing more than one product is counted only once.

TABLE 7

U.S. HYDROCARBON WELL DRILLING AND BARITE CONSUMPTION

Year	Barite used for well drilling (thousand short tons)	Wells drilled (thousands)[1]: Oil	Wells drilled (thousands)[1]: Gas	Wells drilled (thousands)[1]: Dry holes	Wells drilled (thousands)[1]: Total	Successful wells (percent)	Average depth per well (feet)	Average barite per well (short tons)
1968	1,006	14.33	3.46	12.81	30.60	58.1	4,738	32.88
1969	1,235	14.37	4.08	13.74	32.19	57.3	4,881	38.37
1970	1,119	13.02	3.84	11.26	28.12	60.0	4,952	39.79
1971	1,044	11.86	3.83	10.16	25.85	60.7	4,806	40.39
1972	1,183	11.31	4.93	11.06	27.30	59.5	4,932	43.33
1973	1,326	9.90	6.39	10.31	26.60	61.2	5,129	49.85
1974	1,440	12.78	7.24	11.67	31.69	63.2	4,750	45.44
1975	1,638	16.41	7.58	13.25	37.24	64.4	4,685	43.98
1976	1,986	17.06	9.09	13.62	39.77	65.7	4,571	49.94
1977	2,372	18.91	11.38	14.69	44.98	67.3	4,687	52.73
1978	2,632	17.76	12.93	16.25	46.94	65.4	4,829	56.07
1979	2,967	19.38	14.68	15.75	49.81	68.4	4,791	59.57
1980	3,385	26.99	15.74	18.09	60.82	70.3	4,675	55.66
1981	4,526	37.67	17.89	22.97	78.53	70.8	4,602	57.63
1982	4,048	40.30	18.95	26.55	85.80	69.1	4,616	47.18
1983	2,648	37.21	15.63	23.49	76.33	69.2	4,268	34.69
1984	2,695	41.10	15.71	25.23	82.04	69.5	4,246	32.85
1985	2,042	26.24	10.15	15.97	52.36	69.5	4,658	39.00
1986	1,097	15.27	5.53	10.28	31.08	66.9	4,716	35.30
1987	1,294	12.13	4.97	9.04	26.14	65.4	4,779	49.50
1988	1,544	10.54	5.54	8.42	24.50	65.6	5,072	63.02

[1] Includes exploratory and development wells; excludes service wells, stratigraphic tests, and core tests.

Source: American Petroleum Institute.

TABLE 8

BARITE PRICE QUOTATIONS

Item	Price per short ton[1] 1987	1988
Barite:[2 3]		
Chemical, filler, glass grades, f.o.b. shipping point, carlots:		
Handpicked, 95% $BaSO_4$, not over 1% Fe	$90.00	$90.00
Magnetic or flotation, 96% to 98% $BaSO_4$, not over 0.5% Fe	116.00	116.00
Water-ground, 95% $BaSO_4$, 325 mesh, 50-pound bags	$70.00–165.00	$70.00–165.00
Dry-ground:		
Southern, off-color, coarse, bags, carload, f.o.b. mines (per pound)	.09	.11
Water-grade, white, bags, carload, f.o.b. works (per pound)	.13	.13
Unbleached, extra-fine, pigment-grade, carload, f.o.b. works	160.00	160.00
Drilling-mud-grade:		
Dry-ground, 83% to 93% $BaSO_4$, 3% to 12% Fe, specific gravity 4.20 to 4.30, f.o.b. shipping point, carlots	60.00– 90.00	60.00– 90.00
Crude, imported, specific gravity 4.20 to 4.30, f.o.b. shipping point	40.00– 55.00	40.00– 55.00
Barium chemicals:[3]		
Barium carbonate:		
Precipitated, bulk, carlots, freight equalized (per pound)	.25	.25
Electronics-grade, bags	510.00	510.00
Barium chloride:		
Technical crystals, bags, carlots, works	470.00	470.00
Anhydrous, bags, carlots, same basis	590.00	590.00
Barium hydrate: Mono, 55-pound bags, carlots, delivered (100 pounds)	46.00	46.00
Barium sulfate:		
Blanc fixe, technical-grade, bags, carlots	400.00	400.00
U.S.P., X-ray diagnosis-grade, powder, 25-kilogram bags,		
10,000-kilogram lots (per pound)	.59	.59
Barium sulfide (black ash), drums, carlots, works	460.00	460.00

[1] Unless otherwise specified.
[2] Engineering and Mining Journal. V. 189, No. 4, Apr. 1988, p. 21.
[3] Chemical Marketing Reporter. V. 235, No. 1, Dec. 30, 1988, pp. 26–27.

WORLD CAPACITY

The data in table 13 are rated capacity for mines as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period with minimum capital expenditure.

Mine capacity for domestic barite production was aggregated from data voluntarily supplied by the producers. The rated capacity data for the foreign mines were estimated from the previous year's production in cooperation with the Division of International Minerals.

WORLD REVIEW

China

Two unusually mineralized stone deposits, known locally as "wheatstones," have been discovered near Huashan in Shaanxi Province.[9] These geological curiosities contain not only metallic constituents but concentrations of barium and lithium. This new wheatstone discovery postdates earlier finds made in Inner Mongolia and Henan. The mineralogy of the stones from different locations is currently under investigation.

Iran

Exploration activities at the Hafthar Mine, in a suburb of Ardekan in Yazd Province, have delineated barite reserves of more than 700,000 tons.[10] These activities also outlined the reserves of the nearby Ardekan Mine at about 170,000 tons.

TABLE 9

U.S. EXPORTS OF NATURAL BARIUM SULFATE, BY COUNTRY

Country	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Argentina	85	$37	([1])	$44
Australia	—	—	1	2
Canada	196	194	35	61
Chile	—	—	—	—
Colombia	—	—	29	132
Ecuador	508	46	—	—
France	—	—	18	42
Hong Kong	—	—	3	2
Mexico	13	6	112	47
Nigeria	1,655	147	—	—
Paraguay	150	14	—	—
Philippines	5	3	—	—
United Kingdom	—	—	10	11
Venezuela	6,386	249	18	12
Zaire	85	9	—	—
Other	1	11	—	—
Total	**[2]9,083**	**716**	**226**	**353**

[1] Less than 1/2 unit.
[2] Data do not add to total shown because of independent rounding.
Source: Bureau of the Census.

Korea, Republic of

Daehan Specialty Chemical Co. Ltd., a 50–50 joint venture for the production of barium and strontium chemicals, has been formed by Kali-Chemie and Samsung Corning Co. Ltd.[13] The new company will build production facilities on the northwest coast. The new plant, scheduled for completion in 1989, will have an annual capacity of 35,000 to 45,000 tons of barium and strontium carbonate.

Kali-Chemie, a West German subsidiary of the Solvay Group, makes barium and strontium compounds for television, specialty glass, and electronic industries. Samsung Corning, a maker of television envelopes, is a joint venture of Korea's Samsung Group and Corning Glass Works of the United States.

In another action, Kali-Chemie has added the high-temperature superconductor material, yttrium-barium-copper-oxide to its product line.[14] The company's present capacity of 5 kilograms per week was expected to be increased to more than 50 kilograms monthly.

Mexico

The Government-owned Barita de Sonora has been operating at a loss because its main customer, PEMEX (Petróleos Mexicanos), has cutback its drilling program because of a drop in oil prices.[11] The company exports none of its output.

Morocco

The Norwegian drilling fluid company, Norchem Anchor AS, a subsidiary of Aker Norchem AS, has acquired a 55% stake in Cie. Marocaine des Barytes (Comabar), a large barite producer.[12] Comabar is a subsidiary of the Government-owned mining agency, Bureau de Recherches et de Participation Minières, and currently operates two mines, Zelmo and Ighoud, which produce more than one-half of the Moroccan output. Comabar's barite, chiefly drilling-mud-grade, is exported to Norwegian and British markets. Comabar's newly commissioned grinding plant at Safi, opened in 1987, was expected to double its capacity to 25,000 tons per year by yearend.

Tunisia

The joint Tuniso-Algerian lithophone plant has hurt the local market for zinc and barite.[15] The Boujaber Mine, which supplied the barite for the joint venture, was slated for closing within the next 5 years.

TECHNOLOGY

The new high-temperature superconducting material, $Ba_2YCu_3O_7$, yttrium-barium-copper-oxide, discovered in 1987, was the topic of a series of noteworthy papers. One paper outlines in a detailed fashion the chemistry of the high-temperature superconductors, including sections on oxidation states, crytallographic structures, transition temperatures, and mechanisms for superconductivity of the barium-bearing varieties.[16] Another study explored techniques for synthesizing $Ba_2YCu_3O_7$ from bulk materials into thin-film applications and/or fabrication; it also offered an insight as to future prospects and directions in this area.[17]

A new family of barium-bearing superconductors with bismuth-thallium substituting for the yttrium-rare-earth atoms was identified at a new record temperature of 125 kelvin.[18] Another paper on superconductivity details phase identification in the new high-temperature transition systems, principally for the barium-containing conductors.[19] This physicochemical work is devoted to the

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF BARITE, BY COUNTRY

Country	1987		1988	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Crude barite:				
Canada	100	$7	45	$8
Chile	—	—	27,997	837
China	636,336	20,483	832,288	28,274
India	56,520	1,867	238,003	8,438
Mexico	75,405	2,812	35,297	1,238
Morocco	56,890	1,993	114,079	4,643
Total	**825,251**	**27,162**	**1,247,709**	**43,438**
Ground barite:				
Belgium-Luxembourg	22	8	71	28
Canada	8,480	1,751	9,770	2,240
China	—	—	39	6
France	456	121	712	219
Germany, Federal Republic of	206	85	282	119
Japan	—	—	40	81
Mexico	—	—	3,735	515
Morocco	1,598	184	—	—
Netherlands	526	198	532	196
Other	44	10	—	—
Total	**[2]11,333**	**2,357**	**15,181**	**3,403**

[1] C.i.f. value.

[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

yttrium- and thallium-bearing varieties.

The last work describes a novel sol-gel process for low-temperature preparation of $BaTiO_3$ powders.[20] The sol-gel process for the preparation of powders, coatings, and monolithic ceramics and glasses is rapidly evolving. The process uses inexpensive barium acetate as a starting material, instead of high-purity oxides, and could make inroads into the fabrication of the new superconducting materials.

A detailed geologic work on the barite deposits of Montana was published.[21] This work includes a deposit-to-deposit description, including maps, of all known locations within the State. Special sections on the origin, history, and exploration techniques for barite are also emphasized. In-depth reviews were published on the industrial minerals of Mexico,[22] Nova Scotia[23] and Newfoundland, and Labrador.[24] These included detailed sections on barite, local geology, mineralogy, mining and milling flowsheets, and indigenous mining methods. The Mexican report focused on the individual operating companies and their long-range goals in the current climate of depressed worldwide demand. The Canadian papers highlight the commercial opportunities for barite in the U.S. eastern seaboard marketplace.

The mainstay of the barite industry, drilling for oil and gas reserves, and its performance over the last few years was analyzed technically.[25] The article reviewed the current state of the industry and focused on worldwide producers and their operations, drilling specifications, and markets. A highlight of the report includes a worldwide review of the non-drilling-mud-grade producers and consumers of barite.

Two articles reviewed the uses of mineral fillers and extenders in the pharmaceutical[26] and adhesives and sealants[27] industries. The pharmaceutical paper discusses the main applications of minerals in the manufacture of tablets, as fillers, and formulation aids. The article looks at the specialized low-tonnage, high-value minerals and the exacting specifications demanded from the industry that uses them. Chemically precipitated barium sulfate, blanc fixe, and very pure barite play an important role in gastrointestinal radiology examinations because of its high X-ray adsorption, enhancing contrast ability, and harmlessness. The sealant article technically evaluates the plethora of minerals involved in these industries and discusses their functions and suitabilities. The current state of the market is also reviewed, along with new applications yet to make a market impact. Barite is a unique functional filler because its low oil absorption and low binder demand allows highly filled systems to be made with little influence on the highly important working properties and adhesion. Other useful barite properties brought to bear in sealants include its chemical resistance, high specific gravity, particle shape and distribution.

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TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF BARIUM CHEMCIALS

Year	Lithopone		Blanc fixe (precipitated) barium sulfate)		Barium chloride		Barium hydroxide	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1984	NA	NA	9,302	$6,381	3,680	$1,576	5,452	$3,973
1985	NA	NA	8,971	6,295	2,839	1,125	5,708	3,959
1986	NA	NA	10,449	8,530	1,919	733	4,925	3,960
1987	NA	NA	11,469	8,586	1,979	775	5,247	4,147
1988	NA	NA	25,713	8,754	4,616	834	9,434	4,109

Year	Barium nitrate		Barium carbonate, precipitated		Other barium compounds	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1984	1,278	$478	14,476	$7,269	1,020	$847
1985	1,339	643	12,457	5,400	1,593	2,556
1986	1,143	504	11,365	4,809	1,802	3,197
1987	1,459	579	12,851	5,485	9,442	2,500
1988	3,036	567	21,174	4,803	2,387	3,439

NA Not available.

Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF CRUDE, UNGROUND, AND CRUSHED OR GROUND WITHERITE[1]

Year	Crude, unground		Crushed or ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1984	41	$24	185	$129
1985	1	6	141	68
1986	2	8	145	70
1987	364	97	72	47
1988	126	23	1,251	230

[1] Barium carbonate.

Source: Bureau of the Census.

TABLE 13

WORLD BARITE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

Country	Rated capacity[1]
Afghanistan	3
Algeria	120
Argentina	70
Australia	25
Austria	1
Belgium	45
Boliva	2
Brazil	170
Burma	10
Canada	80
Chile	120
China	1,800
Colombia	6
Czechoslovakia	70
Egypt	6
France	170
Finland	12
German Democratic Republic	40
Germany, Federal Republic of	225
Greece	10
Guatemala	4
India	550
Iran	200
Ireland	200
Italy	150
Japan	70
Kenya	5
Korea, North	100
Korea, Republic of	4
Malaysia	50
Mexico	600
Morocco	600
Pakistan	40
Peru	100
Philippines	5
Poland	110
Portugal	1
Romania	90
South Africa, Republic of	10
Spain	9
Thailand	200
Tunisia	25
Turkey	450
U.S.S.R.	600
United Kingdom	100
United States	1,700
Yugoslavia	50
Zimbabwe	1
Total	**9,009**

[1] Includes capacity at operating plants as well as at plants on standby basis.

TABLE 14

BARITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Afghanistan[e 3]	2	2	2	2	2
Algeria	97	66	66	[e]66	66
Argentina	49	57	65	32	33
Australia	22	25	6	11	11
Belgium[e]	43	44	44	44	39
Bolivia	1	1	([4])	1	—
Brazil	158	157	114	[r e]121	138
Burma[5]	11	9	9	19	13
Canada	52	78	44	46	60
Chile	24	60	59	57	55
China[e]	1,100	1,100	1,100	[r]1,380	1,650
Colombia	4	6	5	5	4
Czechoslovakia[e]	66	66	66	66	66
Egypt	6	5	[e]5	5	4
Finland	10	10	8	12	12
France	163	133	128	115	110
German Democratic Republic[e]	39	37	37	35	35
Germany, Federal Republic	184	189	222	191	184
Greece[6]	3	4	3	2	3
Guatemala	([4])	[r]4	1	—	[7]3
India	492	639	379	233	265
Iran[e]	100	100	100	100	100
Ireland	243	236	141	[r e]77	33
Italy	118	141	124	124	125
Japan	73	85	58	35	—
Kenya	([4])	([4])	([4])	([4])	([4])
Korea, Republic of	3	3	4	3	3
Malaysia	26	26	19	43	33
Mexico	470	516	354	442	[7]583
Morocco	619	551	209	158	[7]354
Pakistan	30	33	43	11	11
Peru	51	24	11	11	11
Philippines	1	—	—	—	—
Poland	89	100	85	81	83
Portugal	([4])	1	([4])	1	([4])
Romania[e]	80	80	80	80	80
South Africa, Republic of	5	5	10	10	[7]10
Spain	76	74	54	37	22
Thailand	193	255	157	37	45
Tunisia	13	[e]22	[e]22	16	15
Turkey	218	[r]243	341	325	[7]427
U.S.S.R.[e]	580	595	595	595	595

See footnotes at end of table.

TABLE 14—Continued

BARITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
United Kingdom	69	118	96	99	94
United States[8]	775	739	297	448	[7]445
Yugoslavia	45	[e]40	20	21	22
Zimbabwe	1	([4])	([4])	([4])	([4])
Total	**6,404**	**[r]6,679**	**5,183**	**5,197**	**5,844**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 14, 1989.
[2]In addition to the countries listed, Bulgaria also produces barite, but available information is inadequate to make reliable estimates of output levels.
[3]Data are for fiscal year beginning Mar. 21 of that stated.
[4]Less than 1/2 unit.
[5]Data are for fiscal year beginning Apr. 1 of that stated.
[6]Barite concentrates.
[7]Reported figure.
[8]Sold or used by producers.

BAUXITE AND ALUMINA

By Patricia A. Plunkert[1] and Ruth A. Hough[2]

World production of bauxite and alumina increased significantly in 1988 in response to the increased demand for alumina for the production of aluminum metal. Increases in the domestic production of alumina and imports for consumption of alumina totaled more than 1 million metric tons compared with that of the previous year. Tight alumina supplies throughout the world encouraged several companies to announce capacity expansions and the reopening of alumina refinery capacity.

August 1988 marked the 100th anniversary of the issuance of the patent for the Bayer process, a process that has remained virtually unchanged since its conception by Karl Josef Bayer.

DOMESTIC DATA COVERAGE

Domestic production and consumption data for bauxite and alumina are developed by the Bureau of Mines from five separate voluntary surveys of U.S. operations. Typical of these quarterly and annual surveys is the "Consumption of Alumina" survey. Of the 22 operations canvassed, all responded.

LEGISLATION AND GOVERNMENT PROGRAMS

In response to a directive of the U.S. Court of Appeals for the District of Columbia Circuit, the Environmental Protection Agency proposed a list of specific solid wastes from ore and mineral processing that would remain within the Bevill exclusion amendment to the Resource Conservation and Recovery Act (RCRA) as special wastes. Red and brown muds from the bauxite refining process were among 15 processing wastes proposed for exclusion from regulation as hazardous wastes under subtitle C of RCRA.[3]

On February 25, 1988, the President signed Executive Order 12626 designating the Secretary of Defense to be the manager of the National Defense Stockpile (NDS).[4] The Secretary delegated operational management functions of the NDS to the Defense Logistics Agency (DLA). Previously, the NDS responsibilities were distributed among the U.S. Department of Defense, the Federal Emergency Management Agency, and the General Services Administration.

NDS goals for bauxite remained unchanged at 21.3 million tons of Jamaica-type and 6.2 million tons of Suriname-type metal grade bauxite. Goals for calcined abrasive grade and refractory grade bauxite were 1 million and 1.4 million tons, respectively. At yearend, DLA listed an inventory of 12.7 million tons of Jamaica-type and 5.4 million tons of Suriname-type metal grade bauxite. The NDS contained no stocks of abrasive grade bauxite and 279,000 tons of calcined refractory grade bauxite.

DOMESTIC PRODUCTION

Bauxite was produced from surface mining operations in Alabama, Arkansas, and Georgia. At Benton, AR, the Aluminum Co. of America (Alcoa) calcined bauxite for the abrasive and proppant industries and processed crude ore at the company's local Bayer refinery to produce specialty aluminum oxides and hydroxides. American Cyanamid Co. closed its mining operations in Arkansas, but continued to process a small amount of calcined bauxite at its Bryant, AR, plant for shipment to other company-owned plants. Harbison-Walker Refractories Div. of Dresser Industries Inc. shipped bauxite from its mines in Alabama to its local calcining plant and to Carbo Ceramic Co.'s proppant plant in Eufaula, AL. Mullite Co. of America (Mulcoa) mined bauxite in Alabama and Georgia, which was shipped to Mulcoa's processing plant in Andersonville, GA.

Ormet Corp. announced the reopening of its Burnside, LA, alumina plant, which had been closed since December 1985. Ormet reportedly entered into a 3-year tolling agreement with Clarendon Ltd. Ormet was expected to share in part of the refinery's production in subsequent years. Ormet also announced that it had reached a tentative 3-year labor agreement with the United Steelworkers of America that reportedly included wage concessions in exchange for a stock bonus plan and profit sharing.

TABLE 1

SALIENT BAUXITE STATISTICS

(Thousand metric tons and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Production: Crude ore (dry equivalent)	856	674	510	576	588
Value[e]	$15,643	$12,855	$10,361	[r]$10,916	$10,566
Exports (as shipped)	82	56	69	201	63
Imports for consumption[1]	9,435	7,158	6,456	9,156	9,944
Consumption (dry equivalent)	10,519	8,206	6,901	9,548	10,074
World: Production	[r]87,177	[r]84,189	87,755	[p]93,969	[e]98,859

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Excludes calcined bauxite. Includes bauxite imported to the U.S. Virgin Islands.

TABLE 2

MINE PRODUCTION OF BAUXITE AND SHIPMENTS FROM MINES AND PROCESSING PLANTS TO CONSUMERS IN THE UNITED STATES

(Thousand metric tons and thousand dollars)

Year	Mine production			Shipments from mines and processing plants to consumers[1]		
	Crude	Dry equivalent	Value[2]	As shipped	Dry equivalent	Value[2]
1986	617	510	10,361	776	740	36,276
1987	689	576	[r]10,916	756	680	22,173
1988	714	588	10,566	770	688	24,703

[r] Revised.

[1] May exclude some bauxite mixed in clay products.

[2] Computed from values assigned by producers and from estimates of the Bureau of Mines.

KaiserTech Ltd. announced the sale of its Baton Rouge, LA, specialty alumina plant and other industrial chemical facilities to LaRoche Chemicals Inc. KaiserTech retained ownership of its metal-grade alumina refinery in Grammercy, LA.

CONSUMPTION AND USES

Bauxite consumption rose in 1988 compared with that of 1987, with significant gains in calcined refractory grades and crude and dried metallurgical grades. Most of the increase was supplied from imports. Consumption by the chemical industries was essentially unchanged in 1988, while calcined abrasive grade bauxite consumption increased slightly, reversing the downward trend begun in 1985. About 90% of the bauxite consumed in the United States during 1988 was refined to alumina, and an estimated average of 1.92 tons of dried bauxite was required to produce 1 ton of calcined alumina. Twenty-two primary aluminum smelters reported a consumption of 7 million tons of calcined alumina. An estimated 87% of alumina shipped by U.S. refineries went to domestic

TABLE 3

RECOVERY OF DRIED, CALCINED, AND ACTIVATED BAUXITE IN THE UNITED STATES

(Thousand metric tons)

Year	Crude ore treated	Total processed bauxite recovered[1]	
		As recovered	Dry equivalent
1987	131	62	102
1988	W	W	W

W Withheld to avoid disclosing company proprietary data.

[1] Dried, calcined, and activated bauxite. May exclude some bauxite mixed in clay products.

TABLE 4

PERCENT OF DOMESTIC BAUXITE SHIPMENTS, BY SILICA CONTENT

SiO_2 (percent)	1984	1985	1986	1987	1988
Less than 8	11	74	77	70	71
From 8 to 15	55	14	—	7	5
More than 15	34	12	23	23	24

TABLE 5

PRODUCTION AND SHIPMENTS OF ALUMINA IN THE UNITED STATES

(Thousand metric tons)

Year	Calcined alumina	Other alumina[2]	Total[1]	
			As produced or shipped[3]	Calcined equivalent
Production:[e]				
1984	4,160	560	4,720	4,545
1985	2,860	860	3,725	3,465
1986	2,570	750	3,320	3,105
1987	3,555	830	4,385	4,150
1988	3,885	1,220	5,105	4,650
Shipments:[e]				
1984	4,230	570	4,800	4,620
1985	2,890	760	3,650	3,425
1986	2,590	740	3,330	3,120
1987	3,530	845	4,375	4,135
1988	4,645	1,115	5,760	5,340

[e] Estimated.

[1] Data may not add to totals shown because of independent rounding.

[2] Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.

[3] Includes only the end product if one type of alumina was produced and used to make another type of alumina.

TABLE 6

CAPACITIES OF DOMESTIC ALUMINA PLANTS[1] DECEMBER 31

(Thousand metric tons per year)

Company and plant	1986	1987	1988
Aluminum Co. of America:			
Bauxite, AR	340	340	340
Point Comfort, TX	1,735	1,735	1,735
Total	**2,075**	**2,075**	**2,075**
Kaiser Aluminum & Chemical Corp.: Gramercy, LA	795	795	795
Ormet Corp.: Burnside, LA	—	—	545
Reynolds Metals Co.: Corpus Christi, TX	1,700	1,700	1,700
Grand total	**4,570**	**4,570**	**5,115**

[1] Capacity may vary depending upon the bauxite used.

TABLE 7

U.S. CONSUMPTION OF BAUXITE, BY INDUSTRY

(Thousand metric tons, dry equivalent)

Industry	Domestic	Foreign	Total
1987:			
Alumina	[1]490	[1]8,335	8,601
Abrasive[2]	W	W	224
Chemical	[3]34	[3]267	243
Refractory	68	354	422
Other	W	W	58
Total	**592**	**8,956**	**9,548**
1988:			
Alumina	[1]506	[1]8,738	8,970
Abrasive[2]	W	W	274
Chemical	W	W	236
Refractory	[4]140	[4]690	524
Other	W	W	70
Total	**646**	**9,428**	**10,074**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes "Abrasive."
[2] Includes consumption by Canadian abrasive industry.
[3] Includes "Other."
[4] Includes "Chemical" and "Other."

primary smelters. Consumption by abrasives, chemicals, refractories, and other industries accounted for the balance of the alumina in calcined, hydroxide, activated, tabular, and other forms.

PRICES

Contract terms for the purchase of metal grade bauxite and cell-grade alumina in world markets are not normally made public, and, consequently, prices for these commodities are not published by trade journals. Price quotes are generally limited to certain specialty forms of bauxite and alumina for nonmetallurgical uses.

In 1988, the Bureau of Mines estimated the average value of domestic crude bauxite shipments, f.o.b. mine or plant, to be $15 per ton. The average value of calcined domestic bauxite was estimated to be $183 per ton. Quoted base prices for imported calcined refractory grade bauxite were as follows: Chinese, typical 85% Al_2O_3, f.o.b. barge, Burnside, LA, $95 to $120 per ton; and Guyanese, f.o.b. rail car, Baltimore, MD, or f.o.b. barge, gulf coast, $164.28 per ton. These base prices were subject to adjustment for grain-size specifications, size of order, and fuel cost factors.

The average value of domestic calcined alumina shipments was estimated to be $175 per ton. The average value of imported calcined alumina indicated by trade data of the Bureau of the Census was $181 per ton, f.a.s. port of shipment, and $193 per ton, c.i.f. U.S. ports.

FOREIGN TRADE

Exports of dried bauxite totaled 49,000 tons in 1988, a dramatic decrease from the 1987 total of 146,000 tons. Canada received 42,000 tons and Mexico 7,000 tons. Exports of calcined bauxite totaled 13,900 tons in 1988, about one-fourth the level of these exports in 1987. Mexico received 10,200 tons, Canada, 3,300 tons, and minor amounts were shipped to Chile, Peru, Singapore, and Venezuela. Brazil, Canada, Ghana, and Mexico were the major recipients of U.S. exports of alumina in 1988 and accounted for 95% of total U.S. shipments.

Imports for consumption of crude and dried bauxite increased from 1987 receipts, and the three traditional principal suppliers, Australia, Guinea, and Jamaica, provided 88% of the total. China was the dominant supplier of

TABLE 8

U.S. CONSUMPTION OF CRUDE AND PROCESSED BAUXITE

(Thousand metric tons, dry equivalent)

Type	Domestic origin	Foreign origin	Total
1987:			
Crude and dried	W	W	8,924
Calcined and activated	W	W	624
Total	**592**	**8,956**	**9,548**
1988:			
Crude and dried	W	W	9,259
Calcined and activated	W	W	815
Total	**646**	**9,428**	**10,074**

W Withheld to avoid disclosing company proprietary data, included in "Total."

TABLE 9

PRODUCTION AND SHIPMENTS OF SELECTED ALUMINUM SALTS IN THE UNITED STATES IN 1987

Item	Number of producing plants	Production (thousand metric tons)	Total shipments including interplant transfers: Quantity (thousand metric tons)	Total shipments including interplant transfers: Value (thousands)
Aluminum sulfate:				
Commercial and municipal (17% Al_2O_3)	86	1,147	1,101	$130,625
Iron-free (17% Al_2O_3)	23	147	135	18,396
Aluminum chloride:				
Liquid and crystal	2	W	W	W
Anhydrous (100% $AlCl_3$)	4	W	W	W
Aluminum fluoride, technical	3	W	W	W
Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$)	6	556	635	135,221
Aluminates[1]	15	66	67	23,134
Other aluminum compounds[2]	NA	NA	NA	44,944

NA Not available. W Withheld to avoid disclosing company proprietary data.
[1] Prior to 1986, aluminates (sodium aluminate, potassium aluminate, etc.) was included in other aluminum compounds and is now reported separately.
[2] Includes light aluminum hydroxide, cryolite, etc.
Source: Data are based upon Bureau of the Census 1987 Current Industrial Reports, Series MA-28A, "Inorganic Chemicals."

calcined bauxite to the United States in 1988. Australia remained the principal supplier of U.S. alumina imports for consumption, accounting for slightly more than three-fourths of the total receipts.

WORLD CAPACITY

The data in table 19 are rated annual capacity for plants producing alumina as of December 31 for the years shown. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures for labor, energy, feed materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditures.

WORLD REVIEW

World production of bauxite and alumina increased significantly in 1988 to keep pace with the rising demand for alumina to make primary aluminum metal. In addition to the announced expansion of alumina refinery capacity in Australia, previously closed refineries in Jamaica and the United States have been slated for reopening. These planned increases in refinery operating capacity were expected to ease the tight alumina supply conditions evident during the year.

Australia

The Broken Hill Pty. Co. Ltd. (BHP) announced the sale of its 20% stake in Worsley Alumina Pty. Ltd. Existing partners, Reynolds Alumina Australia Ltd. and Shell Co. of Australia Ltd., increased their stakes in the refinery. The new ownership breakdown of Worsley was as follows: Reynolds Australia (50%), Shell Australia (37.5%), Kobe Alumina Associates (Australia) Pty. Ltd. (10%), and Nissho Iwai Alumina Pty. Ltd. (2.5%).

Alcoa of Australia Ltd. announced that the oldest of its alumina refineries in Western Australia, the Kwinana plant, began producing chemical-grade alumina. The company stated that, although it planned to make the Kwinana plant a major world producer of chemical-grade alumina, smelter-grade alumina would remain the plant's principal product.

Alcoa also announced plans to increase alumina production capacity at its three Western Australia refineries, Pinjarra, Kwinana, and Wagerup, by

TABLE 10

STOCKS OF BAUXITE IN THE UNITED STATES,[1] DECEMBER 31

(Thousand metric tons, dry equivalent)

Sector	1987[r]	1988
Producers and processors	183	168
Consumers	2,836	2,867
Government	18,472	18,472
Total	**21,491**	**21,507**

[r] Revised.
[1] Domestic and foreign bauxite; crude, dried, calcined, activated; all grades.

TABLE 11

STOCKS OF ALUMINA IN THE UNITED STATES,[1] DECEMBER 31

(Thousand metric tons, calcined equivalent)

Sector	1987[r]	1988
Producers	1,519	[e]732
Primary aluminum plants	1,211	1,252
Total	**2,730**	**[e]1,984**

[e] Estimated. [r] Revised.
[1] Excludes consumers' stocks other than those at primary aluminum plants.

TABLE 12

AVERAGE VALUE OF U.S. IMPORTS OF CRUDE AND DRIED BAUXITE[1]

(Per metric ton)

Country	1987 Port of shipment (f.a.s.)	1987 Delivered to U.S. ports (c.i.f.)	1988 Port of shipment (f.a.s.)	1988 Delivered to U.S. ports (c.i.f.)
To U.S. mainland:				
Australia	$13.96	$22.45	$14.75	$22.42
Brazil	24.14	29.24	25.55	33.72
Guinea	19.66	26.88	22.89	29.63
Guyana	31.89	44.20	30.53	42.84
Jamaica	30.54	34.24	29.25	33.70
Suriname	23.77	32.22	34.15	48.04
Weighted average	**23.32**	**29.48**	**23.90**	**30.34**

[1]Computed from quantity and value data reported to U.S. Customs Service and compiled by the Bureau of the Census, U.S. Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.

TABLE 13

MARKET QUOTATIONS ON ALUMINA AND ALUMINUM COMPOUNDS

(Per metric ton, in bags, carlots, freight equalized)

Compound	Dec. 31, 1987	Dec. 30, 1988
Alumina, calcined	$418.88	$418.88
Alumina, hydrated, bulk	209.44	209.44
Alumina, activated, granular, works	905.00	905.00
Aluminum sulfate, commercial, ground,(17% Al_2O_3)	225.97	239.20
Aluminum sulfate, iron-free, dry (17% Al_2O_3)	330.69	369.27

Source: Chemical Marketing Reporter.

320,000 tons per year, bringing the total annual production capacity at these plants to 5.5 million tons.

Brazil

Companhia Brasiliera de Bauxite announced plans to begin production of washed refractory grade bauxite from its mine in northern Para State at the rate of 100,000 tons per year. Initially, the washed bauxite would be sold to domestic customers, but the company reportedly was building a calcining plant on-site, scheduled for completion in April 1989, which would absorb all of the mine's output for export.

Companhia Vale de Rio Doce (CVRD) announced that negotiations had begun with potential partners on the resumption of construction at the Aluminio do Norte do Brasil S.A. (Alunorte) alumina plant. If financing were made available, construction work could resume in 1989, and the 1.1-million-ton-per-year plant reportedly could be in operation by the end of 1991. According to CVRD, completion of the Alunorte plant would help to secure alumina supplies for Brazil's announced expansions of its aluminum smelting industry.

Canada

Alcan Chemicals, a division of Alcan Aluminium Corp., announced plans to build a new specialty alumina hydrate plant at Jonquière, Quebec. The $28 million project, scheduled for completion toward the end of 1989, reportedly would augment the production coming from Alcan's existing plants in Canada, Japan, and the Federal Republic of Germany.

Germany, Federal Republic of

Alcoa reported the closure of its 140,000-ton-per-year alumina refinery in Ludwigshafen.

Guyana

Hydro Aluminium of Norway and the state-owned Bauxite Industry Development Co. (Bidco) of Guyana reported the signing of an agreement to conduct a feasibility study on the reopening of Bidco's 300,000-ton-per-year alumina refinery at Linden. The study was scheduled to be completed in 6 months, and, if both parties agreed to proceed, the plant could reopen 18 months later. As part of the agreement, Hydro Aluminium would purchase the plant's entire production under a long-term contract. The bauxite for the plant reportedly would come from the recently reopened mine at Ituni, 30 miles south of Linden.

Jamaica

The Government and private bauxite and alumina companies reached an agreement on a new fiscal policy to replace the old bauxite levy system. The new arrangements include a basic levy based on a fixed minimum rate per ton for bauxite mined that is linked to the average realized price (ARP) for aluminum metal. In essence, the basic levy was lowered from 7.5% to 3% of the ARP for aluminum ingot. After the deduction of the levy, an income tax at the rate of 33.3% would be applied to company profits. A significant element of the new agreement was the requirement that companies operate their fa-

TABLE 14

U.S. EXPORTS OF ALUMINA,[1] BY COUNTRY

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	1	624	1	629	1	740
Belgium-Luxembourg[2]	2	3,485	2	2,543	3	2,955
Brazil	—	593	75	10,789	115	19,780
Canada	263	47,491	575	89,890	509	91,337
France	—	1,259	1	2,005	1	1,422
Germany, Federal Republic of	3	4,379	1	2,989	2	3,372
Ghana	77	12,540	270	38,942	183	27,854
Japan	21	6,426	24	8,162	20	7,491
Mexico	91	23,627	150	32,431	175	35,341
Netherlands	1	2,365	2	2,274	3	3,520
Norway	11	645	(3)	13	(3)	12
United Kingdom	2	2,441	2	2,134	6	3,448
Venezuela	1	1,573	2	1,512	4	3,028
Other	14	r17,872	22	r13,723	16	15,806
Total[4]	**487**	**125,322**	**1,127**	**208,037**	**1,036**	**216,107**

r Revised.

[1] Includes exports of aluminum hydroxide (calcined equivalent) as follows: 1986—12,199 tons; 1987—18,727 tons; and 1988—15,656 tons.

[2] For 1986 and 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

[3] Less than 1/2 unit.

[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 15

U.S. IMPORTS FOR CONSUMPTION OF BAUXITE, CRUDE AND DRIED,[1] BY COUNTRY

(Thousand metric tons)

Country	1986	1987	1988
Australia	579	1,167	1,612
Brazil	100	451	792
China	21	5	20
Dominican Republic[2]	1	70	33
Ghana	—	36	—
Guinea	3,356	4,256	4,526
Guyana	169	244	225
Indonesia	—	—	39
Jamaica[2]	2,119	2,799	2,654
Malaysia	—	23	12
Sierra Leone	—	—	29
Suriname	112	104	3
Total[3]	**6,456**	**9,156**	**9,944**

[1] Includes bauxite imported to the U.S. Virgin Islands from foreign countries.

[2] Dry equivalent of shipments to the United States.

[3] Data may not add to totals shown because of independent rounding.

Note.—Total U.S. imports of crude and dried bauxite (including the U.S. Virgin Islands) as reported by the Bureau of the Census were as follows: 1986—6,854,083 tons; 1987—9,827,818 tons; and 1988—10,498,913 tons.

Sources: Bureau of the Census and The Jamaican Bauxite Institute.

cilities at full production levels. The effective dates of these agreements were as follows: Alcoa, February 1988; Kaiser Aluminum and Chemical Corp., December 1988; and Alcan Aluminium, January 1989.

The Government reported the acquisition of 44% more of the shares in Alcoa's Clarendon Alumina refinery. The $26.5 million purchase increased the Government's interest to 50% and made it an equal partner with Alcoa in the plant. As part of the agreement, plans were being made to expand the refinery's capacity from 750,000 tons to 1 million tons of alumina annually.

Kaiser Aluminum and Reynolds Metals Co., joint owners of Alumina Partners of Jamaica (Alpart), announced plans to reopen the Alpart alumina refinery at Nain and the supporting bauxite mines. The companies expected production at the 1.2-million-ton-per-year plant to commence during the first half of 1989. At the end of 1988, Reynolds was negotiating the possible sale of its 50% interest in Alpart. Under discussion was the possible purchase of a 25% interest by Hydro Aluminium and the purchase of Reynolds' remaining 25% interest by co-owner Kaiser Aluminum. The possible sale of 10% of Kaiser Aluminum's share to Hydro Aluminium, thereby dividing ownership of the plant between Kaiser Aluminum (65%) and Hydro Aluminium (35%), was also discussed.

South Africa, Republic of

Alusaf Pty. Ltd. reported the development of a new crushing and flotation system to recover alumina from previously unclaimed wastes at its Richards Bay aluminum smelter. The new plant, scheduled to be commissioned in late 1988, was expected to separate alumina and carbon from the wastes and to recycle the recovered alumina through the smelter.

U.S.S.R.

Comalco Ltd. of Australia reported the signing of an agreement with the Soviet Union's Ministry of Non-Ferrous Metals to carry out a feasibility study on the construction of an aluminum smelter and refinery project on the east coast of the U.S.S.R. near Vladivostock. Comalco reportedly would ship 2 million tons per year of bauxite from its mining complex in Weipa, Australia, to the planned 1-million-ton-per-year alumina refinery. Co-

TABLE 16

U.S. IMPORTS FOR CONSUMPTION OF CALCINED BAUXITE, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1987				1988			
	Refractory grade		Other grade		Refractory grade		Other grade	
	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]
Australia	—	—	6	416	—	—	20	1,788
China	163	10,708	10	714	103	6,696	152	8,765
Guyana	107	14,995	22	1,230	98	12,948	15	836
Suriname	—	—	4	160	5	175	—	—
Other	—	—	(2)	26	(2)	15	(2)	7
Total[3]	**270**	**25,703**	**43**	**2,545**	**206**	**19,834**	**188**	**11,396**

[1] Value at foreign port of shipment as reported to U.S. Customs Service.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

malco was expected to receive aluminum metal from the planned 500,000-ton-per-year smelter as payment for the bauxite ore.

TECHNOLOGY

Research conducted at the Oak Ridge National Laboratory (ORNL) reportedly has demonstrated that microwave heating made ceramic materials that were not only stronger than ceramics made with conventional sintering methods, but could also be made in less time and for less money. Sintering, the firing process that turns ultrafine powders into extremely hard materials, is a critical factor in the production of advanced ceramics. In microwave heating, energy was absorbed throughout the volume of the material without gradients in temperature. ORNL chose alumina for its initial research and developed hardware and methods for uniformly heating ceramic parts of large volume and irregular shapes to temperatures in excess of 1,600° C in a vacuum or pressurized atmosphere.[5]

In Jamaica, tests using solar heat to dry thickened red mud resulting from refining bauxite to alumina showed

TABLE 17

U.S. IMPORTS FOR CONSUMPTION OF ALUMINA,[1] BY COUNTRY

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1986		1987		1988	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
Australia	3,051	458,965	3,361	431,041	3,532	562,479
Brazil	20	4,720	25	4,977	65	15,574
Canada	42	16,109	59	25,078	91	39,241
France	5	12,019	7	13,825	6	14,740
Germany, Federal Republic of	13	14,924	14	20,922	20	27,328
Guinea	—	—	13	2,484	—	—
India	—	—	—	—	79	1,761
Israel	—	—	25	3,612	—	—
Italy	—	—	20	3,037	(3)	783
Jamaica	140	20,370	90	13,107	201	47,890
Japan	3	3,371	6	6,688	7	8,503
Suriname	268	30,465	324	40,568	417	77,124
Venezuela	55	9,712	111	13,936	207	34,286
Other	6	3,555	r13	r2,586	8	22,142
Total[4]	**3,603**	**574,210**	**4,068**	**581,864**	**4,634**	**851,851**

r Revised.
[1] Includes imports of aluminum hydroxide.
[2] Value at foreign port of shipment as reported to U.S. Customs Service.
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 18

BAUXITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Australia	31,537	31,839	32,384	34,102	[2]36,192
Brazil	6,433	5,846	6,544	[r] [e]8,750	8,750
China[e]	1,600	1,650	1,650	2,400	3,200
Dominican Republic[3]	—	—	—	211	[2]106
France	1,607	1,530	1,379	1,271	[2]878
Germany, Federal Republic of	([4])	([4])	([4])	([5])	—
Ghana	44	170	226	230	[2]300
Greece	2,296	2,453	2,230	2,472	2,400
Guinea[6]	[r]12,740	[r]11,790	13,300	[r] [e]13,500	15,600
Guyana[3]	1,333	[e]1,675	2,074	2,785	[2]1,774
Hungary	2,994	2,815	3,022	3,101	[2]2,906
India	2,093	2,281	2,322	2,736	[2]3,829
Indonesia	1,003	830	650	635	[2]513
Italy	—	—	—	17	[2]2
Jamaica[3 7]	[r]8,735	[r]6,239	6,944	7,660	[2]7,408
Malaysia	680	492	566	482	[2]361
Mozambique	—	5	4	[r] [e]6	8
Pakistan	3	2	3	3	4
Romania[e]	620	600	600	600	600
Sierra Leone	1,040	[r]1,185	1,246	1,390	1,400
Spain	7	2	[e]7	3	3
Suriname	3,454	3,738	3,731	2,581	[2]3,434
Turkey	132	214	280	247	[2]269
U.S.S.R.[e 8]	4,600	4,600	4,600	4,600	4,600
United States[3]	856	674	510	576	[2]588
Venezuela	—	—	—	217	700
Yugoslavia	3,347	3,538	3,459	3,394	[2]3,034
Zimbabwe	23	21	24	([5])	—
Total	**[r]87,177**	**[r]84,189**	**87,755**	**93,969**	**98,859**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 5, 1989.
[2]Reported figure.
[3]Dry bauxite equivalent of crude ore.
[4]Less than 1/2 unit.
[5]Revised to zero.
[6]Dry bauxite equivalent of ore processed by drying plant.
[7]Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.
[8]In addition to the bauxite reported in the body of the table, the U.S.S.R. produces nepheline syenite concentrates and alunite ore as sources of aluminum. Nepheline syenite concentrate production was as follows, in thousand metric tons: 1984—1,600 (revised, estimate); 1985—1,615; 1986—1,638; 1987—1,660; and 1988—1,670 (estimated). Estimated alunite ore production was as follows, in thousand metric tons: 1984—615; 1985—615; 1986—620; 1987—625; and 1988—625. Nepheline syenite concentrate grades 25% to 30% alumina, and alunite ore grades 16% to 18% alumina; these commodities may be converted to their bauxite equivalent by using factors of 1 ton of nepheline syenite concentrate equals 0.55 ton of bauxite and 1 ton of alunite equals 0.34 ton of bauxite.

that the degree of drying achieved depended on the accurate grading of the solar drying area and control of the predewatering of the mud. The most important design feature for success with solar drying was that the thickened mud layer exposed to the sun be limited to a depth of a few inches. As the depth of the layer increased beyond 4 inches, the drying rate fell rapidly. Mud, discharged onto a slope with an angle equal to the natural angle of repose of the mud, dried uniformly and reached 75% solids in 15 to 20 days in Jamaican climatic conditions.[6]

August 1988 marked the 100th anniversary of the issuing of the patent for the Bayer Process. This process accounts for more than 90% of the world's alumina production and has remained virtually unchanged since its conception by Karl Josef Bayer. In honor of this occasion, several papers were presented at the TMS Light Metals Committee Annual Meeting in a special session entitled "Bayer: The Man and the Process."[7]

[1]Physical scientist, Branch of Nonferrous Metals.

[2]Supervisory mineral data assistant, Branch of Nonferrous Metals.

[3]Federal Register. Environmental Protection Agency. Mining Waste Exclusion. V. 53, No. 203, Oct. 20, 1988, pp. 41288-41300.

[4]———. National Defense Stockpile Manager. V. 53, No. 39, Feb. 29, 1988, p. 6114.

[5]Swain, B. Microwave Sintering of Ceramics. Adv. Mater. & Proc., v. 134, No. 3, Sept. 1988, pp. 76-82.

[6]Chandler, J. L. Solar Drying of Red Mud. Paper in Light Metals 1988, ed. by L. G. Boxall. Metall. Soc. AIME, Warrendale, PA, pp. 55-60.

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Hudson, L. K. Evolution of Bayer Process Practice in the United States. Paper in Light Metals 1988, ed. by L. G. Boxall. Metall. Soc. AIME, Warrendale, PA, pp. 31-36.

TABLE 19

WORLD ANNUAL ALUMINA PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand metric tons)

Country	1986	1987	1988
Australia	9,750	9,750	10,000
Brazil	1,150	1,150	1,150
Canada	1,225	1,225	1,225
China	850	850	1,300
Czechoslovakia	100	100	100
France	1,040	1,040	1,040
German Democratic Republic	65	65	60
Germany, Federal Republic of	1,745	1,745	1,745
Greece	500	500	500
Guinea	700	700	700
Guyana	355	355	355
Hungary	920	920	920
India	675	675	1,000
Ireland	800	800	800
Italy	920	920	720
Jamaica	2,825	2,825	3,100
Japan	975	975	550
Romania	540	540	540
Spain	800	800	800
Suriname	1,350	1,350	1,350
Turkey	200	200	200
U.S.S.R.	4,600	4,600	4,600
United Kingdom	120	120	120
United States	4,570	4,570	5,115
Venezuela	1,000	1,000	1,300
Yugoslavia	1,635	1,635	1,635
Total	**39,410**	**39,410**	**40,925**

TABLE 20

ALUMINA: WORLD PRODUCTION,[1] BY COUNTRY[2]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Australia	8,781	8,792	9,423	10,109	[3]10,518
Brazil	891	1,096	1,258	1,326	1,300
Canada	1,126	1,019	1,015	953	950
China[e]	800	825	825	1,200	2,200
Czechoslovakia[e]	[3]85	85	85	85	85
France	[r]902	[r]736	740	711	[3]563
German Democratic Republic	43	47	46	51	51
Germany, Federal Republic of	[r]1,701	[r]1,657	1,560	1,313	[3]1,163
Greece	482	380	470	518	520
Guinea	538	572	556	543	[3]590
Hungary	811	798	856	858	[3]873
India	588	587	586	650	[3]1,188
Ireland	653	555	686	784	[3]843
Italy	[r]625	555	618	700	[3]708
Jamaica	[r]1,713	[r]1,622	1,586	1,572	[3]1,522
Japan	1,172	978	607	358	[3]415
Romania	552	548	555	[e]550	550
Spain[4]	742	725	748	801	800
Suriname	1,208	[4]1,242	[4]1,471	[4]1,363	[3 4]1,632
Turkey	75	113	144	95	[3]182
U.S.S.R.[e]	3,300	3,500	[r]3,500	[r]3,500	3,500
United Kingdom	105	110	108	110	110
United States[e]	4,545	3,465	3,105	4,150	[3]4,650
Venezuela	1,139	[e]1,085	1,269	1,381	1,350
Yugoslavia	1,135	1,138	1,117	1,113	1,110
Total[5]	**[r]33,712**	**[r]32,230**	**32,935**	**34,794**	**37,372**

[e]Estimated. [p]Preliminary. [r]Revised.
[1] Figures represent calcined alumina or the total of calcined alumina plus the calcined equivalent of hydrate, when available; exceptions, if known, are noted.
[2] Table includes data available through July 5, 1989.
[3] Reported figure.
[4] Hydrate.
[5] Data may not add to totals shown because of independent rounding.

BERYLLIUM

By Deborah A. Kramer[1]

Domestic production and consumption of beryllium ore decreased in 1988, but beryllium alloys garnered new applications in automotive electronics and increased their usage in computer systems. Following the significant increase in exports of beryllium in 1987, exports in 1988 returned to normal levels. Beryl ore imports declined significantly and reflected a decrease in apparent consumption.

Beryllium and its alloys were important components in aerospace, defense, telecommunications systems, electronics, and computers. Significant strides in metal near-net-shape forming capabilities have resulted in improved properties of beryllium materials and lower costs.

DOMESTIC DATA COVERAGE

Domestic production data are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Beryllium Mineral Concentrate and Beryllium Ore" survey. Of the 11 operations to which a survey request was sent, all responded, representing 100% of the total mine shipments shown in tables 1 and 6.

LEGISLATION AND GOVERNMENT PROGRAMS

In June, the Government awarded a contract to supply 30 short tons of vacuum hot-pressed beryllium billets for the National Defense Stockpile (NDS) to Brush Wellman Inc., Cleveland, OH. Delivery of the metal, worth an estimated $19 million, was scheduled to take place between September 1988 and yearend 1989. Government stocks of beryllium materials in the NDS at yearend 1988 were beryl, 17,987 tons; beryllium-copper master alloy, 7,387 tons; and beryllium metal, 290 tons. NDS goals for these materials were beryl, 18,000 tons; beryllium-copper master alloy, 7,900 tons; and beryllium metal, 400 tons.

On February 25, 1988, the President signed Executive Order 12616, designating the Secretary of Defense to be the manager of the NDS.[2] The Office of the Secretary of Defense delegated operational management functions of the NDS to the Defense Logistics Agency. Previously, the NDS responsibilities were distributed among the Department of Defense, Federal Emergency Management Agency, and the General Services Administration.

In December, the Environmental Protection Agency (EPA) proposed a list of processing wastes to be exempted from regulation under the Resource Conservation and Recovery Act. In the list were several wastes generated at beryllium ore-processing facilities: Beryl plant discard, barren filtrate, processing raffinate, and sludge-leaching slurry. EPA sent the list to the Office of Management and Budget for review, and the final list was due in February 1989.

DOMESTIC PRODUCTION

Shipments of beryllium ore continued to decline. Production of beryllium-copper master alloy and beryllium oxide decreased, while beryllium metal production increased slightly. Brush Wellman was the sole ore processor in the United States, treating both bertrandite from its mine near Spor Mountain, UT, and imported beryl. These ores were converted into beryllium hydroxide at Brush Wellman's plant in Delta, UT, and then shipped to plants in Ohio and Pennsylvania to be manufactured into beryllium metal, beryllium-copper alloys, and beryllium oxide. Small quantities of beryl were recovered domestically, principally as a byproduct of pegmatite mining.

Hecla Mining Co. and Mount Wheeler Mines Inc., a wholly owned subsidiary of NTM Inc., were negotiating to mine beryl from NTM's properties in eastern Nevada. It was estimated that negotiations and market studies would require at least 1 year. Approximately 280,000 tons of ore was cored at the property, and NTM company officials estimated that from 300,000 to 500,000 tons of ore remains.

A test mine, mine feasibility study, and mill feasibility study were completed at the Sierra Blanca project near El Paso, TX. Development of this property was a joint venture between Cabot Corp. and Cyprus Minerals Co.

TABLE 1

SALIENT BERYLLIUM MINERAL STATISTICS

(Short tons of beryllium metal equivalent unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Beryllium-containing ores:					
Mine shipments	241	230	261	242	234
Imports for consumption, beryl[1]	53	66	60	92	39
Consumption, reported	360	316	318	356	268
Price, approximate, per short ton unit BeO, imported cobbed beryl at port of exportation	$88	$87	$88	$84	$93
Stocks, Dec. 31	226	199	195	181	174
World: Production[1]	r396	359	395	p372	e366

e Estimated. p Preliminary. r Revised.
1 Based on a beryllium metal equivalent of 4% in beryl.

The companies plan to mine bertrandite and produce a beryllium hydroxide product. Design of processing facilities, permitting, and marketing activities were yet to be completed by yearend 1988.

NGK Metals Corp. planned to invest $30 million over the next 3 years to increase beryllium-copper alloy production capacity at its Reading, PA, facility. NGK's annual production capacity was expected to increase from 900 tons to 1,900 tons within 3 years.

Olin Specialty Metals Corp. planned to begin production of beryllium-copper alloy strip at its plant in East Alton, IL, in the first half of 1989. Although no capacity estimates were released, Olin would be the third supplier of beryllium-copper strip in the United States, along with Brush Wellman and NGK.

CONSUMPTION AND USES

Although total beryllium consumption declined in 1988, beryllium alloys continued to gain new applications. Beryllium-nickel alloys were used in new applications, including the sensor in airbags recently introduced in some automobile models, and beryllium alloys were used in a hydraulic sensor to regulate transmission performance in some new automobiles. Beryllium-copper alloys, the most widely used end product, were fabricated into connectors, switches, springs, and relays for use in computers and other electronic devices.

Beryllium metal was used principally in aerospace and defense applications. Current applications for beryllium included guidance system components, satellite structures, mirrors, and space telescopes. Commercial applications for beryllium were X-ray windows and audio components in home entertainment systems. A review was published citing many current and potential applications and properties of beryllium metal.[3]

High-density electronic circuits were the principal end use for beryllium oxide ceramic material. These circuits, used in automotive electronic systems, telecommunications systems, and high-performance computers, rely on beryllium oxide's excellent ability to dissipate heat. Beryllium oxide ceramics were used also as plasma tubes for ion lasers.

TABLE 2

U.S. EXPORTS OF BERYLLIUM ALLOYS, WROUGHT OR UNWROUGHT, AND WASTE AND SCRAP,[1] BY COUNTRY

Country	1987		1988	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg[2]	105	$68	—	—
Brazil	183	19	260	$3
Canada	10,799	469	4,634	331
China	110	5	381	38
France	5,590	1,243	12,355	2,271
Germany, Federal Republic of	4,699	555	10,899	1,145
Hong Kong	6,000	26	8	11
India	—	—	160	10
Ireland	—	—	791	7
Israel	1,323	130	—	—
Italy	—	—	240	4
Japan	3,551	887	5,019	808
Korea, Republic of	1,063	48	1,217	15
Malaysia	—	—	71	7
Mexico	164	4	166	17
Netherlands	2,672	212	2,844	138
Peru	—	—	670	7
Singapore	—	—	40	8
South Africa, Republic of	493	5	—	—
Switzerland	470	52	656	159
Taiwan	128,777	390	33,733	135
United Kingdom	4,371	886	8,742	1,778
Other	38	14	3	2
Total	**170,408**	**5,013**	**82,889**	**6,894**

[1] Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.
[2] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

PRICES AND SPECIFICATIONS

Metals Week quoted the price of beryl ore at a range of $78 to $85 per short ton unit (20 pounds) of contained beryllium oxide. This price range was the same as that at yearend 1987. At yearend 1988, the following prices for beryllium and its alloys were quoted in American Metal Market in dollars per pound, except for beryllium-copper master alloy, which was quoted in dollars per pound of contained beryllium:

Vacuum cast ingot, 98.5% pure	$225
Metal powder, in 1,000- to 4,999-pound lots and 98.5% pure	196
Beryllium-copper master alloy	160
Beryllium-copper casting alloy	$5.52– 6.30
Beryllium-copper in rod, bar, wire	8.90
Beryllium-copper in strip	8.00
Beryllium-aluminum alloy, in 100,000-pound lots	260
Beryllium oxide powder	65.65

FOREIGN TRADE

The sharp drop in exports of beryllium alloys from 1987 to 1988 was a result of the decline in exports to Taiwan.

Some exports of beryllium-copper alloys were combined with other copper alloys by the Bureau of the Census and could not be separately identified. The Journal of Commerce Port Import/Export Reporting Service (PIERS), a computer data base, provides information on some quantities of these beryllium-copper alloys. This service reports only materials that are transported by ship and may not reflect total trade of beryllium-copper alloys. According to PIERS, 26,630 pounds (gross weight) of beryllium-copper master alloy was exported to Belgium, France, the Federal Republic of Germany, and Brazil, in declining order. In addition, 945,941 pounds (gross weight) of beryllium-copper strip, rod, and scrap were exported, primarily to France.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF BERYL, BY COUNTRY

Country	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Argentina	35	$33	—	—
Brazil	883	748	732	$677
China	509	490	135	161
France	721	552	64	10
Hong Kong	50	49	33	55
Madagascar	—	—	11	8
United Kingdom	23	8	—	—
Zimbabwe	81	64	—	—
Total	**2,302**	**1,944**	**975**	**911**

Source: Bureau of the Census.

PIERS also provides data on imports of beryllium-copper alloys. In 1988, 479,410 pounds (gross weight) of beryllium-copper strip and rod were imported into the United States, mainly from Japan.

WORLD CAPACITY

Data in table 5 are estimates of rated annual capacity for beryl- and bertrandite-producing mines as of December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating mines and mines temporarily closed that, in the judgment of the author, can be brought into production within a short period with minimum capital expenditure.

U.S. mine capacity was based on a 1-shift-per-day, 5-day-per-week operation. The United States was the only country among market economy countries that employed mechanized mining methods; other countries use manual labor to hand-cobb beryl from the host rock. Consequently, capacity data for the rest of the world were based primarily on the number of workers.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF BERYLLIUM METAL AND COMPOUNDS

Year	Beryllium-copper master alloy Quantity (pounds)	Beryllium-copper master alloy Value (thousands)	Beryllium, wrought Quantity (pounds)	Beryllium, wrought Value (thousands)	Beryllium, unwrought and waste and scrap Quantity (pounds)	Beryllium, unwrought and waste and scrap Value (thousands)	Beryllium oxide and carbonate Quantity (pounds)	Beryllium oxide and carbonate Value (thousands)	Beryllium compounds n.s.p.f. Quantity (pounds)	Beryllium compounds n.s.p.f. Value (thousands)
1986	24,160	$114	20,467	$50	22,487	$55	248	$3	2,010	$42
1987	53,802	246	92,422	290	18,294	159	6,669	99	29,424	90
1988	210,516	936	21,911	66	3,391	84	—	—	77,957	183

Source: Bureau of the Census.

TABLE 5

WORLD ANNUAL BERYL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988, RATED CAPACITY

(Short tons, contained beryllium)

	Capacity
North America: United States[2]	400
South America:	
Argentina	4
Brazil	70
Total	**74**
Europe:	
Portugal	3
U.S.S.R.	85
Total	**88**
Africa:	
Madagascar	5
Mozambique	3
Rwanda	3
South Africa, Republic of	3
Zimbabwe	5
Total	**19**
Asia: China	80
World total	**661**

[1] Includes capacity at operating plants as well as at plants on standby basis.
[2] Includes bertrandite ore.

TABLE 6

BERYL: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina	[r]79	34	55	51	44
Brazil	1,551	967	1,000	937	990
Madagascar[e 2]	[3]51	55	55	55	55
Mozambique	[3]8	7	7	7	7
Portugal	11	2	—	—	—
Rwanda (concentrate, gross weight)	49	30	—	—	—
South Africa, Republic of	1	6	3	([4])	([3 4])
U.S.S.R.[e]	2,100	2,100	2,100	2,100	2,100
United States[5] (mine shipments)	6,030	5,738	6,533	6,062	[3]5,857
Zimbabwe (concentrate, gross weight)	21	42	114	91	90
Total	**[r]9,901**	**[r]8,981**	**9,867**	**9,303**	**9,143**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] In addition to the countries listed, China produced beryl, and Bolivia and Namibia may also have produced beryl, but available information is inadequate to formulate reliable estimates of production. Nepal reports producing small amounts. Table includes data available through May 2, 1989.
[2] Includes ornamental and industrial products.
[3] Reported figure.
[4] Less than 1/2 unit; reported amounts are 298 pounds and 159 pounds for 1987 and 1988, respectively.
[5] Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.

WORLD REVIEW

Plans to produce beryllium metal in Brazil were delayed because of financial difficulties related to the construction of the beryllium hydroxide production facility. The Institute of Nuclear Energy (IEN), a Government entity in Brazil, announced that beryllium metal production of 11 pounds per month would begin by yearend 1988 or the beginning of 1989. Feed material for the plant would be supplied by the Farquhar Foundation in the State of Minas Gerais, and IEN planned to transfer the technology to the private sector for commercial-scale production.

TECHNOLOGY

Brush Wellman received a $1 million contract from the U.S. Air Force to develop a process for manufacturing optical-grade beryllium powder for high-precision, space-based mirrors. The contract also called for delivery of 600 pounds of beryllium powder. Both developmental work and powder production was expected to take place over 2 years at Brush Wellman's Elmore, OH, facility. Also in 1988, an $8 million near-net-shape beryllium production facility became fully operational in Elmore. The near-net-shape technology involving hot isostatic pressing and cold isostatic pressing resulted in increased material yields, reduced machining requirements, and consequently a lower finished part cost. Some of the near-net-shape processing techniques also resulted in improved material properties.

Corning Glass Works announced that it was awarded a 2-year, $700,000 contract with the U.S. Navy for research on beryllium fluoride for use in optical fibers. The company planned to use a vapor-deposition process to fabricate the fluoride glass systems, which would produce high-performance optical fibers by processing steps similar to those used in manufacturing silica fibers.

By embedding a radioactive beryllium isotope in the surface of a silicon nitride ceramic target, then measuring the quantity of radioactivity remaining on the surface, researchers at Michigan State University claimed the capability to determine the amount of wear that occurred during testing. This procedure has the potential to be used by industry to measure wear in metals, ceramics, plastics, and other materials, and it also has the potential to reduce the testing time of the material. Researchers claim that, by making the surface radioactive, it is possible to measure wear as small as one-millionth of an inch. Thus, wear could be determined after only a few hundred hours of operation and then extrapolated to calculate wear after thousands of hours of operation. This could be particularly useful to the automotive industry, in which engines are run for thousands of hours to create enough wear to make accurate measurements.[4]

Beryllium-copper golf clubs were becoming more popular with professional and amateur golfers. Although prices were about $20 more than standard stainless steel clubs, many golfers felt that the beryllium-copper clubs improved their game.[5]

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Federal Register. Presidential Documents. Executive Order 12626, National Defense Stockpile Manager. V. 53, No. 39, Feb. 29, 1988, p. 6114.

[3] Hunt, M. Surprising Beryllium. Mater. Eng., v. 105, No. 11, Nov. 1988, pp. 46–49.

[4] Advanced Materials & Processes. Pardon Me, But Your Beryllium-7 Is Showing. V. 135, No. 1, Jan. 1989, p. 6.

[5] Rappleyca, W. Beryllium-Copper Golf Club Catching On, Karsten Says. Am. Met. Mark., v. 96, No. 125, June 28, 1988, p. 4.

BISMUTH

By Stephen M. Jasinski[1]

Domestic production of bismuth was derived as a byproduct of lead refining. One company accounted for all primary production in the United States. The aluminum, chemical, cosmetic, pharmaceutical, and steel industries were the major consumers. Domestic consumption remained near the level of 1987, and demand in all categories remained strong. Prices rose throughout the year as consumption increased and production declined worldwide.

The use of bismuth in free-machining steels and pharmaceutical applications continued as leading areas of consumption. Research increased on the development of a bismuth-strontium-calcium-copper-oxygen compound as a high-temperature superconductor.

DOMESTIC DATA COVERAGE

The only U. S. bismuth refinery voluntarily furnishes domestic production data to the Bureau of Mines. To avoid disclosing company proprietary information, the data are not published.

LEGISLATION AND GOVERNMENT PROGRAMS

Government stocks remained at 2,018,298 pounds. The National Defense Stockpile goal remained at 2,200,000 pounds. Federal laws provide a depletion allowance of 22% for domestic companies' operations and 14% for U.S. companies producing in other countries.

DOMESTIC PRODUCTION

The ASARCO Incorporated refinery at Omaha, NE, slightly increased primary production in 1988. Several firms produced small quantities of secondary bismuth from scrap.

CONSUMPTION AND USES

Domestic consumption decreased 4% from that of 1987 to 3.4 million pounds. Use of bismuth in metallurgical additives for free-machining steels and aluminum rose, reaching almost 33% of total consumption. The percentage used in the chemical category continued to decline.

PRICES

The price range for bismuth, as quoted by Metals Week, gradually increased from $4.70 to $4.80 per pound in the beginning of the year to $6.55 to $6.75 at yearend. A series of nationwide miners' strikes temporarily halted shipments from Peru and caused the price to increase rapidly in August and September. Heavy foreign buying led to a swift increase in December.

FOREIGN TRADE

Mexico became the largest supplier of bismuth to the United States, surpassing Peru, which dropped to fourth place. Belgium and the United Kingdom were second and third, respectively. Exports of bismuth reached a 5-year high but imports declined.

Under the Harmonized Tariff Schedule of the United States that was to be in effect January 1, 1989, the import duty for bismuth articles, including waste and scrap (Harmonized code 8106.00.0000), was free for Most Favored Nations (MFN) and 7.5% ad valorem for non-MFN.

CAPACITY

The data in table 5 are rated capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materi-

TABLE 1

SALIENT BISMUTH STATISTICS

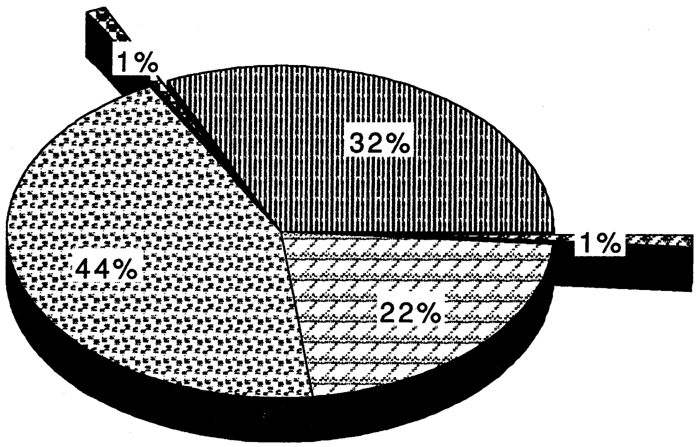
(Thousand pounds unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Consumption	2,648	2,644	2,919	3,521	3,376
Exports[1]	312	269	93	84	324
Imports for consumption	1,948	1,999	2,490	3,485	3,619
Price, average, domestic dealer, per pound	$4.27	$5.18	$3.25	$3.65	$5.78
Stocks, Dec. 31: Consumer	480	507	763	648	954
World:[2]					
Mine production (metal content)	7,614	9,722	7,616	p6,372	e6,106
Refinery production	7,028	9,538	9,463	p9,306	e7,740

e Estimated. p Preliminary.
[1] Includes bismuth, bismuth alloys, and waste and scrap.
[2] Excludes the United States.

FIGURE 1

BISMUTH METAL CONSUMED IN THE UNITED STATES IN 1988



Metallurgical Additives
Other Alloys
Chemicals
(Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals)
Fusible Alloys
Other
(Includes experimental)

als, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

Mine and refinery capacities for bismuth are based on a combination of data on engineering capacity provided by some companies and estimates by the Bureau of Mines.

WORLD REVIEW

World mine production of bismuth, contained mainly in lead and copper ores, decreased 4% in 1988. The release of previously stockpiled bismuth-rich residues from Australia into the world market is believed to have caused world refinery production to surpass mine production for the period 1986–88. The bismuth content of the ores varied greatly. Only in Bolivia was bismuth mined for itself. Production in Japan decreased slightly due to shortages of feedstock for the lead and copper smelters and lower bismuth content of the ore mined. However, consumption and imports in Japan increased substantially. Japan became a net importer of refined bismuth for the first time, relying heavily upon China and the Republic of Korea. China established a domestic Bismuth Institute in Septem-

TABLE 2

BISMUTH METAL CONSUMED IN THE UNITED STATES, BY USE

(Thousand pounds)

Use	1984	1985	1986	1987	1988
Chemicals[1]	1,573	1,325	1,462	1,650	1,497
Fusible alloys	609	610	639	736	733
Metallurgical additives	424	668	772	1,088	1,086
Other alloys	20	21	28	24	26
Other[2]	22	20	18	23	34
Total	**2,648**	**2,644**	**2,919**	**3,521**	**3,376**

[1] Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.
[2] Includes experimental.

ber and was expected to work with the International Bismuth Institute in Brussels, Belgium, to promote research and development of the metal.

Major world refiners of bismuth included Dowa Mining Co. Ltd., Mitsui Mining & Smelting Co. Ltd., and Nippon Mining Co. Ltd. in Japan; Empresa Minera del Centro del Péru in Peru; Indústria Minera México S.A. and Industrias Peñoles S.A. de C.V. in Mexico; Korea Tungsten Mining Co. Ltd. in the Republic of Korea; Mining and Chemical Products Ltd. in the United Kingdom; Métallurgie Hoboken-Overpelt S.A. and Société Industrielle d'Etudes et d'Exploitations Chimique in Belgium; Cominco Ltd. in Canada; and Norddeutsche Affinerie AG in the Federal Republic of Germany.

TECHNOLOGY

Research at Kitasato University in Tokyo, Japan, has shown that bismuth subnitrate significantly reduces the toxicity of an antitumor drug. The bismuth compound allows the drug to affect the tumor while decreasing the risk to surrounding healthy tissue.[2]

A bismuth-containing pigment, molybdenum-tungsten yellow, was developed at Beijing Normal University in China. The pigment can be used in plastics, paint, and printing inks. The nontoxicity of bismuth makes the pigment well suited for use in toys and stationery or any other application requiring high safety standards. This development was considered to have significant potential for increasing bismuth usage in the chemical field in the next few years.[3]

[1] Physical scientist, Branch of Nonferrous Metals.

[2] The Bulletin of the Bismuth Institute. No. 56, 1989, pp. 1-5.

[3] Page 11 of work cited in footnote 2.

TABLE 3

U.S. EXPORTS OF BISMUTH, BISMUTH ALLOYS, AND WASTE AND SCRAP, BY COUNTRY

Country	1987 Quantity (pounds)	1987 Value (thousands)	1988 Quantity (pounds)	1988 Value (thousands)
Argentina	—	—	55	$2
Australia	22	$2	—	—
Belgium	—	—	1,633	10
Canada	37,509	337	51,158	401
France	256	25	839	5
Germany, Federal Republic of	6,468	29	44,513	27
Greece	25	2	300	3
Hong Kong	2,223	15	—	—
India	132	5	—	—
Israel	63	2	300	2
Italy	12	2	—	—
Jamaica	—	—	250	2
Japan	189	7	57,961	175
Korea, Republic of	1,381	13	4,599	49
Malaysia	1,049	104	—	—
Mexico	1,070	7	879	5
Netherlands	—	—	358	2
New Zealand	—	—	76	2
Panama	—	—	1,547	4
Saudi Arabia	—	—	514	3
Singapore	1,729	11	1,037	8
Switzerland	68	6	294	2
Taiwan	6,100	19	2,380	42
United Arab Emirates	440	2	—	—
United Kingdom	24,949	53	153,911	462
Venezuela	—	—	1,000	7
Total	**83,685**	**641**	**323,604**	**1,213**

Source: Bureau of the Census.

TABLE 4

U.S. IMPORTS[1] FOR CONSUMPTION OF METALLIC BISMUTH, BY COUNTRY

Country	1987		1988	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg[2]	959,030	$2,866	749,918	$3,781
Canada	114,996	288	180,904	889
China	16,529	52	450,426	2,315
Germany, Federal Republic of	20,307	22	613	11
Hong Kong	4,741	14	50,268	280
Italy	7,176	26	11,207	56
Japan	35,840	69	29,019	96
Korea, Republic of	119,550	281	85,674	417
Mexico	862,597	2,359	988,863	5,048
Netherlands	55,453	230	44,291	240
Peru	971,003	1,559	416,546	2,096
Switzerland	—	—	39,677	167
United Kingdom	317,491	1,003	571,321	2,958
Total	**3,484,713**	**8,769**	**3,618,727**	**18,354**

[1] General imports and imports for consumption were the same in 1987 and 1988.
[2] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

TABLE 5

WORLD ANNUAL BISMUTH PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand pounds)

Country	Mine	Refinery
Australia	4,000	—
Belgium	—	2,500
Bolivia	1,500	600
Canada	1,500	600
China[e]	800	800
Germany, Federal Republic of[e]	—	900
Italy	—	200
Japan	1,500	2,700
Korea, Republic of	400	400
Mexico	2,500	2,200
Peru	2,000	1,800
Romania[e]	200	200
United Kingdom	—	800
United States	1,500	1,100
U.S.S.R.[e]	200	200
Yugoslavia[e]	300	300
World total	**16,400**	**15,300**

[e] Estimated.

TABLE 6

BISMUTH: WORLD MINE AND REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand pounds)

Country[2]	Mine output, metal content					Refined metal				
	1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987[p]	1988[e]
Australia[e] [3]	2,980	3,090	2,200	772	880	—	—	—	—	—
Belgium[e]	—	—	—	—	—	850	1,350	2,200	1,900	1,750
Bolivia	7	351	95	2	40	—	—	—	—	—
Canada[4]	366	443	337	364	430	[e]330	[e]395	[e]310	[e]330	385
China[e]	570	570	570	570	600	570	570	570	570	600
France	174	154	209	[e]200	200	—	—	—	—	—
Germany, Federal Republic of	—	—	—	—	—	[e]880	[e]880	[e]880	[e]880	—
Italy	—	—	—	—	—	57	119	146	97	100
Japan[5]	[e]375	[e]430	[e]420	[e]365	355	1,241	1,415	1,411	1,204	[6]1,155
Korea, Republic of[5]	[e]278	[e]298	[e]300	[e]320	310	278	298	300	320	310
Mexico[5]	[e]1,005	[e]2,140	[e]1,740	[e]2,350	2,160	955	2,039	1,651	2,231	[6]2,059
Peru	1,433	1,731	1,334	908	730	1,111	1,627	1,254	853	680
Romania[e]	180	180	180	170	145	180	180	180	170	145
U.S.S.R.[e]	180	185	185	190	190	180	185	185	190	190
United Kingdom[e]	—	—	—	—	—	330	330	330	400	300
United States	W	W	W	W	W	W	W	W	W	W
Yugoslavia[5]	[e]66	[e]150	[e]46	[e]161	66	66	150	46	161	66
Total	**7,614**	**9,722**	**7,616**	**6,372**	**6,106**	**7,028**	**9,538**	**9,463**	**9,306**	**7,740**

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; excluded from "Total."

[1]Table includes data available through Apr. 5, 1989. Bismuth is produced primarily as a byproduct of other metals, mostly lead, and only in Bolivia is it mined for itself.

[2]In addition to countries listed, Brazil, Bulgaria, the German Democratic Republic, Greece, Mozambique, and Namibia are believed to have produced bismuth, but available information is inadequate for formulation of reliable estimates of output levels.

[3]It is believed that bismuth-rich residues were stockpiled at the mine head during the period 1983-85 and released into the world market in subsequent years.

[4]Figures listed under mine output are reported in Canadian sources as production of refined metal and bullion plus recoverable bismuth content of exported concentrate.

[5]Mine output figures have been estimated based on reported metal output figures.

[6]Reported figure.

BORON

By Phyllis A. Lyday[1]

U.S. production and sales of boron minerals and chemicals decreased during the year. Glass fiber insulation was the largest use for borates, followed by sales to distributors, textile-grade glass fibers, and borosilicate glasses.

California was the only domestic source of boron minerals. The United States continued to provide essentially all of its own supply while maintaining a strong position as a source of sodium borate products and boric acid to foreign markets.

Supplementary U.S. imports continued of Turkish calcium borate and calcium-sodium borate ores, borax, and boric acid, primarily for various glass uses.

DOMESTIC DATA COVERAGE

Domestic data for boron are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Of the three operations to which a production survey request was sent, all responded, representing 100% of the total boron sold or used shown in tables 1 and 8. A Bureau canvass of the three U.S. producers also collected data on domestic consumption of boron minerals and compounds shown in tables 2 and 3.

LEGISLATION AND GOVERNMENT PROGRAMS

The Bureau of Export Administration, U.S. Department of Commerce, issued the final rule for the Commodity Control List, which identifies those items subject to Commerce export controls. The revisions resulted from a review of strategic controls maintained by the United States and certain allied countries through the Coordinating Committee. The materials added to the export list included the following: base materials having borides of zirconium and carbides and nitrides of boron containing 5,000 parts per million of complex compounds, single borides or single nitrides; and ceramic-ceramic composite materials containing carbides or nitrides of silicon or boron and borides or nitrides of zirconium or borides, carbides, or nitrides of hafnium, or any combination of these materials.[2]

The Occupational Safety and Health Administration, U.S. Department of Labor, proposed final rules for amending its existing air contaminants standard, which included anhydrous, decahydrate, and pentahydrate borax, boron oxide, boron tribromide, and boron trifluoride.[3]

Boron nitride was suggested as a substitute for beryllium oxide in a memorandum dated August 1 from the U.S. Department of Defense Hazardous Materials Minimization Program to Defense suppliers of electrical and electronic components. The substi-

TABLE 1

SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[1]	1,367	1,269	1,251	1,385	1,267
Boron oxide (B_2O_3) content	667	636	629	689	637
Value	$456,687	$404,775	$426,086	$475,092	$429,667
Exports:					
Boric acid:[2]					
Quantity	45	49	42	67	62
Value	$24,402	$21,598	$23,562	$34,180	$35,301
Sodium borates:					
Quantity[3]	576	623	624	609	602
Value[e]	$134,000	$151,000	$161,000	$243,600	$240,800
Imports for consumption:[4]					
Boric acid:					
Quantity	4	6	6	2	3
Value	$3,449	$5,121	$3,824	$2,900	$2,020
Colemanite:					
Quantity	20	33	16	8	19
Value	$12,123	$24,620	$8,770	$2,763	$7,790
Ulexite:					
Quantity	47	31	42	52	34
Value	$10,202	$11,120	$17,766	$20,597	$7,480
Consumption: Boron oxide (B_2O_3) content	375	360	338	369	392
World: Production	2,776	[r]2,761	2,767	[p]2,975	[e]3,043

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[2] Includes orthoboric and anhydrous boric acid.
[3] The Journal of Commerce Port Import/Export Reporting Service.
[4] Boron oxide (B_2O_3) content. In addition, borax imports from Turkey were 5,000 tons in 1987 and 9,000 tons in 1988.

tution was being considered for every item Defense managed and purchased because of the toxic dust generated when material containing beryllium oxide is machined. Defense believed that boron nitride would be a suitable substitute for beryllium oxide because of its excellent electrical resistance, high thermal conductivity, low dielectric constant, and good machinability. It can be formed by hot pressing and then machined to a high-quality finish.[4]

The U.S. Bureau of Mines released a new film, "Boron: Light Heavyweight," which was the winner of the Golden Eagle award from the Council of International Nontheatrical Events. The 28-minute film was produced in cooperation with the United States Borax & Chemical Corp., which paid production costs and provided copies for distribution. The film can be borrowed free of charge by any interested professional, civic, or educational group. Borrowers pay only the return postage.[5]

DOMESTIC PRODUCTION

The majority of the boron production continued to be from Kern County, CA, with the balance from San Bernardino County.

American Borate Co., a wholly owned subsidiary of Owens-Corning Fiberglas Corp., continued sales of colemanite and ulexite/probertite from storage at Dunn, CA.

Kerr-McGee Chemical Corp. operated the Trona and Westend plants at Searles Lake, in San Bernardino County, to produce refined sodium borate compounds and boric acid from the mineral-rich lake brines. At the Trona plant, a differential evaporative process was used to produce boric acid, pentahydrate borax, and anhydrous borax. Byproducts included potassium compounds. The Westend plant continued production of sodium borate by a carbonation process that also produced lime, sodium carbonate, and sodium sulfate.

U.S. Borax, a part of RTZ Borax Ltd. of the RTZ Corp. PLC of London, United Kingdom, continued to be the primary world supplier of sodium borates. U.S. Borax mined and processed crude and refined hydrated sodium borates, their anhydrous derivatives, and anhydrous boric acid at Boron, in Kern County. A second plant at Boron used a proprietary process to produce technical-grade boric acid from U.S. Borax's extensive kernite ore reserves. The boric acid was produced to compete with imported colemanite used in glass manufacture.

During the first quarter of 1988, U.S. Borax agreed in principle to sell its consumer products line of soaps and detergents to Dial Corp. The price of the sale was not disclosed. The Boraxo and Luron trademark names were sold, but the 20 Mule Team name will remain with U.S. Borax and will be selectively licensed to Dial.[6]

The majority of boron material was shipped to U.S. Borax's storage facility, Wilmington, CA, which also produced some boron specialty chemicals and borated soap products. Products made at Wilmington included ammonium borates, potassium borates, sodium metaborates, and zinc borate. Other boron compounds were used in fertilizers, herbicides, and wood preservatives.

Mountain States Mineral Enterprises Inc., Tucson, AZ, continued studying the boron market to determine if commercial development of the Fort Cady colemanite deposit in California would be feasible.

CONSUMPTION AND USES

U.S. consumption of borates increased. Glass fiber insulation and glass fiber primarily used as reinforcement for plastics continued to be the largest consuming industries.

The use of borates in glass fiber thermal insulation, primarily used in new construction, was the largest area of demand for borates. Demand for cellulosic insulation, the seventh largest use, decreased.

The second major market for borates, manufacturing high-tensile-strength glass fiber materials for use in a range of products, showed an increase in demand. Fiberglass accounts for approximately 90% of the reinforced-plastic market. The two most common reinforcement grades of glass fiber are "E," electrical, and "S," high-strength, grades.

Increased usage of fiberglass pipe since the 1950's has followed the issuance and acceptance of national standards. The ASTM Committee D-20 standards published in May 1987 covered gravity and pressure applications. The pipe has been used in chemical processing, oil and gas production, municipal and wastewater systems, and power and desalination plants. The growth and market penetration was a result of the versatility and installation characteristics of the systems, including corrosion resistance; weight; hydraulic efficiency; flexibility in lengths, fittings, joints, and diameters; and quality control. Fiberglass pipe used in oil and gas fields can withstand pressures up to 2,500 pounds per square inch at temperatures up to 150° F.[7]

The marine industry at 21% of the market and the aircraft, aerospace, and military sector at 12% were leading the demand growth for composites, including glass fiber. Demand for glass fiber was being met primarily through improved processing.[8] Manville Corp. announced an $80 million expansion at its fiberglass production facilities. The company planned to build a new fiberglass furnace at a site still under negotiation for production of continuous filament glass fiber. It also planned to expand its plants at Etowah, TN, Waterville, OH, and Willows, CA.[9]

Consumption of borates in borosilicate glasses remained the third major end use, and demand increased. Boron added to glass reduced the viscosity of the melt and assisted with fiber formation. Borosilicate glass among other uses was processed into glass staple, fiber slivers, yarns and twisted yarns, hybrid yarns, needled glass fiber mats, and fleece materials. Borosilicate glass fiber was used as an asbestos substitute in noncombustible, nontoxic, decay-proof, and temperature- and chemical-resistant products.[10]

Degussa Corp. began using a boron process for decorating glass tableware that gives the enamel excellent resistance to leaching from dishwashing detergents and does not use toxic elements, such as lead, in the manufacturing of the frit.[11]

Electronic materials containing boron are becoming increasingly important in areas that were traditionally the domain of metals. The physical properties and light-transmitting capabilities of glass fibers made them useful for optical transmission, semiconductors, for lasers and etectors, and nonlinear materials for optical switching.

Boron compounds in cleaning and bleaching were the fourth major end use. In 1986, production and sales of about 1,200 different chemical compounds or groups of compounds as surface-active agents were reported, including powdered sodium perborate for use as a bleach in heavy-duty detergents.[12] The Procter & Gamble Co. announced development of a chemical that reacts with perborate to create a surface-active, color-safe bleach. Degussa was marketing a perborate monohydrate that offered 50% more active oxygen than the domestically produced perborate tetrahydrate and was solubilized faster. The market was estimated to be 60 million pounds of perborate in detergent applications in 1988.[13]

Boron compounds continued to be used in biological-growth-control chemicals in water treatment, algicides, fertilizers, herbicides, and insecticides. Boron can be applied as a spray, and incorporated in herbicides, fertilizers, and irrigation water. The average cost for using boron as a fertilizer was reported as \$3 to \$6 per acre.[14]

Boron compounds were also used in metallurgical processes as fluxes, as shielding slag in the nonferrous metallurgical industry, and as components in electroplating baths. Small amounts of boron and ferroboron were constituents of certain nonferrous alloys and specialty steels, respectively.

"Soft" magnets containing boron, such as Allied-Signal Corp.'s Metglas, are used in amplifiers, semiconductor noise suppressors, and high-frequency transformers. The magnets are produced by powder metallurgy through pressing, sintering, and machining to specifications.[15]

Neodymium-iron-boron permanent (soft) magnets were reported being used in cranking motors, computer disk drives, and other applications where low volume, low weight, and high magnetic saturation can be utilized at relatively low temperatures. They are cast, wrought, and produced by powder metallurgy and melt-spinning techniques in a variety of shapes. These magnets are less brittle than samarium-cobalt magnets and provide higher tensile strength up to temperatures of about 250° F.[16]

Magnetic Transit of America Inc., Los Angeles, CA, planned to use neodymium-iron-boron magnets in the Las Vegas people mover system between Cashman Field and downtown Las Vegas, a distance of 1.2 miles. The Las Vegas project, expected to be operational in 1991, was based on pioneering work done in the Federal Republic of Germany by Magnetbahn GmbH and AEG AG. In the people mover, six vehicles, containing 160 magnets each, will operate by the magnetic levitation (maglev) principle of attraction-suspension with conventional electromagnets powered by onboard batteries. The magnets line the inner lip of a flange on the vehicle that is beneath the rails. The vehicle is raised toward the rails by attraction. Maglev was first developed in the United States in the early 1970's at the Massachusetts Institute of Technology. The Federal Republic of Germany and Japan have been

TABLE 2

U.S. CONSUMPTION[1] OF BORON MINERALS AND COMPOUNDS, BY END USE

(Short tons of boron oxide content)

End use	1987	1988
Agriculture	14,821	15,832
Borosilicate glasses	30,818	37,629
Enamels, frits, glazes	12,365	10,938
Fire retardants:		
Cellulosic insulation	12,971	12,310
Other	1,065	707
Glass-fiber insulation	123,165	113,929
Metallurgy	4,223	5,704
Miscellaneous uses	20,735	31,773
Nuclear applications	590	749
Soaps and detergents	24,251	29,152
Sold to distributors, end use unknown	85,067	83,061
Textile-grade glass fibers	38,445	50,067
Total	**368,516**	**391,851**

[1] Includes imports of borax, boric acid, colmanite, and ulexite.

TABLE 3

U.S. CONSUMPTION[1] OF ORTHOBORIC ACID, BY END USE

(Short tons of boron oxide content)

End use	1987	1988
Agriculture	74	230
Borosilicate glasses	4,432	5,532
Enamels, frits, glazes	1,959	1,675
Fire retardants:		
Cellulosic insulation	1,220	1,950
Other	1,065	707
Insulation-grade glass fibers	125	774
Metallurgy	400	403
Miscellaneous uses	9,598	9,475
Nuclear applications	590	562
Soaps and detergents	333	202
Sold to distributors, end use unknown	29,090	30,061
Textile-grade glass fibers	26,764	25,444
Total	**75,650**	**77,015**

[1] Includes imports.

competing to complete the first commercial system.

PRICES

Prices for sodium borates remained at 1987 levels except for bulk anhydrous borax, which increased. Boric acid and calcium borate prices increased. The trend has been for large consumers of borates to purchase through 1- to 5-year contracts.

FOREIGN TRADE

The majority of boron material exported from the United States went to Western Europe. Much of the material shipped to the Netherlands was shipped subsequently by rail to many European countries.

WORLD CAPACITY

The data in table 7 are rated capacity for mines and refineries as of December 31, 1988. Rated capacity was defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for boron was based on rated capacity as reported by the company, by another government agency, or another published source.

TABLE 4

BORATE PRICES PER SHORT TON[1]

Product	Price Dec. 31, 1988 (rounded dollars)
Borax, technical, anhydrous, 99%, bulk, carload, works[2]	613 - 620
Borax, technical, anhydrous, 99%, bags, carload, works[2]	647
Borax, technical, granular, decahydrate, 99.5%, bags, carload, works[2]	243
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works[2]	198
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works[2]	271
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, works[2]	226
Boric acid, technical, granular, 99.9%, bags, carload, works[2]	671
Boric acid, technical, granular, 99.9%, bulk, carload, works[2]	626
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound bags, carlots	2,415
Colemanite, Turkish, 40% to 42% B_2O_3, ground to a minus 70-mesh, f.o.b. railcars, Kings Creek, SC[3]	410

[1] U.S. f.o.b. plant or port prices per short ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.

[2] Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 234, No. 26, Dec. 26, 1988, pp. 26–34.

[3] American Borate Co.

WORLD REVIEW

Argentina

Production of between 1,100 to 1,600 tons per year of borate ore ground to 30 to 40 mesh and sold in 50-kilogram bags was reported during 1988. Boric acid was also produced at a plant with a capacity of 550 tons per year.[17]

Chile

In May, Corporación de Fomento de la Producción (CORFO) announced that it would sell a 25% interest in Sociedad Minera Salar de Atacama Ltda. (MINSAL). MINSAL had planned to operate a potassium chloride, potassium sulfate, boric acid, and lithium operation in the Salar de Atacama with estimated reserves of 4 million tons of boric acid. Feed for the boric acid plant would be the bitterns of solar evaporation used to produce the coproducts. The bitterns would be acidified with 8 grams of acid per liter to precipitate boric acid. Molibdenos y Metales S.A. (Molymet), a local molybdenum refiner with diversified local interests, would have the option to increase its ownership to 20%. AMAX Exploration Inc., a subsidiary of AMAX Inc., United States, had a second option if Molymet declined the increased ownership.

At yearend, Jacobs Engineering Group Inc., Pasadena, CA, announced that it had been awarded a contract to prepare for completion in 1989 a feasibility study of the MINSAL project. The bulk fertilizer products, potassium chloride and potassium sulfate, would probably be shipped through a new port facility. The project will also require new railroad storage and loading facilities.[18]

Química e Industrial del Borax Ltda. (QUIBORAX), formerly Cia. Minera Ñandú, mined ulexite at the rate of 1,100 tons per year of 28% boron oxide from three locations at Salar de Surire in Arica Province. Solar-dried ulexite

TABLE 5

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY

Country	1987			1988		
	Boric acid[1]		Sodium borates[2] (short tons)	Boric acid[1]		Sodium borates[2] (short tons)
	Quantity (short tons)	Value (thousands)		Quantity (short tons)	Value (thousands)	
Argentina	—	—	—	13	$12	—
Australia	1,877	$899	8,762	1,733	899	7,992
Bangladish	30	18	39	—	—	121
Belgium-Luxembourg	63	42	175	1,556	481	1,075
Brazil	72	49	5,184	97	63	1,657
Canada	5,736	2,889	[3]36,600	6,438	2,952	[3]54,118
Chile	3	4	18	—	—	6
China	2,703	1,365	52,422	216	112	4,586
Colombia	185	124	2,625	143	92	1,883
Costa Rica	12	7	303	6	4	1,514
Dominican Republic	2	2	5	—	—	96
Ecuador	—	—	906	—	—	825
El Salvador	12	4	6	—	—	27
France	622	373	57	—	—	85
Germany, Federal Republic of	—	—	—	1,425	798	273
Guatemala	7	3	80	—	—	34
Haiti	—	—	134	—	—	600
Honduras	—	—	70	—	—	42
Hong Kong	15,446	7,009	49,203	2,374	1,226	8,749
India	—	—	5,424	—	—	3,694
Indonesia	214	123	5,271	315	182	7,971
Israel	57	50	262	58	36	250
Jamaica	9	3	—	16	6	0
Japan	25,265	13,903	54,891	28,594	16,328	63,577
Korea, Republic of	3,662	1,710	21,591	2,763	1,358	24,520
Malaysia	130	75	4,602	147	78	4,385
Mexico	3,734	1,707	[3]73,970	3,480	1,729	[3]31,791
Netherlands	335	188	225,935	4,244	4,011	331,707
New Zealand	918	454	3,166	1,241	676	2,563
Pakistan	6	2	271	—	—	1,051
Panama	18	8	47	11	4	47
Papua New Guinea	110	51	514	106	57	176
Peru	39	18	104	24	15	140
Philippines	114	87	2,053	125	69	2,431
Romania	371	224	—	309	176	—
Saudi Arabia	4	5	480	31	19	915
Singapore	278	172	3,808	455	249	4,509
South Africa, Republic of	146	101	1,876	116	75	1,738
Spain	—	—	28,447	—	—	13,502
Sri Lanka	21	12	20	—	—	—

See footnotes at end of table.

of 30% boron oxide content was processed into boric acid at a pilot plant at Salar de Surire. During 1987, QUIBORAX began expanding the boric acid plant, and the capacity was expected to reach 26,000 tons per year by 1989. Ulexite ore of 32% boron oxide content was also sold ground and bagged. QUIBORAX employed 260 workers at the three locations. In addition, 40 employees under contract transported the ulexite to the pilot plant. Upon completion of the expansion, QUIBORAX expected to employ 40 additional contractors and 70 additional workers. QUIBORAX also owned the mineral rights to another ulexite deposit in the Salar de Ascotan, located north of Salar de Surire.

Minera del Boro, Iquique, the only other boron producer, produced boric acid from deposits in the Salar de Pintados, the Salar de Cariquima, and the Salar de Quillagua, in Tarapacá Province.

France

Cie. de St. Gobain, the French glass and packaging group, made a series of equity bids in five countries for six companies. In the United States, St. Gobain increased its offer for outstanding equity in CertainTeed Corp. In Argentina, St. Gobain was buying Pilkington's 40% share in Vidrieria Argentina S.A., a domestic glass producer. In Belgium, St. Gobain bid for the outstanding 31.2% equity in Glacieres de St. Roch S.A. In the Federal Republic of Germany, St. Gobain made a bid that involved the purchase of a 35% stake in Oberland Glas, the country's second largest glass packaging company.[19]

Italy

Societá Chimica Larderello S.p.A. (SCL), part of the state-owned Ente Nazionale Idrocarburi (EniChem) Group through EniChem Anic, was a producer of boric acid and borates at two plants in Larderello, Tuscany. At yearend 1988, SCL was absorbed into Stablimenti di Saline e Larderello (SAMATEC)

TABLE 5—Continued

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY

Country	1987 Boric acid[1] Quantity (short tons)	1987 Boric acid[1] Value (thousands)	1987 Sodium borates[2] (short tons)	1988 Boric acid[1] Quantity (short tons)	1988 Boric acid[1] Value (thousands)	1988 Sodium borates[2] (short tons)
Taiwan	2,690	$1,215	15,720	3,705	$2,093	18,629
Thailand	158	108	1,246	452	291	2,218
Trinidad and Tobago	—	—	—	—	—	3
United Kingdom	—	—	89	71	73	262
Uruguay	7	4	20	2	2	17
Venezuela	1,528	1,154	1,999	1,905	1,130	1,764
Zimbabwe	10	5	—	—	—	20
Other	21	9	496	15	5	294
Total	**66,615**	**34,180**	**[4]608,893**	**62,186**	**35,301**	**601,857**

[1] Bureau of the Census.
[2] The Journal of Commerce Port Import/Export Reporting Service.
[3] U.S. exporters of sodium borates.
[4] Data do not add to total shown because of independent rounding.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY

Country	1987 Quantity (short tons)	1987 Value[1] (thousands)	1988 Quantity (short tons)	1988 Value[1] (thousands)
Canada	18	$13	90	$70
Chile	23	11	779	300
France	40	39	—	—
Germany, Federal Republic of	2	10	23	53
Italy	2,094	1,460	2,120	1,580
Japan	25	29	—	—
United Kingdom	39	1,337	18	17
Total	**2,241**	**2,900**	**3,030**	**2,020**

[1] U.S Customs declared values.

Source: Bureau of the Census.

S.p.A., another company of the ENI Group as a result of a reorganization of certain chemical operations.

Turkey

Turkey was the second largest producer of boron minerals in the world. Etibank, the Turkish state mining organization, mined and concentrated colemanite ores at Bigadic, Emet, and Kestelek for export worldwide. Ulexite concentrates, produced at Bigadic, were also exported, primarily to Japan and the United States, for manufacture of insulation-grade fiberglass.

United Kingdom

PPG Industries Inc., United States, proposed to spend $40 million over the next 2 years at its Wigan fiber plant, near Manchester, which was purchased in October 1987, from T & N PLC. The unit, named PPG Glass Fibres Ltd., produces 15,000 tons per year of rein-

TABLE 7

WORLD BORON ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons of boron oxide content)

	Rated capacity[1]
North America: United States	810
South America:	
Argentina	31
Chile	6
Peru[e]	6
Total	**43**
Europe: U.S.S.R.[e]	45
Asia:	
China[e]	6
Turkey	520
Total	**526**
World total	**[2]1,400**

[e] Estimated.
[1] Includes capacity at operating plants as well as plants on standby basis.
[2] Data do not add to total shown because of independent rounding.

forcement material. PPG planned to increase capacity by 30,000 tons per year by building a new plant. An extra furnace was already in the design stage. Most of the production will be continuous strand reinforced fiber for use in electronic circuit boards.[20]

TECHNOLOGY

Small amounts of boron added to mixtures of nickel and aluminum, known as nickel aluminide, produce a metal that strengthens at a higher temperature. The addition of 200 parts per million of boron gives ductility to the mixture.[21] Forty companies, some potential users and others potential suppliers, are working with the alloys, which are reported near commercialization.[22]

GTE Corp. and SPX Corp. succeeded in developing two plasma-sprayed coatings with wear resistance superior to that of commercial flame-sprayed coatings. Boron, chromium, nickel, and molybdenum formed nickel-molybdenum and nickel-chromium alloys during spraying.[23]

About 50% of domestic usage of boron compounds was in glass. Boron represents about 25% of the cost for batch glass because of losses during the melt cycle. The exhaust gas from glass melting contains particulates and volatile components, including boron oxide. The recycling of exhaust gas will decrease these losses. Recuperators for glass melting furnaces can boost thermal efficiency from 25% to 40% by recycling the waste gas.[24]

The first aluminum-nitrogen analog of borazine, a boron-nitrogen analog of benzene, has been synthesized. The compound is thermally stable but highly reactive with oxygen and water and could be used as a reducing agent to yield aluminum, ammonia, and hydrogen.[25]

Glass and ceramic spheres of soda-lime or borosilicate glass can displace part of the glass fiber reinforcement in composite materials, thereby reducing cost by allowing more effective filling of the reinforcement. The borosilicate spheres of "E" glass contain about 7% boron oxide. Their low specific gravity helps to reduce the density of the material. Besides plastics, the spheres can be used in coatings, putties, and caulking compounds to reduce weight and make application and sanding easier. In automobile manufacture, they can be used in sealants and adhesives.[26]

TABLE 8

BORON MINERALS: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina	157	[r]174	211	203	204
Chile	4	5	7	15	11
China[e]	30	30	30	30	30
Peru[e]	11	11	[2]25	[r]22	11
Turkey	987	1,052	1,023	[e]1,100	1,300
U.S.S.R.[e]	220	220	220	220	220
United States[2]	1,367	1,269	1,251	1,385	[3]1,267
Total	**2,776**	**[r]2,761**	**2,767**	**2,975**	**3,043**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through May 20, 1989.
[2] Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[3] Reported figure.

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Federal Register. Revision to the Commodity Control List Based on COCOM Review: Metals, Minerals and their Manufactures; Chemicals, Metalloids, Petroleum Products and Related Materials. V. 53, No. 179, Sept. 15, 1988, pp. 35803-35806.

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BROMINE

By Phyllis A. Lyday[1]

Of the 892 million pounds of bromine produced worldwide in 1988, the United States produced 40%, followed by Israel, 28%; the U.S.S.R., 16%; the United Kingdom, 6%; and other countries, 10%. The U.S. portion of world production has decreased steadily since 1973, when the United States produced 71% of the world supply. The decrease in world share has been a result of environmental constraints and the emergence of Israel as a major producer. The quantity of bromine sold or used in the United States was about 360 million pounds valued at $144 million. Exports of bromine compounds amounted to 26.1 million pounds. The price of elemental bromine in bulk was 43 to 46 cents per pound. Primary uses of bromine compounds were in flame retardants, as a scavenger for lead in gasoline, and in oil and gas well fluids.

DOMESTIC DATA COVERAGE

Domestic production data for bromine are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the six operations to which a survey request was sent, three responded, representing 50% of total elemental bromine sold or used. The other operations were estimated by using quantity of brine produced and estimated bromine concentration.

LEGISLATION AND GOVERNMENT PROGRAMS

During 1988, brines produced in Arkansas required the payment of $2 per 1,000 barrels in severance taxes, and capital equipment was subject to the payment of property taxes. Bromine produced in the United States was subject to Superfund taxes of $4.45 per ton and was manufactured using chlorine, which was also subject to a Superfund tax of $2.70 per ton of chlorine.

The Environmental Protection Agency (EPA) planned to incinerate all leftover stocks of the pesticide fumigant ethylene dibromide (EDB). The disposal included 328,000 gallons of EDB stored at various locations around the country. A trial burn of EDB was completed in December.

The Occupational Safety and Health Administration proposed massive revision of permissible exposure levels for hundreds of chemicals in the workplace, including bromine, bromine pentafluoride, and ethyl bromide. The new regulation required lower permissible exposure levels for 234 chemicals. Exposure levels were required for the first time for 168 other chemicals.[2]

DOMESTIC PRODUCTION

Ethyl Corp. and Great Lakes Chemical Corp. produced and marketed bromine chemicals. These two companies accounted for about 90% of U.S. elemental bromine capacity at yearend 1988. Elemental bromine plant capacity did not reflect production capacity, which was dependent upon brine supplies, concentration of the bromine in the brine, and individual plant extraction processes. In Arkansas, one supply and one disposal well were required for each 10 million pounds per year of bromine produced. Because bromine concentrations in the brine decrease as waste brine depleted of bromine is reinjected into its source, wells must be drilled to provide adequate reserves to insure future demands of elemental bromine. Each supply well requires an investment in excess of $1 million and has an average life of about 10 to 15 years. Arkansas brines contained about 5,000 parts per million and Michigan brines about 2,600 parts per million of bromine. During 1988, the Arkansas Oil and Gas Commission reported that 62 bromine producing wells were in operation. Several reinjection wells were drilled during 1988. A small amount of bromine produced as a byproduct of wells in Michigan was not of commercial quality and was reprocessed before consumption.

Ethyl had concluded an agreement with The Dow Chemical Co. to purchase Dow's facility in Magnolia, AR, and other bromine assets in 1987. Included were the brine field leases located in the Magnolia area, distribution equipment, facilities, and inventories around the world as well as certain patents pertaining to Dow's bromine chemical technology. Under a consent decree reached with the U.S. Department of Justice, Dow and Ethyl agreed to exclude Dow's brominated clear brine fluids business from the transaction. As part of the consent decree, Dow sold its brominated clear brine fluids business on May 13, 1988, to Tetra Technologies Inc., The Woodlands, TX.

Tetra was incorporated in 1981 as Tetra Resources Inc. to offer technology in the production of oil and natural gas, including well fluids: completion brines, drilling fluids, and suspended solids control. Tetra was the first service company to make clear brine products readily available at key distribution points in Texas, Oklahoma, Louisiana, the gulf coast, and California. In addition, Tetra offered filtration of clear brines at the wellsite. Tetra instituted an alteration of the name in 1987 to better address the company's entire scope of business, which included various wastewater treatment processes. Tetra was evaluating the fluids market for clear brines at yearend to determine when the company would begin production.

Great Lakes continued construction of a manufacturing plant to produce a proprietary monomer with a bromine-containing product that renders the monomer flame retardant. Great Lakes continued to diversify. Bromine derived-chemicals constituted only 23% of sales in 1988. The company's proprietary

TABLE 1

SALIENT BROMINE AND BROMINE COMPOUND STATISTICS

(Thousand pounds and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Bromine sold or used:[1]					
Quantity	385,000	320,000	310,000	335,000	360,000
Value	$95,000	$80,000	$93,000	$107,000	$144,000
Exports:					
Elemental bromine:					
Quantity	[2]68,200	[2]6,252	[3]17,900	[3]7,380	[3]9,541
Value	[e]$15,200	[e]$1,400	[3]$8,170	[3]$3,526	[3]$3,379
Bromine compounds:[3 4]					
Gross weight	53,200	61,000	28,000	48,300	30,700
Contained bromine	45,100	51,900	23,000	41,100	26,100
Value	$16,200	$23,400	$23,900	$18,000	$13,000
Imports:[3]					
Elemental bromine:					
Quantity	9	11	342	547	566
Value	$17	$9	$87	$166	$194
Compounds:					
Ammonium bromide:					
Gross weight	1,450	2,786	5,721	4,946	3,659
Contained bromine	1,183	2,729	4,667	3,778	2,985
Value	$854	$1,593	$2,994	$2,257	$2,180
Calcium bromide:					
Gross weight	1,598	5,093	6,218	8,075	9,450
Contained bromine	1,278	4,072	4,972	6,456	7,555
Value	$203	$917	$741	$833	$1,360
Potassium bromate:					
Gross weight	661	1,069	641	3,063	9,174
Contained bromine	350	512	340	1,466	4,390
Value	$610	$899	$669	$849	$1,107
Potassium bromide:					
Gross weight	367	968	697	1,910	1,870
Contained bromine	246	650	468	1,282	1,256
Value	$268	$685	$486	$1,122	$1,278
Sodium bromide:					
Gross weight	1,916	2,901	467	1,448	4,245
Contained bromine	1,488	2,253	364	1,124	3,297
Value	$851	$1,108	$217	$507	$1,936
Other:					
Gross weight	15,150	10,087	10,112	18,286	72,514
Contained bromine	11,535	6,863	8,004	11,220	23,875
Value	$8,210	$5,863	$4,627	$13,669	$35,531
World: Production	875,150	839,982	824,380	[p]857,530	[e]892,230

[e]Estimated. [p]Preliminary.
[1]Elemental bromine sold as such to nonproducers, including exports, or used in the preparation of bromine compounds by primary U.S. producers.
[2]The Journal Commerce Port Import/Export Reporting Service.
[3]Bureau of the Census.
[4]Includes methyl bromine and ethylene dibromide.

space fumigant, based on methyl bromide, was used throughout the world for controlling nematodes, insects, and various soilborne diseases. This sector of sales decreased from 26% in 1979 to 6% in 1988 primarily because environmental legislation limited its use. Fire control chemicals, which included halons, represented about 37% of sales.[3]

Morton Thiokol Inc. reported selling its bromine inventory and its technology for the production of inorganic bromides to Rhône-Poulenc Inc. through its subsidiary, Potasse et Produits Chimiques, on February 10.

CONSUMPTION AND USES

The U.S. International Trade Commission (ITC) publication, "Synthetic Organic Chemicals, 1987" reported that the Dyes & Pigments Div. of Mobay Chemical Corp. produced Pigment Red 168, dibromoanthranthrone orange. Red 168 was used in automotive metallic applications because of its transparency.

Tetrabromobisphenol-A is the largest volume brominated flame retardant. Its primary markets are epoxy circuit boards, acrylonitrile-butadiene-styrene or ABS, and polycarbonates. Decabromodiphenyl oxide is the second largest volume brominated flame retardant. Its primary markets are in television cabinets, video cassette recorder housings, wire, cable, and textile coatings. Tetrabromophthalic anhydride is used as a reactive flame retardant in unsaturated polyester resin. It is also used as an intermediate to make other flame retardants, which are used in polyolefin and polyvinyl chloride wire and cable coatings, rigid polyurethane foam insulation, and fabric and wood treatments. Ethyl and Great Lakes are primary suppliers to the domestic market.[4] Ameribrom Inc., a member of the Israeli Dead Sea Bromine Co. Ltd. (DSB), estimated that the U.S. market for tetrabromodiphenyl oxide and decabromodiphenyl oxide is approximately $55 million per year. Brominated fire extinguishers are used to protect closed spaces, such as computer rooms, and in portable fire extinguishers.

Demand for ethylene dibromide (EDB), primarily as a gasoline additive, was about 18% of total consumption. The ITC's "Synthetic Organic Chemicals, 1987" listed Great Lakes and Ethyl as the only producers of EDB used in gasoline additives during 1987.

Fire retardants were estimated to be about 28% of consumption, primarily as tetrabromobisphenol-A and decabromodiphenyl oxide. About 25% of bromine consumption was in clear brine drilling fluids used in work-over and completion fluids. Agriculture uses, primarily as methyl bromide, were about 15% of consumption, principally as methyl bromide used as a soil fumigant. Bromine used in water treatment as a slime and biocidal control product and other uses accounted for an estimated 14% of consumption. Other uses accounted for 18% of consumption.

PRICES

Bromine was sold under contracts negotiated between buyer and seller. Price quotations do not necessarily represent prices at which transactions actually occurred, nor do they represent bid and asked prices. They were quoted here to serve only as a guide to yearend price levels. Great Lakes reported that prices for three brominated flame retardants increased by 8 to 10 cents per pound on July 1.

FOREIGN TRADE

The ITC was requested by the President to institute an investigation with respect to 14 Harmonized Tariff Schedule subheadings contained in the United States-Israeli Free Trade Area Agreement (Public Law 99-47), which was signed into law June 11, 1985. Among the 14 being considered for a staged elimination of U.S. duties, sodium bromide, decabromodiphenyl oxide, and tetrabromobisphenol-A were considered the most economically important to Israel.

Three major factors were reported to affect U.S. imports of sodium bromide from Israel: demand for most bromide compounds increased, development of a market for sodium-bromide water treatment, and processing byproduct hydrobromic acid into higher profit

TABLE 2

BROMINE-PRODUCING PLANTS IN THE UNITED STATES IN 1988

State and company	County	Plant	Production source	Elemental bromine plant capacity (million pounds)
Arkansas:				
Arkansas Chemicals Inc.	Union	El Dorado	Well brines	50
Ethyl Corp.	Columbia	Magnolia	do.	110
Do.	do.	do.	do.	160
Great Lakes Chemical Corp.	Union	El Dorado	do.	105
Do.	do.	Marysville	do.	80
Do.	do.	El Dorado	do.	50
Michigan:				
The Dow Chemical Co.	Mason	Ludington	do.	[1]20
Morton Thiokol Inc.	Manistee	Manistee	do.	[2]5
Total				**580**

[1] Bromine produced at this plant is reprocessed in Arkansas.
[2] Plant closed officially Feb. 10, 1988.

TABLE 3

YEAREND 1988 PRICES FOR ELEMENTAL BROMINE AND SELECTED COMPOUNDS

Product	Value per pound (cents)
Ammonium bromide, National Formulary (N.F.), granular, drums, carlots, truckloads f.o.b. works	131
Bromine:	
Drums, truckloads, works[1]	103
Bulk, tank cars, works[1]	43- 46
Bromochloromethane, drums, carload, f.o.b. Midland, MI	118
Calcium bromide, bulk[2]	16
Ethyl bromide, technical, 98%, drums, truckloads	120
Ethylene dibromide, drums, carload, tank cars	45- 47
Hydrobromic acid, 48%, drums, carload, truckloads, f.o.b.	54- 65
Hydrogen bromide, anhydrous, cylinders, 2,500 pounds, truckloads	390
Methyl bromide, tank car	72
Potassium bromate, granular, powdered, 200-pound drums, carload, f.o.b. works	106
Potassium bromide, N.F., granular, drums, carload, f.o.b. works	112
Sodium bromide, technical, truckload	65- 68

[1] Delivered prices for drums and bulk shipped west of the Rocky Mountains, 1 cent per pound higher. Bulk truck prices 1 to 2.5 cents per pound higher for 30,000-pound minimum and 4 to 5.5 cents per pound higher for 15,000-pound minimum.
[2] Bureau of the Census. Average c.i.f. import value.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 234 No. 26, Dec. 26, 1988, pp. 26-34.

compounds. Demand for sodium bromide has closely followed the oil well completion market, and U.S. and world demand was expected to grow.[5]

The General Agreement on Tariffs and Trade (GATT) negotiations included proposed tariff reductions on chemicals, including bromine and brominated compounds. The U.S. chemical industry claimed that European countries can institute protective barriers. About a quarter of chemical trade in Europe was cross-border trade. Two goals of the 1992 GATT talks were expected to be harmonization of chemical product standards and reduction of delays at the border in importation of chemicals.[6]

TABLE 4

WORLD BROMINE ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988, RATED CAPACITY[2]

(Million pounds)

	Capacity
North America: United States	575.0
Europe:	
France	49.0
German Democratic Republic	7.7
Germany, Federal Republic of	5.5
Italy	2.0
Spain	2.0
United Kingdom	66.0
U.S.S.R.	160.0
Total	**292.2**
Middle East: Israel	250.0
Asia:	
China	1.0
India	1.6
Japan	53.0
Total	**55.6**
World total	**[3]1,200.0**

[1] Actual capacity limited by brine supply.
[2] Includes capacity at operating plants as well as at plants on standby basis.
[3] Data do not add to total shown because of independent rounding.

WORLD CAPACITY

The data in table 4 are rated capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for bromine is based on rated capacity as reported by the company, by another Government agency, or another published source.

WORLD REVIEW

China

In May 1987, it was announced that China was to begin production of elemental bromine. Steetley Engineering, United Kingdom, was involved in the design and coordination of a package to construct a 2-million-pound-per-year plant in the Shandong Province of China. Sinomay Import and Export of New York was the main contractor.[7]

Israel

Israeli Chemicals Ltd. (ICL) announced a search for a buyer of a 50% share of the company. ICL has been targeted as a priority for privatization, given the demand on the world market for chemicals. The state company controls 25 active subsidiaries, including 89% of DSB, which is most likely to be privatized first because of its profitability and strong position in the world bromine market. DSB has annual sales of about $240 million or about a 30% share in the world bromine market or approximately 60% of the market outside the United States.[8] DSB announced increased profitability during 1988. Increased prices for bromine and bromine compounds were reported to contribute to the profitability.

DSB announced plans to expand bromine and bromine compounds from 220 million pounds to 280 million pounds per year at Sdom. Production capacity of bromine chemicals will increase from 140 million pounds to 200 million pounds per year with emphasis on flame retardants and bromine intermediates. The expansion will occur in the Netherlands, through the subsidiary Broomchemie BV, and in Israel.

Japan

A joint venture between DSB and Nippon Chemicals was planned to produce a bromine compound, which would be marketed in Japan and Southeastern Asia. DSB would provide production technology for the venture.

United Kingdom

London-based Associated Octel Co. Ltd. was the sole producer of bromine in the United Kingdom at a seawater plant at Amlwch, Anglesey. Octel was founded in 1938 by the British Government to produce fuel additives for fighter planes, that is, leaded antiknock compounds for gasoline containing bromine as a scavenger.[9]

TECHNOLOGY

The Fire Retardant Chemicals Association's Hazard Assessment Committee sponsored a study by the National Bureau of Standards Center for Fire Research (NBS-CFR). The NBS-CFR investigated the fire hazard of a wide array of fire-retardant (FR) containing products relative to non-fire-retardant (NFR) products. The purpose of the investigation was to determine whether FR additives effect a tradeoff between decreased burning and increased emission of toxic gases and whether there was a net safety benefit from the use of FR's.

Five types of commercial products were rated for overall fire hazard. For the FR tests, the average available escape time was more than fifteen-fold greater than for the occupants of the NFR room. The amount of material consumed in the fire for the FR tests was less than one-half the amount lost in the NFR tests. The FR tests indicated an amount of heat released from the fire that was one-fourth that released by the NFR tests. The total quantities of toxic gases produced in the room fire tests, expressed in "CO equivalents," were one-third for the FR products, compared to the NFR ones. The production of smoke was not significantly different between the room fire tests using NFR products and those with FR products. The tests showed that the proper selection of fire retardants can markedly improve the fire safety of specific products.[10]

The Brominated Flame Retardant Industry Panel (BFRIP) was formed in 1985 by the four basic bromine producers. After the completion of stage 1 of the BFRIP program, one company sold its bromine assets and withdrew from the program. The BFRIP was formed to respond to issues raised about bromine chemicals, including the combustion toxicity of brominated diphenyl oxides, aquatic fate studies of tetrabromobisphenol-A, and the Toxic Substances Control Act, Section 4 Test Rule on halogenated products, all of which could affect the bromine market.

In response to the issues, the BFRIP has completed one study, initiated a 90-day oral feeding study on a specific dioxin and dibenzofurans, and was evaluating testing of other polymer-brominated compound systems. In response to studies of a polymer and a brominated fire retardant completed in 1987 at the Frezenius Institute, Federal Republic of Germany, the BFRIP initiated processing studies with major polymer producers who used brominated diphenyl oxides. The results of the studies were submitted to the EPA. EPA decided to obtain further information on the potential hazard of these materials before making a judgment.

In addition, two polymer producers reported studies to the BFRIP on health monitoring of their employees in plants that showed no significant difference in the health history of these workers compared to control groups. The National Institute for Occupational Safety and Health undertook an air sampling study with a major polymer producer and the BFRIP. The study was nearing completion, and preliminary findings were consistent with other studies showing no significant difference in the health of workers compared to control groups.[11]

Two new brominated compounds have proven effective in making urethane and thermoplastics fire retardant, thus increasing the materials in which bromine can be used. The thermal stability of the FR's at high-temperature processing environments common to engineering plastics proved stable until melting at 230° F and 435° F, respectively. Studies indicated that in polycarbonate (PC), mineral-filled polybutylene terephthlate (PBT), PC/PBT blends, and modified

TABLE 5

WORLD BROMINE ANNUAL PLANT CAPACITIES AND SOURCES,[1] DECEMBER 31, 1988

Country and company	Location	Capacity (million pounds)	Source
China: Laizhou Bromine Works	Shandong	1	Underground brines.
France:			
Atochem	Port-de-Bouc	30	Seawater.
Mines de Potasse d'Alsace S.A.	Mulhouse	19	Bitterns of mined potash production.
German Democratic Republic	Bleicherode	NA	Do.
Government	Sondershausen	7.7	Do.
Germany, Federal Republic of: Kali und Salz AG: Salzdetfurth Mine	Bad Salzdetfurth	5.5	Do.
India:			
Hindustan Salts Ltd.	Jaipur		
Mettur Chemicals	Mettur Dam	1.6	Seawater bitterns from salt production
Tata Chemicals	Mithapur		
Israel: Dead Sea Bromine Co. Ltd.	Sdom	250	Bitterns of potash production from surface brines.
Italy: Societa Azionaria Industrial Bromo Italiana	Margherita di Savoia	2	Seawater bitterns from salt production.
Japan:			
Asahi Glass Co. Ltd.	Kitakyushu	9	Seawater bitterns.
Toyo Soda Manufacturing Co. Ltd.	Tokuyama	44	Do.
Spain: Derivados del Etilo S.A.	Villaricos	2	Seawater.
U.S.S.R: Government	NA	160	Well brines
United Kingdom: Associated Octel Co. Ltd.	Amlwch	66	Do.

NA Not available.
[1] Excludes U.S. production capacity. See table 2.

TABLE 6

BROMINE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand pounds)

Country[2]	1984	1985	1986	1987[p]	1988[e]
France[e]	38,600	44,000	42,000	41,000	39,700
Germany, Federal Republic of	7,288	6,784	[e]5,500	[e]5,500	5,500
India[e]	770	770	770	770	770
Israel[e]	198,400	220,000	231,500	[r]242,500	253,500
Italy[e]	1,100	1,320	990	1,100	1,100
Japan[e]	26,500	26,500	33,000	33,000	33,000
Spain[e]	660	800	620	660	660
U.S.S.R.[e]	154,000	154,000	143,000	143,000	143,000
United Kingdom	62,832	65,808	[e]57,000	[e]55,000	55,000
United States[3]	385,000	320,000	310,000	335,000	[4]360,000
Total	**875,150**	**839,982**	**824,380**	**857,530**	**892,230**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 3, 1989.
[2]In addition to the countries listed, several other nations produce bromine, is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.
[3]Sold or used by producers.
[4]Reported figure.

polyethylene ether resins, the brominated products function as efficient FR's without the addition of antimony oxide.[12]

Silver bromide was identified as a substance that can be separated from a solvent or surfactant by a carrier using a new process named emulsion liquid membranes (ELM). Operating costs for the extraction for recovery of some substances were lower than costs associated with solvent extraction and ion exchange. The only commercial process applications of liquid membrane technology were in waste treatment, where low concentration substances must be removed from large volumes of effluent. The process would be extremely useful for the removal of heavy metal from aqueous streams.[13]

A bench top gas chromatograph detector was capable of identifying any element, except helium, in an effluent. The detector can be used as a means of identification or as a screening tool. Software included with the instrument allowed detection of 15 elements, including bromine.[14]

A report of the latest finding of bromine in the ozone layer found that atmospheric abundance of Halon-1211 and Halon-1301, which are used as fire extinguishers, could increase 12% and 5% per year, respectively. The two substances contributed 10% to 30% of the organically bound bromine in the atmosphere.[15] If these materials are banned, demand for bromine would decrease in fire extinguisher uses.

An unusual chromium bromine complex yielded 97% activated molecular oxygen. The complex could have potential use as an organic oxidant, thus increasing demand for bromine.[16]

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[1]Physical scientist, Branch of Industrial Minerals.

[2]Federal Register. Occupational Safety and Health Administration (Dep. Labor). Air Contaminants; Proposed Rule. V. 53, No. 109, June 7, 1988, pp. 20960–21393.

[3]Great Lakes Chemical Corp. 1988 Annual Report. Available upon request from the company at Box 2200, West Lafayette, IN 47906.

[4]Hall, D. A. (Great Lakes Chemical Corp.) Written communication submitted to U.S. International Trade Commission, Feb. 6, 1989, pp. 5, 6; available upon request from the Office of the Secretary, U.S. International Trade Commission, Washington, DC.

[5]Macrory, P. F. J. (Arnold & Porter). Written communication submitted to U.S. International Trade Commission, Jan. 17, 1989, 4 pp; available upon request from the Office of the Secretary, U.S. International Trade Commission, Washington, DC.

[6]Chemical Marketing Reporter. Non-Tariff Barriers Major Chemical Goal. V. 234, No. 24, 1988, pp. 5, 22.

[7]Roskill Information Services Ltd. (London). The Economics of Bromine 1988. 1988, p. 8.

[8]European Chemical News. Israel Steps Up Privatization Plans. V. 51, No. 1352, 1988, p. 31.

[9]Layman, P. L. Diversification Poses Major Challenge for U.K.'s Octel. Chem. & Eng. News, v. 66, No. 28, 1988, pp. 16–17.

[10]Babrauskas, V., R. H. Harris, Jr., R. G. Gann, B. C. Levin, B. T. Lee, R. D. Peacock, M. Paabo, W. Twilley, M. F. Yoklavich, and H. M. Clark. Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products. Nat. Bu. Stand. Spec. Publ. 749, 1988, 86 pp.

[11]Hughes, K. A. Brominated Flame Retardant Industry Panel Research Efforts. Paper in Fire Retardant Coatings and Technical Research Developments for Improved Fire Safety. Fire Retard. Chem. Assoc., Annapolis, MD, Oct. 2-5, 1988, pp. 161–183.

[12]Modern Plastics. FR Innovations Described at Meeting. V. 65, No. 6, 1988, pp. 32–33.

[13]Nobel, R. D., C. A. Koval, and J. J. Pellegrino. Facilitated Transport Membrane Systems. Chem. Eng. Prog., v. 85, No. 3, 1989, pp. 58–70.

[14]Chemical & Engineering News. Atomic-Emission Detector for Gas Chromatography Introduced. V. 67, No. 3, 1989, pp. 37–38.

[15]——. Rising Bromine Levels Threaten Ozone Layer. V. 66, No. 34, 1988, p. 6.

[16]——. Science/Technology Concentrates. V. 66, No. 50, 1988, p. 22.

CADMIUM

By Thomas O. Llewellyn[1]

Cadmium metal production in the United States increased significantly in 1988, and four companies operating four plants produced all of the domestic cadmium. Imports for consumption of cadmium metal decreased, but exports increased. Dramatic increases in cadmium prices in 1988 were attributed to the tight supply of cadmium, heavy speculative trading, and the large quantities of cadmium being bought by the nickel-cadmium battery industry, particularly in Japan. The New York dealer-price range of cadmium metal, at $3.00 to $3.20 per pound at the beginning of the year, increased dramatically by yearend to $8.20 to $8.50 per pound.

DOMESTIC DATA COVERAGE

Domestic production data for cadmium metal and compounds are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the four metal-producing plants to which a survey request was sent, all responded, representing 100% of the total cadmium metal production shown in tables 1 and 3. Of the 11 operations that produced cadmium compounds to which a survey request was sent, all responded, representing 100% of the cadmium content of production of cadmium compounds shown in table 2.

LEGISLATION AND GOVERNMENT PROGRAMS

Under section 110 of the Superfund Amendments and Reauthorization Act of 1986 (Public Law 99-499), the U.S. Department of Health and Human Services and the Environmental Protection Agency were directed to prepare a list of the most hazardous substances found in designated Superfund sites, and develop toxicological profiles for each of the substances. Cadmium was included on a list of the 100 most hazardous substances published on April 17, 1987, in the Federal Register. A draft toxicological profile for cadmium published by the Agency for Toxic Substances and Disease Registry, U.S. Public Health Service, was issued in November 1987, and the public comment period ended on February 22, 1988.[2] The final issue of the toxicological profile for cadmium was expected to be published during the first half of 1989.

On February 25, 1988, the President signed Executive Order 12616, designating the Secretary of Defense to be the manager of the National Defense Stockpile (NDS).[3] The Office of the Secretary of Defense delegated operational management functions of the NDS to the Defense Logistics Agency. Previously, the NDS responsibilities were distributed among the U.S. Department of Defense, the Federal Emergency Management Agency, and the General Services Administration.

The NDS goal for cadmium metal remained at 5,307 metric tons. No inventory acquisitions or sales were made during the year, and as of December 31, 1988, the stockpile inventory was 2,871 tons of cadmium metal.

DOMESTIC PRODUCTION

Domestic production of cadmium metal increased significantly in 1988, due to continued strong world demand and very high prices. AMAX Inc. sold its zinc subsidiary in Sauget, IL, to Big River Minerals Corp., a private investment corporation based in St. Louis, MO. The Sauget plant was the largest domestic producer of cadmium. The new owners renamed the Sauget operation Big River Zinc Corp. and retained most of its employees. Terms of the AMAX sale were not disclosed.

Cadmium metal also was produced by ASARCO Incorporated, Denver, CO; Jersey Minière Zinc Co., Clarksville, TN; and Zinc Corp. of America (ZCA), Bartlesville, OK.

TABLE 1

SALIENT CADMIUM STATISTICS

		1984	1985	1986	1987	1988
United States:						
Production[1]	metric tons	1,686	1,603	1,486	1,515	1,885
Shipments by producers[2]	do.	1,811	1,791	2,030	1,916	2,074
Value	thousands	$2,581	$2,436	$1,883	$1,861	$5,389
Exports	metric tons	106	86	38	241	613
Imports for consumption, metal	do.	1,889	1,988	3,174	2,701	2,482
Apparent consumption	do.	3,300	3,720	4,385	4,178	3,620
Price, average per pound, in 1 to 5 short ton lots:						
New York dealer		$1.32	$0.92	$1.07	$1.60	$6.91
Producer		$1.69	$1.21	$1.25	$1.99	[3]$7.90
World: Refinery production	metric tons	[r]19,617	[r]19,063	19,064	[p]18,996	[e]19,773

[e]Estimated. [p]Preliminary. [r]Revised.
[1] Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.
[2] Includes metal consumed at producer plants.
[3] Major cadmium producers stopped quoting a published price for cadmium metal effective Sept. 1988. Producer price average of Jan.-Aug. 1988.

TABLE 2

U.S. PRODUCTION OF CADMIUM COMPOUNDS

(Metric tons, cadmium content)

Year	Cadmium sulfide[1]	Other cadmium compounds[2]
1984	771	1,510
1985	477	1,021
1986	645	1,459
1987	540	1,511
1988	345	1,497

[1] Includes cadmium lithopone and cadmium sulfoselenide.
[2] Includes plating salts and oxide.

CONSUMPTION AND USES

The apparent consumption of cadmium in 1988 was 13% lower than that of 1987, mainly because of the exceptionally high price of the metal.

The Bureau of Mines does not collect actual consumption data. However, an estimated apparent consumption pattern for 1988 was as follows: batteries, 32%; coating and plating, 29%; pigments, 15%; plastics and synthetic products, 15%; and alloys and other uses, 9%.

TABLE 3

SUPPLY AND APPARENT CONSUMPTION OF CADMIUM

(Metric tons)

	1986	1987	1988
Stocks, Jan. 1	686	923	720
Production	1,486	1,515	1,885
Imports for consumption, metal	3,174	2,701	2,482
Total supply	**5,346**	**5,139**	**5,087**
Exports	38	241	613
Stocks, Dec. 31	923	720	854
Consumption, apparent[1]	4,385	4,178	3,620

[1] Total supply minus exports and yearend stocks.

The Cadmium Council Inc., which is the trade association for the North American cadmium industry, was reorganized in 1988. Membership in the reorganized Cadmium Council increased and now it represents most of the domestic primary cadmium metal and oxide producers, together with consumers in the pigment, battery, stabilizer, and electroplating sectors.

STOCKS

Total inventories of cadmium metal increased to a level that was approximately double that of 1987. Total stocks of cadmium in compounds decreased about 19%.

PRICES

The two major cadmium producers, Big River and ZCA, stopped quoting a price for cadmium metal effective September 1988, and subsequently Metals Week discontinued publishing U.S. producer prices for cadmium.

The New York dealer price of cadmium metal continued a 2-year trend of sharp increases. The dealer price of cadmium at the beginning of 1988 ranged from \$3.00 to \$3.20 per pound, which was three times the price range quoted at the beginning of 1987. A dramatic second round of price hikes took place in February 1988, and the dealer price quotation increased to a range between \$6.80 to \$7.10 per pound. The market was so tight during this period that major cadmium producers did not have any material to sell on the spot market and would not make commitments for near-term sales at a specific price. In March, the cadmium market gained momentum once more, and the New York dealer price ranged from \$8.50 to \$9.10 per pound. The prices for cadmium metal fluctuated during the next few months but trended downward and by mid-October ranged from \$5.70 to \$6.00 per pound. During the last 2 months of 1988, prices increased considerably and closed the year in the range of \$8.20 to \$8.50 per pound. The 1988 price increases were attributed to the tight supply of cadmium, heavy speculative trading, and world labor disputes. The supply squeeze was further affected by the large quantities of cadmium purchased by the nickel-cadmium battery industry, particularly in Japan.

FOREIGN TRADE

Exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap increased in 1988, continuing an upward trend that started in the previous year. Japan, the Federal Republic of Germany, the United King-

TABLE 4

INDUSTRY STOCKS, DECEMBER 31

(Metric tons)

	1987		1988	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	126	W	332	W
Compound manufacturers	98	457	128	372
Distributors	37	2	21	1
Total	**261**	**459**	**481**	**373**

W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."

dom, and Mexico, in descending order of receipts, received about 93% of total exports. Cadmium metal imports for consumption in 1988 continued to decline but at a lower rate compared with that of 1987. The principal supplying countries, in descending order of receipts, were Canada, Mexico, the Federal Republic of Germany, and Australia.

The Bureau of the Census reported that the United States exported nearly 10.5 million nickel-cadmium batteries in 1988, most of which went to Hong Kong. Imports of nickel-cadmium batteries, including those incorporated into other products, totaled about 139 million batteries. Japan, Hong Kong, and Mexico supplied approximately 90% of total battery imports.

Under the new Harmonized Tariff Schedule of the United States, which was to be in effect January 1, 1989, cadmium sulfide and pigments and preparations based on cadmium compounds from most favored nations (MFN) were subject to a 3.1% ad valorem duty and for non-MFN a 25% ad valorem duty was imposed. For unwrought cadmium, waste and scrap, and powders, imports from MFN were duty free. A statutory duty of 33 cents per kilogram was imposed on these materials from non-MFN.

WORLD CAPACITY

The data in table 7 represent rated capacity for mines and refineries on December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in

TABLE 5

U.S. EXPORTS OF CADMIUM METAL AND CADMIUM IN ALLOYS, DROSS, FLUE DUST, RESIDUES, AND SCRAP

Year	Quantity (metric tons)	Value (thousands)
1986	38	$188
1987	241	660
1988	613	3,697

Source: Bureau of the Census.

FIGURE 1

AVERAGE ANNUAL PRICE OF CADMIUM METAL, DOLLARS PER POUND

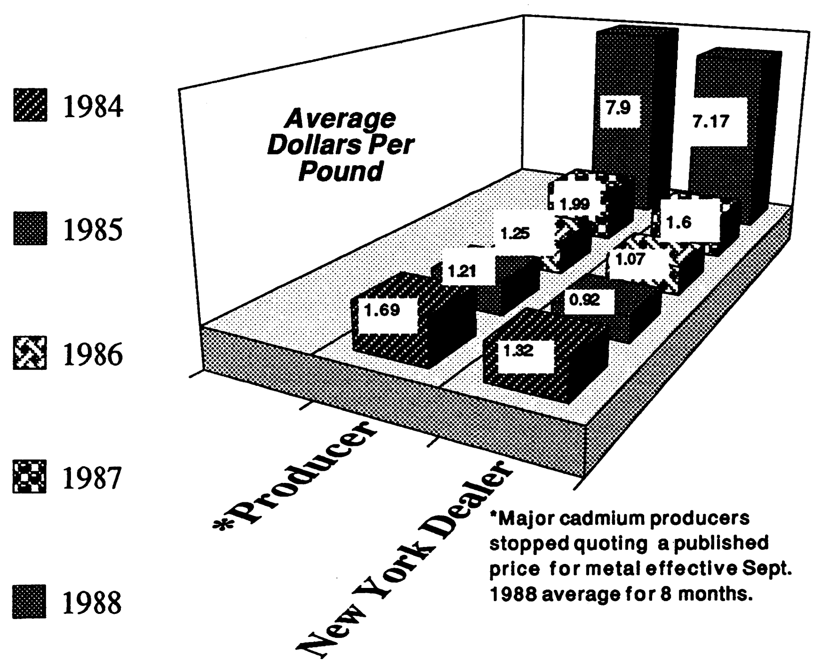

TABLE 6

U.S. IMPORTS FOR CONSUMPTION[1] OF CADMIUM METAL, BY COUNTRY

Country	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Argentina	—	—	31	$331
Australia	427	$1,201	309	4,462
Belgium-Luxembourg[2]	18	36	19	44
Brazil	—	—	80	1,099
Canada[3]	1,164	3,503	858	9,816
China	117	283	25	360
Finland[3]	25	62	30	371
France	6	19	—	—
Germany, Federal Republic of	272	764	372	4,979
Japan	3	8	—	—
Korea, Republic of	10	44	—	—
Mexico	496	1,524	590	7,670
Namibia	5	22	5	40
Netherlands	5	13	26	113
Norway	27	54	—	—
Peru	70	188	5	39
Poland	—	—	12	75
South Africa, Republic of	—	—	([4])	2
Spain	—	—	55	465
Taiwan	[3]37	[3]57	42	68
United Kingdom[3]	20	40	23	1,147
Total[5]	**2,701**	**7,818**	**2,482**	**31,081**

[1] General imports and imports for consumption were the same in 1987 and 1988.
[2] For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
[3] Includes waste and scrap (gross weight).
[4] Less than 1/2 unit.
[5] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 7

WORLD CADMIUM ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Metric tons, cadmium content)

	Mine	Refinery
North America:		
Canada	4,600	2,000
Mexico	2,100	1,300
United States	1,800	3,100
Total	**8,500**	**6,400**
Central America	350	—
South America:		
Peru	1,900	650
Other	800	250
Total	**2,700**	**900**
Europe	8,000	11,400
Africa	1,100	700
Asia:		
Japan	850	5,100
Other	2,900	1,500
Total	**3,750**	**6,600**
Oceania: Australia	2,350	1,300
World total	**[1]26,800**	**27,300**

[1] Data do not add to total because of independent rounding.

the judgment of the author can be brought into production within a short period with minimum capital expenditure.

Cadmium is principally a byproduct of zinc production. Therefore, cadmium mine capacity was estimated based on zinc mine capacity, and cadmium refinery capacity was estimated based on rated zinc refinery capacity, discussions with officials from private industry, past and present production rates, the author's knowledge of the type of facility, and published capacity data.

WORLD REVIEW

The European Community issued a draft proposal to tighten controls on the disposal of batteries containing more than 25 milligrams of mercury, or more than 0.025% cadmium by weight, or more than 0.4% lead. The proposal was aimed at reducing the hazard to health and the environment resulting from the leaching of the metals contained in such batteries into water or from emissions generated by municipal waste incinerators. Under the proposal, each member state would be required to submit plans for recycling programs every 4 years. The first formal proposal was to be submitted before July 1, 1989.[4]

France

Société d'Accumulateurs Fixés et de Traction (SAFT) of France formed a new subsidiary, SAFT China, located in Shekow in the Province of Guangdong, China. The manufacturing equipment for this new plant was designed by SAFT American Portable Battery Div. in Valdosta, GA. The new plant would produce sealed nickel-cadmium batteries and would guarantee a place for SAFT in the market in the Far East for these products.[5]

Mexico

Sanyo Electric Co. Ltd. opened a plant in Tijuana, Mexico, to produce rechargeable nickel-cadmium batteries for markets in North America. The new plant had an initial design capacity of 800,000 units per month of batteries for fast-charging, high-temperature, heat-resistant, and memory applications.[6]

TECHNOLOGY

The Cadmium Association, England; the Cadmium Council Inc., New York; and the International Lead Zinc Research Organization Inc., North Carolina, published the Proceedings of the Fifth International Cadmium Conference held in San Francisco, CA, February 1986. The proceedings presented an excellent review of all aspects of the use of cadmium together with health and environmental problems associated with the metal.[7] Developments in cadmium technology during the year were abstracted in Cadscam, a quarterly publication available through the Cadmium Association, 42 Weymouth Street, London, WIN 3LQ, England.

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Toxicological Profile for Cadmium (U.S. EPA contract 68-02-4228, Life Systems Inc.). Oak Ridge National Lab., Nov. 1987, 112 pp.

[3] Federal Register. National Defense Stockpile Manager. V. 53, No. 39, Feb. 29, 1988, p. 6114.

[4] JEC Battery Newsletter. No. 5—Set. Oct. 1988, p. 12.

[5] Advanced Battery Technology. V. 27, No. 10, Oct. 1988, p. 1.

[6] ———. V. 24, No. 7, July 1988, p. 2.

[7] Wilson, D., and R. A. Volpe (ed.). Cadmium 86. (Fifth International Cadmium Conference, San Francisco, CA, 1986), Feb. 1988, 174 pp.

TABLE 8

CADMIUM: WORLD REFINERY PRODUCTION,[1] BY COUNTRY

(Metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Algeria	80	128	124	[e]125	125
Argentina	46	46	47	46	40
Australia	1,082	910	915	950	900
Austria	49	52	52	26	20
Belgium	[r]1,476	1,252	1,374	1,308	1,450
Brazil	225	[r]224	233	214	[2]283
Bulgaria[e]	200	200	200	180	180
Canada	1,605	1,717	1,484	1,481	[2]1,742
China[e]	[r]450	[r]540	[r]650	[r]680	700
Finland	614	565	522	690	650
France	568	337	431	400	400
German Democratic Republic[e]	15	15	18	18	18
Germany, Federal Republic of	1,111	1,095	1,218	1,125	1,150
India	148	194	[e]160	214	240
Italy	452	526	411	320	300
Japan	2,423	2,535	2,489	2,450	2,560
Korea, North[e]	100	100	100	100	100
Korea, Republic of	320	—	—	—	—
Mexico	838	905	1,016	935	900
Namibia	40	58	61	51	50
Netherlands	636	594	557	517	500
Norway	150	159	154	147	145
Peru	390	[e]420	438	461	360
Poland[e]	570	600	600	600	600
Romania[e]	75	75	75	75	75
Spain	290	268	247	297	300
U.S.S.R.[e]	3,000	3,000	3,000	3,000	3,000
United Kingdom	390	370	379	467	500
United States[3]	1,686	1,603	1,486	1,515	[2]1,885
Yugoslavia	270	279	259	305	300
Zaire	318	296	364	299	300
Total	**[r]19,617**	**[r]19,063**	**19,064**	**18,996**	**19,773**

[e] Estimated. [p] Preliminary. [r] Revised.

[1] This table gives unwrought production from ores, concentrates, flue dusts, and other materials of both domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included; where known, this has been indicated by a footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, London) and from Metal Statistics (published by Metallgesellschaft Aktiengesellschaft, Frankfurt am Main). Cadmium is found in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not reported in this table to avoid double counting. Table includes data available through Apr. 5, 1989.

[2] Reported figure.

[3] Includes secondary.

CALCIUM AND CALCIUM COMPOUNDS

By David E. Morse[1]

Calcium, the fifth most abundant element in the Earth's crust, is chemically very active and is found in a host of minerals that occur in nearly every geologic environment. The Bureau of Mines publishes reports for a variety of calcium-containing minerals and compounds because of their commercial significance and contribution to the quality of human life. Calcium fluoride is sold as fluorspar; calcium sulfate as gypsum or anhydrite; calcium oxide and hydroxide as lime; calcium phosphate (apatite) as phosphate rock; and calcium carbonate as either limestone, marble, calcareous marl or shell. Information on these commodities can be obtained in the chapters of the Bureau of Mines Minerals Yearbook entitled "Fluorspar," "Gypsum," "Lime," "Phosphate Rock," "Crushed Stone," and "Dimension Stone." Other calcium compounds are discussed in the chapter concerning the element with which calcium is combined; for example, calcium bromide is covered in the "Bromine" chapter. This chapter includes calcium metal, calcium chloride, and various other calcium compounds not covered elsewhere.

Calcium metal was manufactured by one company in Connecticut. Natural calcium chloride was produced by three companies in California, two companies in Michigan, and one company in Washington. Synthetic calcium chloride was manufactured by two companies in Louisiana and one company in Washington.

DOMESTIC DATA COVERAGE

The Bureau of Mines develops domestic production data for calcium chloride from a voluntary survey of U.S. operations entitled "Calcium Chloride and Calcium-Magnesium Chloride." Of the 10 operations polled, 8 responded, representing less than one-half of the total production shown in table 1. Production for the nonrespondents was estimated using published plant capacity and information from trade journals and research reports.

DOMESTIC PRODUCTION

Pfizer Inc. produced calcium metal at Canaan, CT, by the Pidgeon process, in which high-purity calcium oxide (produced by calcining limestone) and aluminum powder are briquetted and heated in vacuum retorts. The vaporized calcium metal product collects as a crown in a water-cooled condenser.

Pfizer produced commercial-grade 98.5% calcium in seven shapes, high-purity redistilled 99.2% metal in four shapes, and an 80%-20% calcium-magnesium alloy. Pfizer also produced a 75%-25% calcium-aluminium alloy for maintenance-free batteries and a pure calcium wire used in the steel industry to modify inclusions. Elkem Metals Co., a Norwegian-owned company with headquarters at Pittsburgh, PA, produced calcium alloys at its plant in Alloy, WV, including a calcium-silicon alloy containing about 30% calcium, 65% silicon, and 5% iron, and two proprietary alloys that contain barium, and barium and aluminum. ASARCO Incorporated and the Pesses Co. also produced calcium alloys.

Michigan was the leading State in natural calcium cloride production; California was a distant second. The Dow Chemical Co. and Wilkinson Chemical Corp. recovered calcium chloride from brines in Lapeer and Mason Counties, MI. Dow's Ludington plant produced calcium chloride pellets and flake; Wilkinson marketed calcium chloride solutions only. National Chloride Co. of America, Cargill Inc.'s Leslie Salt Co., and Hill Bros. Chemical Co. produced calcium chloride from dry-lake brine wells in San Bernardino County, CA. Hill Bros. Chemical also produced from a second operation near Cadiz Lake, CA. Tahoma Chemical Co. Inc. produced natural calcium chloride in Washington State.

Allied Signal Inc. recovered synthetic calcium chloride as a byproduct at its Baton Rouge, LA, plant using hydrochloric acid and limestone; Texas United Chemical Corp. produced calcium chloride from purchased hydrochloric acid and limestone at its plant near Lake Charles, LA; and Occidental Chemical Corp. manufactured calcium chloride at Tacoma, WA, using limestone and hydrochloric acid.

Calcium hypochlorite was produced by Olin Corp. and PPG Industries Inc. Total domestic calcium hypochlorite capacity was 165,000 tons per year.

TABLE 1

U.S. PRODUCTION OF CALCIUM CHLORIDE (75% $CaCl_2$ EQUIVALENT)

(Thousand short tons and thousand dollars)

Year	Natural		Synthetic		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1984[e]	838	93,000	198	31,500	1,036	125,000
1985	W	W	W	W	940	135,000
1986	W	W	W	W	780	109,000
1987[e]	W	W	W	W	773	87,400
1988[e]	W	W	W	W	657	86,700

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

CONSUMPTION AND USES

Calcium metal was used in the manufacture of batteries, as an aid in removing bismuth in lead refining, as a desulfurizer and deoxidizer in steel refining, and as a reducing agent to recover refractory metals such as chromium, rare earths, and thorium from their oxides. Some minor uses were in the preparation of vitamin B and chelated calcium supplements, and as a cathode coating in some types of photoelectric tubes. Calcium metal was used to reduce uranium dioxide, a fuel in some types of fission reactors. The nuclear applications of calcium metal gave it strategic significance; the U.S. Department of State would not permit sales to countries not signatory to the United Nations Nuclear Nonproliferation Treaty.

Calcium chloride was used to deice pavements, to control dust, to stabilize road bases, to thaw coal and other bulk materials, in oil and gas drilling, for concrete-set acceleration, as tire ballasting, and in miscellaneous uses. The principal use of calcium chloride was to melt snow and ice from roads. Calcium chloride is more effective at lower temperatures than rock salt and has been used mainly in the Northern and Eastern States. Because of its considerably higher price, it was used in conjunction with rock salt for maximum effectiveness and economy.

Calcium hypochlorite was used to disinfect swimming pools, which accounted for 85% of domestic demand, and in other municipal and industrial bleaching and sanitation processes. It was used as an algicide, bactericide, deodorant, water purifier, disinfectant, fungicide, and bleaching agent.

Calcium nitrate was used as a concrete additive to inhibit corrosion of steel reinforcement bars, accelerate setting time, and enhance strength.

Calcium carbide and calcium-silicon alloy were used to remove sulfur from molten pig iron as it was carried in transfer ladles from the blast furnace to the steelmaking furnace.

Precipitated calcium carbonate was used as a pigment for brightness and opaqueness in premium-quality coated and uncoated papers.

PRICES AND SPECIFICATIONS

The published price of calcium metal crowns in quantities greater than 20,000 pounds was unchanged from the quote of January 1987. The published price of calcium-silicon alloy remained unchanged. Yearend published prices and specifications were as follows:

	Value per pound 1987	Value per pound 1988
Calcium metal, 1-ton lots, 50-pound full crowns, 10 by 18 inches, Ca + Mg 99.5%, Mg 0.7	$3.92	$3.92
Calcium-silicon alloy, 32% calcium, carload lots, f.o.b. shipping point	.72	.72

Source: Metals Week. V. 58, No. 52, 1987, p. 5; v. 59, No. 52, 1988, p. 5.

Calcium metal was usually sold in the form of crowns, broken crown pieces or nodules, or billets, which were produced by melting crowns in an argon atmosphere. The metal purity in these forms was at least 98%. Higher purity metal was obtained by redistillation. Calcium metal was usually shipped in polyethylene bags under argon in airtight steel drums.

Calcium chloride was sold as flake or pellet averaging about 75% $CaCl_2$, or as a liquid concentrate averaging 40% $CaCl_2$. Yearend 1988 published prices and specifications were as follows:

	Value per short ton
Calcium chloride concentrate, regular grade, 77% to 80%, flake, bulk, carload, works	$153.00
100-pound bags, carload, same basis	196.00
Anhydrous, 94% to 97%, flake or pellet, bulk, carload, same basis	217.00
80-pound bags, carload, same basis	279.00
Brining grade, 80-pound bags	285.00
Calcium chloride liquid, 100% basis, tank car, tank truck, barge	99.75
45%, same basis	118.00
Calcium chloride, United States Pharmacopeia, granular, 225-pound drums, truckload, freight equalized	1,580.00

Source: Chemical Marketing Reporter. V. 235, No. 1, Jan. 2, 1989, p. 27.

FOREIGN TRADE

U.S. exports of calcium chloride decreased significantly in 1988; exports to Canada, the largest importer, were less than one-half the reported quantity in 1987. Calcium hypochlorite was exported in small quantities to 79 countries worldwide for an export value of $35 million, or an increase of $7 million compared with that of 1987. Exports of calcium phosphates, which were used as a feed additive for livestock, were valued at $78.4 million and went to over 50 countries, primarily in the Western Hemisphere. The combined customs value for exported calcium borate, calcium carbide, calcium chloride, and other calcium compounds was $13 million.

Imports for consumption of calcium metal increased 89% in quantity and were from seven countries. China supplied nearly 50%; the U.S.S.R., about 33%; France, 8%; Canada, 7%; and others, 2%. Imports of crude calcium chloride decreased slightly. Canada supplied more than 75% of U.S. imports.

WORLD REVIEW

Calcium metal was produced in Canada, China, France, Japan, and the U.S.S.R., in addition to the United States. Market economy country production was estimated to be about 1,500 short tons. Total world production was an estimated 2,200 tons. Calcium chloride was a byproduct of synthetic soda ash production, especially in Eastern and Western Europe, and in many cases it was treated as a waste product. The calcium chloride brine from many facilities was dumped into rivers and estuaries. This practice, because of increased pressure from Government agencies and environmental interest groups, was expected to be severely curtailed, which could significantly increase the quantity of calcium chloride available.

[1] Physical scientist, Branch of Industrial Minerals.

TABLE 2

U.S. EXPORTS OF CALCIUM CHLORIDE, BY COUNTRY

Country	1987		1988	
	Short tons	Value [1]	Short tons	Value [1]
Canada	28,718	$4,007,252	12,156	$2,046,478
Mexico	704	231,133	1,088	279,933
Netherlands	471	686,332	516	130,960
Sweden	524	216,624	445	272,229
Switzerland	857	179,986	1,543	283,105
United Arab Emirates	330	50,226	465	78,327
Venezuela	1,159	400,180	76	91,131
Other	1,955	885,566	2,421	2,350,233
Total	**34,718**	**6,657,299**	**18,710**	**5,532,396**

[1] U.S. Customs declared value.

Source: Bureau of the Census.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF CALCIUM AND CALCIUM CHLORIDE

Year	Calcium		Crude calcium chloride		Other calcium chloride	
	Pounds	Value [1]	Short tons	Value [1]	Short tons	Value [1]
1984	248,973	$669,586	21,803	$1,341,166	275	$475,749
1985	492,244	1,395,198	75,381	9,059,352	2,355	1,907,976
1986	566,170	1,310,084	143,328	14,403,393	2,098	1,263,552
1987	776,225	1,918,099	229,964	20,916,867	1,282	706,370
1988	1,464,794	3,243,663	221,926	21,215,695	3,530	1,796,714

[1] U.S. Customs, insurance, freight.

Source: Bureau of the Census.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF CALCIUM CHLORIDE, BY COUNTRY

Country	1987		1988	
	Short tons	Value [1]	Short tons	Value [1]
Crude:				
Canada	180,786	$13,533,501	177,159	$13,158,601
Germany, Federal Republic of	18,957	2,234,665	13,061	2,023,953
Mexico	5,422	952,860	17,096	3,130,215
Sweden	11,219	1,479,925	2,780	365,755
Other	13,580	2,715,916	11,830	2,537,171
Total	**229,964**	**20,916,867**	**221,926**	**21,215,695**
Other:				
Canada	489	433,831	690	492,281
Germany, Federal Republic of	54	83,699	319	496,070
Sweden	2	2,927	5	5,887
Other	737	185,913	2,515	802,476
Total	**1,282**	**706,370**	**[2]3,530**	**1,796,714**

[1] U.S. Customs, insurance, freight.
[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 5

U.S. IMPORTS OF OTHER CALCIUM COMPOUNDS

	1987		1988	
	Short tons	Value [1]	Short tons	Value [1]
Calcium borate (crude)	19,149	$3,326,187	25,132	$5,828,965
Calcium bromide	4,038	1,016,511	4,725	1,558,272
Calcium carbide	15,881	5,502,804	18,161	6,843,414
Calcium carbonate, precipitated	16,001	7,883,693	14,065	7,634,854
Calcium carbonate, chalk whiting	5,319	1,174,752	5,534	1,376,203
Calcium carbonate, (crude) natural chalk	[r]257,360	1,596,521	352,371	1,887,045
Calcium cyanamide	2,422	1,172,710	3,535	1,592,096
Calcium hypochlorite	8,192	11,811,590	5,278	7,834,702
Calcium nitrate	[r]151,699	16,505,195	171,054	19,463,769
Dicalcium phosphate	2,161	2,301,958	2,623	2,688,120
Limestone for fertilizer manufacture	[r]422,443	3,605,978	357,794	2,578,255
Total	**XX**	**55,897,899**	**XX**	**59,285,695**

[r] Revised. XX Not applicable.
[1] U.S. Customs declared value.

Source: Bureau of the Census.

CEMENT

By Wilton Johnson[1]

U.S. demand for cement declined slightly, following 5 consecutive years of growth. The value of new construction put in place increased slightly, precipitated by small increases in public works construction activity. Among the consuming regions of the country only the East North Central, Pacific, and South Atlantic regions experienced gains in cement consumption.

Domestic production declined for the third year in a row as producers continued to rely on lower cost imports to fill the supply-demand gap. The average reported per ton value of portland cement sold declined to its lowest level since 1979. The value of masonry cement sold also declined, after reaching a record high in 1987.

Acquisition of U.S. cement plants continued. By yearend, approximately 65% of U.S. cement production capacity had been acquired by foreign owners.

DOMESTIC DATA COVERAGE

Domestic production and consumption data for cement are developed by means of the portland and masonry cement voluntary survey. Of the 131 cement manufacturing plants to which an annual survey collection request was made, 130 responded, representing 99.2% of the cement production and consumption data shown in table 1. Estimates were made for the one nonrespondent using prior year data.

DOMESTIC PRODUCTION

One State agency and 49 companies operated 131 plants in 39 States. In addition, two companies operated two plants in Puerto Rico, manufacturing hydraulic cement.

Some of the data are arranged by State or by groups of States that form cement districts. A cement district may represent a group of States or a portion of a State. The States of California, Illinois, New York, Pennsylvania, and Texas are divided to provide more definitive marketing information within those States. Divisions for these States are as follows:

California, Northern.—Points north and west of the northern borders of San Luis Obispo and Kern Counties and the western borders of Inyo and Mono Counties.

California, Southern.—All other counties in California.

Chicago, Metropolitan.—The seven Illinois counties of Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will.

Illinois.—All other counties in Illinois.

New York, Western.—All counties west of a dividing line following the eastern boundaries of St. Lawrence, Lewis, Oneida, Madison, Chenango, and Broome Counties.

New York, Eastern.—All counties east of the above dividing line, except Metropolitan New York.

New York, Metropolitan.—The five counties of New York City (Bronx, Kings, New York, Queens, and Richmond) plus Westchester, Rockland, Suffolk, and Nassau Counties.

Pennsylvania, Eastern.—All counties east of the eastern boundaries of Potter, Clinton, Centre, Huntingdon, and Franklin Counties.

Pennsylvania, Western.—All other counties in Pennsylvania.

Texas, Northern.—All counties north of a dividing line following the northern borders of Burnet, Crockett, Jasper, Jeff Davis, Llano, Madison, Mason, Menard, Milam, Newton, Pecos, Polk, Robertson, San Jacinto, Schleicher, Tyler, Walker, and Williamson Counties.

Texas, Southern.—All counties south of the above dividing line.

TABLE 1

SALIENT CEMENT STATISTICS

(Thousand short tons unless otherwise specified)

	1984	1985	1986	1987	1988
United States:[1]					
Production[2]	77,700	77,895	78,786	78,198	76,867
Shipments from mills[2 3]	80,166	83,032	87,592	89,131	89,015
Value[2 3 4] thousands	$4,152,258	$4,286,399	$4,407,722	$4,393,684	$4,370,463
Average value per ton[2 3 4]	$51.80	$51.61	$50.32	$49.29	$49.10
Stocks at mills,[2] Dec. 31	6,866	7,232	6,725	6,159	5,997
Exports	80	98	59	52	101
Imports for consumption	8,689	14,120	16,128	17,536	17,366
Consumption, apparent[5 6]	84,313	87,456	91,501	93,886	93,256
World: Production	[r]1,037,321	[r]1,057,489	1,100,908	[p]1,151,060	[e]1,212,724

[e]Estimated. [p]Preliminary. [r]Revised.
[1] Excludes Puerto Rico and the Virgin Islands.
[2] Portland and masonry cement only.
[3] Includes imported cement shipped by domestic producers.
[4] Value received, f.o.b. mill, excluding cost of containers.
[5] Quantity shipped plus imports minus exports.
[6] Adjusted to eliminate duplication of imported clinker and cement shipped by domestic cement manufacturers.

Clinker Production

Clinker production in the United States, excluding Puerto Rico, increased slightly to 69.2 million tons. California continued to lead all States in clinker production, accounting for approximately 14% of the total. More than two-thirds of the clinker came from eight plants in the southern part of the State. Texas followed with about 10% of total production. Pennsylvania ranked third, with most of the clinker produced at plants in the eastern part of the State, followed by Michigan and Missouri. Together, these five States accounted for 45% of total U.S. clinker production.

By yearend, multiplant operations were being run by 23 companies. The size of individual companies, as a percentage of total U.S. clinker production capacity, ranged from 0.2% to 7%. The 5 largest producers provided 28% of total clinker production; the 10 largest producers provided a combined 48%. The 10 largest companies, in decreasing order of size of clinker production, were Lone Star Industries Inc., General Portland Inc., Lehigh Portland Cement Co., Blue Circle Industries PLC, Dundee Cement Co., Ideal Basic Industries Inc., Southwestern Portland Cement Co., Gifford-Hill & Co. Inc., Coplay Cement Co., and CalMat Co.

Portland Cement

Portland cement production declined slightly to 73.3 million tons. This was the second straight year of decline following 3 consecutive years of growth. The decline was attributed to greater reliance on imports of finished cement to fill the supply-demand gap.

Because several plants were either closed or were utilized as distribution terminals during the year, finished cement grinding capacity declined 3% to 98.7 million tons, but the capacity utilization rate increased slightly to 74.3%.

The industry operated 131 cement producing plants including 9 grinding facilities to produce various types of finished hydraulic cement, compared with 134 plants in 1987. California continued to lead all States with 14% of production, followed by Texas and Pennsylvania with 9% each, Michigan with 7%, and Missouri with 6%. Together these five States accounted for 45% of total U.S. cement production.

The size of individual companies, as a percentage of total U.S. finished cement production capacity, ranged from 0.1% to 7.5%. The top 10 producing companies, in declining order of production, were Lone Star Industries Inc., General Portland Inc., Ideal Basic Industries Inc., Dundee Cement Co., Lehigh Portland Cement Co., Blue Circle Industries PLC, Gifford-Hill & Co., Coplay Cement Co., Southwestern Portland Cement Co., and CalMat Co.

Masonry Cement

Production of masonry cement remained essentially unchanged. At yearend, 87 plants were manufacturing masonry cement in the United States. Two plants producing masonry exclusively were Chaney Lime & Cement Co., Allgood, AL; and Riverton Corp., Riverton, VA.

Aluminous Cement

Aluminous cement, also known as calcium aluminate cement, high-alumina cement, and Cement Fondu, is a nonportland hydraulic cement. It continued to be produced at the following three plants in the United States: Lehigh, Buffington, IN; Lone Star Lafarge Inc., Chesapeake, VA; and Aluminum Co. of America, Bauxite, AR.

Plant Closings

Four plants were taken out of production during the year because of either declining markets or increased competition from imports. Lone Star ceased production at its New Orleans, LA, and Salt Lake City, UT, plants. The New Orleans plant was leased to Ideal Basic Industries, and the Salt Lake City plant was leased to Mountain Cement Co. Both plants were expected to be used as distribution terminals. The Lone Star/Moore McCormack joint venture plant in Superior, OH, was closed. Allied Products Co. closed its Birmingham, AL, plant and began using it as a distribution terminal for shipping cement purchased from Ideal Basic's Theodore, AL, plant.

Corporate Changes

CalMat Co. reached an agreement with Onoda USA, a subsidiary of Onoda Cement Co. Ltd. of Japan, that would give Onoda an option to acquire CalMat's cement and ready-mix concrete operations in the Los Angeles metropolitan area and Arizona. Cimentaries CBR of Belgium purchased the Bellingham, WA, cement plant from Columbia Northwest Cement Co. Cementa AB sold its Hanibal, MO, cement plant to a joint venture formed between Scancem and Materials Services Corp. of Chicago. Dragon Cement Co., owned by the Passamaquoddy Indian Tribe, sold its Thomaston, ME, cement plant to CDN USA, a Massachusetts based subsidiary of Cementos del Norte of Spain. Kaiser Cement Co., a subsidiary of Hanson Trust PLC of the United Kingdom, sold its Lucern Valley, CA, plant to Longhorn Cement Co., a subsidiary of the Italian firm Presa S.P.A. Lone Star Industries formed joint ventures with Kosmos Cement Co. to operate plants at Kosmosdale, KY, and Pittsburgh, PA, with RMC Group P.L.C. of the United Kingdom to operate its Davenport, CA, plant. Lone Star leased its plant and two terminals near Miami, FL. to Tarmac Roadstone USA of the United Kingdom, with the option to purchase at a future date. The Moore McCormack Resources Knoxville, TN, plant was purchased by Southdown, Inc., and its Glens Falls, NY, plant was purchased by Dyckerhoff A.G. of Wiesbaden, Federal Republic of Germany. Monolith Portland Cement Co. sold its Monolith, CA, plant to Cimentaries CBR of Belgium. Rinker Materials Corp. sold its Miami, FL, plant to CSR Ltd, (Colonial Sugar Refineries) of Australia, and National Portland Cement

TABLE 2

PORTLAND CEMENT PRODUCTION, CAPACITY, AND STOCKS IN THE UNITED STATES, BY DISTRICT[1]

District	1987					1988				
	Plants active during year	Production[2] (thousand short tons)	Capacity[3]		Stocks[4] at mills, Dec. 31 (thousand short tons)	Plants active during year	Production[2] (thousand short tons)	Capacity[3]		Stocks[4] at mills, Dec. 31 (thousand short tons)
			Finish grinding (thousand short tons)	Percent utilized				Finish grinding (thousand short tons)	Percent utilized	
New York and Maine	5	3,720	4,068	91.4	254	5	3,459	4,265	81.1	310
Pennsylvania, eastern	8	4,759	5,734	82.9	293	8	4,840	5,821	83.1	308
Pennsylvania, western	4	1,538	2,417	63.6	162	4	1,523	2,417	63.0	169
Maryland	3	1,863	2,035	91.5	139	3	1,824	2,030	89.8	143
Ohio	5	1,717	2,460	69.8	164	4	1,495	2,200	67.9	147
Michigan	5	4,925	6,442	76.5	341	5	5,127	6,090	84.1	348
Indiana	4	2,692	2,732	98.5	178	4	2,629	3,140	83.7	188
Illinois	4	1,731	2,548	67.9	308	4	2,033	2,580	78.7	196
Georgia and Tennessee	4	2,194	2,565	85.5	186	4	2,273	2,595	87.5	180
South Carolina	3	2,459	3,447	71.3	101	3	2,482	3,440	72.1	117
Kentucky, Virginia, West Virginia	3	2,480	2,852	86.9	164	3	2,351	3,052	77.0	143
Florida	6	3,383	4,761	71.0	238	6	3,349	4,761	70.3	229
Nebraska and Wisconsin	1	W	W	W	W	1	W	W	W	W
Alabama	6	3,762	5,291	71.1	332	6	3,806	5,326	71.4	235
Arkansas, Louisiana, Mississippi	4	1,508	2,790	54.0	146	3	1,385	2,040	67.8	133
Utah	3	897	1,365	65.7	71	3	778	1,365	56.9	63
South Dakota	1	621	1,800	34.5	65	1	577	1,800	32.0	58
Iowa	4	2,172	2,732	79.4	254	4	2,006	2,725	73.6	219
Missouri	5	4,795	4,950	96.8	308	5	4,460	4,780	93.3	332
Kansas	5	1,743	2,435	71.5	203	5	1,607	2,460	65.3	206
Oklahoma	3	1,603	2,099	76.3	240	3	1,579	2,048	77.0	218
Texas, northern	8	3,252	5,665	57.4	213	8	3,202	6,055	52.8	291
Texas, southern	7	4,163	6,448	64.5	160	6	3,561	5,090	69.9	178
Idaho and Montana	3	679	960	70.7	107	3	836	960	87.0	92
Colorado and Wyoming	4	1,286	2,720	47.2	158	4	1,282	2,720	47.1	200
Alaska and Oregon	2	W	W	W	W	2	W	W	W	W
Arizona, Nevada, New Mexico	4	2,013	3,015	66.7	147	4	2,114	2,910	72.6	132
California, northern	3	2,830	3,025	93.5	160	3	2,873	3,150	91.2	156
California, southern	8	7,106	9,196	77.2	316	8	7,483	8,833	84.7	318
Hawaii	1	327	350	93.5	31	1	357	650	54.9	34
Washington	4	1,201	2,029	59.2	153	3	753	1,270	59.2	150
Total or average	**130**	**74,557**	**101,351**	**73.6**	**5,708**	**126**	**73,272**	**98,673**	**74.3**	**5,559**
Puerto Rico	2	1,303	2,176	59.8	34	2	1,385	2,116	65.4	19

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes Puerto Rico. Includes data for three white cement facilities as follows: California (1), Pennsylvania (1), and Texas (1). Includes data for grinding plants (11 in 1987 and 9 in 1988) as follows: Alaska (1), Florida (2), Iowa (1), Michigan (1), Pennsylvania (1), Texas (1), Utah (1) in 1988, Washington (2) in 1987 and (1) in 1988, and Wisconsin (2) in 1987.

[2] Includes cement produced from imported clinker (1987–3,242,000 tons, 1988–2,339,720 tons).

[3] Grinding capacity based on fineness necessary to grind Types I and II cement, making allowance for downtime required for maintenance.

[4] Includes imported cement. Source of imports withheld to avoid disclosing company proprietary data.

TABLE 3

CLINKER CAPACITY AND PRODUCTION IN THE UNITED STATES,[1] BY DISTRICT, AS OF DECEMBER 31, 1988

District	Active plants: Process used: Wet	Dry	Both	Total	Number of kilns	Daily capacity (thousand short tons)	Average number of days for maintenance	Apparent annual capacity[2] (thousand short tons)	Production[3] (thousand short tons)	Percent utilized
New York and Maine	4	1	—	5	6	12	65	3,605	3,337	92.5
Pennsylvania, eastern	2	5	—	7	16	16	54	4,990	4,636	92.9
Pennsylvania, western	3	1	—	4	8	7	54	2,043	1,478	72.3
Maryland	1	2	—	3	7	6	27	2,032	1,763	86.7
Ohio	2	1	1	4	7	7	65	2,104	1,485	70.5
Michigan	2	2	—	4	9	16	61	4,872	4,553	93.4
Indiana	2	2	—	4	9	10	65	3,002	2,559	85.2
Illinois	—	4	—	4	8	8	63	2,423	2,039	84.1
Georgia and Tennessee	1	2	1	4	7	7	26	2,379	2,237	94.0
South Carolina	2	1	—	3	7	8	62	2,431	2,329	95.8
Kentucky, Virginia, West Virginia	1	2	—	3	9	8	49	2,531	2,351	92.8
Florida	2	2	—	4	8	10	23	3,420	2,761	80.7
Nebraska and Wisconsin	—	1	—	1	2	W	76	W	W	W
Alabama	1	5	—	6	8	14	41	4,543	3,372	74.2
Arkansas, Louisiana, Mississippi	3	—	—	3	6	6	30	2,012	1,337	66.4
Utah	1	1	—	2	3	3	85	840	721	85.8
South Dakota	—	—	1	1	4	3	29	1,009	503	49.8
Iowa	—	3	—	3	6	8	58	2,462	1,853	75.2
Missouri	2	3	—	5	7	14	64	4,780	4,279	89.5
Kansas	3	2	—	5	15	7	85	1,962	1,608	81.9
Oklahoma	1	2	—	3	7	6	78	1,727	1,614	93.4
Texas, northern	5	3	—	8	17	16	43	5,165	3,241	62.7
Texas, southern	—	4	1	5	6	14	45	4,484	3,539	78.9
Idaho and Montana	3	—	—	3	4	2	7	960	780	81.3
Colorado and Wyoming	1	3	—	4	6	7	55	2,170	1,199	55.2
Alaska and Oregon	—	1	—	1	1	W	120	W	W	W
Arizona, Nevada, New Mexico	—	4	—	4	11	8	45	2,560	1,919	74.9
California, northern	—	3	—	3	3	10	61	3,047	2,790	91.5
California, southern	1	7	—	8	22	26	46	8,308	6,900	83.0
Hawaii	—	1	—	1	1	1	116	249	236	94.7
Washington	1	1	—	2	3	2	19	692	578	83.5
Total or average[4]	**44**	**69**	**4**	**117**	**233**	**264**	**54**	**84,251**	**69,159**	**82.1**
Puerto Rico	2	—	—	2	9	8	104	2,090	1,280	61.2

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes Puerto Rico and white-cement-producing facilities.
[2] Calculated on individual company data; 365 days, minus average days for maintenance, times the reported 24-hour capacity.
[3] Includes production reported for plants that added or shut down kilns during the year.
[4] Data may not add to totals shown because of independent rounding.

Co. of Florida, Inc., sold a 41% interest in its Tampa, FL, plant to three cement producers from Spain: Cementos Molins, S.A., Uniland Cementera, S.A., and Asland S.A.

ENERGY

The trend toward energy conservation continued as the industry focused on installing state-of-the-art raw material processing and calcination technology designed to improve overall operating efficiency.

Approximately 76% of the energy consumed in cement production was in the form of fuel for kiln firing to produce clinker. Average energy consumption per ton of clinker produced was 3.9 million British thermal units (Btu), about 5% less than that required in 1987.

The average consumption of electrical energy decreased slightly to 133 kilowatt hours per ton. Assuming a 40% energy efficiency in conversion of fuel to electrical energy, this represents a fuel equivalent of 1.1 million Btu per ton. Thus, average fuel consumption for kiln firing plus electrical energy, primarily for finish grinding, was approximately 5.0 million Btu per ton, 7% less than in 1987.

Average fuel consumption for kiln firing in wet-process plants, 4.7 million Btu per ton, was 28% higher than average fuel consumption in dry-process plants, 3.4 million Btu per ton. Approximately 64% of clinker was produced by the dry-process method.

The industry reported 64 suspension and 12 grate preheaters in use during the year. Kilns without preheaters averaged 4.5 million Btu per ton of clinker produced; those with suspension preheaters averaged 3.3 million Btu per ton, and those with grate-type preheaters averaged 4.9 million Btu per ton.

Coal accounted for 93% of kiln fuel consumption, natural gas accounted for 4%, and oil and waste fuel accounted for the remainder.

TABLE 4

DAILY CLINKER CAPACITY IN THE UNITED STATES,[1] DECEMBER 31, 1988

Short tons per 24-hour period	Number: Plants	Number: Kilns[2]	Total capacity (short tons)	Percent of total capacity
1987:				
Less than 1,150	17	27	13,460	4.8
1,151 to 1,700	31	57	45,978	16.5
1,701 to 2,300	21	36	40,622	14.5
2,301 to 2,800	20	40	49,598	17.8
2,801 and over	34	96	129,723	46.4
Total	**123**	**256**	**279,381**	**100.0**
1988:				
Less than 1,150	15	25	11,548	4.2
1,151 to 1,700	31	55	45,327	16.5
1,701 to 2,300	23	38	44,802	16.3
2,301 to 2,800	16	34	39,760	14.5
2,801 and over	34	90	132,930	48.5
Total	**119**	**242**	**274,367**	**100.0**

[1] Includes Puerto Rico and white-cement-producing facilities.
[2] Total number in operation at plants.

TABLE 5

RAW MATERIALS USED IN PRODUCING PORTLAND CEMENT IN THE UNITED STATES[1]

(Thousand short tons)

Raw materials	1986	1987	1988
Calcareous:			
Limestone (includes aragonite, marble, chalk)	78,995	81,143	79,517
Cement rock (includes marl)	23,495	17,959	23,398
Coral	1,040	935	783
Other	428	—	9
Argillaceous:			
Clay	5,734	4,766	4,784
Shale	3,282	4,906	4,126
Other (includes staurolite, bauxite, aluminum dross, alumina, volcanic material, other)	261	263	310
Siliceous:			
Sand and calcium silicate	1,934	1,873	2,011
Sandstone, quartzite, other	709	758	993
Ferrous: Iron ore, pyrites, millscale, other iron-bearing material	1,081	1,079	1,036
Other:			
Gypsum and anhydrite	4,103	4,939	4,174
Blast furnace slag	74	109	86
Fly ash	689	803	940
Other, n.e.c.	346	386	348
Total[2]	**122,169**	**119,920**	**122,515**

[1] Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.

TABLE 6

MASONRY CEMENT PRODUCTION AND STOCKS IN THE UNITED STATES, BY DISTRICT

District	1987			1988		
	Plants active during year	Production (thousand short tons)	Stocks[1] at mills, Dec. 31 (thousand short tons)	Plants active during year	Production (thousand short tons)	Stocks[1] at mills, Dec. 31 (thousand short tons)
New York and Maine	4	114	12	4	157	16
Pennsylvania, eastern	6	288	32	7	288	36
Pennsylvania, western	4	86	13	4	95	15
Maryland	2	W	W	2	W	W
Ohio	4	142	22	3	133	17
Michigan	5	259	50	4	264	51
Indiana	4	416	54	4	412	57
Illinois	2	W	W	1	W	W
Georgia and Tennessee	4	230	29	4	212	28
South Carolina	2	W	W	2	W	W
Kentucky, Virginia, West Virginia	4	335	21	4	345	23
Florida	4	435	18	4	480	28
Nebraska and Wisconsin	1	W	W	1	W	W
Alabama	7	278	30	7	260	33
Arkansas, Louisiana, Mississippi	2	W	W	2	W	W
Utah	1	W	W	1	W	W
South Dakota	1	6	3	1	3	2
Iowa	2	W	W	2	W	W
Missouri	4	186	19	4	160	9
Kansas	5	46	15	5	48	18
Oklahoma	3	40	13	2	W	W
Texas, northern	6	89	14	6	82	8
Texas, southern	4	68	8	3	51	4
Idaho and Montana	3	W	W	2	W	W
Colorado and Wyoming	2	W	W	2	W	W
Arizona, Nevada, New Mexico	3	82	7	3	70	7
California, northern	1	W	W	—	—	—
California, southern	1	W	W	1	W	W
Hawaii	1	10	1	1	10	1
Washington	2	W	W	1	W	W
Total or average[2]	**94**	**3,641**	**451**	**87**	**3,595**	**438**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes imported cement.
[2] Data may not add to totals shown because of independent rounding.

TRANSPORTATION

The pattern of cement transport did not differ significantly from that of recent years. U.S. shipments of portland cement to consumers were primarily in bulk, 95%; by truck, 90%; and made directly from cement manufacturing plants (rather than from distribution terminals), 61%.

With respect to shipments of cement from plants to terminals, the preferred modes of transportation were railroads, 43%, and waterways, 42%; transportation by truck accounted for 12%. Cement used at producing plants accounted for the remaining 3%.

CONSUMPTION AND USES

Consumer demand for cement in the United States, excluding Puerto Rico, declined slightly to 93.3 million tons. This was the first year of decline following 5 consecutive years of growth after the 20-year low experienced at the depth of the recession in 1982. According to U.S. Department of Commerce data, housing starts declined 9% to 1.5 million units. However, the value of residential construction only declined 2% because of marked gains in the average house size and increased spending on home improvement.[2] Although the construction industry experienced small increases in public works construction, these were more than offset by declines in private construction activity. The total current dollar value of new construction put in place was $403 billion, slightly higher than that recorded in 1987.

Among the consuming States, California continued to lead all areas in the amount of portland cement consumed, followed by, in order of shipments received, Texas, Florida, Pennsylvania, New York, and Illinois. Together, these States consumed 43% of total U.S. tonnage.

TABLE 7

CLINKER PRODUCED IN THE UNITED STATES,[1] BY FUEL

Fuel	Clinker produced: Plants active during year	Clinker produced: Quantity (thousand short tons)	Clinker produced: Percent of total	Fuel consumed: Coal[2] (thousand short tons)	Fuel consumed: Oil (thousand 42-gallon barrels)	Fuel consumed: Natural gas (thousand cubic feet)
1987:						
Coal	21	9,533	14.0	1,771	—	—
Coal and oil	30	20,212	29.0	3,673	708	—
Coal and natural gas	56	29,549	42.0	4,026	—	10,244,178
Oil and natural gas	—	—	—	—	—	—
Coal, oil, natural gas	16	10,568	15.0	1,843	347	1,749,183
Total	**123**	**69,862**	**100.0**	**11,313**	**1,055**	**11,993,361**
1988:						
Coal	17	9,701	13.8	1,762	—	—
Natural gas	3	1,114	1.6	—	—	150,769
Coal and oil	30	21,166	30.1	3,745	383	—
Coal and natural gas	49	26,150	37.1	3,543	—	8,363,116
Oil and natural gas	2	170	.2	—	159	300,726
Coal, oil, natural gas	18	12,139	17.2	1,578	417	2,718,967
Total	**119**	**70,440**	**100.0**	**10,628**	**959**	**11,533,578**

[1] Includes Puerto Rico.
[2] Includes 1% anthracite, 95% bituminous coal, and 4% petroleum coke in 1987 and 1988.

TABLE 8

CLINKER PRODUCED AND FUEL CONSUMED BY THE PORTLAND CEMENT INDUSTRY IN THE UNITED STATES,[1] BY PROCESS

Process	Clinker produced: Plants active during year	Clinker produced: Quantity (thousand short tons)	Clinker produced: Percent of total	Fuel consumed: Coal[2] (thousand short tons)	Fuel consumed: Oil (thousand 42-gallon barrels)	Fuel consumed: Natural gas (thousand cubic feet)
1987:						
Wet	48	23,919	34.2	4,525	545	4,084,751
Dry	71	43,702	62.6	6,459	507	7,783,432
Both	4	2,241	3.2	329	3	125,178
Total	**123**	**69,862**	**100.0**	**11,313**	**1,055**	**11,993,361**
1988:						
Wet	46	23,270	33.0	4,326	368	3,899,033
Dry	69	44,940	63.8	5,993	586	7,501,096
Both	4	2,230	3.2	309	5	133,449
Total	**119**	**70,440**	**100.0**	**10,628**	**959**	**11,533,578**

[1] Includes Puerto Rico.
[2] Includes 1% anthracite, 95% bituminous coal, and 4% petroleum coke in 1987 and 1988.

Among the nine census regions of the country, only the East North Central, Pacific, and South Atlantic regions registered increases in cement consumption. Because of the sustained level of construction activity in southern California, the Pacific region continued to lead all other regions of the country in cement consumption. Only marginal increases in consumption were registered in the East North Central and South Atlantic regions. Shipments to all other regions declined slightly or remained essentially unchanged.

Shipments of domestically produced cement from U.S. mills declined slightly. The gap between production and consumption was again made up with imports shipped by producers and independent importers. The level of imports required to meet consumer demands declined slightly, accounting for 19% of consumption.

The end-use distribution pattern for portland cement was essentially the same as that of recent years. Ready-mix concrete producers were the primary consumers, accounting for about 74% of the total, followed by concrete product manufacturers with 11%. Smaller amounts were consumed by highway and other contractors; building material dealers; Federal, State, and other government agencies; and a variety of other miscellaneous users.

PRICES

The average mill value of portland cement declined slightly for the fourth consecutive year, reaching its lowest point since 1979, despite near record shipments to meet consumer demand. The decline can be attributed in part to consumption of near record levels of imports, and to extreme competition among producers for a greater share of the domestic market. The average price of imported cement shipped by producers increased 5% to $48.19, the highest level since 1984. The average mill value

TABLE 9

ELECTRIC ENERGY USED AT PORTLAND CEMENT PLANTS IN THE UNITED STATES,[1] BY PROCESS

Process	Electric energy used: Generated at portland cement plants: Active plants	Generated at portland cement plants: Quantity (million kilowatt-hours)	Purchased: Active plants	Purchased: Quantity (million kilowatt-hours)	Total: Quantity (million kilowatt-hours)	Total: Percent	Finished cement produced (thousand short tons)	Average electric energy used per ton of cement produced (kilowatt-hours)
1987:								
Wet	—	—	46	3,028	3,028	29.7	25,851	117.1
Dry[2]	5	582	76	6,248	6,830	66.9	47,652	143.3
Both	—	—	4	344	344	3.4	2,357	145.9
Total or average	**5**	**582**	**126**	**9,620**	**10,202**	**100.0**	**75,860**	**134.5**
Percent of total electric energy used	—	5.7	—	94.2	—	—	—	—
1988:								
Wet	—	—	44	2,993	2,993	30.1	24,345	122.9
Dry[2]	7	733	72	5,873	6,606	66.4	47,989	137.7
Both	—	—	4	345	345	3.5	2,323	148.5
Total or average	**7**	**733**	**120**	**9,211**	**9,944**	**100.0**	**74,657**	**133.2**
Percent of total electric energy used	—	7.4	—	92.6	—	—	—	—

[1] Includes Puerto Rico. Includes grinding plants and white cement facilities.
[2] Includes data for grinding plants.

TABLE 10

SHIPMENTS OF PORTLAND CEMENT FROM MILLS IN THE UNITED STATES,[1] IN BULK AND IN CONTAINERS, BY TYPE OF CARRIER

(Thousand short tons)

Type of carrier	Shipments from plant to terminal: In bulk	Shipments from plant to terminal: In containers	Shipments to ultimate consumer: From terminal to consumer: In bulk	From terminal to consumer: In containers	From plant to consumer: In bulk	From plant to consumer: In containers	Total shipments[2]
1987:							
Railroad	9,050	86	768	202	3,755	207	4,932
Truck	3,231	195	25,536	682	47,381	3,656	77,255
Barge and boat	8,917	12	75	—	229	—	304
Unspecified[3]	539	—	879	68	296	19	1,262
Total[2]	**21,738**	**294**	**27,257**	**953**	**51,661**	**3,882**	**[4]83,753**
1988:							
Railroad	9,496	91	1,479	([5])	3,562	26	5,066
Truck	2,333	335	28,620	731	45,306	3,491	78,148
Barge and boat	9,289	10	2,199	—	334	—	2,533
Unspecified[3]	514	—	419	2	568	18	1,006
Total[2]	**21,632**	**436**	**32,717**	**732**	**49,769**	**3,535**	**[6]86,753**

[1] Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes cement used at plant.
[4] Bulk shipments were 94.2% and container (bag) shipments were 5.8%.
[5] Less than 1/2 unit.
[6] Bulk shipments were 95.1% and container (bag) shipments were 4.9%.

TABLE 11

PORTLAND CEMENT SHIPPED BY PRODUCERS IN THE UNITED STATES, BY DISTRICT[1]

District	1987 Quantity (thousand short tons)	1987 Value (thousands)	1987 Average per ton	1988 Quantity (thousand short tons)	1988 Value (thousands)	1988 Average per ton
New York and Maine	3,511	$180,281	$51.35	3,293	$168,033	$51.02
Pennsylvania, eastern	4,852	266,963	55.02	4,800	258,807	53.91
Pennsylvania, western	1,473	67,746	45.99	1,509	70,827	46.93
Maryland	1,829	90,020	49.22	1,808	89,083	49.27
Ohio	1,748	83,661	47.86	1,424	70,816	49.73
Michigan	4,755	207,332	43.60	5,253	231,141	44.00
Indiana	2,320	103,177	44.47	2,315	107,179	46.29
Illinois	2,119	86,210	40.68	2,307	101,760	44.10
Georgia and Tennessee	2,262	108,729	48.07	2,307	114,455	49.61
South Carolina	2,567	117,878	45.92	2,533	118,670	46.84
Kentucky, Virginia, West Virginia	2,357	109,101	46.29	2,463	117,482	47.69
Florida	3,565	165,944	46.55	3,682	168,719	45.82
Nebraska and Wisconsin	W	W	W	W	W	W
Alabama	3,600	160,878	44.69	3,524	157,214	44.61
Arkansas, Louisiana, Mississippi	1,759	74,667	42.45	1,698	68,590	40.39
Utah	935	50,565	54.08	771	39,664	51.44
South Dakota	W	W	W	W	W	W
Iowa	2,139	104,457	48.83	2,029	98,930	48.75
Missouri	5,110	185,317	36.27	4,679	184,755	39.48
Kansas	1,697	81,045	47.76	1,569	72,805	46.40
Oklahoma	1,415	54,870	38.78	1,432	42,131	29.42
Texas, northern	3,206	158,944	49.58	3,270	162,816	49.79
Texas, southern	4,112	161,052	39.17	3,730	129,440	34.70
Idaho and Montana	607	34,121	56.21	719	39,638	55.12
Colorado and Wyoming	1,265	70,194	55.49	1,258	60,327	47.95
Alaska and Oregon	W	W	W	W	W	W
Arizona, Nevada, New Mexico	2,136	132,623	62.09	2,325	136,045	58.51
California, northern	2,838	167,658	59.08	3,076	177,733	57.78
California, southern	7,099	426,201	60.04	7,347	423,419	57.63
Hawaii	324	26,550	81.94	354	28,880	81.58
Washington	1,282	63,600	49.61	979	48,233	49.26
Total[2 3] or average	**74,868**	**3,646,561**	**48.71**	**74,074**	**3,575,906**	**48.27**
Foreign imports[4]	10,480	480,212	45.82	11,267	542,942	48.19
Puerto Rico	1,296	106,185	81.93	1,397	113,966	81.57
Grand total[3 5] or average	**86,644**	**4,232,959**	**48.85**	**86,738**	**4,232,814**	**48.80**

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes Puerto Rico. Includes data for three white cement facilities as follows: California (1), Pennsylvania (1), and Texas (1). Includes data for grinding plants (11 in 1987 and 9 in 1988) as follows: Alaska (1), Florida (2), Iowa (1), Michigan (1), Pennsylvania (1), Texas (1), Utah (1) in 1988, Washington (2) in 1987 and (1) in 1988, and Wisconsin (2) in 1987.

[2] Includes cement produced from imported clinker.

[3] Data may not add to totals shown because of independent rounding.

[4] Cement imported and distributed by domestic producers only.

[5] Does not include cement consumed at plant.

TABLE 12

MASONRY CEMENT SHIPPED BY PRODUCERS IN THE UNITED STATES,[1] BY DISTRICT

District	1987			1988		
	Quantity (thousand short tons)	Value (thou-sands)	Average per ton	Quantity (thousand short tons)	Value (thou-sands)	Average per ton
New York and Maine	131	$8,155	$62.25	171	$9,966	$58.28
Pennsylvania, eastern	306	22,973	75.08	296	21,065	71.16
Pennsylvania, western	92	7,491	81.42	95	7,648	80.50
Maryland	W	W	W	W	W	W
Ohio	139	11,964	86.07	129	11,140	86.35
Michigan	263	23,004	87.45	265	22,915	86.47
Indiana	422	32,299	76.53	405	27,442	67.75
Illinois	W	W	W	W	W	W
Georgia and Tennessee	230	16,809	73.08	213	14,620	68.63
South Carolina	W	W	W	W	W	W
Kentucky, Virginia, West Virginia	328	21,886	66.73	338	22,093	65.36
Florida	390	24,069	61.72	411	25,892	62.99
Nebraska and Wisconsin	W	W	W	W	W	W
Alabama	291	17,626	60.55	273	16,457	60.28
Arkansas, Louisiana, Mississippi	80	4,651	58.14	W	W	W
Utah	W	W	W	W	W	W
South Dakota	4	W	W	W	W	W
Iowa	W	W	W	W	W	W
Missouri	167	10,027	60.04	153	6,310	41.24
Kansas	52	3,150	60.58	50	2,988	59.76
Oklahoma	41	2,436	59.41	W	W	W
Texas, northern	103	7,589	73.68	81	7,216	89.08
Texas, southern	69	3,694	53.54	55	3,584	65.16
Idaho and Montana	W	W	W	W	W	W
Colorado and Wyoming	W	W	W	W	W	W
Alaska and Oregon	W	W	W	W	W	W
Arizona, Nevada, New Mexico	82	6,365	77.62	71	5,468	77.01
California, northern	W	W	W	—	—	—
California, southern	W	W	W	W	W	W
Hawaii	10	1,559	155.90	10	1,531	153.10
Washington	W	W	W	W	W	W
Total[2] or average	**3,680**	**259,926**	**70.63**	**3,574**	**243,941**	**68.25**
Foreign imports[3]	103	6,985	67.82	100	7,674	76.74
Grand total[2] or average	**3,783**	**266,911**	**70.55**	**3,674**	**251,615**	**68.48**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Does not include quantities produced on the job by masons.
[2] Data may not add to totals shown because of independent rounding.
[3] Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

of masonry cement declined 3%, driven by a corresponding reduction in demand.

The average price of cement as reported by Engineering News-Record (ENR) declined slightly to about $63.53 per ton. The ENR prices are based on an average per ton value of cement delivered to 20 cities. The prices ranged from a low of $45.00 per ton in Dallas, TX, to a high of $75.00 in New York City and Seattle, WA.[3]

FOREIGN TRADE

According to trade data reported by the U.S. Department of Commerce, Bureau of the Census, cement imported for consumption into the United States and its possessions and territories was slightly lower than in 1987. This was the first decline following 3 consecutive years of record-high imports, and corresponded to marginal decline in total demand. Mexico, Canada, and Greece were the principal import sources, accounting for more than 62% of the total. Seventy-seven percent of cement and clinker imports was brought in by producers. The industry continued to increase its focus on imports of finished cement rather than on clinker for grinding. Finished cement imports increased 11%, but clinker imports decreased 48%. This was the third consecutive year that clinker imports declined, reaching its lowest level since 1983.

Florida led all States in the amount of imports received, accounting for 22% of the total. Sixty-three percent, or 2.4 million tons, of the Florida imports was shipped through the Tampa Customs District. Imports made up about 54% of Florida's portland cement consumption, compared with 19% of consumption nationally. Los Angeles was the second largest recipient of imported cement, receiving 1.8 million tons or 10% of the total. The customs districts of Buffalo, NY,

TABLE 13

CEMENT SHIPMENTS, BY DESTINATION AND ORIGIN[1]

(Thousand short tons)

Destination and origin	Portland cement[2]			Masonry cement		
	1986	1987	1988	1986	1987	1988
Destination:						
Alabama	1,302	1,405	1,423	112	137	122
Alaska[3]	121	94	84	W	—	W
Arizona	2,400	2,299	2,131	W	W	W
Arkansas	803	766	690	48	43	37
California, northern	3,438	3,598	3,958	W	W	W
California, southern	7,844	8,121	8,584	W	W	W
Colorado	1,450	1,110	992	22	16	13
Connecticut[3]	1,037	1,029	990	21	24	24
Delaware[3]	224	254	277	12	15	15
District of Columbia[3]	142	146	198	1	1	1
Florida	6,360	6,819	7,002	499	531	561
Georgia	3,224	3,321	3,170	242	248	238
Hawaii	287	329	355	7	10	10
Idaho	291	251	324	1	([4])	([4])
Illinois	1,511	1,498	1,278	30	30	30
Chicago, metropolitan[3]	1,803	2,037	2,294	59	66	69
Indiana	1,580	1,704	1,773	97	103	108
Iowa	1,046	1,199	1,225	13	12	12
Kansas	1,218	1,351	1,147	21	25	21
Kentucky	1,115	1,201	1,138	85	92	91
Louisiana	1,964	1,761	1,527	48	43	36
Maine	336	361	366	12	12	15
Maryland	1,666	1,645	1,722	144	156	171
Massachusetts[3]	1,686	1,589	1,439	53	51	49
Michigan	2,478	2,740	2,720	127	146	152
Minnesota[3]	1,464	1,582	1,464	47	51	48
Mississippi	827	787	760	55	53	48
Missouri	2,221	2,091	2,165	47	53	48
Montana	241	175	199	1	1	1
Nebraska	764	720	749	11	10	10
Nevada	670	754	1,081	([4])	([4])	([4])
New Hampshire[3]	387	345	337	16	15	15
New Jersey[3]	1,972	1,932	1,720	87	88	83
New Mexico	572	517	507	9	8	6
New York, eastern	670	746	638	42	46	42
New York, western	986	989	1,070	53	57	55
New York, metropolitan[3]	1,932	1,851	1,915	54	55	52
North Carolina[3]	1,980	2,145	2,179	264	283	281
North Dakota[3]	277	278	223	4	4	4
Ohio	3,028	3,314	3,439	174	189	205
Oklahoma	1,107	1,076	1,061	34	34	28

See footnotes at end of table.

TABLE 13—Continued

CEMENT SHIPMENTS, BY DESTINATION AND ORIGIN[1]

(Thousand short tons)

Destination and origin	Portland cement[2]			Masonry cement		
	1986	1987	1988	1986	1987	1988
Oregon	626	728	799	([4])	([4])	([4])
Pennsylvania, eastern	1,994	2,132	2,446	74	87	99
Pennsylvania, western	1,222	1,350	1,215	77	82	79
Rhode Island[3]	199	244	215	6	6	7
South Carolina	1,052	1,138	1,213	136	152	151
South Dakota	332	272	275	4	5	4
Tennessee	1,655	1,863	1,698	184	203	185
Texas, northern	4,705	3,799	3,270	140	96	87
Texas, southern	4,531	4,267	3,940	74	69	66
Utah	940	804	620	2	1	1
Vermont[3]	172	173	209	5	6	6
Virginia	2,410	2,557	2,604	219	225	241
Washington	1,251	1,361	1,187	7	8	6
West Virginia	426	455	375	28	31	30
Wisconsin	1,475	1,587	1,635	47	46	47
Wyoming	342	317	257	1	1	1
U.S. total[5]	**87,756**	**88,977**	**88,275**	**3,556**	**3,727**	**3,711**
Foreign countries[6]	145	185	184	105	114	33
Puerto Rico	1,132	1,296	1,397	—	—	—
Total shipments[5]	**89,033**	**90,458**	**89,856**	**3,659**	**3,841**	**3,744**
Origin:						
United States[7]	75,181	74,868	73,743	3,525	3,715	3,468
Puerto Rico	1,132	1,296	1,397	—	—	—
Foreign:[8]						
Domestic producers	8,814	10,480	11,267	72	60	210
Others	3,909	3,814	3,448	62	67	66
Total shipments[5]	**89,033**	**90,458**	**89,856**	**3,659**	**3,841**	**3,744**

W Withheld to avoid disclosing company proprietary data; included with "Foreign countries."

[1] Includes cement produced from imported clinker and imported cement shipped by domestic producers, Canadian cement manufacturers, and other importers. Includes Puerto Rico.

[2] Excludes cement (1987—305,000 tons and 1988—318,000 tons) used in the manufacture of prepared masonry cement.

[3] Has no cement-producing plants.

[4] Less than 1/2 unit.

[5] Data may not add to totals shown because of independent rounding.

[6] Direct shipments by producers to foreign countries and U.S. possessions and territories; includes States indicated by symbol W.

[7] Includes cement produced from imported clinker by domestic producers.

[8] Imported cement distributed by domestic producers, Canadian cement manufacturers, and other importers. Origin of imports withheld to avoid disclosing company proprietary data.

New Orleans, LA, and New York, NY, each received 1 million tons or more of imported cement.

Exports of hydraulic cement and clinker as reported by the Bureau of the Census nearly doubled to 101,000 tons. Cement was shipped to more than 40 countries, with Canada receiving 90% of the total.

In other trade developments, Asland Cement Co. docked a 270,000-ton-capacity silo ship in the Port of New Orleans. The company imported cement from Spain to serve markets in Louisiana and Texas.

Santee Portland Cement Co., a subsidiary of Dundee Cement Co., purchased the Georgetown, SC, import terminal recently constructed by Delta Cement Co. The terminal has a storage capacity of 20,000 tons and a throughput capacity of 500,000 tons per year.

WORLD CAPACITY

The data in table 24 are rated capacity for plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

During 1988, clinker-producing cement plants in an estimated 132 countries were on line with a combined annual capacity of 1.3 billion tons. In addition, numerous smaller plants that cannot be accounted for were believed to be operating in various parts of the world. Of the top 10 producing countries, China led in clinker production capacity, followed by the U.S.S.R., the

TABLE 14

CEMENT SHIPMENTS,[1] BY REGION AND SUBREGION

Region and subregion[2]	Portland cement: Thousand short tons 1987	Portland cement: Thousand short tons 1988	Portland cement: Percent of grand total 1987	Portland cement: Percent of grand total 1988	Masonry cement: Thousand short tons 1987	Masonry cement: Thousand short tons 1988	Masonry cement: Percent of grand total 1987	Masonry cement: Percent of grand total 1988
Northeast:								
New England	3,742	3,556	4.2	4.0	114	115	3.1	3.1
Middle Atlantic	9,001	9,005	10.1	10.2	416	411	11.2	11.1
Total[3]	**12,742**	**12,561**	**14.3**	**14.2**	**530**	**526**	**14.3**	**14.2**
South:								
Atlantic	18,480	18,740	20.8	21.2	1,641	1,645	44.0	44.3
East Central	5,255	5,019	5.9	5.7	485	431	13.0	11.6
West Central	11,674	10,488	13.1	11.9	285	255	7.6	6.9
Total[3]	**35,409**	**34,247**	**39.8**	**38.8**	**2,412**	**2,331**	**64.6**	**62.8**
Midwest:								
East	12,881	13,139	14.5	14.9	580	669	15.6	18.0
West	7,494	7,248	8.4	8.2	160	147	4.3	4.0
Total[3]	**20,374**	**20,387**	**22.9**	**23.1**	**740**	**816**	**19.9**	**22.0**
West:								
Mountain	6,228	6,112	7.0	6.9	28	22	.7	.6
Pacific	14,231	14,967	16.0	17.0	18	16	.5	.4
Total[4]	**20,459**	**21,079**	**23.0**	**23.9**	**46**	**38**	**1.2**	**1.0**
Grand total[3]	**88,985**	**88,275**	**100.0**	**100.0**	**3,727**	**3,711**	**100.0**	**100.0**

[1] Includes imported cement shipped by domestic and Canadian cement manufacturers and other importers.
[2] Geographic regions as designated by the U.S. Department of Commerce, Bureau of the Census.
[3] Data may not add to totals shown because of independent rounding.
[4] Does not include proprietary data from table 13.

United States, Japan, Greece, Brazil, the Federal Republic of Germany, Italy, Spain, and the Republic of Korea. Together, these countries controlled 56% of the world's production capacity.

In the United States, 45% of the clinker production capacity was concentrated in five States: California, Texas, Pennsylvania, Michigan, and Missouri. At yearend, 235 kilns at 125 plants were being operated, excluding Puerto Rico. The average downtime experienced by the industry for maintenance was 54 days, 20% more than in 1987 but slightly less than in 1986. The average annual kiln capacity increased 4% to 363,000 tons, but the average annual plant capacity decreased 5% to 683,000 tons.

WORLD REVIEW

World cement production increased 5% to 1.2 billion tons. China continued to lead all nations with 18% of production, followed by the U.S.S.R. with 13%, Japan with 7%, and the United States with 6%. Worldwide, the industry operated at an estimated 93% of capacity. Countries with excess capacity continued to seek new markets for their product, and the United States continued to be a principal recipient of imports. Twenty-eight countries exported cement to the United States in 1988, four more than in 1987.

Foreign buyers continued to show interest in the U.S. cement industry. By yearend, approximately 65% of U.S. cement production capacity had been acquired by foreign firms from nine countries. Eight of the top 10 producing companies were either wholly owned or owned in part primarily by Western European producers. In 1988, Japanese firms purchased U.S. capacity for the first time.

Worldwide, there was considerable activity in plant construction, modernization, or expansion by the industry. The introduction of new technology, primarily the installation of high-pressure grinding rollers and high-efficiency separators continued to attract interest as the industry sought to improve operating efficiency. The international issue of Rock Products magazine described indi-

TABLE 15

PORTLAND CEMENT SHIPMENTS IN 1988, BY DISTRICT OF ORIGIN AND TYPE OF CUSTOMER[1]

District of origin	Building material dealers		Concrete product manufacturers		Ready-mixed concrete		Highway contractors		Other contractors		Federal, State, and other government agencies		Miscellaneous including own use		Total[2] (thousand short tons)
	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	
New York and Maine	150	4.6	578	17.6	2,318	70.4	102	3.1	133	4.0	1	—	11	.3	3,293
Pennsylvania, eastern	425	8.9	1,027	21.4	3,059	63.7	139	2.9	23	.5	43	.9	84	1.7	4,800
Pennsylvania, western	169	11.2	247	16.4	929	61.5	125	8.3	39	2.6	—	—	([3])	—	1,509
Maryland	101	5.6	388	21.5	1,250	69.1	20	1.1	38	2.1	—	—	11	.6	1,808
Ohio	48	3.4	205	14.4	1,105	77.6	65	4.5	1	.1	([3])	—	([3])	—	1,424
Michigan	187	3.6	671	12.8	3,933	74.9	349	6.6	85	1.6	7	.1	20	.4	5,253
Indiana	118	5.1	301	13.0	1,716	74.1	165	7.1	1	.1	—	—	14	.6	2,315
Illinois	12	.5	166	7.2	1,922	83.3	190	8.2	17	.7	—	—	1	.1	2,308
Georgia and Tennessee	133	5.8	416	18.0	1,558	67.5	92	4.0	98	4.2	1	.1	9	.4	2,307
South Carolina	44	1.7	417	16.5	1,837	72.5	90	3.6	64	2.5	3	.1	79	3.1	2,533
Kentucky, Virginia, West Virginia	124	5.0	361	14.7	1,752	71.1	150	6.1	57	2.3	2	.1	16	.7	2,463
Florida	331	9.0	501	13.6	2,557	69.4	117	3.2	65	1.7	2	.1	110	3.0	3,682
Nebraska and Wisconsin	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Alabama	202	5.7	510	14.5	2,338	66.3	200	5.7	112	3.2	6	.2	156	4.4	3,524
Arkansas, Louisiana, Mississippi	51	3.0	193	11.3	1,079	63.5	112	6.6	200	11.8	10	.6	54	3.2	1,698
Utah	13	1.7	62	8.0	494	64.1	32	4.1	120	15.5	([3])	—	51	6.6	771
South Dakota	6	1.2	26	5.3	266	54.3	107	21.8	38	7.8	([3])	—	47	9.6	490
Iowa	46	2.3	403	19.8	1,299	64.0	246	12.1	10	.5	6	.3	20	1.0	2,030
Missouri	80	1.7	264	5.6	3,774	80.6	346	7.4	69	1.5	—	—	149	3.2	4,683
Kansas	86	5.5	98	6.2	1,145	73.0	124	7.9	47	3.0	([3])	—	69	4.4	1,569
Oklahoma	56	3.9	102	7.1	890	62.1	85	5.9	121	8.5	1	.1	177	12.4	1,433
Texas, northern	138	4.2	352	10.8	1,881	57.5	212	6.5	428	13.1	77	2.4	181	5.5	3,271
Texas, southern	132	3.6	384	10.3	2,532	67.9	187	5.0	124	3.3	16	.4	355	9.5	3,730
Idaho and Montana	15	2.1	49	6.9	402	55.9	93	13.0	100	13.9	([3])	—	59	8.2	719
Colorado and Wyoming	34	2.7	112	8.9	872	69.3	193	15.4	40	3.2	([3])	—	6	.5	1,258
Alaska and Oregon	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Arizona, Nevada, New Mexico	81	3.5	370	15.9	1,490	64.0	18	.8	357	15.3	7	.3	5	.2	2,327
California, northern	178	5.8	340	11.1	2,309	75.1	63	2.0	111	3.6	([3])	—	74	2.4	3,076
California, southern	217	3.0	917	12.5	5,574	75.9	25	.3	395	5.4	40	.5	179	2.4	7,347
Hawaii	22	6.2	47	13.3	262	73.5	4	1.1	12	3.4	5	1.4	4	1.1	354
Washington	37	3.8	52	5.3	784	80.1	3	.3	70	7.1	([3])	—	33	3.4	979
Foreign Imports[4]	—	—	—	—	11,243	99.8	—	—	—	—	—	—	24	.3	11,267
Total[2] or average	**3,249**	**3.8**	**9,651**	**11.3**	**63,466**	**74.4**	**3,773**	**4.4**	**2,984**	**3.5**	**230**	**.3**	**2,003**	**2.3**	**85,355**
Puerto Rico	604	43.2	71	5.1	671	48.0	18	1.3	32	2.3	1	.1	([3])	—	1,397

W Withheld to avoid disclosing company proprietary date; included in "Total."
[1] Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.
[4] Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

dividual plant activities of the cement-producing nations.[4] World Cement Magazine also published a round up of projects under construction or recently completed in 51 countries.[5]

Australia.—Cement production in Australia fluctuated during the last 5 years. In response to mounting concern that cement and clinker imports were threatening to take a significant share of the country's market, a national study was undertaken to assess the industry's vulnerability to import competition. The study compared the Australian cement industry with industries in the United States and some European countries facing similar threats. The study concluded that while imports may not dominate the domestic market, they will come to represent a significant source of supply in certain parts of Australia.[6]

Canada.—Canadian cement production increased only slightly due primarily to increases in commercial, institutional, and engineering construction, although residential construction re-

FIGURE 1

SHIPMENTS OF CEMENT BY GEOGRAPHIC REGION OF DESTINATION IN 1988

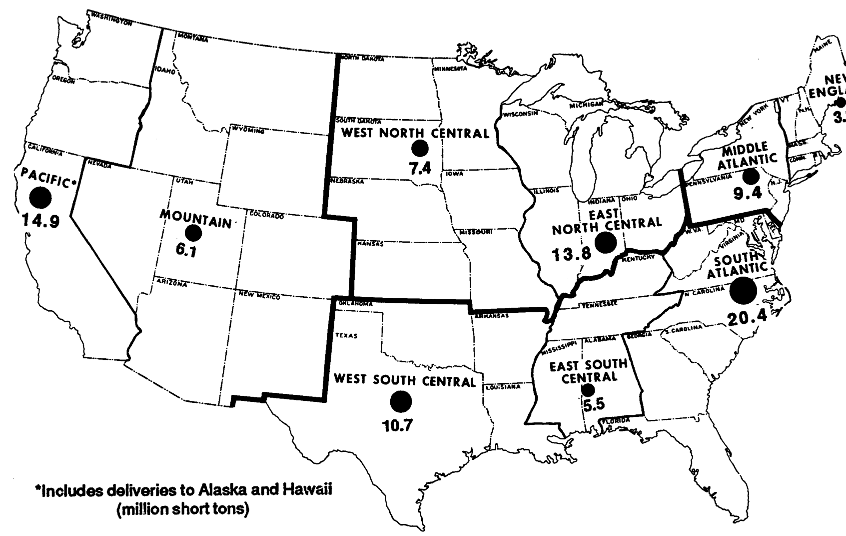

TABLE 16

PORTLAND CEMENT SHIPPED FROM PLANTS IN THE UNITED STATES,[1] BY TYPE

	1987			1988		
	Quantity (thousand short tons)	Value[2] (thousands)	Average per ton	Quantity (thousand short tons)	Value[2] (thousands)	Average per ton
General use and moderate heat (Types I and II)	79,499	$3,808,456	$47.91	79,943	$3,826,576	$47.87
High-early-strength (Type III)	3,318	175,160	52.80	3,359	178,149	53.04
Sulfate-resisting (Type V)	716	39,389	55.01	697	36,600	52.51
Oil well	899	45,054	50.12	916	48,193	52.61
White	345	59,873	173.54	365	61,155	167.54
Portland slag and portland pozzolan	773	39,827	51.51	625	33,454	53.52
Expansive	50	4,641	92.82	64	5,595	87.42
Miscellaneous[3]	1,045	60,558	57.95	769	43,092	56.03
Total[4] [5] or average	**86,644**	**4,232,959**	**48.85**	**86,738**	**4,232,814**	**48.80**

[1] Includes Puerto Rico.
[2] Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, less all freight charges to customer, less all freight charges from producing plant to distribution terminal if any, less total cost of operating terminal if any, less cost of paper bags and pallets.
[3] Includes waterproof, low-heat (Type IV), and regulated fast-setting cement.
[4] Data may not add to totals shown because of independent rounding.
[5] Does not include cement consumed at plant.

TABLE 17

AVERAGE MILL VALUE, IN BULK, OF CEMENT IN THE UNITED STATES[1]

(Per short ton)

Year	Portland cement	Prepared masonry cement[2]	All classes of cement
1984	$51.62	$67.02	$52.24
1985	51.30	66.64	51.87
1986	50.10	65.68	50.73
1987	48.85	70.55	49.76
1988	48.80	68.48	49.60

[1] Includes Puerto Rico. Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, less all freight charges from producing plant to distribution terminal if any, less total cost of operating terminal if any, less cost of paper bags and pallets.
[2] Masonry cement made at cement plants only.

TABLE 18

U.S. EXPORTS OF HYDRAULIC CEMENT AND CEMENT CLINKER, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value
Bahamas	2	152	1	58	2	161
Canada	54	7,688	45	7,025	91	6,381
Dominican Republic	([1])	7	([1])	31	2	12
Mexico	1	445	3	1,355	4	1,164
Venezuela	([2])	20	1	331	1	597
Other[2]	1	[r]712	2	[r]763	1	592
Total[3]	**59**	**9,024**	**52**	**9,563**	**101**	**8,907**

[r] Revised.
[1] Less than 1/2 unit.
[2] Includes 41 countries in 1986; 38 in 1987; and 27 in 1988.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 19

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1986			1987			1988		
	Quantity	Value		Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Canada	3,272	123,220	133,907	4,154	146,693	157,606	3,628	139,968	143,889
Colombia	913	22,566	28,070	612	14,914	22,090	647	16,798	23,924
France	669	18,355	24,016	772	15,152	24,373	758	27,085	34,473
Greece	1,275	26,710	33,507	1,641	36,559	49,141	2,271	62,450	78,470
Japan	750	20,325	24,833	723	18,351	25,108	1,758	46,719	57,619
Korea, Republic of	456	11,814	15,202	616	14,241	18,095	520	11,326	14,521
Mexico	4,242	110,390	133,403	4,960	125,666	156,585	4,992	124,527	149,885
Spain	3,176	90,479	110,230	3,044	80,745	106,996	1,857	54,463	68,860
Venezuela	1,290	31,739	41,673	766	17,534	24,498	641	16,530	22,484
Other	276	13,395	17,586	438	18,677	22,096	416	15,857	21,982
Total	**16,319**	**468,993**	**562,427**	**17,726**	**488,532**	**606,588**	**17,488**	**515,723**	**616,107**

[1] Cost, insurance, and freight.

Source: Bureau of the Census.

mained very strong. Cement shipments represented about 86% of capacity. Canada remained the second largest supplier of cement to the United States, supplying markets primarily through ports in Boston, MA, Detroit, MI, Seattle, WA, and Saint Albans, VT.

China.—China continued to be the world's largest producer of cement. Its production continued to increase at a dramatic rate, reaching an estimated 224 million tons in 1988. Although Chinese cement has not been a factor on the international market, it is conceivable that the country could become an exporter in the near future. China continues to import production technology and aggressively seeks to upgrade its industry.

Greece.—Cement production in Greece as reported to the Bureau of Mines declined slightly during the last 3 years. Greek exports, however, continued to increase. Greece was the third largest supplier of cement to the United States with 13% of total imports. New York, NY, and Miami, FL, were the principal recipients of cement from Greece.

India.—The Indian cement industry is the most aggressive of that of all countries in terms of new plant construction, modernization and expansion. Cement production in India reached an all-time high of 45 million tons, a 10% increase over that of 1987. This was the sixth consecutive year of production growth. Although India has never been a major cement exporter, this situation could change as the industry completes more than 20 projects currently in various stages of development that will add considerably to existing production capacity.

Japan.—Japan has maintained its position as the third highest producer in the world despite reductions in capacity and an influx of imports from South Korea and Taiwan. These imports have caused Japan to expand existing markets or seek new markets as their traditional Asian and Middle Eastern markets declined. Japanese imports into the United States increased to 1.8 million tons in 1988, compared with 723,000 tons in 1987. Sixty-six percent of Japanese exports to the United States was shipped to the Los Angeles area.

Korea, Republic of.—Korea's cement production increased steadily over the last 5 years, reaching about 32 million tons in 1988. Japan continues to be a major market of Korean exports. Exports to the United States were primarily to the Los Angeles area.

Mexico.—Cement production in Mexico remained essentially unchanged. Mexico was the major supplier of foreign cement to the United States accounting for 29% of the total imported by the United States. Overall, imports from Mexico increased slightly in 1988 to 4.99 million tons. Clinker imports declined 64%, but white cement increased 169% over the 1987 level. Seventeen of the thirty-six customs districts reported receiving cement from Mexico. Tampa, FL, was the largest recipient of Mexican cement with 22% of the total.

TECHNOLOGY

Cement

Lone Star Industries announced the creation of a new cement that will meet the Nation's need for producing

TABLE 20

U.S. IMPORTS FOR CONSUMPTION OF CLINKER, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1986			1987			1988		
	Quantity	Value		Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Canada	358	10,534	12,768	846	25,056	28,150	417	12,943	14,163
Colombia	280	5,814	7,031	58	1,265	1,515	39	946	1,235
France	529	11,328	14,324	342	7,839	9,818	402	11,801	15,006
Greece	507	9,598	13,159	343	6,330	8,272	53	1,098	1,101
Japan	234	4,897	4,839	37	883	1,222	137	3,030	4,281
Mexico	1,095	19,199	23,823	1,215	21,114	26,241	437	8,363	10,415
Spain	711	13,726	17,653	734	14,121	17,543	344	8,282	10,889
Other	258	4,603	6,970	93	2,765	2,941	90	2,163	3,007
Total	**3,972**	**79,699**	**100,567**	**3,668**	**79,373**	**95,702**	**1,919**	**48,626**	**60,097**

[1] Cost, insurance, and freight.

Source: Bureau of the Census.

a stronger, faster setting, more durable concrete product. The company claims that the product, called Pyrament Cement, enjoys several advantages over conventional portland cement concrete in that it can support normal highway traffic just 4 hours after it is placed. In addition, it can be placed at temperatures below freezing using conventional equipment, and it is resistant to salt and other corrosives. It is said to be particularly suitable for bridges, highways, airports, and other applications where repairs must be done rapidly under extremely adverse conditions. The product was expected to be produced at plants in Houston, TX, Greencastle, IN, and Nazareth, PA.[7]

The use of waste fuel for kiln firing continues to attract interest in the United States and abroad. Although only five plants reported use of some form of waste fuel in the United States during the year, the practice is much more widespread among some European producers. One firm from the Federal Republic of Germany reported the results of a study that detailed the successes of using combustible parts of concrete have taken place in the last general household waste as an alternative fuel for clinker processing. The study concluded that in this particular case, waste fuel utilized was equivalent to 70% of total primary energy intake.[8]

Efforts to improve overall operating efficiency by increasing production capacity and reducing energy consumption continued to be high on the industry's agenda. The use of high-pressure grinding rollers and high-efficiency separators continued to attract the most attention. At the Rock Products 24th International Cement Seminar in December 1988, 5 of the 18 papers presented by representatives of the cement industry and equipment manufacturers detailed individual experiences and successes using this new and emerging technology in which capacity increases of up to 40% and energy savings of up to 30% have been realized.[9]

Concrete

The American Concrete Institute, Committee Number 548, published a "Guide for Mixing and Placing Sulfur Concrete in Construction." Major advances in the development of sulfur decade including extensive research by the U.S. Bureau of Mines in cooperation with the Sulfur Institute to investigate and develop new uses for sulfur. Sulfur concrete construction materials are now used in many specialized applications throughout the construction industries. The materials can achieve compressive strengths in excess of 9,000 pounds per square inch within 1 day of casting, are impervious to moisture permeation, and are extremely resistant to attack by mineral acids and salts.[10]

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[1] Mineral industry specialist, Branch of Industrial Minerals.

[2] U.S. Department of Commerce, International Trade Administration. Construction Review. V. 34, No. 6, Nov.-Dec. 1988, pp. 2-23.

[3] Engineering News-Record. ENR Materials Prices. V. 222, No. 1, Jan. 1989, pp. 68-70.

[4] Rock Products. Cement International. V. 91, No. 4, Apr. 1989, pp. 51-82.

[5] World Cement. V. 20, No. 5, May 1989, pp. 165-188.

[6] Australian Cement Industry; Structure and Performance. Res. Rep. 28, 1988, pp. 1-26.

[7] Lone Star Industries. 1988 Annual Report. Pp. 12-16.

[8] International Cement Review, Nov. 1988, pp. 32-36.

[9] Rock products. Proceedings, Rock Products 24th International Cement Seminar, 1988, pp. 199-211, 274-302.

[10] ACI Materials Journal. July-Aug. 1988, pp. 314-324.

TABLE 21

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand short tons and thousand dollars)

Customs district and country	1987			1988		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Anchorage:						
Canada	8	431	766	8	654	953
Japan	30	1,263	1,514	37	990	1,218
Korea, Republic of	10	322	516	—	—	—
Total	**48**	**2,016**	**2,796**	**45**	**1,644**	**2,171**
Baltimore:						
Bahamas	13	327	414	—	—	—
Canada	—	—	—	22	595	644
Colombia	19	492	693	—	—	—
Germany, Federal Republic of	(2)	8	9	—	—	—
Greece	189	4,431	4,808	169	4,084	4,470
Japan	—	—	—	(2)	45	57
Mexico	13	373	501	131	2,585	3,129
Netherlands	(2)	28	29	(2)	104	113
Spain	—	—	—	82	2,138	2,315
Venezuela	84	2,144	2,587	6	150	163
Total[3]	**318**	**7,803**	**9,041**	**411**	**9,701**	**10,892**
Boston:						
Canada	147	4,048	4,224	6	145	149
Colombia	—	—	—	6	157	302
Greece	123	2,885	3,090	336	12,465	13,351
Mexico	7	158	173	—	—	—
Netherlands	—	—	—	(2)	11	14
Spain	26	1,891	1,988	54	2,960	3,351
United Kingdom	—	—	—	15	736	746
Total[3]	**303**	**8,982**	**9,474**	**417**	**16,474**	**17,912**
Buffalo:						
Canada	964	37,582	37,868	1,017	45,139	45,139
Japan	(2)	12	12	—	—	—
United Kingdom	—	—	—	(2)	4	4
Total[3]	**964**	**37,594**	**37,880**	**1,017**	**45,142**	**45,142**
Charleston:						
Canada	(2)	5	5	—	—	—
Germany, Federal Republic of	(2)	6	8	(2)	3	3
Mexico	—	—	—	46	978	1,260
Netherlands	—	—	—	(2)	6	6
Panama	31	681	853	—	—	—
Spain	30	780	980	108	2,363	2,984
Total[3]	**61**	**1,472**	**1,845**	**154**	**3,351**	**4,254**

See footnotes at end of table.

TABLE 21—Continued

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand short tons and thousand dollars)

Customs district and country	1987			1988		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Chicago:						
Canada	—	—	—	([2])	3	3
Germany, Federal Republic of	([2])	225	252	—	—	—
Japan	([2])	7	10	([2])	29	33
Lebanon	—	—	—	24	781	1,315
Total[3]	**([2])**	**232**	**262**	**24**	**813**	**1,349**
Cleveland:						
Canada	176	5,781	7,558	135	4,735	5,901
Spain	([2])	2	2	—	—	—
United Kingdom	([2])	24	24	—	—	—
Total[3]	**176**	**5,807**	**7,585**	**135**	**4,735**	**5,901**
Detroit:						
Canada	938	33,120	35,354	650	25,283	26,570
Germany, Federal Republic of	—	—	—	([2])	6	7
Netherlands	—	—	—	([2])	23	27
Spain	93	1,943	1,976	—	—	—
Total[3]	**1,031**	**35,063**	**37,331**	**650**	**25,312**	**26,604**
Duluth:						
Canada	77	2,294	2,849	144	4,449	4,995
Greece	36	887	1,432	—	—	—
Total[3]	**113**	**3,181**	**4,282**	**144**	**4,449**	**4,995**
El Paso: Mexico	595	20,950	20,950	450	16,961	16,961
Great Falls:						
Canada	([2])	13	13	([2])	2	2
Yugoslavia	([2])	10	10	([2])	13	13
Total[3]	**([2])**	**23**	**23**	**([2])**	**15**	**15**
Honolulu:						
Australia	2	155	155	—	—	—
Japan	25	540	708	137	3,030	4,281
Korea, Republic of	21	1,063	1,138	12	461	643
Total[3]	**48**	**1,758**	**2,001**	**149**	**3,491**	**4,923**
Houston:						
Colombia	33	789	891	—	—	—
Germany, Federal Republic of	([2])	54	64	([2])	24	28
Italy	—	—	—	([2])	3	5
Mexico	74	1,453	2,182	317	6,323	8,882
Spain	642	12,644	17,502	62	1,525	2,131
Total[3]	**749**	**14,940**	**20,639**	**378**	**7,875**	**11,046**

See footnotes at end of table.

TABLE 21—Continued

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand short tons and thousand dollars)

Customs district and country	1987			1988		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Laredo:						
Mexico	301	8,978	8,978	229	8,155	8,223
Panama	—	—	—	1	31	31
Total[3]	**301**	**8,978**	**8,978**	**229**	**8,186**	**8,254**
Los Angeles:						
Bahamas	91	3,006	3,497	—	—	—
Denmark	13	451	1,115	18	571	1,533
France	202	4,569	6,107	([2])	973	1,232
Germany, Federal Republic of	([2])	40	48	—	—	—
Japan	435	10,347	15,503	1,158	32,044	37,847
Korea, Republic of	454	10,283	13,138	508	10,865	13,878
Spain	([2])	72	130	23	822	974
Taiwan	23	525	714	115	2,783	3,720
Yugoslavia	([2])	47	88	1	91	136
Total[3]	**1,218**	**29,340**	**40,340**	**1,823**	**48,149**	**59,322**
Miami:						
Bahamas	50	1,434	1,618	—	—	—
Belgium-Luxembourg	2	128	242	3	188	284
Brazil	—	—	—	([2])	2	2
Colombia	—	—	—	12	355	447
Denmark	4	349	400	6	372	452
France	10	320	407	—	—	—
Germany, Federal Republic of	2	6	8	([2])	5	7
Greece	53	1,161	1,677	505	12,499	16,276
Mexico	323	6,561	15,242	449	9,102	12,954
Spain	447	12,664	17,357	296	10,786	13,420
Sweden	—	—	—	4	148	170
Venezuela	428	9,949	13,255	128	3,200	4,210
Total[3]	**1,318**	**32,572**	**50,203**	**1,404**	**36,657**	**48,220**
Milwaukee:						
Germany, Federal Republic of	([2])	14	16	—	—	—
Mobile:						
France	31	1,213	1,228	—	—	—
Greece	166	2,820	3,631	52	1,098	1,101
Mexico	339	5,001	6,835	334	5,232	6,789
Spain	40	682	915	—	—	—
United Kingdom	29	496	659	—	—	—
Total	**605**	**10,212**	**13,268**	**386**	**6,330**	**7,890**

See footnotes at end of table.

TABLE 21—Continued

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand short tons and thousand dollars)

Customs district and country	1987			1988		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
New Orleans:						
Belgium-Luxembourg	31	650	905	—	—	—
Canada	61	3,860	4,665	26	865	1,040
France	179	1,217	6,719	293	8,982	11,354
Greece	222	5,135	6,528	—	—	—
Mexico	657	15,176	20,723	300	6,034	10,223
Spain	463	12,385	15,806	439	10,484	13,555
Total[3]	**1,613**	**38,423**	**55,346**	**1,059**	**26,364**	**36,172**
New York City:						
Canada	32	716	868	—	—	—
Colombia	2	49	77	—	—	—
France	58	1,590	1,594	119	3,303	4,605
Germany, Federal Republic of	([2])	43	45	—	—	—
Greece	638	15,432	21,969	743	19,727	26,251
Mexico	162	3,645	5,464	161	3,222	4,865
Saudi Arabia	—	—	—	36	613	1,076
Spain	434	15,382	22,273	208	6,952	8,718
Sweden	—	—	—	35	1,042	1,397
Switzerland	—	—	—	([2])	2	2
United Kingdom	—	—	—	5	145	210
Venezuela	22	503	613	—	—	—
Total[3]	**1,346**	**37,360**	**52,902**	**1,308**	**35,004**	**47,123**
Nogales: Mexico	381	13,039	13,039	418	9,915	9,915
Norfolk:						
Bahamas	10	248	385	6	217	268
Colombia	—	—	—	34	902	1,317
France	70	2,468	3,118	51	7,801	9,206
Germany, Federal Republic of	([2])	11	13	([2])	15	19
Greece	16	386	621	141	4,503	5,545
Mexico	—	—	—	38	1,060	1,500
Netherlands	—	—	—	([2])	1	1
Spain	323	8,560	11,812	52	1,509	1,960
United Kingdom	—	—	—	6	242	309
Venezuela	31	820	1,276	156	4,283	6,526
Total[3]	**451**	**12,493**	**17,225**	**486**	**20,533**	**26,652**
Ogdenburg:						
Canada	514	15,801	15,817	279	9,089	9,089
Netherlands	([2])	244	294	—	—	—
Total	**514**	**16,045**	**16,111**	**279**	**9,089**	**9,089**

See footnotes at end of table.

TABLE 21—Continued

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand short tons and thousand dollars)

Customs district and country	1987 Quantity	1987 Value Customs	1987 Value C.i.f.[1]	1988 Quantity	1988 Value Customs	1988 Value C.i.f.[1]
Pembina: Canada	103	4,645	4,645	190	8,780	8,780
Philadelphia:						
France	—	—	—	41	1,124	1,528
Germany, Federal Republic of	([2])	187	204	([2])	112	123
Greece	62	1,209	1,424	104	2,271	3,605
Netherlands	([2])	82	104	—	—	—
Spain	135	4,545	4,890	202	5,825	7,634
Venezuela	17	404	629	—	—	—
Total[3]	**214**	**6,427**	**7,251**	**347**	**9,332**	**12,890**
Portland, ME:						
Canada	12	584	584	14	697	697
Mexico	—	—	—	2	64	64
Portugal	—	—	—	20	777	942
Spain	—	17	20	—	—	—
Total[3]	**12**	**601**	**604**	**36**	**1,538**	**1,704**
Portland, OR:						
Japan	104	1,029	1,192	125	2,911	3,878
Korea, Republic of	31	1,939	2,470	—	—	—
Total[3]	**135**	**2,968**	**3,661**	**125**	**2,911**	**3,878**
Providence:						
Canada	40	1,278	1,613	—	—	—
Colombia	105	2,585	5,128	131	3,262	5,961
Greece	—	—	—	119	3,145	4,254
Mexico	45	1,046	1,674	—	—	—
Spain	—	—	—	62	1,654	2,412
Venezuela	6	162	258	5	186	246
Total[3]	**196**	**5,071**	**8,673**	**317**	**8,247**	**12,872**
St. Albans:						
Canada	406	12,650	12,650	567	17,502	17,504
Netherlands	—	—	—	([2])	62	72
Total[3]	**406**	**12,650**	**12,650**	**567**	**17,564**	**17,576**
San Diego:						
Japan	52	1,533	1,870	25	737	909
Mexico	631	21,507	22,347	661	22,942	23,595
Morocco	—	—	—	([2])	4	4
Mozambique	10	259	273	—	—	—
Total[3]	**693**	**23,299**	**24,489**	**686**	**23,683**	**24,508**
San Francisco:						
Canada	121	3,196	6,485	—	—	—

See footnotes at end of table.

TABLE 21—Continued

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand short tons and thousand dollars)

Customs district and country	1987			1988		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Japan	—	—	—	39	1,221	1,605
Korea, Republic of	25	634	835	—	—	—
Mexico	233	6,027	6,371	274	7,066	7,781
Yugoslavia	—	—	—	(2)	4	7
Total[3]	**380**	**9,857**	**13,691**	**313**	**8,290**	**9,393**
San Juan, PR:						
Belgium-Luxembourg	7	495	862	7	461	787
Brazil	1	51	70	—	—	—
Colombia	25	528	694	39	946	1,235
Denmark	9	786	1,004	13	1,069	1,424
Honduras	56	1,577	2,312	32	853	1,303
Italy	—	—	—	(2)	2	3
Japan	(2)	13	14	(2)	5	5
Mexico	34	773	919	31	832	1,123
Spain	16	711	746	—	—	—
Total[3]	**149**	**4,934**	**6,621**	**122**	**4,168**	**5,881**
Savannah:						
Colombia	—	—	—	9	258	273
Germany, Federal Republic of	(2)	19	23	—	—	—
Mexico	—	—	—	30	688	728
Spain	72	2,181	2,284	48	1,749	1,844
Venezuela	10	239	329	—	—	—
Total[3]	**82**	**2,439**	**2,636**	**88**	**2,695**	**2,846**
Seattle:						
Canada	556	20,592	21,641	569	22,026	22,417
Colombia	—	—	—	(2)	3	3
Japan	151	3,619	4,285	237	5,708	7,787
Yugoslavia	—	—	—	(2)	5	9
Total[3]	**707**	**24,211**	**25,926**	**806**	**27,742**	**30,215**
Tampa:						
Colombia	286	6,819	9,329	331	8,693	11,210
Denmark	51	W	W	59	W	W
France	220	W	W	253	W	W
Greece	137	3,100	3,960	101	2,657	3,617
Mexico	1,167	20,979	31,637	1,121	23,367	31,893
Spain	321	6,346	8,441	221	5,696	7,561
Sweden	—	—	—	5	202	237
Venezuela	136	3,313	4,714	286	7,657	10,250
Total[3]	**2,318**	**48,671**	**68,494**	**2,376**	**57,073**	**76,234**

See footnotes at end of table.

TABLE 21—Continued

U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand short tons and thousand dollars)

Customs district and country	1987 Quantity	1987 Value Customs	1987 Value C.i.f.[1]	1988 Quantity	1988 Value Customs	1988 Value C.i.f.[1]
Virgin Islands of the United States:						
Bahamas	—	—	—	1	35	37
Barbados	—	—	—	1	73	94
Canada	—	—	—	2	4	5
Colombia	7	225	238	2	171	179
Dominican Republic	(2)	14	15	—	—	—
Leeward and Windward Islands	1	15	29	(2)	8	10
Sweden	—	—	—	3	114	116
Venezuela	33	794	838	60	1,054	1,089
Total[3]	**41**	**1,048**	**1,119**	**68**	**1,459**	**1,530**
Wilmington, NC:						
Colombia	139	3,414	5,041	79	2,051	2,998
Grand total[3]	**17,726**	**488,532**	**606,588**	**17,488**	**515,723**	**616,107**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Cost, insurance, and freight.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 22

U.S. IMPORTS FOR CONSUMPTION OF CEMENT AND CLINKER

(Thousand short tons and thousand dollars)

Year	Roman, portland, other hydraulic cement Quantity	Roman, portland, other hydraulic cement Value (customs)	Hydraulic cement clinker Quantity	Hydraulic cement clinker Value (customs)	White nonstaining portland cement Quantity	White nonstaining portland cement Value (customs)	Total[1] Quantity	Total[1] Value (customs)
1984	6,379	204,899	2,215	59,801	252	29,507	8,846	294,207
1985	9,581	306,472	4,633	103,067	274	27,890	14,487	437,429
1986	12,086	361,149	3,972	79,699	261	28,145	16,319	468,993
1987	13,782	384,989	3,668	79,373	276	24,170	17,726	488,532
1988	15,225	438,978	1,919	48,626	344	28,119	17,488	515,723

[1] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 23

HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Afghanistan[3]	123	85	[e]95	[e]110	110
Albania[e]	[4]948	940	940	945	880
Algeria[e]	6,100	6,720	7,120	7,170	7,170
Angola[e]	390	390	390	390	390
Argentina	[r]5,758	[r]5,104	6,122	6,947	[4]6,667
Australia	6,022	6,489	6,534	6,469	6,600
Austria	5,400	5,027	5,036	4,985	5,100
Bahamas	—	—	([5])	—	—
Bangladesh[6]	301	265	322	342	[4]342
Barbados	[e]165	[e]240	219	226	[4]203
Belgium	[r]6,292	6,103	6,349	6,271	6,000
Benin[e]	331	331	331	331	331
Bolivia	315	418	326	437	[4]425
Brazil	21,761	22,721	27,885	28,076	[4]27,919
Bulgaria	6,302	5,838	6,285	6,056	6,100
Burma	343	526	478	429	[4]385
Canada	9,489	11,235	11,687	13,892	[4]13,901
Chile	[r]1,543	[r]1,570	1,580	1,757	1,760
China[e]	[4]133,468	157,100	178,000	198,000	224,000
Colombia	5,816	6,294	7,094	7,237	[4]7,456
Congo	NA	64	[e]64	[6]42	64
Costa Rica	517	524	573	613	[4]613
Cuba	3,689	3,508	3,643	3,902	4,100
Cyprus	940	727	952	941	950
Czechoslovakia[e]	[4]11,607	11,300	11,200	11,200	11,200
Denmark	1,839	1,917	2,237	[e]2,200	2,200
Dominican Republic	1,260	1,110	1,175	[e]1,200	[4]1,648
Ecuador	1,910	2,167	[e]2,300	1,765	2,200
Egypt	7,165	6,337	8,391	9,641	9,900
El Salvador	440	496	488	669	660
Ethiopia[e]	265	275	275	275	275
Fiji	108	103	102	([7])	—
Finland	1,814	1,773	1,567	1,572	1,650
France	25,049	25,955	25,900	25,970	26,500
Gabon	229	270	232	151	165
German Democratic Republic	12,737	12,795	13,214	13,702	13,800
Germany, Federal Republic of	31,867	28,393	29,299	27,853	34,180
Ghana	252	400	241	302	[4]526
Greece	14,904	15,067	14,706	14,515	14,300
Guadeloupe	188	190	199	[e]210	220
Guatemala	462	580	710	1,459	[4]1,660
Haiti[e]	240	240	200	220	220

See footnotes at end of table.

TABLE 23—Continued

HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Honduras	589	383	386	[e]440	440
Hong Kong	2,037	2,023	2,465	2,454	[4]2,413
Hungary	4,569	4,054	4,239	4,578	[4]4,269
Iceland	130	126	125	144	148
India	32,000	36,409	40,124	40,763	[4]44,900
Indonesia	9,765	11,112	12,060	13,055	[4]13,495
Iran	13,011	13,739	13,529	14,031	13,800
Iraq[e]	8,800	8,800	8,800	11,000	11,600
Ireland	1,518	1,606	1,541	1,596	1,540
Israel	2,275	2,227	2,270	[e]2,270	2,270
Italy	41,648	40,429	38,956	[e]39,900	[4]41,069
Ivory Coast	591	748	855	719	770
Jamaica	288	264	266	337	[4]431
Japan	86,928	[r]80,300	78,555	78,871	[4]85,489
Jordan	2,192	2,230	1,978	[e]2,500	[4]1,962
Kenya	1,283	934	1,446	1,456	[4]1,366
Korea, North[e]	8,800	8,800	8,800	[r]9,900	11,000
Korea, Republic of	22,501	22,514	25,797	28,287	[4]31,961
Kuwait	1,305	1,315	1,118	[e]1,120	1,120
Lebanon[e]	[4]1,378	1,100	1,000	1,000	1,000
Liberia	93	105	107	116	[4]117
Libya[e]	6,600	7,200	[4]2,289	[4]2,976	3,000
Luxembourg	375	325	429	561	606
Madagascar[e]	39	39	39	39	39
Malawi	77	68	77	80	72
Malaysia	3,824	3,448	3,501	3,221	[4]3,818
Mali	28	21	[e]22	[r e]24	28
Martinique[e]	210	220	220	220	220
Mexico	20,322	22,796	21,772	25,077	[4]25,212
Mongolia	155	166	[e]220	[r e]195	276
Morocco	3,955	4,072	4,125	[e]4,200	4,200
Mozambique[e]	496	496	496	496	496
Nepal	43	35	102	167	[4]237
Netherlands	3,501	3,209	3,417	[e]3,440	3,400
New Caledonia[e]	66	66	[r]44	55	66
New Zealand	907	[r]1,069	999	970	990
Nicaragua[e]	110	110	110	110	110
Niger[e]	42	42	42	44	44
Nigeria[e]	3,300	3,680	3,860	3,860	3,680
Norway	1,705	1,764	1,929	[e]1,870	1,870
Pakistan[e]	[4]5,178	5,765	5,760	7,530	8,000
Panama	335	336	370	[e]385	385

See footnotes at end of table.

TABLE 23—Continued

HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Paraguay	120	51	197	288	[4]354
Peru	[r]2,146	1,937	2,432	2,849	2,800
Philippines	4,025	3,395	3,910	3,660	[4]4,700
Poland	18,409	16,535	17,416	17,747	16,500
Portugal	6,106	5,913	6,001	[e]6,400	6,300
Qatar	527	350	340	[e]330	335
Romania	15,450	13,490	15,670	15,760	15,400
Saudi Arabia	7,882	9,149	10,130	[e]10,140	10,500
Senegal	424	449	397	410	413
Singapore	3,110	2,195	1,989	1,684	[4]1,759
South Africa, Republic of	9,025	7,754	7,402	7,424	[4]9,142
Spain (including Canary Islands)[8]	28,038	26,673	[e]26,500	[e]25,800	26,500
Sri Lanka[e]	551	660	660	660	440
Sudan	194	213	[e]220	134	193
Suriname[e]	55	55	55	55	55
Sweden	2,638	[r]2,341	2,336	[e]2,425	2,425
Switzerland	4,609	4,689	4,842	5,089	5,200
Syria	4,720	4,736	4,630	[e]4,630	4,630
Taiwan	15,690	15,893	16,321	17,226	[4]19,049
Tanzania[e]	[4]408	330	330	330	330
Thailand	9,083	8,726	8,723	10,931	[4]12,692
Togo	268	313	384	407	[4]416
Trinidad and Tobago	447	362	372	[r e]360	[4]397
Tunisia	3,061	3,372	3,289	[e]3,750	5,500
Turkey	17,348	19,380	22,050	24,228	[4]24,995
Uganda[e]	22	22	22	22	22
U.S.S.R.	143,453	144,096	148,943	151,462	153,000
United Arab Emirates	4,415	[e]4,400	2,745	2,750	3,600
United Kingdom	14,860	14,704	14,785	[e]14,770	14,880
United States (including Puerto Rico)	78,699	78,859	79,916	79,501	[4]78,252
Uruguay	368	346	375	442	[4]479
Venezuela	5,272	5,836	6,335	6,735	[4]6,833
Vietnam[e]	1,210	1,430	1,700	[4]1,667	1,650
Yemen (Sanaa)	1,532	1,543	1,279	838	880
Yugoslavia	10,268	9,952	10,061	9,880	[4]9,744
Zaire	589	489	[e]440	[e]440	440
Zambia	266	349	368	413	385
Zimbabwe[e]	715	770	825	[4]894	[4]855
Total	**[r]1,037,321**	**[r]1,057,489**	**1,103,091**	**1,151,060**	**1,212,724**

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Table includes data available through July 5, 1989.

[2]In addition to the countries listed, Cameroon produces cement, but available information is inadequate to make reliable estimates of output levels.

[3]Data are for the year beginning Mar. 21 of that stated.

[4]Reported figure.

[5]Less than 1/2 unit.

[6]Data are for the year ending June 30 of that stated.

[7]Revised to zero.

[8]Excludes natural cement.

TABLE 24

WORLD CEMENT ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Million short tons)

	Rated clinker capacity[1]
North America:	
United States	89
Canada	16
Mexico	33
Total	**138**
South America:	
Argentina	12
Brazil	44
Venezuela	7
Other	21
Total	**84**
Europe:	
Belgium	8
Czechoslovakia	10
France	26
German Democratic Republic	14
Germany, Federal Republic of	44
Greece	15
Italy	44
Poland	21
Portugal	8
Romania	20
Spain	38
U.S.S.R.	154
United Kingdom	17
Yugoslavia	12
Other	109
Total	**540**
Africa:	
Egypt	21
South Africa, Republic of	12
Other	45
Total	**78**
Asia:	
China	215
India	56
Indonesia	19
Japan	98
Korea, North	11
Korea, Republic of	34
Thailand	12
Taiwan	24
Other	42
Total	**511**
Oceania:	
Australia	9
Other	1
Total	**10**
World total	**1,361**

[1] Includes capacities of operating plants as well as plants on standby basis.

CHROMIUM

By John F. Papp[1]

In 1988, reported chromium consumption was 402,136 metric tons.[2] The reported consumption of chromite by the chemical and metallurgical industry and by the refractory industry increased. Metallurgical industry chromite consumption includes material consumed as part of the National Defense Stockpile (NDS) program to convert chromite to ferrochromium. Imports of chromite increased, and imports of chromium ferroalloys increased compared with those of 1987. Chromium supply to the steel industry was strained. A year of record-high world stainless steel production following a year of strong stainless steel production resulted in inadequate ferrochromium supply. As a result, domestic ferrochromium imports declined while stainless steel production increased. Ferrochromium stocks declined, and the delay between orders for and deliveries of stainless steel increased. As a result of short supply, ferrochromium prices increased. Numerous projects to increase ferrochromium production capacity were conceived by current producers and potentially new producers. Some of these projects were started with the expectation of completion in 1989 or 1990.

DOMESTIC DATA COVERAGE

Domestic data coverage of the primary consuming industries—metallurgical, refractory, and chemical—are developed by the Bureau of Mines by means of the voluntary monthly "Chromite Ores and Chromium Products" survey. The companies listed in table 3 by industry accounted for 100% of the chromite consumption data by industry in table 5. All of the refractory companies and all of the chemical companies that consumed chromite in 1988 reported to the Bureau, while 67% of the metallurgical companies reported. Consumption was estimated for the remaining 33% of the metallurgical firms.

Domestic production data for chromium ferroalloys and metal are developed by the Bureau of Mines by means of two separate voluntary surveys. These two surveys are the monthly "Chromium Ores and Chromium Products" and the annual "Ferroalloys." Production by the metallurgical companies listed in table 3 represented 100% of the domestic production shown in table 4. Sixty-seven percent of those companies responded to both surveys. Production for the remaining 33% was estimated.

LEGISLATION AND GOVERNMENT PROGRAMS

Under authority of Executive Order 12626 of February 25, 1988, management and operation of the NDS were transferred to the Department of Defense from the Federal Emergency Management Agency and the General Services Administration. Within Defense, those functions have been delegated to the Assistant Secretary of Defense (Production and Logistics) through and under the supervision of the Under Secretary of Defense (Acquisition). Operational activities for the NDS were performed by the Defense Logistics Agency (DLA).[3]

DLA planned to fund a research project aimed at producing ferrochromium using plasma arc smelting technology. DLA planned to contract a group (including South Carolina Research Authority, Clemson University, Massachusetts Institute of Technology, Arthur D. Little Co., and Macalloy Corp.) to design and develop a 2,000 kilowatt test furnace that would produce about 500 kilograms of ferrochro-

TABLE 1

SALIENT CHROMIUM STATISTICS

(Thousand metric tons, gross weight)

	1984	1985	1986	1987	1988
			CHROMITE		
United States:					
Exports	50	91	84	1	4
Reexports	4	3	1	5	1
Imports for consumption	277	376	443	490	615
Consumption	465	508	388	504	551
Stocks, Dec. 31: Consumer	297	272	285	330	390
World Production	r9,776	r10,516	11,094	p10,917	e11,665
			CHROMIUM FERROALLOYS[1]		
United States:					
Production[2]	86	100	95	107	120
Exports	14	9	5	5	8
Reexports	1	1	1	2	2
Imports for consumption	394	304	361	303	431
Consumption	358	335	331	396	413
Stocks, Dec. 31: Consumer	23	29	29	23	30
World Production[3]	2,831	2,971	2,895	3,035	3,114

e Estimated. p Preliminary. r Revised. NA Not available.
[1] High- and low-carbon ferrochromium plus ferrochromium-silicon.
[2] Includes chromium metal, exothermic chromium additives, and other miscellaneous alloys.
[3] As reported in the Ferroalloys chapter.

mium per hour. The test furnace was to be located on Macalloy's plant site at Charleston, SC. The objective of this project would be to develop a competitive production process under U.S. production conditions.

In accordance with the President's November 1982 directive and Public Law 99-591, DLA continued to upgrade NDS chromium ore to high-carbon ferrochromium. DLA reported conversion of chromium ore to ferrochromium on a calendar year contract basis as follows:

Contract year	Ore converted (metric tons)	High-carbon ferrochromium produced (metric tons)		Cost (millions)
		Gross	Content	
1984	113,968	45,590	30,180	$22.3
1985	124,298	44,872	29,630	22.5
1986	85,301	31,994	20,898	17.6
1987	125,739	52,414	40,058	33.6
1988	111,105	41,511	26,727	26.7

Source: Defense Logistics Agency.

The DLA exercised its third-year option, under terms of an agreement signed in 1987 with Macalloy of Charleston, SC, to extend the ferrochromium upgrading program into 1989. Under the extension, Macalloy is expected to upgrade 124,627 short tons of chromium ore to ferrochromium at a cost of about $30 million. This upgrade is in the sixth year of a 10-year upgrading program. The DLA planned to contract for the conversion of the remaining 559,796 short tons of chromium ore to high-carbon ferrochromium.

DLA planned to convert 1,500 short tons of nonspecification-grade low-carbon ferrochromium to electrolytic chromium metal in order to make chromium materials that are usable for superalloy production available in the NDS. This conversion project awaited congressional approval at yearend.

The Bureau of Mines assessed the direct and indirect cost that would result from a U.S. embargo of chromium (including chromium ore and ferrochromium) from the Republic of South Africa. The Bureau conducted the analysis at the request of the Department of State to assist the President and Congress in determining the national implications of such a prohibition. Under Section 303 of the Comprehensive Anti-Apartheid Act of 1986 (Public Law 99–440), U.S. imports of products produced, manufactured, marketed, or exported by parastatal organizations of the Republic of South Africa are prohibited except for minerals certified strategic and critical, and unavailable from reliable and secure suppliers. Chromium was so certified in 1987 and continues to be so certified. Assuming average 1983–86 chromium consumption, a 15% premium, and a 5-year embargo, the Bureau estimated direct average annual economic cost to the United States at about $30 million. The Bureau also recognized that there were chromium ore and ferrochromium suppliers other than the Republic of South Africa and that an embargo would result in trade pattern changes.[4]

The General Accounting Office (GAO) studied trade between the United States and the Republic of South Africa over the past 5 years. GAO reviewed Bureau of Mines reports and reported interviews with steel industry contacts. While the Bureau reported the existence of chromium ore and ferrochromium suppliers other than the Republic of South Africa, industry contacts reported that alternative suppliers were fully occupied supplying non-U.S. markets. Iron and steel manufacturers reported some success in locating alternate chromium suppliers. However, specialty steel manufacturers reported no such success.[5] GAO found the Bureau direct cost impact of a chromium embargo to be conservative, owing to the increased cost of chromium between the time of the Bureau analysis and the GAO review.[6]

Congress enacted the Harmonized Tariff Schedule of the United States through passage of the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100–418, Section 1204(a); 19 U.S.C. 3004(a)) and conferred authority upon the President to implement and modify the Harmonized Tariff Schedule consistent with the International Convention on the Harmonized Commodity Description and Coding System. As a result of conversion to the Harmonized Tariff System, commodity nomenclature and numbers in the Tariff Schedule of the United States are changed from those previously used, effective January 1, 1989. Tariff duty rates have been retained. (See Foreign Trade section of this chapter for a complete description of the Harmonized Tariff Schedule of the United States and duty rates for chromium-containing materials.)

The United States-Canada Free Trade Agreement was approved by Congress and by the Canadian government. The agreement was to take effect on January 1, 1989. Under the free-trade agreement, Canadian chromium ferroalloys (including ferrochromium and ferrochromium-silicon) were to enter the United States duty-free upon implementation of the agreement. The rate of duty for other chromium containing materials originating in Canada are to be reduced according to the schedule shown in the Tariff table.

The Environmental Protection Agency (EPA) included slag from roasting-leaching of chromite ore among 15 materials to be covered by the Bevill exclusion of the Resource

Nomenclature	Harmonized tariff schedule subheading	Jan. 1, 1989	Jan. 1, 1990	Jan. 1, 1991	Jan. 1, 1992	Jan. 1, 1993–98
Chromium oxides and hydroxides:						
Chromium trioxide	2819.10.00	2.9%	2.2%	1.4%	0.7%	Free.
Other	2819.90.00	2.9%	2.2%	1.4%	.7%	Do.
Sulfates; alums; peroxosulfates (persulfates): Other sulfates: Of chromium	2833.23.00	2.9%	2.2%	1.4%	.7%	Do.
Salts of oxometallic or peroxometallic acids:						
Chromates of zinc and lead	2841.20.00	2.9%	2.2%	1.4%	.7%	Do.
Sodium dichromate	2841.30.00	1.9%	1.4%	.9%	.4%	Do.
Potassium dichromate	2841.40.00	1.2%	.9%	.6%	.3%	Do.
Other chromates and dichromates; peroxochromates	2841.50.00	2.4%	1.8%	1.2%	.6%	Do.
Carbides, whether or not chemically defined: Other: Of chromium	2849.90.20	3.3%	2.5%	1.6%	.8%	Do.
Pigments and preparations based on chromium[1]	3206.20.00	2.9%	2.2%	1.4%	.7%	Do.
Metal and alloys: Ferrochromium:						
High-carbon	7202.41	Free	Free	Free	Free	Do.
Medium-carbon	7202.49.10	do.	do.	do.	do.	Do.
Low-carbon	7202.49.50	do.	do.	do.	do.	Do.
Ferrosilicon chromium	7202.50	do.	do.	do.	do.	Do.
Other base metals; cermets; articles thereof: Chromium: Other	8112.20.60	do.	do.	do.	do.	Do.

[1] Includes chrome yellow (3206.20.0010), molybdenum orange (3206.20.0020), zinc yellow (3206.20.0030), and other (3206.20.0050).

Conservation and Recovery Act (RCRA).[7] This material was included under the Bevill exclusion because it was considered a high-volume waste. It will be the subject of further study. All other (except the 15 identified materials) solid waste from the extraction, beneficiation, and processing of ores and minerals will be covered by RCRA. EPA listed emissions from the production of ferrochromium-silicon (RCRA waste number KO90) and ferrochromium (RCRA waste number KO91) as hazardous waste.[8]

The Minerals Marketing Corp. of Zimbabwe petitioned the United States Trade Representative (USTR) to designate low-carbon ferrochromium and ferrochromium-silicon eligible for duty-free status under the Generalized System of Preferences. The petition was made under sections 503(a) and 131(b) of the Trade Act of 1974 (19 U.S.C. 2463(a)). USTR denied the petition.

The Department of the Interior and the State of Oregon formed a task force to study chromium-containing black sand deposits off the coast of Oregon. The task force was directed to define the extent of the black sand deposits and to evaluate their economic and strategic importance. The black sands are located in coastal terraces off the shore of Oregon and at the mouth of the Columbia River. They were explored during World War II.

DOMESTIC PRODUCTION

The major marketplace chromium materials are chromite ore and chromium metal, ferroalloys, and chemicals. In 1988, the United States produced chromium metal, ferroalloys, and chemicals, but no chromite ore.

Metallurg Inc. merged its U.S. trading subsidiary with its U.S. production company, Shieldalloy Corp., to form Shieldalloy Metallurgical Corp.

Chrome Corp. International, a subsidiary of Boulder Gold (Australia),

TABLE 2

U.S. GOVERNMENT STOCKPILE GOALS AND YEAREND INVENTORIES FOR CHROMIUM IN 1988

(Thousand metric tons, gross weight)

Material	Stockpile goals	Physical inventory		
		Stockpile-grade	Nonstockpile-grade	Total
Chromite, metallurgical	2,903	1,491	216	1,707
Chromite, chemical	612	220	—	220
Chromite, refractory	771	355	—	355
High-carbon ferrochromium	168	487	1	488
Low-carbon ferrochromium	68	272	17	289
Ferrochromium-silicon	82	52	1	53
Chromium metal	18	3	—	3

Source: Defense Logistics Agency.

studied the possibility of mining chromite from the Stillwater Complex (Montana) and producing ferrochromium. Chrome Corp. International worked with Krupp Industrietechnik (Federal Republic of Germany) to determine the applicability of Krupp's kiln roasting process to the Stillwater chromite ore. Chrome Corp. also drilled to confirm ore reserves and prepared an environmental impact statement. The company planned a facility with a ferrochromium production capacity of about 120,000 tons per year of charge-grade high-carbon ferrochromium containing 53% chromium, and a mine with a capacity of about 600,000 tons per year containing 20% Cr_2O_3.

Elkem Metals Co. sold 70% interest of its Marietta, OH, power generation plant to American Municipal Power—Ohio. The plant has a capacity to produce 250 megawatts in the form of electricity and process steam. Elkem uses power from the coal-fired plant to produce chromium metal, high- and low-carbon ferrochromium, and other ferroalloys at its Marietta plant. Elkem resumed production of charge-grade high-carbon ferrochromium. One furnace was restarted at the Marietta plant. Production capacity of the 12-megawatt furnace was about 21,600 tons per year. Elkem planned to start a second furnace with a capacity of 17,000 tons per year if ferrochromium demand remained strong.

American Chrome & Chemical Inc., a member of the Harcross Group, planned to increase chromic acid production capacity at its Corpus Christi, TX, plant by 1990. American Chrome's chromic acid production capacity was in the range of 14,000 to 16,000 tons per year. Occidental Chemical Corp., Castle Hayne, NC, increased its chromic acid production capacity. Chromic acid demand for use in wood preservation was strong.

Strong world demand for ferrochromium by the stainless steel industry resulted in the short supply and increased cost of ferrochromium in the

TABLE 3

PRINCIPAL PRODUCERS OF CHROMIUM PRODUCTS IN 1988, BY INDUSTRY

Industry and Company	Plant
Metallurgical:	
Elkem AS, Elkem Metals Co.	Marietta, OH, and Alloy, WV.
Macalloy Corp.	Charleston, SC.
Shieldalloy Metallurgical Corp.	Newfield, NJ.
Moore McCormack Resources Inc., Globe Metallurgical Inc.	Beverly, OH.
Satra Concentrates Inc.	Steubenville, OH.
SKW Alloys Inc.	Calvert City, KY, and Niagara Falls, NY.
Refractory:	
General Refractories Co.	Lehi, UT.
Harbison-Walker Refractories, a division of Dresser Industries Inc.	Hammond, IN.
National Refractories & Mining Corp.	Moss Landing, CA, and Columbiana, OH.
North American Refractories Co. Ltd.	Womelsdorf, PA.
Chemical:	
American Chrome & Chemicals Inc.	Corpus Christi, TX.
Occidental Chemicals Corp.	Castle Hayne, NC.

TABLE 4

PRODUCTION, SHIPMENTS, AND STOCKS OF CHROMIUM FERROALLOYS AND CHROMIUM METAL IN THE UNITED STATES

(Metric tons)

Material	Net Production: Gross weight	Net Production: Chromium content	Net shipments	Producer stocks, Dec. 31
1987:				
Low-carbon ferrochromium, High-carbon ferrochromium, Chromium concentrate	104,817	66,731	109,156	3,875
Ferrochromium-silicon, Chromium metal, Other[1]	1,899	1,883	5,578	1,239
Total	**106,716**	**68,614**	**114,734**	**5,114**
1988:				
Low-carbon ferrochromium, High-carbon ferrochromium, Chromium concentrate	109,504	67,739	107,003	6,040
Ferrochromium-silicon, Chromium metal, Other[1]	10,141	5,543	8,496	2,791
Total	**119,645**	**73,282**	**115,499**	**8,831**

[1] Includes exothermic chromium additives and other miscellaneous chromium alloys.

United States. As a result, one domestic company, Elkem, restarted ferrochromium production, and domestic consumers acquired ferrochromium from several nontraditional suppliers. Short supply of ferrochromium limited stainless steel production, causing the time between ordering and delivery to reach about 20 weeks for some stainless steel industry products. Increased ferrochromium prices resulted in the imposition of surcharges on stainless steel products based on nickel and chromium raw material costs. (See Prices and Foreign Trade sections of this chapter.)

CONSUMPTION AND USES

Domestic consumption of chromite ore and concentrate was 550,636 tons in 1988. Of the total chromite consumed, the chemical and metallurgical industry used 462,066 tons; and the refractory industry, 88,570. Much of the chromite consumed and ferrochromium produced by the metallurgical industry were part of the NDS conversion program. (See Legislation and Government Programs section of this chapter.)

Chromium has a wide range of uses in the three primary consumer groups. In the metallurgical industry, its principal use in 1988 was in stainless steel. Of the 418,924 tons of chromium ferroalloys, metal, and other chromium-containing materials reported consumed, stainless steel accounted for 80%; full-alloy steel, 8%; and other end uses, 12%. The primary use of chromium in the refractory industry was in the form of chromite to make refractory bricks to line metallurgical furnaces. Chromite consumption by the refractory industry increased to 88,570 tons.

The chemical industry consumed chromite for manufacturing sodium bichromate, chromic acid, and pigments. Sodium and potassium chromate and bichromate are the materials from

TABLE 5

CONSUMPTION OF CHROMITE AND TENOR OF ORE USED BY PRIMARY CONSUMER GROUPS IN THE UNITED STATES

Year	Chemical and metallurgical industry		Refractory industry		Total[1]	
	Gross weight (metric tons)	Average Cr_2O_3 (percent)	Gross weight (metric tons)	Average Cr_2O_3 (percent)	Gross weight (metric tons)	Average Cr_2O_3 (percent)
1984	376,198	44.0	88,422	37.4	464,620	42.8
1985	449,216	41.5	59,189	38.1	508,406	41.2
1986	342,281	40.3	45,303	37.1	387,584	40.2
1987	458,536	41.0	45,737	39.0	504,272	41.0
1988	462,066	43.1	88,570	38.9	550,636	42.4

[1] Data may not add to totals shown because of independent rounding.

TABLE 6

U.S. CONSUMPTION OF CHROMIUM FERROALLOYS AND METAL IN 1988, BY END USE

(Metric tons, gross weight)

End Use	Ferrochromium		Ferro-chromium -silicon	Other	Total
	Low-carbon	High-carbon			
Steel:					
Carbon	3,582	3,304	151	W	7,037
Stainless and heat-resisting	11,401	316,677	8,051	467	336,596
Full-alloy	4,760	25,781	1,372	W	31,913
High-strength, low-alloy and electric	1,808	4,720	W	W	6,528
Tool	W	3,714	W	W	3,714
Cast irons	814	6,200	27	W	7,041
Superalloys	4,023	4,415	W	2,884	11,323
Welding materials[1]	319	W	—	142	462
Other alloys[2]	563	353	W	2,242	3,158
Miscellaneous and unspecified	1,393	885	8,295	580	11,152
Total[3]	**28,663**	**366,049**	**17,897**	**[4]6,315**	**418,924**
Chromium content	19,228	212,254	6,475	4,924	242,881
Stocks, Dec. 31, 1988	5,683	23,135	647	[5]960	30,424

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] Includes structural and hardfacing welding material.
[2] Includes magnetic and nonferrous alloys.
[3] Includes estimates.
[4] Includes 4,235 tons of chromium metal.
[5] Includes 7,681 tons of chromium metal.

TABLE 7

U.S. CONSUMER STOCKS OF CHROMITE, DECEMBER 31, BY INDUSTRY

(Metric tons, gross weight)

Industry	1984	1985	1986	1987	1988
Chemical and metallurgical	233,783	228,204	249,291	308,870	330,207
Refractory	63,157	44,121	35,379	21,289	59,463
Total	**[1] 296,941**	**272,325**	**284,670**	**330,159**	**389,670**

[1] Data do not add to total shown because of independent rounding.

TABLE 8

U.S. CONSUMER STOCKS OF CHROMIUM FERROALLOYS AND METAL, DECEMBER 31, BY PRODUCT

(Metric tons, gross weight)

Product	1984	1985	1986	1987	1988
Low-carbon ferrochromium	3,062	4,973	4,985	3,169	5,683
High-carbon ferrochromium	18,095	21,877	20,840	18,023	23,135
Ferrochromium-silicon	1,290	1,169	1,324	505	647
Other [1]	1,414	1,161	1,607	826	960
Total [2]	**23,861**	**29,181**	**28,756**	**22,524**	**30,425**

[1] Includes chromium briquettes, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.
[2] Data may not add to totals shown because of independent rounding.

which a wide range of chromium chemicals are made.

STOCKS

Reported consumer stocks of chromite increased from 330,159 tons in 1987 to 389,670 tons in 1988. Chemical and metallurgical industry stocks increased, as did refractory industry stocks. Producer stocks of chromium ferroalloys, metal, and other materials increased from 5,114 tons in 1987 to 8,831 tons in 1988. Consumer stocks increased from 22,524 tons in 1987 to 30,425 tons in 1988. At the 1988 annual rate of chromium ferroalloy and metal consumption, producer plus consumer stocks represented about a 5-week supply.

PRICES

The price of chromite increased. The published price of South African Transvaal chromite, 44% Cr_2O_3 (no specific chromium-to-iron ratio), increased from a range of $40 to $46 per ton, f.o.b. South African ports, to a range of $50 to $56 in July, where it remained through December. The published price of Turkish ore increased from $115 per ton, f.o.b. Turkish ports, to a range of $125 to $135 in May, then increased again to a range of $150 to $180 in July, where it remained through December.

The published price of domestic high-carbon (50% to 55% and 66% to 75% chromium), low-carbon (0.025% and 0.05% carbon), and ferrochromium-silicon remained unchanged. The published price of domestic simplex low-carbon ferrochromium increased from 110 cents per pound of contained chromium to 166 cents. The price increases took place quarterly, increasing from 110 cents to 130 cents in March, to 140 cents in July, to 158 cents in October, then to 166 cents in December. The price of chromium metal increased from a range of $3.15 to $3.75 per pound to $3.75 per pound in September, where it remained through December.

The price of imported high-carbon (50% to 55% and 60% to 65% chromium) and low-carbon (0.05% carbon) increased almost monthly. This was the second consecutive year in which the imported ferrochromium price increased. The published price of 50% to 55% chromium high-carbon ferrochromium increased from a range of 58 to 60 cents per pound of contained chromium to a range of 88 to 93 cents during the year; 60% to 65% chromium high-carbon ferrochromium, from a range of 60 to 65 cents to a range of 93 to 97 cents; and low-carbon ferrochromium, from a range of 100 to 105 cents to a range of 120 to 126 cents.

FOREIGN TRADE

Exports of chromium materials from the United States included chromite ore and chromium metal, ferroalloys, chemicals, and pigments.

Imports for consumption of chromium materials included chromite ore and concentrate made from ore; chromium ferroalloys, including low-carbon ferrochromium, high-carbon ferrochromium, and ferrochromium-silicon; metal; and chromium chemicals and pigments.

The United States planned to adopt the Harmonized Tariff Schedule in 1989. (See Legislation and Government Programs section of this chapter.) The new nomenclature and TSUS codes are shown in the following table:

Nomenclature	Harmonized tariff schedule subheading
Chromium ores and concentrates therefrom:	
Not more than 40% Cr_2O_3	2610.00.0020
More than 40% and less than 46% Cr_2O_3	2610.00.0040
Not less than 46% Cr_2O_3	2610.00.0060
Chromium oxides and hydroxides:	
Chromium trioxide	2819.10.0000
Other	2819.90.0000
Sulfates; alums; peroxosulfates (persulfates):	
Other sulfates: Of chromium	2833.23.0000
Salts of oxometallic or peroxometallic acids:	
Chromates of zinc and lead	2841.20.0000
Sodium dichromate	2841.30.0000
Potassium dichromate	2841.40.0000
Other chromates and dichromates; peroxochromates	2841.50.0000
Carbides, whether or not chemically defined: Other: Of chromium	2849.90.2000
Pigments and preparations based on chromium:	
Chrome yellow	3206.20.0010
Molybdenum orange	3206.20.0020
Zinc yellow	3206.20.0030
Other	3206.20.0050
Metal and alloys: Ferrochromium:	
More than 4% carbon	7202.41.0000
More than 3% and not more than 4% carbon	7202.49.1000
Other (i.e. not more than 3% carbon)	7202.49.5000
Ferrosilicon chromium	7202.50.0000
Other base metals; cermets; articles thereof: Chromium:	
Waste and scrap	8112.20.3000
Other	8112.20.6000

TABLE 9

PRICE QUOTATIONS FOR CHROMIUM MATERIALS AT BEGINNING AND END OF 1988

Material	January	December
	CENTS PER POUND OF CHROMIUM	
High-carbon ferrochromium:		
Domestic:		
50% to 55% chromium	50.25	50.25
66% to 70% chromium	52	52
Imported:		
50% to 55% chromium	58 - 60	88 - 93
60% to 65% chromium	60 - 65	93 - 97
Low-carbon:		
Domestic:		
0.025% carbon	100	100
0.05% carbon	95	95
Simplex	110	166
Imported: 0.05% carbon	100 -105	120 -126
	CENTS PER POUND OF PRODUCT	
Ferrochromium-silicon	38.6	38.6
Electrolytic chromium metal	315 -375	375

Source: Metals Week.

TABLE 10

U.S. EXPORTS AND REEXPORTS OF CHROMIUM ORES AND CONCENTRATES

Year	Exports		Reexports	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1984	49,830	$2,957	3,497	$864
1985	91,453	4,660	3,335	670
1986	83,559	4,143	1,322	511
1987	1,145	707	4,837	352
1988	3,931	1,430	1,032	320

Source: Bureau of the Census.

TABLE 11

U.S. EXPORTS OF CHROMIUM MATERIALS, BY TYPE

Type	1986 Quantity (metric tons)	1987 Quantity (metric tons)	1988 Quantity (metric tons)	1988 Value (thousands)	Principal destinations, 1988
Chromite ore and concentrate	83,559	1,145	3,931	$1,430	Mexico (48%); Canada (42%); Chile (8%).
Metal and alloys:					
Chromium metal[1]	291	376	318	4,847	Netherlands (30%); Japan (28%); Mexico (15%); Australia (6%); United Kingdom (6%); Canada (3%).
Chromium ferroalloys	[2]5,475	[3]4,144	[4]8,041	12,503	Canada (78%); Mexico (12%); Argentina (2%); Federal Republic of Germany (2%).
Chemicals:					
Chromic acid	5,077	4,086	4,174	9,436	Canada (33%); Japan (18%); Republic of Korea (9%); Taiwan (7%); Venezuela (6%); Mexico (4%); Thailand (3%); Turkey (2%).
Potassium chromate and dichromate	19	9	27	47	Mexico (32%); Canada (30%); Taiwan (21%); Hong Kong (8%); Venezuela (4%); Brazil (3%); Japan (2%).
Sodium chromate and dichromate	14,367	15,019	19,977	17,404	Italy (48%); China (11%); Thailand (10%); Republic of Korea (5%); Colombia (4%); Taiwan (4%).
Pigments	2,260	3,216	3,239	11,066	Federal Republic of Germany (25%); Philippines (12%); Republic of Korea (7%); Singapore (7%); Mexico (7%); United Kingdom (6%); Australia (5%); Canada (5%); Japan (5%); Thailand (4%).

[1] Wrought and unwrought and waste and scrap.
[2] Contained 3,172 tons of chromium.
[3] Contained 2,488 tons of chromium.
[4] Contained 4,845 tons of chromium.

Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF CHROMITE, BY COUNTRY

	Not more than 40% Cr_2O_3			More than 40% but less than 46% Cr_2O_3			46% or more Cr_2O_3			Total[1]		
	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)
1987:												
Canada	119	43	$23	—	—	—	—	—	—	119	43	$23
New Caledonia	—	—	—	—	—	—	4,758	2,431	$749	4,758	2,431	749
Philippines	12,455	4,361	1,172	2,420	1,090	$264	11	6	3	14,886	5,457	1,439
South Africa, Republic of	—	—	—	147,266	66,293	6,532	103,499	51,846	4,913	250,765	118,139	11,445
Turkey	172,196	62,227	7,278	24,235	10,107	1,686	3,556	1,641	275	199,988	73,975	9,239
U.S.S.R.	19,384	7,366	879	—	—	—	—	—	—	19,384	7,366	879
Total[1]	**204,155**	**73,996**	**9,352**	**173,922**	**77,489**	**8,483**	**111,824**	**55,924**	**5,940**	**489,901**	**207,410**	**23,775**
1988:												
Finland	—	—	—	30,904	13,908	1,792	—	—	—	30,904	13,908	1,792
New Caledonia	—	—	—	—	—	—	4,200	2,291	664	4,200	2,291	664
Philippines	17,699	6,601	1,660	—	—	—	2,000	700	197	19,699	7,301	1,857
South Africa, Republic of	50,361	17,021	2,323	145,968	65,306	7,684	190,254	96,116	9,618	386,583	178,443	19,625
Turkey	94,137	34,560	5,816	44,775	18,406	8,482	17,018	7,846	3,096	155,930	60,812	17,394
U.S.S.R.	13,016	4,946	593	—	—	—	5,000	2,300	392	18,016	7,246	985
Total[1]	**175,213**	**63,128**	**10,392**	**221,647**	**97,620**	**17,958**	**218,472**	**109,253**	**13,967**	**615,332**	**270,001**	**42,317**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF FERROCHROMIUM, BY COUNTRY

Country	Low-carbon ferrochromium (not over 3% carbon)			High-carbon ferrochromium (over 3% carbon)		
	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)
1987:						
Brazil	—	—	—	4,556	2,443	$1,914
Canada	1	([1])	$2	13	7	6
China	—	—	—	5	4	4
Finland	—	—	—	3,002	1,555	1,141
Germany, Federal Republic of	7,118	5,035	11,432	2,536	1,799	1,303
Greece	—	—	—	6,700	4,115	3,050
Italy	421	307	690	—	—	—
Japan	323	216	477	357	238	461
South Africa, Republic of	18,796	10,969	12,945	177,495	93,239	71,651
Sweden	1,734	1,198	2,419	774	527	611
Turkey	3,530	2,378	3,769	10,800	6,946	5,445
United Kingdom	18	12	33	—	—	—
Yugoslavia	—	—	—	15,559	10,040	7,558
Zimbabwe	6,386	4,325	5,956	35,193	22,881	19,404
Total[2]	**38,325**	**24,440**	**37,723**	**256,989**	**143,793**	**112,546**
1988:						
Albania	—	—	—	1,950	1,228	1,286
Austria	3	2	5	—	—	—
Brazil	—	—	—	10,108	5,280	9,269
Canada	—	—	—	10	7	33
Chile	—	—	—	684	478	832
China	1,624	1,116	2,285	13,350	8,686	10,983
France	—	—	—	4,934	3,362	3,641
Germany, Federal Republic of	15,605	11,115	24,908	1,947	1,276	1,738
Greece	—	—	—	10,107	6,145	7,713
Hong Kong	—	—	—	400	264	548
India	40	29	60	1,300	819	1,779
Italy	1,411	1,031	2,830	2,070	1,318	1,617
Japan	549	368	922	2,875	1,849	3,414
Mexico	—	—	—	2,922	1,962	3,794
Netherlands	—	—	—	36	26	54
Philippines	—	—	—	14,767	9,484	15,521
South Africa, Republic of	13,533	7,928	14,914	155,963	81,061	91,108
Sweden	332	239	875	14,490	8,188	10,821
Switzerland	—	—	—	515	331	452
Taiwan	—	—	—	1,792	919	1,570
Turkey	7,087	4,941	10,284	26,518	17,011	25,521
United Kingdom	303	201	270	146	91	126
Yugoslavia	96	68	135	42,388	27,156	39,245
Zimbabwe	7,856	5,299	6,811	64,094	42,275	57,689
Total[2]	**48,438**	**32,337**	**64,300**	**373,363**	**219,216**	**288,753**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 14

U.S. IMPORTS OF CHROMIUM MATERIALS, BY TYPE

Type	1986 Quantity (metric tons)	1987 Quantity (metric tons)	1988 Quantity (metric tons)	1988 Value (thousands)	Principal sources, 1988
Metals and alloys:					
Chromium metal[1]	4,069	3,952	4,101	$29,656	United Kingdom (32%); Japan (24%); China (22%); France (20%).
Ferrochromium-silicon	[2]8,365	[3]7,580	[4]9,710	5,461	Zimbabwe (73%); Republic of South Africa (27%).
Chemicals:					
Chromic acid	4,197	2,558	1,542	3,155	Italy (82%); China (6%); Federal Republic of Germany (4%).
Chromium carbide	92	157	68	697	Federal Republic of Germany (44%); Japan (29%); Canada (13%); United Kingdom (13%).
Potassium chromate and dichromate	750	1,006	1,327	1,714	United Kingdom (35%); Canada (28%); U.S.S.R. (26%); Federal Republic of Germany (8%)
Sodium chromate and dichromate	6,946	4,755	3,756	4,960	Republic of South Africa (36%); Federal Republic of Germany (32%); Turkey (12%); Mexico (9%).
Pigments:					
Chrome green	24	94	160	366	Canada (51%); France (34%); Federal Republic of Germany (10%); United Kingdom (4%).
Chrome yellow	1,933	3,355	3,999	7,720	Canada (72%); Hungary (14%).
Chrome oxide green	2,566	2,411	4,034	10,073	United Kingdom (48%); Federal Republic of Germany (37%); Japan (10%).
Hydrated chromium oxide green	—	15	([5])	13	All from United Kingdom.
Molybdenum orange	749	1,106	1,131	3,128	Canada (79%); Republic of Korea (10%); Japan (7%).
Strontium chromate	119	119	122	361	France (52%); Belgium (20%); Federal Republic of Germany (15%).
Zinc yellow	1,288	1,207	1,098	1,279	Norway (40%); Hungary (33%); Canada (6%); Federal Republic of Germany (5%).

[1] Wrought and unwrought and waste and scrap.
[2] Contained 3,204 tons of chromium.
[3] Contained 2,827 tons of chromium.
[4] Contained 3,564 tons of chromium.
[5] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 15

U.S. IMPORT DUTIES FOR CHROMIUM-CONTAINING MATERIALS IN 1988

Item	TSUS No.	Most favored nation (MFN)	Non-MFN
Ore: Chrome ore and concentrate therefrom	601.15	Free	Free.
Metal and alloys:			
Ferrochromium:			
Low-carbon	606.22	3.1% ad valorem	30% ad valorem.
High-carbon	606.24	1.9% ad valorem	7.5% ad valorem.
Ferrosilicon chromium	606.42	10% ad valorem	25% ad valorem.
Chromium metal[1]	632.18	3.7% ad valorem	30% ad valorem.
Chemicals:			
Potassium chromate and dichromate	420.08	1.5% ad valorem	3.5% ad valorem.
Sodium chromate and dichromate	420.98	2.4% ad valorem	8.5% ad valorem.
Chromium carbide	422.92	4.2% ad valorem	25% ad valorem.
Chromic acid	423.0092	3.7% ad valorem	Do.
Pigments and preparations based on chromium:			
Chrome green	473.10	3.7% ad valorem	Do.
Chrome yellow	473.12	do.	Do.
Chromium oxide green	473.14	do.	Do.
Molybdenum orange	473.18	do.	Do.
Strontium chromate	473.19	do.	Do.
Zinc yellow	473.20	do.	Do.

[1] Includes wrought and unwrought and wasted and scrap chromium metal.

Note: The special tariff treatment programs—Generalized System of Preferences, Caribbean Basin Economic Recovery Act, United States-Israel Free Trade Area Implementation Act of 1985, and United States-Canada Free Trade Agreement apply to many of these items. Eligible for full tariff reductions are the least developed developing countries in accordance with section 503(a)(2)(A) of the Trade Agreements Act of 1979 (stat. 251).

WORLD CAPACITY

The data in tables 16 and 17 are rated capacity for mines and smelters as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure. Since not all producers make production capacity information available, historical chromium trade data has been used to estimate production capacity.

TABLE 16

WORLD ANNUAL CHROMITE PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand metric tons, contained chromium)

Country	Capacity
Albania	218
Brazil	75
Finland	211
India	181
Madagascar	45
Philippines	60
South Africa, Republic of	1,505
Turkey	181
U.S.S.R.	948
Zimbabwe	151
Other[1]	111
Total	**3,686**

[1] Other chromite producing countries include Burma, Cuba, Greece, Indonesia, Iran, Japan, New Caledonia, Oman, Pakistan, Sudan, and Vietnam.

WORLD REVIEW

Albania

Albania planned to increase its chromium ore and ferrochromium production capacity. Cooperative agreements covering the chromium industry were made with France and the Federal Republic of Germany. Albania reported operating 15 chromium mines. The Kalimash Mines in the Kukes district and Bulquize Mines in the Dibra district made major contributions to Albanian production. Chromite is also mined in the Tropoje district. At the Kalimash Mines, Albania planned to construct a tunnel to connect Kalimash 1 and Kalimash 2 with the beneficiation plant that serves those mines. The tunnel would reduce transportation distance from the mines to the beneficiation plant to 3.4 kilometers. Four new

TABLE 17

WORLD ANNUAL FERROCHROMIUM PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand metric tons, contained chromium)

Country	Capacity
Albania	28
Brazil	75
China	72
Finland	84
Germany, Federal Republic of	31
India	102
Italy	59
Japan	218
Philippines	45
Poland	35
South Africa, Republic of	631
Sweden	97
Turkey	32
United States	83
U.S.S.R.	223
Yugoslavia	58
Zimbabwe	125
Other[1]	102
Total	**2,100**

[1] Other ferrochromium-producing countries include Czechoslovakia, France, German Democratic Republic, Greece, Mexico, Romania, Spain, Taiwan, and the United Kingdom.

new beneficiation plants were planned for the Bulquize Mines, doubling production capacity. Albania planned the construction of a second ferrochromium plant to be located at Elbasan. The new plant was to consume about 100,000 tons per year of chromite to produce about 38,000 tons per year of high-carbon ferrochromium and was expected to start up in 1990. Albania made an agreement with Yugoslavia to obtain electrical power.

Australia

Dragon Resources Ltd., a newly formed company in Perth, sought to raise financing to develop its Range Well lateritic chromite deposit. The deposit is located about 67 kilometers northwest of Perth. Dragon proposed chromium recovery via either a sodium carbonate or a sodium hypochlorite roast-leaching process or by the production of ferrochromium. Australia's Bureau of Mineral Resources, Mineral Commodities Branch, reported chromium resources as follows: demonstrated subeconomic paramarginal resources, 2.34 million tons; demonstrated subeconomic submarginal resources, 520,000 tons; and inferred subeconomic resources, 20 million tons.

Brazil

Indústria e Comércio de Minérios S.A. (ICOMI) identified chromium resources in Território Federal do Amapá, município de Mazagão, and formed Cia. Ferroligas da Amapá for the purpose of exploiting those resources. ICOMI is a member of the Caemi mining group. Reserves of about 4.48 million tons graded at about 33.5% Cr_2O_3 were expected to have been approved. Chromite was planned to be mined and smelted into ferrochromium in Amapá for export. The mine reportedly had already started production, smelting tests had been successfully carried out, and some chromite was exported. A ferrochromium smelter was planned for the Macapa area. The smelter was planned to have an annual production capacity of about 19,000 tons and was to be completed in 1990 at a cost of about $14 million. Cia. Ferroligas da Amapá will be Brazil's second ferrochromium producer after Cia. de Ferro Ligas da Bahia S.A. and will add about 15% to Brazil's current annual high-carbon ferrochromium production capacity of about 130,000 tons.

Italmagnésio S.A. Indústria e Comércio planned to construct a ferrochromium plant in Venezuela. (See Venezuela in this section.)

Burma

Burma started production of metallurgical-grade chromite. About 5,000 tons was produced. Continued production was thought to depend on the establishment of long-term purchase agreements with Japanese consumers.

Canada

Sherwood Metallurgical Corp. planned a low-carbon ferrochromium smelter for Vancouver, British Columbia. The smelter was planned to have an initial production capacity of 25,000 tons and a construction cost of about $33 million.[9] Sherwood is owned 40% by Wooding Corp. (United States) and Elders Finance Group Ltd. (Australia). Production was to be marketed in Europe and the United States. In addition, a high-carbon ferrochromium smelter was planned for Becancour, Quebec. The smelter was planned to start production in 1991 with a capacity of about 80,000 tons. Major proponents of the project included the Government of Quebec, Société Generale de Financement, and Mitsui and Co. (Canada) Ltd. Canada continued to study the development potential of the Bird River chromite deposits in southeastern Manitoba.

China

In September, a 40% export duty was applied to ferrochromium. China's Ministry of Foreign Economic Relations and Trade identified chromium ore and ferrochromium among 12 items for export restriction because of shortages. Chromium ore and ferrochromium were among six materials identified as materials to be banned from export effective January 1, 1989. The export ban was found necessary because the alternative of increasing imports was not possible because of a shortage of foreign exchange.

Tibet sought foreign financial investment and technology for the development of its chromium resources. Tibet identified financing, transportation, and energy as areas that needed development in order that chromium resources could be exploited.

European Community (EC)

The EC set its duty-free quota for

ferrochromium containing greater than 6% carbon at 210,000 tons in March. That quota was revised to 390,000 tons in July.

Finland

Outokumpu Oy planned to increase its annual high-carbon ferrochromium production capacity by about 30% to 200,000 tons. The expanded facility was scheduled for completion in 1990 at a cost of about $20 million.[10] Outokumpu planned to achieve the expanded production capacity through modification of its furnace feed in order to supply more ferrochromium for its stainless steel production unit while maintaining supplies of ferrochromium for its foreign customers. Utilization of the expanded capacity would require Outokumpu to reduce ore exports. Outokumpu planned to increase its ore beneficiation plant capacity by 50% to 300,000 tons per year by constructing a new plant to replace the old one. To accommodate the increased concentrate production from the new ore beneficiation plant, the sintering plant capacity was to be increased by 100% to 300,000 tons per year. A new steel-belt-sintering method developed by LKAB (Sweden) was to be used. Outokumpu operated two submerged electric arc furnaces (a 36-megavolt-ampere furnace constructed in 1968 and a 75-megavolt-ampere furnace constructed in 1985) to supply about 50,000 tons per year of ferrochromium to its Tornio stainless steel plant and about 100,000 tons of ferrochromium to the export market—mostly European. The increased use of sintered beneficiated ore will permit Outokumpu to increase ferrochromium output from those furnaces to about 200,000 tons per year. The current high demand for ferrochromium and for stainless steel restrains Outokumpu from increasing its market share of either product. This increase in ferrochromium production capacity will permit Outokumpu to increase its stainless steel production while maintaining its ferrochromium supply obligations.

France

Chromeurope S.A., Gravelines, France, a subsidiary of Ferroaleaciones Españolas S.A. (FESA) of Spain, started production in March 1988 with a 12-megavolt-ampere furnace capable of producing 18,000 tons per year of high-carbon ferrochromium (containing 65% to 67% chromium). Chromeurope was constructing a second furnace at Dunkerque that was rated at 16 megavolt-amperes with production capacity of 25,000 tons per year of high-carbon ferrochromium (containing 65% to 67% chromium). The furnace was expected to be completed in the second quarter of 1989. Chromeurope represented all of the ferrochromium production capacity in France after Ugine Aciers ceased production at Ardoise in 1984 and Pechiney Electrometallurgie ceased production at Saint Beron in 1985. Ferrochromium was expected to be supplied primarily to European consumers. Chromeurope's location near port facilities made export to overseas markets a possibility. It is thought that FESA developed this venture because of a lack of available power to operate its plant in Spain. Location of this plant in the Dunkerque Industrial Zone offered an abundant (nuclear) electrical energy supply on a long-term basis, a site 800 meters from raw-materials-discharging facilities, and proximity to European consumers.

Disposal of high-carbon ferrochromium from the French national stockpile was reported.

India

The Geological Survey of India, the Orissa State Geological Survey, and mining companies conducted field surveys to better define India's chromite resources. The Geological Survey of India extended friable chromite reserves by 3 million tons in the Sukinda valley of Orissa.

Ferro Alloys Corp. Ltd. (FACOR) operated a domestic-oriented ferrochromium plant at Shreeramnagar and an export-oriented plant at Randia. FACOR also operated chromite-producing mines in Orissa. FACOR planned the construction of a captive 30-megawatt powerplant at its Garividi smelter, Shreeramnagar, Andra Pradesh State, at a cost of about $24 million.[11] The decision to construct a diesel power generation plant results from severe power cuts imposed by Andra Pradesh State Electricity Board (APSEB). APSEB cut electrical energy supply to FACOR by 60% and anticipated increasing that to 80%. The new plant was expected to meet 50% of FACOR's power requirements and was to be constructed by MAN B&W of the Federal Republic of Germany. FACOR will depend on APSEB for the remainder of its power needs. The Shreeramnagar plant operated seven electric furnaces producing ferroalloys for domestic use. The Garividi plant produced ferrochromium for domestic consumption with an annual capacity of 25,000 tons of high-carbon ferrochromium and 8,000 tons of low-carbon ferrochromium, accounting for about 15% of Indian ferrochromium production capacity. FACOR's construction of a 30-megawatt captive powerplant would permit FACOR to continue ferrochromium production despite electrical energy reductions imposed on them by APSEB. Reliable ferrochromium supply to India's steel industry would eliminate the need to import ferrochromium and thereby conserve India's hard currency reserves.

Indian Metals and Ferro Alloys Ltd. (IMFA) operated a domestic-oriented ferrochromium plant at Therubali, Orissa State, and an export-oriented plant under its subsidiary, Indian Charge Chrome Ltd. (ICCL), at Choudhar, Orissa State. ICCL started operation of a captive coal-fired powerplant, making ICCL independent of State supplied power. The ferrochromium plant, located near Choudhar, Cuttack District, Orissa State, was to have a production capacity of 62,500 tons per year of charge-grade high-carbon ferrochromium. The new ferrochromium plant was constructed with the technical collaboration of Elkem

A.S. (Norway) at a cost of about $103 million. The powerplant and ferroalloy plant complex cost about $149 million. The powerplant was to have a capacity of 108 megawatts produced from four 27-megawatt units. ICCL planned to have ferrochromium available for export after mid-1989. Upon completion, this plant would account for about 25% of Indian ferrochromium production capacity. ICCL was to market its ferrochromium through Elkem.

Owing to high demand for high-carbon ferrochromium, Industrial Development Corp., a public corporation of Orissa State, and a producer of low-carbon ferrochromium, shifted production from low- to high-carbon ferrochromium for sale in the world market.

OMC Alloys Ltd., a subsidiary of Orissa Mining Corp., operated a ferrochromium plant at Bamnipal, Orissa. OMC relined its furnace during the year. Pellet production was unsatisfactory requiring OMC to use more lump ore than anticipated. OMC's process was designed to use 20% lump and 80% pellets. OMC obtained chromite from its Kaliapani Mine, where it planned to have a beneficiation plant completed in 1990. The beneficiation plant was to have an output capacity of about 63,000 tons of 51%-Cr_2O_3 concentrate and 21,000 tons of 54%-Cr_2O_3 concentrate.

Tata Iron & Steel Co. (TISCO) developed its chromite and ferrochromium production capacity. Chromite production capacity at its mining operations at Sukinda Valley, Orissa, was being expanded to 200,000 tons per year of chromite, including 155,000 tons per year of fines and 45,000 tons per year of lump. A beneficiation plant for concentrate production was planned to consume about 300,000 tons per year of previously unused chromite graded at 20% to 30% Cr_2O_3 to produce about 100,000 tons per year of chromite concentrate graded at 48% to 52% Cr_2O_3. The beneficiation plant was planned to be completed in 1989 at a cost of $15 million, and the mine expansion in 1990 at a cost of $17 million. Upon completion of the mine expansion and beneficiation plant, TISCO also will have an annual chromite production capacity of about 300,000 tons. In addition, TISCO planned a briquetting plant for completion in 1990. The briquettes were to be used for the production of ferrochromium. TISCO planned to convert a furnace currently used for ferromanganese production to ferrochromium production at its Orissa ferromanganese plant.

Indonesia

P.T. Palmabim Mining started shipping chromite sand from its chromite mine on the east coast of central Sulawesi (Celebes) on Tolo Bay. The mine is co-owned by P.T. Palmabim Mining and P.T. Bituminusa, both Indonesian companies. The mine was developed with the technical and financial assistance of Girond Ltd. (United Kingdom) and Elders Resources Finance Group (Australia). The mining and processing plant was completed in March at a cost of about $3 million. The chromite sand is graded at about 43% Cr_2O_3, with less than 1% SiO_2. It is shipped from the private jetty of the mine and used as a casting sand. Reserves were adequate to support a 20-year mine life at a production rate of 40,000 tons per year. The chromite is recovered by surface mining. After removal of second growth jungle and a few centimeters of topsoil, the chromite sand is found within a 3-meter thick deposit of sand and gravel. Ore is mined by front end loader, sized, concentrated by spirals, dewatered and dried, sorted through screens, and subjected to electrostatic separation.

Japan

The Ministry of International Trade and Industry (MITI) budgeted about $16 million[12] to purchase stockpile materials in fiscal year 1989 (April 1, 1989–March 31, 1990). MITI planned to purchase an amount of ferrochromium equivalent to Japanese consumption of about 2.8 days, thereby reaching a stockpile quantity equivalent to about 24.4 days of consumption. In addition to the government stockpile purchase, about 1.2 day's worth of ferrochromium supply was planned to be purchased for the private stockpile. The stockpile goal is 60-day supply. The amount of ferrochromium held in the stockpile at the end of the 1988 fiscal year was about 49,000 tons.

Japan reported record-high stainless steel production of 2.8 million tons in 1988. Consumption of an estimated 800,000 tons of ferrochromium was reported. Japan's ferroalloy industry produced about 290,000 tons of ferrochromium, surpassing 1987 production by 30,000 tons and surpassing anticipated 1988 production by 20,000 tons. Japan's ferroalloy industry achieved this high level of ferrochromium production by reactivating previously idled furnaces. Japan's ferrochromium production declined from a range of about 300,000 to 340,000 tons per year in the 1980–85 period to a range of 260,000 to 290,000 tons per year in the 1986–88 period. High-carbon ferrochromium imports have increased their market share from about 40% in the early 1980's to about 60% in the 1987–88 time period. Over the same time period (early to late 1980's), the value of the yen had strengthened relative to the U.S. dollar, making Japanese-produced ferrochromium less competitive on the world (and Japanese) market. Japanese ferrochromium producers benefited from the short world supply of ferrochromium in 1988.

Owing to high demand for and low stocks of high-carbon ferrochromium, NKK Corp. reactivated ferrochromium production from furnace 1 (F1) at its ferrochromium production plant at Toyama, Toyama Prefecture, Japan. NKK started F1 production in October and produced at a rate of about 20,000 to 24,000 tons per year in the fourth quarter of 1988, then increased the production rate to 36,000 tons per year. NKK reactivated F1 to supplement production in

November 1987 when its furnace 2 (F2) was idled and continued production from F1 through March 1988, when it was put on standby status. F1 was expected to continue operation through the first quarter of 1989, when F2 is scheduled for routine maintenance.

For most of the year, Pacific Metals Co. operated one of two ferrochromium furnaces at its Hachinohe plant, Aomori Prefecture, Japan, and reactivated its second furnace in December. The furnaces were rated at 15 megavolt-amperes and 18 megavolt-amperes. The company reactivated its second furnace in December. Since electrical energy contracts are long term, Pacific Metals had to assure itself that demand and price would remain at current or higher levels for the duration of an electrical energy contract before making a commitment. Pacific Metals had been producing about 30,000 tons per year from one furnace while keeping the other idle and importing about 8,000 tons per year. Ferrochromium was produced for the company's stainless steel plant also located at Hachinohe. At the 1988 price of South African ferrochromium in Japan (about $0.67 per pound of contained chromium) and at 1988 demand levels for ferrochromium resulting from high demand for stainless steel, Pacific Metals could economically produce ferrochromium.

Korea, Republic of

Pohang Iron and Steel Co. Ltd. (Posco) continued construction of its stainless steel plant at Pohang. The plant was to have a stainless steel production capacity of about 240,000 tons per year, including 190,000 tons of hot-rolled coil and 50,000 tons of wire rod. Production was expected to start in early 1989 and reach capacity by 1990. The plant was designed for potential expansion to an annual capacity of 360,000 tons. This new stainless steel production capacity will add to the Republic of Korea's current capacity of about 44,000 tons annually. Domestic production was expected to displace part of the Republic of Korea's current imports of about 300,000 tons annually.

New Caledonia

Australmin Holdings (Australia) sought a partner for the development of an offshore sedimentary chromite deposit. The deposit graded at about 3.5% chromic oxide contained in about 100 million cubic meters of sediment. Mining was to be by dredging followed by gravity, magnetic, and electrostatic separation methods to produce chromite concentrate in the range of 100,000 to 200,000 tons per year.

Pakistan

Pakistan Chrome Mines Ltd. started strip mining a chromite deposit at Gowal. Production was planned to be in the range of 70 to 300 tons per day of run-of-mine ore. Pakistan Chrome Mines acquired the chromite deposit of Paracha Brothers (Pvt.) Ltd. in Baluchistan.

Philippines

The United Nations Fund for Natural Resources Exploration and the Philippine Bureau of Mines and Geosciences planned chromite exploration on Palawan, Surigao, and Dinagat Islands. Exploration was to include historical data collection, geologic mapping, gravimetric surveys, trenching, and preliminary drilling.

Ferro Chemicals Inc. reactivated a 10-megavolt-ampere furnace for the production of ferrochromium, owing to strong demand. Operation of the reactivated furnace, along with a smaller furnace that had been in continuous operation, brought Ferro Chemicals' annual production capacity up to about 30,000 tons of high-carbon ferrochromium.

Integrated Chrome, a joint venture among Nippon Denko (Japan) and Philippine principals, planned to convert the idle 20-megavolt-ampere furnace of Electro Alloys Corp. to high-carbon ferrochromium production. Ferrochromium production was planned to start in 1989.

Poland

Poland operated the Siechnice ferrochromium plant at Wroclaw. The Polish government planned to end production from the plant by 1991 owing to environmental contamination resulting from the plant operation. The plant was found to pose a threat to water resources around Wroclaw. Poland planned to construct an environmentally safe ferrochromium plant.

South Africa, Republic of

The Republic of South Africa is the major market economy chromium ore and ferrochromium producer, accounting for about half of market economy supply. Strong demand for chromium from the stainless steel producers resulted in record-high levels of chromium ore and ferrochromium production and in ferrochromium capacity expansion projects. The Republic of South Africa started or continued expansion projects that were expected to increase its ferrochromium production capacity by about 30% by the end of 1989. The Minerals Bureau reported 1987 South African ferrochromium production of 948,046 tons.

Applied Industrial Minerals Corp. (Aimcor) (United States) put the Lavino Mine up for sale. Lavino production was about 300,000 tons per year with a capacity of about 500,000 tons per year. Lavino was the only major chromite mine owned independently of the major South African mining houses and ferrochromium producers. Sale of Lavino was anticipated to be made to Anglovaal Ltd., a South African mining group.

Chromecorp Technology, a new ferrochromium producer, completed construction and initial startup of its two 30-megavolt-ampere furnaces at Randburg, Transvaal, Republic of South Africa, becoming that nation's fifth ferrochromium producer. Chromecorp expected to reach an annual production rate of about 120,000 tons of high-carbon ferrochromium in 1989. Chromecorp's capacity represented about 10%

of South African capacity. Construction cost for this smelter was about $25 million.[13] Chromecorp secured chromium ore feed material by purchasing the Chrombronne Mine near the smelter. Chromecorp invested about $1 million to expand mine production capacity from about 100,000 tons per year to about 240,000 tons per year.

Middelburg Steel and Alloys (Pty.) Ltd. (MS&A) decided to expand its ferrochromium and stainless steel production capacity. MS&A operated ferrochromium production plants at Krugersdorp and Middelburg, Transvaal, and the Republic of South Africa's only stainless steel plant at Middelburg. MS&A had high-carbon ferrochromium production capacity of about 100,000 tons per year at Krugersdorp and 130,000 tons per year at Middelburg and stainless steel production capacity of 100,000 tons per year at Middelburg. The Krugersdorp direct current transferred electric arc plasma furnace, the only commercial transferred-arc plasma furnace in production, was being upgraded from 16 megavolt-amperes to 40 megavolt-amperes. This upgraded plasma furnace was expected to achieve an annual production capacity of about 50,000 tons of high-carbon ferrochromium by adding about 30,000 tons per year to the current annual capacity of about 20,000 tons at a cost of about $13 million and bringing Krugersdorp's annual production capacity up to about 130,000 tons. Plasma furnace modifications were completed, and new capacity was expected to be achieved in 1989.

MS&A again took an innovative role in the high-carbon ferrochromium industry by introducing its chromite direct reduction (CDR) process. The CDR process applies kiln roast prereduction technology, developed in cooperation with Krupp Industrietechnik (Federal Republic of Germany), to the commercial production of high-carbon ferrochromium. At Middelburg, MS&A planned to install the CDR process to supply an existing furnace with prereduced feed stock. This upgrade was expected to add an annual production capacity of about 120,000 tons of high-carbon ferrochromium production capacity, bringing Middelburg's annual production capacity up to about 300,000 tons. Kiln construction was expected to be completed and new capacity achieved in 1990. The kiln roast process was expected to (1) reduce electric energy consumption by 75% by substituting coal for electricity, (2) permit the use of low-rank coal as a reductant in place of metallurgical-grade coal and to be the primary energy source, and (3) permit the use of UG2 chromite concentrate, a byproduct of platinum mining.

MS&A planned to upgrade its annual stainless steel production capacity to 150,000 tons by feeding molten high-carbon ferrochromium to the stainless steel melting furnaces and adding continuous billet caster capacity, expanding its line of products such as flats, rounds, squares, and channels. MS&A planned to achieve an annual high-carbon ferrochromium production capacity of about 430,000 tons in 1990, nearly double the current annual capacity of about 230,000 tons, and annual stainless steel production capacity of 150,000 tons, a 50% increase over the current 100,000 tons at a cost of about $92 million.

Tubatse Ferrochrome (Pty.) Ltd., of which South African Manganese Amcor Ltd. (Samancor) owns 49%, started construction of two new furnaces to add to its existing three furnaces, each was rated at an annual production capacity of about 60,000 tons. One of the new furnaces came into production in 1988, and the second was expected to come into production in 1989. Each additional furnace cost about $46 million. Tubatse was supplied primarily from the Montrose and Tweefontein Mines.

Consolidated Metallurgical Industries Ltd. (CMI) planned to expand annual production capacity by 50,000 tons to an annual capacity of about 200,000 tons. Capacity expansion of 10,000 tons was to be achieved by improving current processing. An additional 40,000 tons was to be achieved by adding a third furnace.

Purity Minerals Pty. Ltd., a Johannesburg-based company, reported a resource of chromium ore graded at 42% Cr_2O_3, upgradable to 46% Cr_2O_3. Purity sought a joint-venture partner to exploit the resource and to produce ferrochromium.

Swaziland

A ferrochromium plant was planned for construction in Swaziland. Australian Overseas Mining Ltd. (Australia) announced that the Swaziland Government approved a high-carbon ferrochromium plant with annual production capacity of about 120,000 tons. The new plant would use kiln reduction technology developed by Krupp Industrietechnik (Federal Republic of Germany). Use of the Krupp process would limit electrical energy use to about 1,150 kilowatts per ton of product. The remainder of the energy required would be from domestically produced coal. Chromite would be imported from Lebowa (Republic of South Africa). The kiln roast process offers the advantage that chromite feed material need not be agglomerated. Production was anticipated to begin in 1992. Chromine GmbH (Federal Republic of Germany), which already markets Lebowa chromite, was to market the ferrochromium. Swaziland is part of the Lomé agreement, under which it may export to the EC duty free.

Sweden

SwedeChrome AB at Malmö operated two furnaces, producing 30,000 to 40,000 tons of high-carbon ferrochromium containing a range of from 52% to 54% chromium. SwedeChrome planned to produce about 50,000 tons in 1989 and to reach capacity production of about 86,000 tons per year in 1990.

Turkey

Etibank continued construction of two electric furnaces for high-carbon ferrochromium production at its ferrochromium plant located at Elâzig. Each furnace was to have an electrical power capacity of 24 megavolt-amperes and a production capacity of 50,000 tons per year. Turkey currently has an annual high-carbon ferrochromium production capacity of about 50,000 tons at Elâzig. Ore was expected to be supplied from Turkish mines. Etibank increased the annual production capacity of its Kirka concentrator from a range of 250,000 to 400,000 tons to about 500,000 tons. Work continued on the Kefdag concentrator. A facility with production capacity of about 150,000 tons per year was expected to be completed in 1989. Etibank was constructing a beneficiation plant near Elâzig to supply chromite feed stock to the new ferrochromium furnaces. The beneficiation plant was to have a production capacity of about 100,000 tons per year and was to be completed in 1989.

Venezuela

Italmagnésio planned to construct a 189,000-ton ferrochromium plant in Venezuela at a cost of about $114 million for completion between 1992–96. The Italmagnésio plant was proposed to be part of the plan of Venezuelan Government-owned Corporación Venezolana de Guayana (CVG) to build a metals park at Puerto Ordaz. This project was to take advantage of inexpensive electricity, water, and gas available at Puerto Ordaz. The Amapá, Brazil, chromium ore resources were identified as a potential supply source for the ferrochromium smelter. This would be the first ferrochromium smelter in Venezuela. Italmagnésio planned to acquire an idle ferrosilicon furnace from Tinfos Jernverk A/S (Sweden) and an idle ferrochromium furnace from Nippon Denko Co. Ltd. (Japan) for production of ferrochromium in Venezuela.

Yugoslavia

Tvornica Karbida i Ferolegura Dalmacija converted a second 24-megavolt-ampere furnace to ferrochromium production. Dalmacija, with the addition of this furnace, has an annual high-carbon ferrochromium production capacity of 80,000 tons. The conversion cost about $2 million. Dalmacija obtained chromium ore feed material from Albania, Turkey, and the U.S.S.R.

Zimbabwe

Zimbabwe Mining and Smelting Co. (ZIMASCO) recommissioned its No. 2 furnace in February 1988 and installed a remelting furnace with which to remelt ferrochromium fines that are below salable size. The remelting furnace was expected to start production in the second quarter of 1989. ZIMASCO had been operating with a production capacity of about 160,000 tons per year of high-carbon ferrochromium. The No. 2 furnace added capacity of about 24,000 tons per year. The remelting furnace was expected to add annual capacity of about 16,000 tons, giving ZIMASCO a total high-carbon ferrochromium production capacity of about 200,000 tons per year. A transformer failure in the national power grid required ZIMASCO to idle its No. 2 furnace for 4 months. ZIMASCO produced about 170,000 tons of high-carbon ferrochromium in 1988 and was expected to produce as much as 192,000 tons in 1989.

Zimbabwe Alloys Ltd. (ZIMALLOYS) planned to increase its chromium ore reserves by acquiring resources owned by RM Enterprises (Pvt.) Ltd. including the Great Dyke Mine and Myurwi Peak at a cost of about $4 million.[14]

TECHNOLOGY

Geologic conditions associated with chromite deposits were studied. Information about and analysis of principal chromite-bearing ophiolite belts and chromite ore bodies and occurrences contained in them were presented along with analysis of prospecting methods. Areas described include Ural Mountains, northeastern Mediterranean, Minor Caucasus, and deposits in Albania, Cyprus, Greece, India, New Caledonia, Pakistan, Philippines, and Yugoslavia. The chromite-bearing ophiolite belts were found to vary in extent and degree of detail of mapping; exposure and erosion level; and by field and laboratory methods used in the study of those ore bodies.[15] The geological environments, associated host rocks, processes of ore formation, and factors that control chromite ore distribution and grade were studied for selected deposits. Study areas include Appalachian mountains, Bushveld Complex and Great Dyke of southern Africa, and deposits in Cyprus, New Caledonia, Pakistan, and Turkey.[16] The historical development of chromite resources and ferrochromium production were presented on a country basis.[17]

The Bureau of Mines studied the potential for production of ferrochromium or sodium chromate from domestic ores. The Bureau found that high-carbon ferrochromium could be smelted from lateritic residues, provided suitable flux additions were made. Chromium recovery ranged from 78% to 97% in the production of charge-grade high-carbon ferrochromium containing 54% chromium.[18] A procedure was developed for the production of sodium chromate from domestic chromite resources that contain levels of silicon and aluminum impurities too high to permit processing by present industrial processes. The Bureau procedure consists of reacting chromite with molten sodium hydroxide under oxidizing conditions to produce sodium chromate. The reaction product is leached first with methanol to recover unreacted sodium hydroxide, then with water to extract sodium chromate. Sodium chromate product is re-

TABLE 18

CHROMITE: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons, gross weight)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Albania[e]	720,000	825,000	850,000	830,000	750,000
Brazil[3]	259,973	189,504	222,990	[e]225,000	230,000
Cuba	[r]37,900	37,700	50,000	[r][e]60,000	60,000
Finland[4]	445,904	[r]506,200	678,091	543,000	700,000
Greece[5]	61,364	58,948	[e]62,000	63,825	63,000
India	423,000	560,000	629,671	623,591	700,000
Indonesia[e]	—	—	—	—	20,000
Iran	59,000	56,000	[e]56,000	[e]56,000	56,000
Japan	7,420	11,920	10,642	11,815	9,600
Madagascar	59,765	127,415	82,910	106,600	110,000
New Caledonia	84,152	78,820	72,207	61,832	[6]70,341
Oman	7,000	—	4,820	([7])	4,000
Pakistan	2,997	5,188	8,299	9,963	10,000
Philippines	260,889	272,031	174,230	187,900	190,000
South Africa, Republic of[4 8]	3,407,176	3,698,500	3,907,000	3,789,000	4,200,000
Sudan	[e]20,000	8,799	[e]8,500	13,015	13,000
Thailand	—	30	361	5	[6]776
Turkey	487,405	588,576	543,156	[e]600,000	625,000
U.S.S.R.[e 9]	2,940,000	2,940,000	3,185,000	3,150,000	3,240,000
Vietnam[e]	16,000	15,000	15,000	15,000	14,000
Zimbabwe	476,521	536,490	533,105	[e]570,000	600,000
Total	**[r]9,776,466**	**[r]10,516,121**	**11,093,982**	**10,916,546**	**11,665,717**

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data through May 3, 1989.

[2]In addition to the countries listed, Bulgaria, China, and North Korea may also produce chromite, but output is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels. Figures for all countries represent marketable output unless otherwise noted.

[3]Figures are sum of (1) crude ore sold directly for use and (2) concentrate output, both as reported in Brazilian sources. Total run-of-mine crude ore production (not comparable to data for other countries) was as follows, in metric tons: 1984—708,634; 1985—727,125; 1986—763,000; 1987—800,000 (estimated); and 1988—825,000 (estimated).

[4]Direct-shipping lump ore plus concentrate and foundry sand.

[5]Exports of direct-shipping ore plus production of concentrates.

[6]Reported figure.

[7]Revised to zero.

[8]Includes production by Bophuthatswana which was as follows, in metric tons: 1984—401,000; 1985—358,000; 1986—454,000; 1987—450,000 (estimated); and 1988—450,000 (estimated).

[9]Estimates of marketable output based in part on crude chromium ore reported in Soviet sources as 3,360,000 and 3,600,000 metric tons in 1985 and 1987, respectively.

covered by evaporative crystallization from the aqueous solution. Chromite concentrate from the Stillwater Complex in Montana, Red Bluff Bay, and the Kenai Peninsula in Alaska, and a nickel-cobalt laterite from southern Oregon were used as feed materials.[19]

Canada Center for Mineral and Energy Technology (CANMET) of Canada assessed the Bird River chromite deposit and investigated chromite recovery from that deposit. An assessment of the chrome deposit (a part of the Bird River chromite deposit, Manitoba, Canada) found the chromite to be unsuitable for the manufacture of commonly traded ferrochromium alloys. The study found that a facility producing 180,000 tons per year of semifinished nickel-containing stainless steel would be economically viable. About 3,500 tons per day of chromite ore would have to be mined and beneficiated. About 174,000 tons per year of concentrate containing 30% chromic oxide with a chromium to iron ratio of 0.85:1 would have to be smelted.[20] CANMET developed a mineral-processing flowsheet that included grinding, gravity separation, and flotation of Bird River chromite that was applied on a pilot plant scale. Processing resulted in 77% recovery of chromite in a concentrate containing 30% chromic oxide.[21]

The association of platinum deposits

with chromium occurrences was studied as it relates to the Duluth Complex. It was concluded that the Duluth Complex is not likely to contain stratabound chromitite layers at depth.[22]

The Bureau of Mines studied the role of chromium in oxidation protection of iron alloys containing chromium, nickel, silicon, and molybdenum alloying additions. The effect of chromium on the oxidation mechanism and on oxides formed was studied. Chromium concentration was reduced to 10 weight-percent, and oxidation protection continued to exceed that of stainless steel.[23]

The Bureau of Mines studied recycling of superalloys and the recovery of chromium from hard-face alloy-grinding waste and from high-temperature chromium-iron waste catalyst. These were shift catalysts, which shifted the relative concentration of reaction products to enhance production of the desired product. The Bureau found that about 55 million pounds of clean and contaminated superalloy scrap were processed in 1986, most of which was recycled domestically into the same superalloy. It was found that Inconel 718 has become the predominantly produced superalloy.[24] The Bureau developed a procedure to selectively extract chromic oxide from waste high-temperature shift catalysts that contain approximately 6% chromium in oxide form. The Bureau procedure consists of roasting the waste catalyst with sodium hydroxide or sodium carbonate, followed by water leaching. Chromium is recovered from the leach liquor utilizing an oxidation-reduction reaction with pH adjustment to form a hydrous chromic oxide precipitate. An economic evaluation of the process revealed an estimated average production cost of about $5.44 per pound of recovered chromic oxide. At this price, chromic oxide production is not competitive with that from ore. However, this procedure offers a potential alternative to waste disposal through landfill.[25] The Bureau developed a hydrometallurgical process to recover chromium from hard-face alloy grinding waste. The process involved de-oiling the grinding waste, followed by chloride-based dissolution of the de-oiled material. About 79% of chromium could be recovered as chromium chloride.[26]

Chromium substitution was studied by the Bureau of Mines and by the Council for Mineral Technology (MINTEK) of the Republic of South Africa. The Bureau studied an iron-chromium-nickel alloy for the purpose of developing a low-chromium alloy that could be substituted for type 304 stainless steel, the stainless steel grade of largest production. Oxidation resistance of the iron-base alloy, containing 8 weight-percent chromium, 16 weight-percent nickel, with small additions of aluminum, silicon, molybdenum, and/or manganese, was studied in the temperature domain of 600° to 1,000° C for up to 1,000 hours. The synergistic effect of aluminum, chromium, and silicon were found to promote good oxidation resistance. Molybdenum and manganese additions stabilized a fully austenitic microstructure at room temperature. The oxidation behavior of the alloys studied was compared with that of stainless steel and superalloys. Reaction kinetics, oxide morphologies, and oxidation mechanisms of the substitute alloys were described.[27] MINTEK assessed the potential for significant chromium replacement in iron-base alloys and assessed the usefulness of new alloys resulting from chromium-replacement research. In addition to increased corrosion resistance, MINTEK found that the benefits of chromium addition to iron alloys included increased hardenability, the promotion of resistance to softening during tempering, improved resistance to creep, and the formation of wear-resistant precipitates. These additional benefits could be achieved using other alloying elements at a higher raw materials cost. These benefits are also the reason for using chromium in about 20% of chromium use. MINTEK identified three major impediments to chromium substitution in iron-base alloys: (1) Where chromium substitution is technologically possible, it is economically disadvantageous. (2) Chromium is the only alloying element that confers chemical passivity upon iron-base alloys in corrosive environments. (3) One grade of stainless steel (type 304) meets the needs of a wide variety of end users, resulting in economy of scale in production. Substitute alloys appropriate for a small fraction of end uses would not achieve such an economy of scale.[28]

The National Aeronautic and Space Administration (NASA) studied negative-electrode catalysts for iron-chromium redox cells. NASA developed bismuth and bismuth-lead catalyzed surfaces for the chromium electrode in the chromium redox electrochemical energy storage system. The bismuth-lead catalyst provides more consistent electrode performance, is less costly to fabricate, and performs satisfactorily after exposure to air.[29]

The effects of phosphoric acid, sulfuric acid, and chromic acid were determined, and a procedure was developed to improve chromium-plating practice.[30] Defense developed a chromium-plating method for canon barrels that improves erosion resistance and developed control technology for the process.[31]

The EPA developed a hydrometallurgical process to recover chromium from complex metal-finishing hydroxide sludge.[32]

The process by which chromite mineral is smelted into ferrochromium and alternative smelting and steel production processes were studied. The dissolution and reduction behavior of powdered chromite ore in molten slag was studied.[33] Powder chromite ore and synthetic chromite were smelted. It was found that reduction increased with decreasing slag viscosity and that iron-rich chromites reduced at a nearly constant rate.[34] The reduction of pulverized chromite ore by injection into molten iron was studied. It was found that chromium yield deceased with increasing injection rate, particle size, and initial-melt chromium content.[35] The production of stainless steel by combined top and bottom blowing in a converter was studied. Direct production of stainless steel was possible with control of temperature and coke additions.[36] A pilot plant for Elkem's Polar Process, designed for the smelting of chromite, was constructed and tested on iron ore.[37]

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[1] Physical scientist, Branch of Ferrous Metals.

[2] All tonnages are in metric tons unless otherwise specified, a departure from previous Chromium Minerals Yearbook chapters that used units of short tons.

[3] U.S. Department of Defense. Strategic and Critical Materials Report to the Congress. Operation Under the Strategic and Critical Materials Stock Piling Act During the Period Oct. 1987–Mar. 1988. Sept. 1988, p. i.

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[5] U.S. General Accounting Office. Strategic Minerals. Extent Of U.S. Reliance on South Africa. GAO/NSIAD-88-201, June 1988, 28 pp.

[6] ———. South Africa. Summary Report on Trade, Lending, Investment, and Strategic Minerals. GAO/NSIAD-88-228, Sept. 1988, pp. 42–43.

[7] RCRA brought waste from the extraction, beneficiation, and processing (smelting and refining) of ores and minerals under the regulatory control of EPA. In 1980 Congress amended RCRA to temporarily exclude these wastes, calling this act the Bevill Amendment.

[8] Federal Register. Mine Waste Exclusion. V. 53, No. 203, Oct. 20, 1988, pp. 41288–41300.

[9] Values have been converted from Canadian dollars (Can$) to U.S. dollars (US$) at the exchange rate of Can$1 = US$0.81255.

[10] Values have been converted from Finnish marks (FMk) to U.S. dollars (US$) at the exchange rate of FMk1 = $0.023.

[11] Values have been convered from Indian rupees (Rs) to U.S. dollars (US$) at the exchange rate of Rs1 = $0.069.

[12] Values have been converted from Japanese yen (¥) to U.S. dollars (US$) at the exchange rate of ¥1 = US$0.007803.

[13] Values have been convereted from South African rand (R) to U.S. dollars at the exchange rate of R1 = US$0.4168.

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CLAYS

By Sarkis G. Ampian[1]

Total quantity of clays sold or used by domestic producers increased over 3% in tonnage and 17% in value to a new record high of $1.40 billion. This increase in production continues the upward trend in clay output for 6 of the last 7 years. Clays in one or more of six classification categories, ball clay, bentonite, common clay and shale, fire clay, fuller's earth, or kaolin, were produced in 44 States and Puerto Rico during 1988. Clay production was not reported in Alaska, Delaware, the District of Columbia, Hawaii, Rhode Island, Vermont, or Wisconsin. The leading seven States, in descending order, were Georgia, Ohio, North Carolina, Texas, Wyoming, Alabama, and California. The cost of fuels, such as coal, gas, and oil, were still a major concern to clay producers and manufacturers trying to reduce operating costs in the highly competitive marketplace. Industrywide efforts to economize and modernize were prevalent during the year. Environmental restrictions and associated costs, combined with increasing capital costs, began to effect production.

Production of common clay and shale was relatively unchanged because the downturn in construction, which resulted from rising interest rates, offset an otherwise strong demand attributed to a growing economy. Building rates continued to decline because of a soft economy in the oil-producing States of the Southwest. However, firming oil prices for the first three quarters of the year not only increased drilling activity for gas and oil but also improved the overall business atmosphere.

Increases in production for all of the specialty clays, ball clay, bentonite, fire clay, fuller's earth, and kaolin, resulted from an improvement in the overall economy and a continued strong export demand. The steel, oil and gas exploration, and foundry industries, all major consumers of specialty clays, had adjusted to lower levels of production and were experiencing increasing demand by foreign and domestic consumers.

Kaolin accounted for 20% of clay production but nearly 67% of clay value. Kaolin production of 9.89 million tons and exports of 2.36 million tons were record highs. Record highs were also posted for ball clay and fuller's earth.

DOMESTIC DATA COVERAGE

Domestic production data for clays are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 1,101 operations covered by the survey, 1,075 responded, representing 96% of the total clay and shale production sold or used shown in table 1.

DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE, BY KIND AND TYPE OF CLAY

Kaolin

Domestic production of kaolin rose 12% to 9.9 million tons while its reported value increased about 21% to $935 million. Both the reported output and value, for the third consecutive year, reached record highs. Kaolin, in general, and filler grades, in particular, have enjoyed steady growth for the past 16 years, with output increasing from

TABLE 1

SALIENT U.S. CLAYS AND CLAY PRODUCTS STATISTICS[1]

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
Domestic clays sold or used by producers:					
Quantity	43,702	44,974	44,620	47,657	49,069
Value	$1,032,127	$1,011,377	$1,095,179	$1,202,284	$1,400,820
Exports:					
Quantity	2,699	2,780	2,913	3,332	3,897
Value	$295,733	$309,871	$351,161	$512,964	$516,566
Imports for consumption:					
Quantity	32	41	38	38	36
Value	$4,868	$5,981	$7,501	$9,392	$8,835
Clay refractories shipments: Value	$782,308	$629,738	$529,268	$617,493	NA
Clay construction products shipments: Value	$1,342,196	$1,427,851	$1,601,640	$1,782,023	$1,926,630

NA Not available.
[1] Excludes Puerto Rico.

TABLE 2

CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1988, BY STATE[1]

(Short tons unless otherwise specified)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	—	W	1,912,789	113,510	—	48,911	[2]2,075,210	[2]$16,039,585
Arizona	—	28,733	156,887	—	—	—	185,620	1,589,936
Arkansas	—	—	651,698	—	—	279,165	930,863	15,376,026
California	670	137,295	1,940,538	—	—	143,190	2,221,693	31,620,027
Colorado	—	3,965	257,439	8,193	—	3,193	272,790	1,889,604
Connecticut	—	—	W	—	—	—	W	W
Florida	—	—	128,144	—	419,454	44,257	591,855	44,422,762
Georgia	—	—	2,494,920	—	643,039	8,187,569	11,325,528	908,770,424
Idaho	—	W	W	—	—	9,391	22,870	253,425
Illinois	—	—	180,306	—	W	—	[3]180,306	[3]703,945
Indiana	—	—	1,141,813	—	—	—	1,141,813	4,629,731
Iowa	—	—	445,248	—	—	—	445,248	1,587,679
Kansas	—	W	612,517	—	—	—	[2]612,517	[2]2,632,114
Kentucky	W	—	840,397	W	—	—	[4 5]840,397	[4 5]12,723,643
Louisiana	—	—	375,778	—	—	—	375,778	9,535,143
Maine	—	—	W	—	—	—	W	W
Maryland	—	—	394,443	—	—	—	394,443	2,016,225
Massachusetts	—	—	W	—	—	—	W	W
Michigan	—	—	1,375,816	—	—	—	1,375,816	4,431,929
Minnesota	—	—	W	—	—	W	W	W
Mississippi	W	297,000	596,902	—	W	—	1,199,316	30,152,508
Missouri	—	—	1,222,622	359,242	W	—	[3]1,581,864	[3]12,171,526
Montana	—	64,449	36,745	W	—	—	[5]101,194	[5]1,415,898
Nebraska	—	—	237,459	—	—	—	237,459	785,615
Nevada	—	9,366	—	—	W	W	62,689	2,577,030
New Hampshire	—	—	W	—	—	—	W	W
New Jersey	—	—	W	16,484	—	—	[6]16,484	[6]368,482
New Mexico	—	—	29,791	1,685	—	—	31,476	82,703
New York	—	—	607,786	—	—	—	607,786	3,653,827
North Carolina	—	—	3,121,970	—	—	52,796	3,174,766	16,349,445
North Dakota	—	—	84,787	—	—	—	84,787	146,681
Ohio	—	—	3,411,372	298,082	—	—	3,709,454	14,422,907
Oklahoma	—	—	754,054	—	—	—	754,054	1,802,787
Oregon	—	19,538	228,483	—	—	—	248,021	1,048,956
Pennsylvania	—	—	1,338,742	37,094	—	W	[7]1,375,836	[7]5,842,944
Puerto Rico	—	—	163,382	—	—	—	163,382	364,985
South Carolina	—	—	1,115,096	—	150,000	793,831	2,058,927	[3]36,406,649
South Dakota	—	—	W	—	—	—	W	W
Tennessee	721,051	W	563,951	—	W	—	[2 3]1,285,002	[2 3]27,695,522
Texas	W	42,055	2,912,548	5,617	W	W	3,137,091	26,966,706

See footnotes at end of table.

TABLE 2—Continued

CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1988, BY STATE[1]

(Short tons unless otherwise specified)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Utah	—	32,793	307,363	—	—	—	340,156	2,468,220
Virginia	—	—	1,113,459	—	W	—	[3]1,113,459	[3]6,614,323
Washington	—	—	410,436	5,051	—	—	415,487	2,235,271
West Virginia	—	—	263,973	—	—	—	263,973	586,266
Wyoming	—	2,357,616	W	—	—	—	[6]2,357,616	[6]72,174,070
Undistributed	369,449	171,893	606,390	29,736	962,518	328,832	[8]1,919,731	[8]76,629,006
Total	**1,091,170**	**3,164,703**	**32,036,044**	**874,694**	**2,175,011**	**9,891,135**	**49,232,757**	**1,401,184,525**

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Undistributed."
[1] Includes Puerto Rico.
[2] Excludes bentonite.
[3] Excludes fuller's earth.
[4] Excludes ball clay.
[5] Excludes fire clay.
[6] Excludes common clay.
[7] Excludes kaolin.
[8] Incomplete total; difference included with individual State totals.

6.0 million tons in 1973 to this year's record-high tonnage of 9.9 million. The unit value of kaolin rose about 8% to $94.51 per ton with filler- and refractory-grade kaolin leading the way in higher reported values. Kaolin was again produced in 13 States, with Georgia (83%) and South Carolina (8%) accounting for 91% of total production. Georgia accounted for nearly 92% of the posted values. Georgia produced all grades of kaolins: filler, refractory, chemical and water-washed, air-floated, and unprocessed. South Carolina produced only the latter two. Arkansas, California, and North Carolina were the other three major producing states. Arkansas and California produced refractory- and chemical-grade kaolins. Kaolin producers reported major domestic end uses for their clay as follows: paper-coating, 34%; paper-filling, 20%; refractories, 11%; fiberglass and insulation, 6%; face brick, 5%; paint, 4%; rubber and chemicals, 3% each.

Kaolin is defined as a white, claylike material approximating the mineral kaolinite. It has a specific gravity of 2.6 and a fusion point of 1,785° C. The other kaolin-group minerals, such as halloysite and dickite, are encompassed.

Kaolin production was buoyed by the continuing growth of the overall economy, particularly in the record-high level of paper production. Strong demands for paper-, catalyst-, plastic-, and paint-calcined grades, combined with a strong export demand due to a continued weak U.S. dollar, led the way. Capacity increases in water-washed and calcined grades started in the past few years were gradually coming on-stream to meet the projected demand of catalyst, paint, paper, and plastic manufacturers. The anticipated excess capacity was not expected to cause a downward pressure on prices. Kaolin refractory sales were robust during the year. Increased demand for high-alumina, kaolin-base refractory bricks and specialties by the foundry and steel industries were mostly responsible. Sales to cement manufacturers, a major consumer, were restrained during the year because of lower construction rates. The refractory industry, which became acclimated to lower levels of production brought about by changes in steelmaking and refractories technology and imports, was put in an enviable position of meeting the unexpected upsurge in demand. Production of the three paper-grade kaolins increased in 1988 nearly 12% from 5.9 to 6.6 million tons. Low-temperature calcined, delaminated, and water-washed production increased 41%, 25%, and 4%, respectively.

All Georgia and South Carolina kaolin filler-extender-pigment producers, both air-floated and water-washed, continued to modernize, to reduce unit operating costs, and to produce higher valued products. Emphasis continued to be placed on energy related costs and expanding the production capabilities for calcined pigment lines used chiefly by the growing paper, plastics, paint, rubber, and catalyst industries. The major enlargements of calcined clay capacity in Georgia by Engelhard Corp.'s Pigments and Additives Div., Anglo-American Clays Corp. (a subsidiary of English China Clays (ECC) America Inc.), Georgia Kaolin Co. (a subsidiary of Combustion Engineering

TABLE 3

NUMBER OF MINES FROM WHICH PRODUCERS SOLD OR USED CLAYS IN THE UNITED STATES IN 1988, BY STATE[1]

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total
Alabama	—	1	21	6	—	11	39
Arizona	—	4	5	—	—	—	9
Arkansas	—	—	15	—	—	6	21
California	1	5	41	—	—	4	51
Colorado	—	1	27	3	—	1	32
Connecticut	—	—	2	—	—	—	2
Florida	—	—	3	—	6	1	10
Georgia	—	—	16	—	8	59	83
Idaho	—	1	1	—	—	2	4
Illinois	—	—	9	—	2	—	11
Indiana	—	—	13	—	—	1	14
Iowa	—	—	10	—	—	—	10
Kansas	—	1	18	—	—	—	19
Kentucky	5	—	10	1	—	—	16
Louisiana	—	—	6	—	—	—	6
Maine	—	—	2	—	—	—	2
Maryland	—	—	6	—	—	—	6
Massachusetts	—	—	2	—	—	—	2
Michigan	—	—	6	—	—	—	6
Minnesota	—	—	1	—	—	2	3
Mississippi	1	5	11	—	1	—	18
Missouri	—	—	12	47	2	—	61
Montana	—	11	5	1	—	—	17
Nebraska	—	—	5	—	—	—	5
Nevada	—	6	—	—	—	2	8
New Hampshire	—	—	1	—	—	—	1
New Jersey	—	—	1	1	—	—	2
New Mexico	—	—	4	2	—	—	6
New York	—	—	8	—	—	—	8
North Carolina	—	—	46	—	—	2	48
North Dakota	—	—	3	—	—	—	3
Ohio	—	—	48	7	—	—	55
Oklahoma	—	—	15	—	—	—	15
Oregon	—	12	7	—	—	—	19
Pennsylvania	—	—	35	6	—	1	42
South Carolina	—	—	29	—	1	17	47
South Dakota	—	—	1	—	—	—	1
Tennessee	13	—	6	—	3	—	22
Texas	1	5	55	2	1	1	65
Utah	—	3	10	—	—	—	13
Virginia	—	—	14	—	1	—	15
Washington	—	—	8	3	—	—	11
West Virginia	—	—	3	—	—	—	3
Wyoming	—	266	2	—	—	—	268
Puerto Rico	—	—	2	—	—	—	2
Total	**21**	**321**	**545**	**79**	**25**	**110**	**1,101**

[1] Includes both active and idle operations.

Inc.), J. M. Huber Corp., and Nord Kaolin Co. (a subsidiary of Nord Resources Corp.) were all scheduled for completion by yearend 1989. All the major water-washed kaolin producers now either have or will have calcining capability. In noncalcining kaolin developments, J. M. Huber announced plans to spend more than $100 million over the next 4 years to fully computerize and/or automate its Huber and Wrens processing plants. J. M. Huber also ordered a second superconducting high-gradient magnetic separator for its Wrens facility. Wilkinson Kaolin Associates Ltd. and its wholly owned marketing affiliate Wilkinson Minerals Inc. announced plans for a major expansion to nearly triple its air-float kaolin capacity at its Gordon mining and processing complex. The project, scheduled for completion by early 1989, was being financed primarily by Industrial Reserve Authority bonds from the city of Gordon. Early in the year, the Norfolk Southern Corp. started a 6-day-per-week train service, "The Kaolin Express," to improve service between midstate Georgia and the Midwest. The Express will operate from Tennille to Atlanta where the cars will connect with trains directly to the Midwest. A second train was added at midyear because of the increasing kaolin demand. An increase in the use of hopper and tank cars exacerabated an already tight market for the available cars.

In development work, the State Legislative Commission on Minnesota Resources authorized a $480,000 grant to begin a 2-year study on Minnesota River Valley kaolin deposits. The study, to be led by the Minnesota Resources Research Center (MRRC), will attempt to find out what types of kaolin are available in the Valley and how they can marketed. In addition to MRRC, three other State agencies will participate in the effort. The Department of Natural Resources will study the marketing methods, the Minnesota Geological Survey will do the test drilling work, and the Duluth-based Natural Resources Research Institute will also make its expertise available. Presently, kaolin from the Redwood Falls area was used in the manufacture of portland cement in Mason City, Iowa. The Redwood clays and kaolins from the Fairfax area are of interest in these studies. Final results from the study were expected by mid-1989.

The divestiture of Cyprus Minerals Co.'s clay division was of considerable interest during the year. Initially, a letter of intent was signed in the spring to sell the kaolin and ball clay assets to Hale Minerals Inc., Summit, NJ, a major Georgia air-float, soft kaolin producer. The air-float kaolin assets included the mines, mills, and associated reserves of hard kaolin in the Aiken, SC, area and soft kaolin in the Sandersville, GA, area. This agreement was not consummated. In August, another letter of intent was signed with Hecla Mining Co., Coeur d'Alene, ID, to acquire the same assets. Hecla's industrial minerals interests included Kentucky-Tennessee Clay Co., Mayfield, KY, which produces premium-quality ball clay from mines in Kentucky, Mississippi, and Tennessee.

Despite strong foreign competition and the strengthening U.S. dollar, exports of kaolin, reported as clays by the U.S. Department of Commerce, increased more than 16% to 2.36 million tons valued at $335 million. The unit value of the exported clay decreased to $141.82 per ton, or nearly 16% less than that of 1987, indicating that a lower percentage of premium-quality grades was shipped. Kaolin, including calcined material, was exported to 65 countries, 9 more than in 1987. The nine new countries were mostly small importers. The major recipients, in descending order, were Japan, Canada, the Netherlands, Finland, Italy, and Mexico. Exports to Finland increased more than 100% to 206,000 tons. Since 1985, Finnish imports of U.S. kaolin rose from only 23,000 tons to 206,000 tons in 1988. Finnish imports in the

TABLE 4

KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	1987		1988	
	Short tons	Value	Short tons	Value
Alabama	40,441	$1,617,084	48,911	$1,718,220
Arkansas	202,209	7,011,203	279,165	13,864,977
California	87,805	3,082,079	143,190	5,015,151
Colorado	2,948	149,586	3,193	166,962
Florida	38,522	3,089,946	44,257	3,654,680
Georgia	7,423,820	713,524,435	8,187,569	861,334,508
North Carolina	55,516	1,516,127	52,796	1,581,316
South Carolina	809,460	35,516,618	793,831	34,230,599
Other[1]	[r]166,489	9,784,815	338,223	13,250,013
Total	**8,827,210**	**775,291,893**	**9,891,135**	**934,816,426**

[r] Revised.
[1] Includes Idaho, Minnesota, Nevada, Pennsylvania, and Texas.

TABLE 5

KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY KIND

Kind	1987		1988	
	Short tons	Value	Short tons	Value
Air-float	1,571,742	$74,028,189	1,685,871	$80,231,491
Calcined[1]	1,204,459	202,977,802	1,612,488	300,114,258
Delaminated	1,057,857	103,533,884	1,318,771	130,911,947
Unprocessed	713,415	14,695,875	816,380	16,081,244
Water-washed	4,279,737	380,056,143	4,457,625	407,477,486
Total	**8,827,210**	**775,291,893**	**9,891,135**	**934,816,426**

[1] Includes both low-temperature filler and high-temperature refractory grades.

TABLE 6

CALCINED KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	High-temperature		Low-temperature	
	Short tons	Value	Short tons	Value
1987				
Alabama and Georgia	468,809	$33,765,315	[1]495,749	[1]$154,237,336
Other	[2]180,669	[2]8,124,229	[3]59,232	[3]6,850,922
Total	**649,478**	**41,889,544**	**554,981**	**161,088,258**
1988				
Alabama and Georgia	498,412	50,361,214	[1]684,008	[1]224,324,778
Other	[2]330,357	[2]16,086,192	[3]99,711	[3]9,342,074
Total	**828,769**	**66,447,406**	**783,719**	**233,666,852**

[1] Excludes Alabama.
[2] Includes Arkansas, California, Colorado, and Idaho.
[3] Includes Pennsylvania, South Carolina, and Texas.

past, destined for their large domestic papermaking industry, have been largely from the United Kingdom. Kaolin producers reported end uses for their exports as follows: paper-coating, 67%; paper-filling, 18%; rubber, 5%; paint, 2%; and other, including ceramics, plastics, and refractories, 8%.

Kaolin imports for consumption decreased about 20% to 8,379 tons valued at $2.0 million. The unit value rose about 80% to $235.20 per ton, reflecting the strong worldwide demand for premium-quality kaolin. No Chinese imports were noted for the year.

Kaolin prices quoted in the trade journals generally advanced during the year. Chemical Marketing Reporter, December 30, 1988, quoted prices as follows:

Water-washed, fully calcined bags, carload lots, f.o.b. Georgia, per ton	[1] $305.00
Calcined, paper-grade, same basis, per ton	450.00
Paper-grade, uncalcined, bulk, carload lots, f.o.b. Georgia, per ton:	
No. 1 coating	100.00
No. 2 coating	77.00
No. 3 coating	75.00
No. 4 coating	72.00
Filler, general purpose, same basis per ton	64.00
Delaminated, water-washed, uncalcined, paint-grade, 1-micrometer average, same basis, per ton	282.00
Dry-ground, air-floated, soft, same basis, per ton	60.00
National Formulary, powder, colloidal, bacteria controlled, 50-pound bags, 5,000-pound lots, per pound	.25

[1] Average of quoted prices.

TABLE 7

GEORGIA KAOLIN SOLD OR USED BY PRODUCERS, BY KIND

Kind	1987		1988	
	Short tons	Value	Short tons	Value
Air-float	976,909	$38,330,548	1,102,317	$43,064,962
Calcined [1]	924,117	186,385,567	1,144,008	273,084,778
Delaminated	1,057,857	103,533,884	1,318,771	130,911,947
Unprocessed	235,591	8,176,477	219,710	8,505,018
Water-washed	4,229,346	377,097,959	4,402,763	405,767,803
Total	**7,423,820**	**713,524,435**	**8,187,569**	**861,334,508**

[1] Includes both low-temperature filler and high-temperature refractory grades.

FIGURE 1

KAOLIN SOLD OR USED BY DOMESTIC PRODUCERS FOR SPECIFIED USES

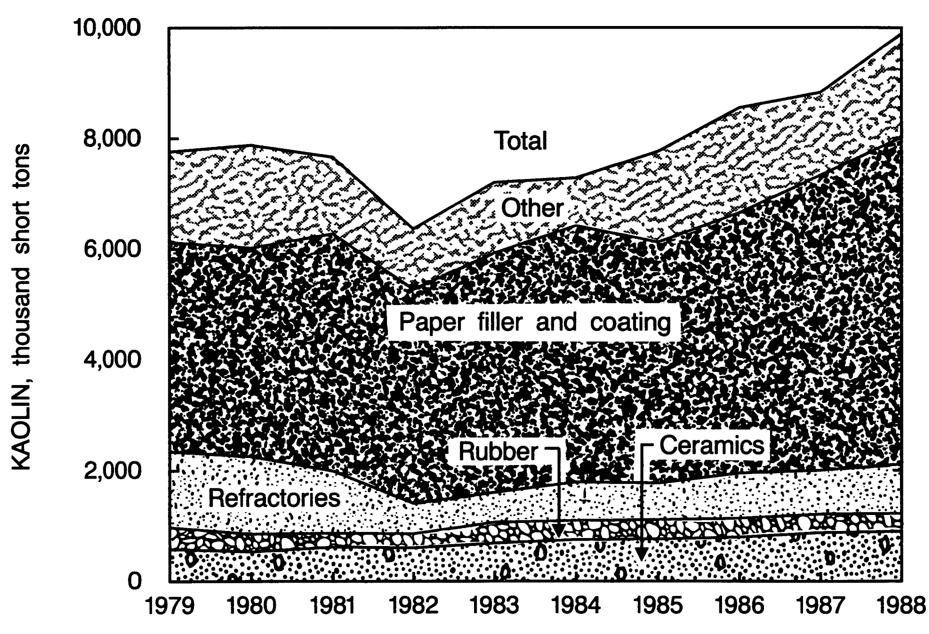


TABLE 8

GEORGIA KAOLIN SOLD OR USED BY PRODUCERS, BY USE

(Short tons)

Use	1987 Air-float	1987 Unprocessed[1]	1987 Water-washed[2]	1987 Total	1988 Air-float	1988 Unprocessed[1]	1988 Water-washed[2]	1988 Total
Domestic:								
Adhesives	26,812	—	19,967	46,779	14,938	—	29,042	43,980
Aluminum sulfate and other chemicals	—	150,947	—	150,947	5,000	150,000	—	155,000
Animal feed	33,950	—	—	33,950	—	—	—	—
Asphalt tile and linoleum	15,558	—	—	15,558	31,419	—	64	31,483
Catalysts (oil-refining)	20,492	—	45,393	65,885	18,873	—	54,752	73,625
Face brick	—	18,132	2	18,134	—	14,010	—	14,010
Fiberglass and mineral wool	214,444	—	59,253	273,697	250,466	—	62,179	312,645
Fine china and dinnerware; crockery and earthenware	22,732	—	—	22,732	46,628	—	158	46,786
Firebrick, blocks and shapes	59,277	8,368	—	67,645	30,000	5,240	94	35,334
Grogs and calcines, refractory	20,225	420,000	469	440,694	40,254	427,000	528	467,782
Medical, pharmaceutical, cosmetic	406	—	1,063	1,469	—	—	1,302	1,302
Paint	15,572	—	237,768	253,340	22,662	—	260,649	283,311
Paper-coating	—	—	2,485,279	2,485,279	—	—	2,737,396	2,737,396
Paper-filling	212,544	—	1,114,071	1,326,615	223,653	—	1,382,179	1,605,832
Plastics	425	—	47,742	48,167	408	—	51,955	52,363
Pottery	61,186	—	—	61,186	27,797	—	1,312	29,109
Refractories[3]	1,555	28,848	5,014	35,417	13,996	7,000	5,792	26,788
Roofing granules	7,313	—	22	7,335	10,699	—	—	10,699
Rubber	28,062	—	31,320	59,382	35,211	—	18,148	53,359
Sanitary ware	56,511	—	—	56,511	24,634	—	—	24,634
Miscellaneous, air-float:								
Common brick, fertilizers, gypsum products, pesticides and related products, roofing and structural tile, other uses not specified	112,176	—	—	112,176	214,479	—	—	214,479
Miscellaneous, unprocessed:								
Fertilizers, pesticides and related products, other uses not specified	—	37,664	—	37,664	—	43,460	—	43,460
Miscellaneous, water-washed:								
Gypsum products, ink, pesticides and related products, waterproofing and sealing, fertilizers, other uses not specified	—	—	197,958	197,958	—	—	209,196	209,196
Total	**909,240**	**663,959**	**4,245,321**	**6,795,429**	**1,011,117**	**646,710**	**4,814,746**	**6,472,573**
Exports:								
Paint	127	—	31,985	32,112	—	—	34,495	34,495
Paper-coating	28,492	—	1,154,774	1,183,266	25,018	—	1,183,127	1,208,145
Paper-filling	22,390	—	284,347	306,737	31,160	—	294,389	325,549
Plastics	41	—	—	41	—	—	—	—
Refractories	—	—	—	—	—	33,000	—	33,000
Rubber	511	—	23,663	24,174	10,000	—	24,495	34,495
Undistributed	16,108	—	42,862	58,970	25,022	—	54,290	79,312
Total	**67,669**	**—**	**1,537,631**	**1,605,300**	**91,200**	**33,000**	**1,590,796**	**1,714,996**
Grand total	**976,909**	**663,959**	**5,782,952**	**7,423,820**	**1,102,317**	**679,710**	**6,405,542**	**8,187,569**

[1] Includes high-temperature calcined.
[2] Includes low-temperature calcined and delaminated.
[3] Includes electrical porcelain; floor and wall tile, ceramic; flue linings; glazes, glass and enamels; high alumina brick and specialties; kiln furniture; refractory mortar and cement.

TABLE 9

SOUTH CAROLINA KAOLIN SOLD OR USED BY PRODUCERS, BY KIND

Kind	1987		1988	
	Short tons	Value	Short tons	Value
Air-float	537,116	$32,017,582	526,116	$32,504,576
Unprocessed	272,344	3,499,036	267,715	1,726,023
Total	**809,460**	**35,516,618**	**793,831**	**34,230,599**

TABLE 10

SOUTH CAROLINA KAOLIN SOLD OR USED BY PRODUCERS, BY KIND AND USE

(Short tons)

Kind and use	1987	1988
Air-float:		
Adhesives	18,208	14,669
Animal feed and pet waste absorbent	3,459	3,836
Ceramics [1]	2,896	5,167
Fertilizers, pesticides and related products	20,308	21,002
Fiberglass	143,498	148,993
Paint	332	518
Paper coating and filling	18,547	20,892
Plastics	9,142	7,944
Rubber	194,283	170,724
Refractories [2]	6,073	9,406
Other uses [3]	63,970	58,841
Exports [4]	56,400	64,124
Total	**537,116**	**526,116**
Unprocessed: Face brick and other uses	272,344	267,715
Grand total	**809,460**	**793,831**

[1] Includes crockery and earthenware (1988); electrical porcelain (1988); fine china and dinnerware (1988); floor and wall tile; pottery; and roofing granules.
[2] Includes refractory calcines and grogs; firebrick, blocks and shapes; refractory mortar and cement (1987); and high-alumina refractories (1987).
[3] Includes animal oil; catalysts (oil refining); chemical manufacturing; ink; medical; sewer pipe; and unknown uses.
[4] Includes ceramics; adhesives; paper-filling; pesticides and related products; and rubber.

TABLE 11

KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Short tons)

Use	1987 Air-float	1987 Unpro-cessed[1]	1987 Water-washed[2]	1987 Total	1988 Air-float	1988 Unpro-cessed[1]	1988 Water-washed[2]	1988 Total
Domestic:								
Adhesives	45,020	—	22,967	67,987	29,607	—	29,042	58,649
Aluminum sulfate and other chemicals	—	210,609	—	210,609	5,000	228,625	—	233,625
Animal feed	37,409	—	4,000	41,409	47	183	4,700	4,930
Brick, extruded and other	—	353,239	2	353,241	60,000	337,606	12,720	410,326
Catalysts (oil and gas refining)	64,261	—	47,911	112,172	58,817	3,586	57,197	119,600
Cement, portland	—	81,288	—	81,288	—	221,578	—	221,578
China and dinnerware	21,827	—	—	21,827	53,304	—	—	53,304
Crockery and other earthenware	9,164	—	—	9,164	3,335	1,604	158	5,097
Electrical porcelain	6,460	—	2,393	8,853	14,036	—	2,445	16,481
Fertilizers[3]	23	—	2,863	2,886	3,836	1,286	315	5,437
Fiberglass, mineral wool and other insulation	358,276	—	100,253	458,529	399,459	11,462	97,325	508,246
Firebrick, blocks and shapes	84,743	33,846	—	118,589	56,525	111,045	5,194	172,764
Floor and wall tile, ceramic; glazes, glass, enamels	12,597	2,723	3,646	18,966	18,712	72	4,125	22,909
Flue linings, high-alumina brick and specialties	694	68,800	—	69,494	798	73,000	—	73,798
Foundry sand	—	—	—	—	552	93	—	645
Grogs and calcines, refractory	22,786	574,956	469	598,211	42,917	562,770	528	606,215
Gypsum products and wallboard	7,746	2,026	4,000	13,772	4,743	4,357	5,100	14,200
Ink	85	—	2,243	2,328	—	—	2,493	2,493
Kiln furniture; refractory mortar and cement	2,619	—	1,368	3,987	5,009	—	1,667	6,676
Linoleum and asphalt tile	16,133	—	5,089	21,222	31,419	—	64	31,483
Medical, pharmaceutical, cosmetic	2,178	—	1,063	3,241	—	—	3,624	3,624
Paint	15,904	3,573	267,768	287,245	23,180	3,777	297,508	324,465
Paper-coating	—	—	2,487,279	2,487,279	—	—	2,737,396	2,737,396
Paper-filling	231,091	—	1,114,071	1,345,162	244,545	—	1,386,679	1,631,224
Pesticides and related products	20,622	17,882	2,300	40,804	21,149	39,616	525	61,290
Plastics	9,567	—	47,742	57,309	8,352	1,025	51,955	61,332
Pottery	65,238	—	—	65,238	31,302	—	1,312	32,614
Roofing granules	7,313	—	22	7,335	11,287	—	—	11,287
Roofing and structural tile	392	—	—	392	—	—	—	—
Rubber	222,345	—	32,320	254,665	205,935	114	18,148	224,197
Sanitary ware	58,437	—	1,000	59,437	26,847	—	—	26,847
Waterproofing and sealing	—	4,950	3,724	8,674	40,000	—	759	40,759
Miscellaneous	120,275	7,334	195,971	323,580	124,699	4,399	246,975	376,073
Total	**1,443,205**	**1,361,226**	**4,350,464**	**7,154,895**	**1,525,412**	**1,606,198**	**4,967,954**	**8,099,564**
Exports:								
Ceramics	9,760	—	—	9,760	18,482	—	—	18,482

See footnotes at end of table.

TABLE 11—Continued

KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Short tons)

Use	1987 Air-float	1987 Unprocessed[1]	1987 Water-washed[2]	1987 Total	1988 Air-float	1988 Unprocessed[1]	1988 Water-washed[2]	1988 Total
Foundry sand, grogs and calcines; other refractories	1,849	—	—	1,849	—	33,000	—	33,000
Paint	127	—	35,985	36,112	—	—	34,495	34,495
Paper-coating	28,492	—	1,154,774	1,183,266	25,018	—	1,183,127	1,208,145
Paper-filling	22,441	—	284,347	306,788	31,213	—	294,389	325,602
Plastics	41	—	—	41	—	—	—	—
Rubber	55,359	—	23,663	79,022	73,598	—	24,495	98,093
Miscellaneous	10,468	1,667	43,342	55,477	12,148	5,951	55,655	73,754
Total	**128,537**	**1,667**	**1,542,111**	**1,672,315**	**160,459**	**38,951**	**1,592,161**	**1,791,571**
Grand total	**1,571,742**	**1,362,893**	**5,892,575**	**8,827,210**	**1,685,871**	**1,645,149**	**6,560,115**	**9,891,135**

[1] Includes high-temperature calcined.
[2] Includes low-temperature calcined and delaminated.
[3] Includes soil conditioners and mulches.

Ball Clay

Production of domestic ball clay increased nearly 11% to about 1.1 million tons valued at about $42 million. The 1988 production figure is an all-time high and more than 100,000 tons higher than 1979 the previous record-high year. Tennessee supplied 66% of the Nation's output, followed, in descending order of production, by Kentucky, Mississippi, Texas, and California. Production increased in all the major producing States. The continuing growth in demand for water-slurried Tennessee ball clays, combined with the number of producers, allowed the publication of additional production statistics. The principal ball clay markets were ceramics, mostly dinnerware, pottery, sanitary ware, and wall tile. Domestic producers continued to enjoy a strong export market, usually about 15% of total production. The domestic industry during the year was spurred on by competitive interest rates, mortgages, and the improved overall economy during the first three quarters of the year, which increased the demand for ball clay. A slowdown in the overall economy during the last quarter tempered an otherwise banner year.

Ball clay is a plastic, white-firing clay used principally for bonding in ceramic ware. The clay is of sedimentary origin and consists mainly of the clay mineral kaolinite and sericite mica.

Increased production capacities, modernization, and/or new plant construction proceeded slowly during the year while acquisitions, divestitures, and/or mergers were prevalent. Ball clay producers were either concentrating on increasing their capabilities to produce, store, and ship (mostly by slurry-tank rail car) water-slurried ball clay for ceramic markets, chiefly sanitary ware, or developing this capability. The divestiture of Cyprus' clay division was of considerable interest during the year (see Kaolin section of this chapter). In August, a letter of intent was signed with Hecla, Coeur d'Alene, ID, to acquire Cyprus' assets. Hecla's industrial minerals interests included Kentucky-Tennessee Clays Co., Mayfield, KY, which produced premium-quality ball clay from two mines in Tennessee (Gleason and Whitlock) and single mines in Mississippi (Sledge) and Kentucky (Mayfield). In another action, Armstrong World Industries Inc., Lancaster, PA, acquired American Olean Tile Co. from Dallas-based National Gypsum Co. for a $300 million purchase of all outstanding shares of capital stock. American Olean is a major integrated ceramic tile producer with 4 consecutive years of record-high sales. American Olean is an excellent addition to Armstrong's core business of resilient flooring and carpets, building products, furniture, and a variety of specialty products for the building trade. In a notable exception to the new plant moratorium, Summitville Tiles Co. Inc., an Ohio-based manufacturer of commercial and residential tiles, broke ground for a new plant in western North Carolina near Glen Alpine, Burke County. The new 160,000-square-foot plant, targeted for operation by yearend, was to produce about 21,000 feet per day of glazed tile.

The average unit value for ball clay reported by domestic producers increased 7% to $38.66 per ton. Chemical Marketing Reporter, December 30, 1988, listed ball clay prices, unchanged from those of 1987, as follows:

Domestic, air-floated, bags, carload lots, Tennessee, per ton	$49.00
Domestic, crushed, moisture-repellent, bulk carload lots, Tennessee, per ton	24.00

Ball clay exports increased approximately 15% to 205,000 tons valued at $8.3 million. Unit value rose more than 15% to $40.41 from $35.05, reflecting a larger percentage of higher valued clays. Shipments were made to 24 countries, 3 less than in 1987. The major recipients, in descending order, were Mexico (70%), Canada (16%), Japan (5%), and the remaining countries (9%). The expanding Mexican ceramic markets continued to be supplied largely with domestic clays because of international financial difficulties. Mexican ceramic exports, mostly to the United States, are made chiefly with U.S. and domestic clays.

Ball clay imports for consumption, beneficiated and not beneficiated, almost entirely from the United Kingdom, increased slightly to 1,778 tons valued at $285,184. The unit value of

TABLE 12

BALL CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	Air-float		Water-Slurried		Unprocessed		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1987								
Tennessee	374,405	$15,230,434	108,473	$3,749,623	208,692	$5,047,865	691,570	$24,027,922
Other[1]	229,632	9,528,799	W	W	W	W	[2]292,235	[2]11,474,807
Total	**604,037**	**24,759,233**	**108,473**	**3,749,623**	**208,692**	**5,047,865**	**[2]983,805**	**[2]35,502,729**
1988								
Tennessee	387,065	16,405,963	111,320	4,097,147	222,666	5,708,846	721,051	26,211,956
Other[1]	227,274	11,276,089	W	W	W	W	[2]370,119	[2]15,976,087
Total	**614,339**	**27,682,052**	**111,320**	**4,097,147**	**222,666**	**5,708,846**	**[2]1,091,170**	**[2]42,188,043**

W Withheld to avoid disclosing company proprietary data.
[1] Includes California (1988), Kentucky, Mississippi, North Carolina (1987), and Texas.
[2] Includes data indicated by symbol W.

TABLE 13

BALL CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Short tons)

Use	1987				1988			
	Air-float[1]	Water-slurried	Un-processed	Total	Air-float[1]	Water-slurried	Un-processed	Total
Ceramics[2]	38,790	—	—	38,790	W	—	W	80,094
Fillers, extenders, and binders[3]	125,070	—	3,924	128,994	W	—	W	120,659
Floor and wall tile	77,950	10,590	55,893	144,433	69,627	11,384	64,258	145,269
Pottery[4]	148,354	234	76,612	225,200	139,592	—	134,007	273,599
Refractories[5]	40,493	—	18,350	58,843	42,343	—	28,478	70,821
Sanitary ware	16,082	95,451	66,918	178,451	16,298	97,146	74,896	188,340
Miscellaneous	26,021	—	41,159	67,180	52,133	—	8,000	60,133
Exports	131,277	2,432	8,205	141,914	142,583	2,160	7,512	152,255
Total	**604,037**	**108,707**	**271,061**	**983,805**	**634,969**	**110,690**	**345,511**	**1,091,170**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes water-slurried.
[2] Includes catalyst (oil refining); fiberglass; glazes, glass, and enamels.
[3] Includes animal feed; asphalt emulsions (1987); asphalt tile; pesticides and related products; rubber; wallboard (1987); other uses not specified.
[4] Includes crockery and other earthenware; fine china and dinnerware.
[5] Includes electrical porcelain; firebrick, block and shapes; high alumina brick and specialties.

these clays increased more than 18% to $160.40 per ton, indicating an increasing percentage of the higher valued beneficiated varieties than in previous years.

Fire Clay

Fire clay sold or used by domestic producers increased about 9% in production and 11% in value over that of 1987. This increase in production coupled with the reported increase in 1987 marks only the second major upturn in production in more than 10 years and was attributed chiefly to the expanding overall economy, exports, and the recovering smokestack industries, which consume the bulk of manufactured fire clay refractories and clays. Fire clay production declined from the record highs of the early 1970's, approximately 4 million tons, to about 2 million tons in the early 1980's, and eventually to the low of 592,000 tons in 1986. Fire clay is defined as detrital material, either plastic or rocklike, containing low percentages of alkalies, iron oxide, lime, and magnesia to enable the material to withstand temperatures of 1,500° C or higher. It is basically kaolinite but usually contains other materials such as ball clay, bauxite clay, diaspore, and shale. Fire clays commonly occur as underclay below coal seams and are generally used for refractories.

Industrywide expansions and modernizations, previously canceled or deferred until economic conditions improved, were cautiously being started again. Manufacturing plants and production lines that were operational were working at full capacity and/or throughput. The increased demand for higher quality fire clay-base product lines were further exacerbating a difficult situation by their slower kiln throughput compared with the lower quality lines.

The clay refractory industry had been in a period of low production because of decreased demand brought about by technological changes and lower consumption levels by its major users, those being steel, nonferrous metals, ceramics, glass, and minerals processing. The technological changes in steelmaking, away from integrated pig iron systems and toward electric furnaces and/or minimills, further compounded the problem by employing shapes and specialty refractories requiring less fire clay.

News of acquisitions and divestitures and/or mergers were commonplace. In a major move, Didier-Werke AG, Wiesbaden, Federal Republic of Germany, acquired a 35% minority interest in North American Refractories Co. (NARCO), Cleveland, OH. It was also intended that Didier would distribute NARCO's products outside of North America. NARCO, a clay and basic refractories manufacturer, operates 11 manufacturing facilities in the United States as well as technical and engineering centers in Pennsylvania. In another move, USG Corp. spunoff its A. P. Green Refractories subsidiary to its stockholders to form a new company, A. P. Green Industries Inc. A. P. Green Industries will also include USG's Lime Div., which processes limestone for a variety of industrial uses and has manufacturing plants in Texas and Virginia. The Refractories subsidiary is headquartered in Mexico, MO, and has nine major refractory production facilities in Alabama, Arkansas, Georgia, Missouri, Idaho, Ohio, Oklahoma, and Texas. In addition, the company operates two wholly owned refractory subsidiaries in Canada and the United Kingdom. An earlier attempt by USG to sell A. P. Green Refractories and its Lime Div. to Adience Equities Inc., Pittsburgh, PA, failed because of obstacles in financing.

Fire clay production was again from mines in 11 States. Missouri, Ohio, and Alabama, in descending order of volume, accounted for nearly 90% of the total domestic production. Output increased in every producing State and resumed in Colorado.

Exports of fire clay increased about 61% to 280,000 tons. The unit value of exported clay decreased about 7% to $67.41 per ton, indicating that despite an increase in exports, the trend of shipping a larger percentage of premium-quality material continued. Fire clay was exported to 32 countries, 6 more than in 1987. The major recipients, in descending order, were Japan, Belgium-Luxem-

TABLE 14

FIRE CLAY[1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	1987		1988	
	Short tons	Value	Short tons	Value
Alabama	126,840	$3,574,802	113,510	$3,352,200
Colorado	—	—	8,193	48,788
Missouri	336,088	7,666,489	359,242	8,244,338
New Jersey	5,985	139,768	16,484	368,482
New Mexico	898	5,165	1,685	10,175
Ohio	291,300	4,588,541	298,082	5,033,560
Pennsylvania	23,373	600,202	37,094	989,039
Texas	4,225	55,897	5,617	78,020
Washington	3,562	36,004	5,051	67,351
Other[2]	11,280	118,232	29,736	464,370
Total	**803,551**	**16,785,100**	**874,694**	**18,656,323**

[1] Refractory uses only.
[2] Includes Indiana (1987), Kentucky, and Montana.

bourg, Switzerland, Australia, Mexico, and Canada. No imports for consumption were reported for fire clay.

The unit value for fire clay, reported by producers, ranged from about $6.00 to $40.00 per ton, indicating a higher valued fire clay was being recovered and processed.

Bentonite

Bentonite production and value increased nearly 13% to about 3.2 million tons and $106.8 million, respectively. This increase marked the first major upturn in production since the record-high year of 1981 when output was 4.9 million tons. The 1987 production figure of 2.8 million tons was the lowest reported figure in the last 16 years. Wyoming, the largest producing State, increased production by nearly 11%. Production also resumed in Montana. Wyoming and Montana are traditionally the first and second largest swelling bentonite producing States, respectively. Domestic consumption for three major end uses, drilling mud, foundry sand, and iron ore pelletizing, except for drilling mud, increased modestly in response to improvements in the overall domestic economy.

Bentonite was produced in 14 States, 2 more than in 1987. The high-swelling or sodium bentonite continued to be produced chiefly in Wyoming. The low-swelling or calcium bentonite continued to be produced in the other States, mostly east of the Mississippi River. Calcium bentonite production in Alabama and Mississippi, the major producing States, is suitable for the production of absorbent, acid-activated, and foundry products.

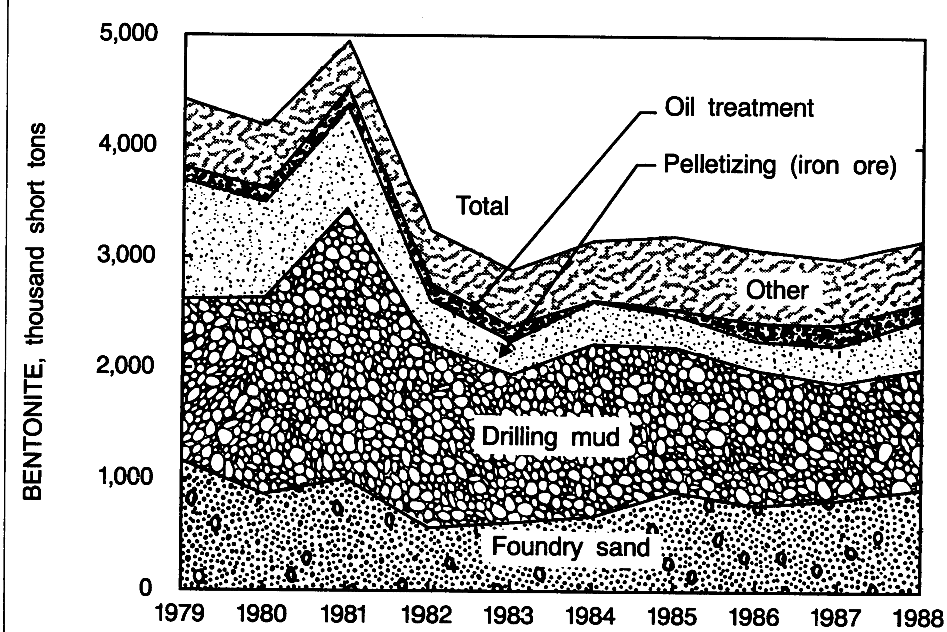
The major and captive producers of bentonite continued to expand their product lines in new marketing areas and restructured to minimize problems associated with industry overcapacity. Black Hills Bentonite Co., Mills, WY, started mining from its new mine on Federal land in the Platt River Resource Area. The firm's Casper Mountain, WY, mine was essentially depleted. The request for a permit from American Bentonite Co., Billings, MT, was pending before the Wyoming Department of Environmental Quality Council (EQC), to mine in the Kaycee (Johnson County) and Bolton-Bates area near Casper. American Bentonite is a wholly owned subsidiary of Kansas-based Davis Mud Chemicals Inc. In other State governmental related action, the EQC efforts on reclaiming the abandoned bentonite mines in Johnson County were so favorably received that the program was being expanded. Bids were being solicited from in- and out-of-state contractors for rehabilitating additional mines in Johnson, Natrona, and Sheridan Counties. About 75% of the $3 to $4 million program was targeted for Johnson County mines.

In calcium bentonite news, Southern Clay Products Inc., Gonzales, TX, a subsidiary of ECC America Inc., Atlanta, GA, completed a major expansion of its organoclay production facility. The multimillion dollar expansion was to increase capacity of existing rheological additive products and provide capabilities for producing new and improved products. Engelhard, citing litigation costs, decided to forgo its attempt to acquire Filtrol Corp.'s fluid catalytic cracking businesses. The U.S. Department of Justice ruling cited reduced competition. Earlier, Engelhard had brought out KaiserTech Ltd.'s Harshaw/Filtrol unit. Harshaw/Filtrol has both calcium bentonite derived desiccant and acid-activated product lines manufactured in Jackson, MS, from local and Arizona clays.

On December 30, 1988, Chemical Marketing Reporter quoted domestic sodium bentonite, 200 mesh bags, car-

FIGURE 2

BENTONITE SOLD OR USED BY DOMESTIC PRODUCERS IN THE UNITED STATES, BY USE



load lots, f.o.b. mines, at $30.50 per ton. The average unit value reported by domestic producers increased 4% to $33.75 per ton. Per ton values reported in the various producing States ranged from $8 to $75 but the average values reported by the larger producers was near the Wyoming average of about $30.61.

Bentonite exports increased more than 16% to 626,000 tons valued at $48.4 million. The unit value of exported bentonite increased about 3% to $77.33 per ton. This increase was attributed to the shipment of higher percentages of the costlier drilling mud and foundry grades shipped over the lower cost iron ore pelletizing grades exported mainly to Canada. Domestic bentonite producers, although benefiting from a relatively soft U.S. dollar and rising foreign oil and gas exploration activities, continued to face increased competion in foreign markets from lower quality material, particularly in the Canadian iron ore markets. In overseas drilling areas, Mediterranean bentonites continued to make inroads into an area traditionally served by domestic producers.

Bentonite was exported to 65 countries, 7 more than in 1987. The five major recipients, in descending order, were Canada, Japan, Singapore, Australia, and Taiwan. Domestic bentonite producers reported their exports were foundry sand, 47%; drilling mud, 43%; and other, 10%.

Bentonite imports for consumption consisted mostly of untreated clay and chemically or artificially activated materials. Total bentonite imports decreased about 14% to nearly 16,000 tons. The chemically activated category, slowly increasing in quantity for most of the last several years, decreased more than 14% to 12,500 tons valued at $4.0 million. Imports from Mexico, the largest source, decreased about 7% to about 95% of the total. Mexican imports usually make up to more than

TABLE 15

BENTONITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	Non-swelling		Swelling		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1987						
Alabama and Mississippi	423,335	$15,609,936	—	—	423,335	$15,609,936
Arizona	28,507	904,272	23	$805	28,530	905,077
California	95,737	6,867,803	20,556	1,762,662	116,293	8,630,465
Colorado	100	1,600	—	—	100	1,600
Nevada	3,013	310,580	8,786	499,914	11,799	810,494
Oregon	—	—	18,147	639,515	18,147	639,515
Texas	12,343	523,267	15,204	212,324	27,547	735,591
Utah	2,000	20,000	27,000	612,960	29,000	632,960
Wyoming	—	—	2,127,645	62,031,122	2,127,645	62,031,122
Other[1]	—	—	23,837	816,740	23,837	816,740
Total	**565,035**	**24,237,458**	**2,241,198**	**66,576,042**	**2,806,233**	**90,813,500**
1988						
Alabama and Mississippi	443,544	17,774,098	—	—	443,544	17,774,098
Arizona	28,710	907,808	23	805	28,733	908,613
California	117,886	8,549,976	19,409	1,527,292	137,295	10,077,268
Colorado	3,815	30,291	150	1,600	3,965	31,891
Nevada	—	—	9,366	542,461	9,366	542,461
Oregon	3,000	120,000	16,538	604,860	19,538	724,860
Texas	40,914	1,441,149	1,141	29,598	42,055	1,470,747
Utah	719	31,000	32,074	798,612	32,793	829,612
Wyoming	—	—	2,357,616	72,174,070	2,357,616	72,174,070
Other[1]	—	—	89,798	2,259,677	89,798	2,259,677
Total	**638,588**	**28,854,322**	**2,526,115**	**77,938,975**	**3,164,703**	**106,793,297**

[1] Includes Idaho, Kansas, Montana (1988), and Tennessee (1988).

TABLE 16

BENTONITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Short tons)

Use	1987			1988		
	Non-swelling	Swelling	Total	Non-swelling	Swelling	Total
Domestic:						
Absorbents	134,371	188	134,559	186,262	958	187,220
Adhesives	7,578	7,582	15,160	—	4,907	4,907
Animal feed	12,594	99,162	111,756	21,672	98,567	120,239
Catalysts (oil-refining)	16,901	—	16,901	13,286	—	13,286
Drilling mud	4,509	946,083	950,592	7,450	918,611	926,061
Filtering, clarifying, decolorizing:						
Animal oils, mineral oils and greases, and vegetable oils	73,944	2,277	76,221	74,762	1,875	76,637
Desiccants	16,343	—	16,343	15,890	—	15,890
Foundry sand	231,771	418,984	650,755	248,291	521,891	770,182
Medical, pharmaceutical, cosmetic	—	7,108	7,108	—	11,651	11,651
Paint	—	7,897	7,897	—	5,287	5,287
Pelletizing (iron ore)	—	337,837	337,837	W	446,718	446,718
Pesticides and related products	10,403	3,277	13,680	5,476	1,871	7,347
Water treatment and filtering	4,638	972	5,610	4,637	1,050	5,687
Waterproofing and sealing	1,648	87,991	89,639	1,853	107,574	109,427
Miscellaneous[1]	11,267	43,547	54,814	38,221	78,471	116,692
Total	**525,967**	**1,962,905**	**2,488,872**	**617,800**	**2,199,431**	**2,817,231**
Exports:						
Drilling mud	1,316	99,646	100,962	—	151,015	151,015
Foundry sand	9,054	169,149	178,203	4,134	158,803	162,937
Other[2]	28,698	9,498	38,196	10,038	23,482	33,520
Total	**39,068**	**278,293**	**317,361**	**14,172**	**333,300**	**347,472**
Grand total	**565,035**	**2,241,198**	**2,806,233**	**631,972**	**2,532,731**	**3,164,703**

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1] Includes data for asphalt emulsions; asphalt tile; cement, portland; ceramic floor and wall tile; face brick; fertilizers; firebrick, blocks and shapes; gypsum products; ink; kiln furniture; mineral wool and insulation; oil well sealing; paper-coating and -filling; plastics; pottery; roofing tile: rubber; uses not specified; and data indicated by symbol W.
[2] Includes absorbents; animal feed; asphalt emulsions; cement; filtering; clarifying, decolorizing; paint; plastics; waterproofing and sealing; and uses not specified.

75% the total activated clay imports. The Federal Republic of Germany, a former major supplier, furnished only 375 tons, and China recorded its first imports of this clay to the United States with an exploratory 10-ton batch. The chemically activated bentonite was imported from 9 countries (2 less than last year), with Mexico supplying 95%; the Federal Republic of Germany and the Republic of South Africa, 4%; and the remaining countries, 1%.

Fuller's Earth

Production of fuller's earth increased 6% to nearly 2.18 million tons valued at $154 million, a record high. The previous high was 2.06 million tons in 1985. This increase in production, except for declines in 1984 and again in 1986, continued the upward trend in production that the industry has enjoyed for more than a decade. A general increase in absorbent-grade clay output was sufficient to offset a 3% decline in Florida attapulgite production. The average unit value increased 6% to $70.66 per ton, indicating that an increasing percentage of higher valued gelling grades are included in the total. Production was again reported in 10 States. The two top producing States, Florida and Georgia, accounted for about one-half of domestic production. All States, except Florida, showed gains in production. Increases in consumption occurred in every major absorbent product line, with pet waste and oil and grease adsorbents leading the way.

Fuller's earth is defined as a nonplastic clay or claylike material, usually high in magnesia, which has adequate absorbing, decolorizing, and purifying properties. Sepiolite-type clays are also included for statistical convenience.

Production from the region that includes Attapulgus, Decatur County, GA, and Quincy, Gadsden County, FL, is composed predominantly of the lath-shaped amphibole-like clay mineral attapulgite. Most of the fuller's earth produced in other areas of the United States contains varieties of montmorillonite and/or other clays.

Industrywide, enlargements, modernizations, acquisitions and/or mergers, and new product development were active during the year. Laporte Industries Ltd., a company based in the United Kingdom, gained access to the U.S. adsorbents market with the acquisition of the Johnson Research Organization Inc. of Philadelphia, PA, for 12.7 million. The organization's principal subsidiary, Waverly Mineral Product Co., Meigs, GA, mines, produces,

FIGURE 3

FULLER'S EARTH SOLD OR USED BY DOMESTIC PRODUCERS FOR SPECIFIED USES

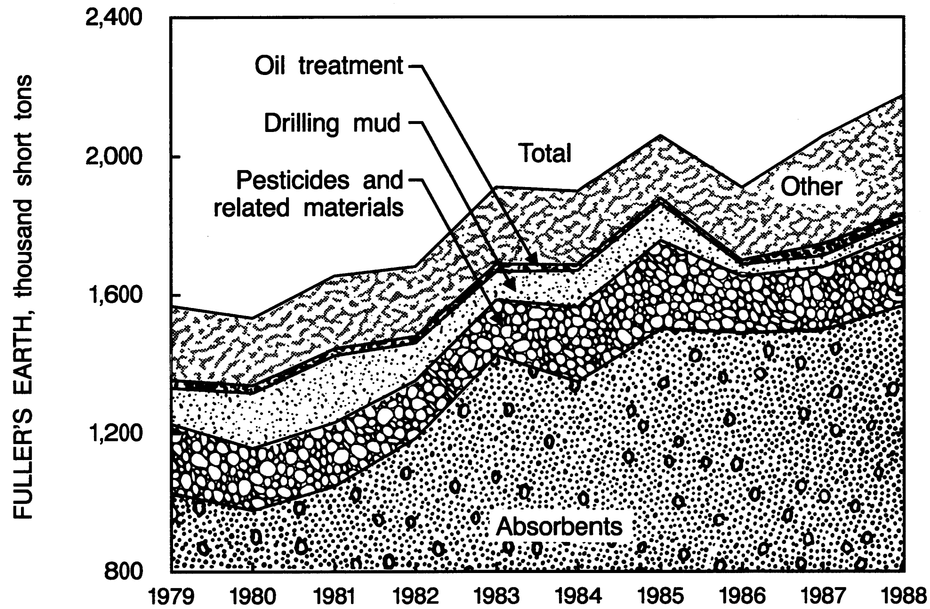


TABLE 17

FULLER'S EARTH SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	Attapulgite		Montmorillonite		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1987						
Florida	431,147	$35,164,373	—	—	431,147	$35,164,373
Georgia	372,411	22,770,533	218,823	$12,442,578	591,234	35,213,111
Southern [1]	—	—	577,558	31,155,549	577,558	[r]31,155,549
Western [2]	16,125	1,199,378	440,727	34,499,946	456,852	35,699,324
Total	**819,683**	**59,134,284**	**1,237,108**	**78,098,073**	**2,056,791**	**137,232,357**
1988						
Florida	419,454	39,461,646	—	—	419,454	39,461,646
Georgia	432,663	26,930,915	210,376	12,472,328	643,039	39,403,243
Southern [1]	—	—	625,010	35,213,566	625,010	35,213,566
Western [2]	19,499	1,600,607	468,009	38,004,712	487,508	39,605,319
Total	**871,616**	**67,993,168**	**1,303,395**	**85,690,606**	**2,175,011**	**153,683,774**

[r] Revised.
[1] Includes Mississippi, South Carolina, Tennessee, and Virginia.
[2] Includes Illinois, Missouri, Nevada, and Texas.

and markets clay-base adsorbents primarily for industrial applications and pet litter. Waverly is established in the eastern United States while Laporte has absorbent businesses worldwide. Another acquisition saw American Colloid Co., Arlington Heights, IL, a major worldwide calcium and sodium bentonite producer, enter the consumer markets by purchasing all the outstanding stocks of Absorbent Clay Products Inc., Anna, IL. Absorbent Clay is a producer of cat litter and agricultural granules with production facilities in Mounds, IL, and mining operations based chiefly in Olmstedt, IL. Absorbent Clay currently markets in the midwest and the east. Generally, the absorbent-producing companies enjoyed a good year while the gel-grade producers experienced a mixed year.

Attapulgite, a fuller's earth-type clay, finds wide application in both absorbent and gelling and/or thickening areas. The thixotropic properties of attapulgite clays provide the important thickening and viscosity controls necessary for suspending solids. Mineral thickeners are used in such diverse markets as paint, joint compound cement, and saltwater drilling muds.

Exports of fuller's earth again went to 28 countries, and the quantity increased nearly 16% to 124,000 tons. The unit value of exported fuller's earth decreased about 6% below that of 1987 to $76.26. The decrease was attributed to a larger percentage of absorbent grades exported in 1987 compared with the percentage of the high-cost gelling and drilling-mud grades shipped. The major recipients

TABLE 18

FULLER'S EARTH SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Short tons)

Use	1987			1988		
	Attapulgite	Montmorillonite	Total	Attapulgite	Montmorillonite	Total
Domestic:						
Adhesives	2,723	—	2,723	232	—	232
Drilling mud	31,949	—	31,949	36,318	—	36,318
Fertilizers	35,540	6,493	42,033	49,624	4,840	54,464
Filtering, clarifying, decolorizing: mineral oils and greases	13,795	—	13,795	8,622	—	8,622
Medical, pharmaceutical, cosmetic	959	—	959	1,075	—	1,075
Oil and grease absorbents	163,796	194,738	358,534	179,476	196,910	376,386
Paint	20,303	—	20,303	19,954	—	19,954
Pesticides and related products	r71,009	104,208	175,217	83,182	117,226	200,408
Pet waste absorbents	308,320	738,114	1,046,434	325,264	782,582	1,107,846
Portland and other cement	—	36,618	36,618	—	33,005	33,005
Other[1]	—	—	—	5,998	—	5,998
Miscellaneous[2]	90,767	139,194	229,961	91,048	150,000	241,048
Total	**739,161**	**1,219,365**	**1,958,526**	**800,793**	**1,284,563**	**2,085,356**
Exports:						
Drilling mud	122	—	122	125	—	125
Oil and grease absorbents	43,309	5,908	49,217	5,184	6,116	11,300
Pesticides and related products	5,463	2,270	7,733	5,601	2,216	7,817
Pet waste absorbents	22,461	9,565	32,026	43,633	10,500	54,133
Miscellaneous[3]	9,167	—	9,167	16,280	—	16,280
Total	**80,522**	**17,743**	**98,265**	**70,823**	**18,832**	**89,655**
Grand total	**819,683**	**1,237,108**	**2,056,791**	**871,616**	**1,303,395**	**2,175,011**

r Revised.

[1] Includes roofing tile (1988); vegetable oils (1988).

[2] Includes animal feed; animal oils; gypsum products; miscellaneous absorbents; miscellaneous fillers, extenders, and binders; miscellaneous filtering, clarifying, and decolorizing; mortar and cement refractories; plastics; roofing tiles; vegetable oils; wallboard; water treatment and filtering; waterproofing and sealing; and other uses not specified.

[3] Includes paint and uses not specified.

were Canada and the Netherlands. A minor amount of beneficiated fuller's earth was imported, mostly from the United Kingdom.

Common Clay and Shale

Domestic sales or use of common clay and shale decreased slightly in tonnage and value to 32.0 million tons and $145 million, respectively. Output of the 10 major producing States rose in Georgia, Indiana, Michigan, Missouri, Ohio, and Pennsylvania, and declined in Alabama, California, North Carolina, and Texas. Common clay and shale represented about 65% of the quantity but only 10% of the value of total domestic clay production.

Domestic clay and shale are generally mined and used captively to fabricate or manufacture products. Less than 10% of the total output is usually sold. The average unit value for all common clay and shale produced in the United States and Puerto Rico decreased slightly to $4.53 ton. The reported unit value ranged from $5 per ton to $35 per ton.

Common clay is a clay or claylike material that is sufficiently plastic to permit ready molding and that vitrifies below 1,100° C. Shale is a sedimentary rock composed chiefly of clay minerals that has been laminated and indurated while buried under other sediments. Clay and shale are used in the manufacture of structural clay products such as brick, drain tile, portland cement clinker, and expanded lightweight aggregates.

Increased production capacities, new plants, and modernizations were either deferred or proceeding cautiously during the year. Mergers and/or acquisitions of domestic heavy clay producers were quite active. The construction industry, the largest consumer of heavy clay products, such as brick, lightweight aggregate, portland cement, sewer pipe, and tiles, generally experienced soft sales the entire year. The large inventories traditionally accumulated during the slack winter months were worked off during the first quarter and by the end of the second quarter, inventories were beginning to climb again. The slack demand was brought on by a combination of rising interest rates, slowdown in the overall economy, and wet weather in the south and eastern part of the country. The slack demand was also largely attributed to the construction downturn, which lowered the demand for heavy clay products. In an attempt to boost sales, many brick manufacturers were actively seeking sales outside of their traditional marketing areas by offering highly competitive pricing. Building rates in the oil-producing States of Colorado, Louisiana, Oklahoma, and Texas, except for Louisiana, continued to be depressed.

In building brick acquisitions, Ibstock Johnson PLC of the United Kingdom acquired the assets and related activities of New Jersey Shale Brick Corp. for $15.2 million. Based in Somerville, NY, the company will complement Ibstock's U.S. subsidiary, Glen-Gery Corp., which conducted the buyout. New Jersey Shale's assets included mines and a processing plant, which consisted of two tunnel kilns and two extrusion lines. Current production is 50 million bricks per year equally divided between half-facing and paving brick. Glen-Gery operated 10 brick plants at locations throughout Ohio, Pennsylvania, and Virginia, whose current output is about 450 million bricks per year. The acquisition of Jersey Shale will further enhance Glen-Gery's presence in the U.S. northeastern seaboard marketplace. Another acquisition saw Old Carolina Brick Co. Inc., Anniston, AL, purchase the assets of Richland Brick Co. Inc., Mansfield, OH. The new Ohio corporation was renamed Richland Molded Brick Co. and operated as a division of Old Carolina Brick. Richland's factory complex, situated on a 540-acre site, will undergo a $3 million renovation and modernization to enable production of about 25 million bricks per year of handmade and wood-molded bricks by the spring of 1989.

Other exceptions to the industrywide slowdown in expansions and modernizations were announced by Steetley PLC, owner of Victor Cushwa and Sons Inc. in Maryland and K-F Bricks Inc. in Connecticut and Massachusetts, and by Baltimore Brick Co., a division of Boral Bricks Inc., Augusta, GA, owned by Boral Ltd. of Australia. Steetley was planning a major multimillion dollar unspecified expansion, including cost-saving equipment for its Cushwa and K-F brick and tile operations. Baltimore Brick completed a $3 million modernization and conversion of its Frederick County, MD, Rocky Ridge plant to sand-molded colonial brick. Previously, extruded bricks were also produced. The modernization included new forming and drying equipment capable of producing upward of 40 million bricks per year of the molded variety. Boral Brick operates 17 brick plants in Georgia, Maryland, Mississippi, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. Total Boral brick production last year was about 1.5 billion bricks.

In a nonbrick event, L. C. Holdings Inc., Boulder, CO, planned to reactivate the former Idealite lightweight aggregate plant near Denver. The shale expansion plant, formerly owned by Ideal Cement Co. Inc. of Denver, was last operated in 1975. Development of mining operations from the nearby Pierre shale outcrop and refurbishing of the plant's production facilities were expected to cost approximately $11 million. Plans stipulated production of about 500,000 cubic yards per year of high-quality structurally-approved aggregate. The planned new Denver International Airport was to provide a large and secure market for the company's expanded shale lightweight aggregates.

A notice of final results of countervailing duty administrative review by the International Trade Administration on bricks from Mexico, effective September 30, 1988, was made.[2]

TABLE 19

COMMON CLAY AND SHALE SOLD OR USED BY PRODUCERS IN THE UNITED STATES,[1] BY STATE

State	1987 Short tons	1987 Value	1988 Short tons	1988 Value
Alabama	2,071,690	$11,024,661	1,912,789	$10,969,165
Arizona	189,621	1,000,240	156,887	681,323
Arkansas	706,185	1,640,259	651,698	1,511,049
California	2,092,234	21,332,999	1,940,538	16,519,568
Colorado	289,002	1,612,269	257,439	1,641,963
Connecticut and New Jersey	248,437	2,599,275	245,081	2,662,599
Florida	127,518	1,241,925	128,144	1,306,436
Georgia	2,439,686	7,355,968	2,494,920	8,032,673
Illinois	232,949	977,048	180,306	703,945
Indiana	1,036,669	4,055,534	1,141,813	4,629,731
Iowa	472,788	1,494,770	445,248	1,587,679
Kansas	603,680	2,575,572	612,517	2,632,114
Kentucky	r883,267	r3,392,581	840,397	3,217,197
Louisiana	356,904	9,191,774	375,778	9,535,143
Maine and Massachusetts	189,562	942,329	130,233	675,231
Maryland	r383,054	1,939,968	394,443	2,016,225
Michigan	1,333,498	5,338,433	1,375,816	4,431,929
Mississippi	559,955	2,706,996	596,902	2,893,727
Missouri	1,139,749	2,748,092	1,222,622	3,927,188
Montana	28,879	98,270	36,745	83,723
Nebraska	223,728	721,059	237,459	785,615
New Mexico	50,350	135,945	29,791	72,528
New York	672,635	3,562,468	607,786	3,653,827
North Carolina	3,173,037	13,765,148	3,121,970	14,768,129
Ohio	2,895,970	8,125,451	3,411,372	9,389,347
Oklahoma	797,301	1,782,741	754,054	1,802,787
Oregon	249,677	346,365	228,483	324,096
Pennsylvania	1,182,748	4,150,511	1,338,742	4,853,905
Puerto Rico	148,029	317,751	163,382	364,985
South Carolina	1,244,886	2,726,808	1,115,096	2,176,050
South Dakota and Wyoming	194,700	1,756,372	159,493	648,096
Tennessee	569,303	1,452,360	563,951	1,483,566
Texas	3,283,652	14,032,898	2,912,548	13,669,960
Utah	286,154	1,325,981	307,363	1,638,608
Virginia	1,171,442	6,291,100	1,113,459	6,614,323
Washington	412,031	2,319,950	410,436	2,167,920
West Virginia	266,037	564,574	263,973	586,266
Other[2]	120,718	329,849	156,370	388,046
Total	**32,327,725**	**146,976,294**	**32,036,044**	**145,046,662**

r Revised.
[1] Includes Puerto Rico.
[2] Includes Idaho, Minnesota, New Hampshire, and North Dakota.

CONSUMPTION AND USES

The manufacture of heavy clay products including: (1) building brick; sewer pipe; and drain, roofing, structural, terra cotta, and other tile; (2) portland cement clinker; and (3) lightweight aggregate accounted for 40%, 18%, and 9%, respectively, of total domestic consumption. In summary, 64% of all clay produced was consumed in the manufacture of these clay- and shale-based construction materials.

Heavy Clay Products

The value reported for shipments by the Bureau of the Census for heavy clay products increased 8% to about $1.9 billion. The million standard brick count for building or common face brick increased 7%. Shipments of clay floor and wall tile increased 6%, while vitrified clay and sewer pipe fittings decreased 3%. Decreases in common clay and shale used in building brick manufacturing occurred in most States, with total domestic production decreasing 3%. Increases were largely under 15% with an average State upturn of about 8%.

Lightweight Aggregates

Consumption of clay and shale in the manufacture of lightweight aggregate decreased about 8% to over 4.2 million tons. The downturn in overall construction of commercial building and highway resurfacing was largely responsible for the decrease in demand. Concrete block, the largest category (61% of total production), declined 8% while the second biggest consuming area, highway surfacing (22% of total production), increased markedly. The third largest segment, structural concrete (12% of production) declined 38% and the other category, the smallest segment consisting essentially of new mar ket areas such as recreational and horticultural uses, rose 52%.

Refractories

All types of clay, except for fuller's earth, were used in manufacturing refractories. Kaolin, bentonite, and fire clay accounted for 31%, 28%, and 28%, respectively, of total clay used for this purpose. The remainder, ball clay and common clay and shale, was used chiefly as bonding agents. Bentonite, both swelling and non-swelling, was used as a bonding agent in proprietary foundry formulations imparting both hot- and green-strength to the sand.

The tonnage of clays used for refractories increased 15% and constituted 6% of total clay produced. The continued use of high-alumina clay-base refractories, mostly calcined kaolin grogs in monoliths, and the upturn in demand for the more conventional refractory bricks and shapes was largely responsible. The major refractory-consuming industries—cement, foundry, and glass, and ferrous and nonferrous metals—continued to undergo major changes in technology and production levels for their products.

Filler

Bentonite, fuller's earth, and kaolin, are the principal filler clays. Kaolin, either air-floated, water-washed, low-temperature calcined, and/or delaminated, was used in the manufacture of adhesives, paint, paper, plastics, and rubber. Fuller's earth was used primarily in pesticides and fertilizers. Clays are in pesticides and fertilizers as either thickeners, carriers, diluents, or prilling agents. Bentonites were used mainly in animal feeds.

Of the total clay produced, 12% was used in filler applications; of this, kaolin accounted for 88%; fuller's earth, 5%; bentonite, 3%; and ball clay, common clay and shale, and fire clay, the remaining 4%. Kaolin consumed as fillers increased 11% to 5.3 million tons. An approximate 21% and 13% increase in paper-filler grades and paint, respectively, increased 20%, which together constitute 32% of the total filler and extender category, were largely responsible. The paper-coating grade kaolin, animal feed, and gypsum products and wallboard, together made up an 8% increase. The total quantity of fuller's earth used in pesticides and related products, such as fungicides, increased nearly 14% from that of 1987.

Absorbent Uses

Absorbent uses for clays accounted for nearly 1.9 million tons, or 4% of total clay consumption. Demand for absorbents increased 8%. Fuller's earth was the principal clay used for absorbent purposes, and this application accounted for 81% of its entire output. Demand for clays in pet waste absorbents, representing 74% of absorbent uses, increased 6%. Use in floor or oil and grease absorbents, chiefly to absorb hazardous oily substances, accounted for another 24% of the absorbent demand, which increased from that of 1987. Increases in the use of pet waste absorbents and oil and grease absorbents in the industrial sector, which consumes large quantities of floor absorbent, were largely responsible for the upturn.

Drilling Mud

Demand for clays in rotary-drilling muds decreased 2% to about 964,000 tons and accounted for 2% of total clay production. This decrease reflects the downward trend, except for the increase noted in 1984, begun in 1982 when a combination of excess oil production and economic uncertainties resulted in lower oil- and gas-well-drilling activities, which depressed bentonite demand. Oil- and gas-well-drilling activity was strong into the third quarter owing to the firming of oil prices and improvements in the overall economy. Swelling-type bentonite remained the principal clay used in drilling mud mixes, although fuller's earth, used mostly in saltwater drilling techniques, and non-swelling sodium-activated bentonites, were also used to a limited extent. Bentonite and fuller's earth accounted for nearly 100% of the total amount of clay used in this category. Small amounts of kaolin were used in specialized formulations.

Floor and Wall Tile

Common clay and shale, ball clay, kaolin, and bentonite, in order of volume, were used in manufacturing floor, wall, and quarry tile. This end-use category accounted for 1% of the total clay production. The competitive and/or declining interest rates for most of the year spurred the demand for more attractively appointed tiled homes.

Pelletizing Iron Ore

Bentonite continued to be used as a binder in forming indurated iron ore pellets. Demand increased nearly 58% to about 535,000 tons. Inroads of inexpensive foreign bentonites into the Great Lakes markets traditionally served exclusively by U.S. bentonite producers, lower production levels, metal imports, and changing technology have all combined to reduce the long-term demand for domestic bentonite in this category.

Ceramics and Glass

Total demand for clay in the manufacture of pottery, sanitary ware, china and dinnerware, and related products (excluding clay flower pots) accounted for 3% of the total clay output. This demand, principally ball and kaolin clays, increased to 1.59 million tons. The strong upturn in residential housing, large consumers of whiteware and sanitary ware, was partially offset by the soft demand for these products at yearend owing to rising interest rates.

TABLE 20

CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES[1] IN 1988, BY USE

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Total
Absorbents:							
Oil and grease	—	W	W	—	376,386	—	376,386
Pet waste absorbents	—	W	W	—	1,107,846	—	1,107,846
Other[2]	—	194,387	159,914	—	19,880	—	374,181
Ceramics and glass:							
Catalysts (oil-refining)	—	13,286	—	—	—	119,600	132,886
Crockery and other earthenware	—	—	W	10,166	—	5,097	15,263
Electrical porcelain	31,655	—	37	—	—	16,481	48,173
Fine china and dinnerware	5,182	—	—	—	—	53,304	58,486
Glazes, glass and enamels	—	—	—	—	—	2,755	2,755
Mineral wool and insulation, fiberglass	W	W	40,709	—	—	508,246	548,955
Pottery	268,417	26,924	71,857	—	1,766	32,614	401,578
Roofing granules	—	—	—	—	—	11,287	11,287
Sanitary ware	188,340	—	—	5,832	—	26,847	221,019
Other[2]	80,094	W	W	87	—	62,892	143,073
Chemical manufacturing	—	—	—	—	—	233,625	233,625
Civil engineering and sealing	—	122,265	118,732	557	150,000	84,346	475,900
Drilling mud	—	926,061	—	—	36,318	1,162	963,541
Fillers, extenders and binders:							
Adhesives	—	4,907	3,000	—	232	58,649	66,788
Animal feed	W	120,239	W	—	W	4,930	125,169
Fertilizers	—	W	—	—	54,464	5,437	59,901
Gypsum products and wallboard	W	—	—	—	22,453	14,200	36,653
Ink	—	W	—	—	—	2,493	2,493
Medical, pharmaceutical, cosmetic	—	11,651	—	—	1,075	3,624	16,350
Paint	—	W	—	—	19,954	324,465	344,419
Paper-coating	—	—	—	—	—	2,737,396	2,737,396
Paper-filling	—	W	—	—	—	1,631,224	1,631,224
Pesticides and related products	W	7,347	4,401	—	200,408	61,290	273,446
Plastics	—	W	5,078	—	W	61,332	66,410
Rubber	W	W	—	W	—	224,197	224,197
Other[2]	146,159	18,665	85,588	W	23,719	208,337	482,468
Filtering, clarifying, decolorizing:							
Animal oils, mineral oils and greases, and vegetable oils	—	76,637	—	—	20,758	643	98,038
Desiccants	—	W	—	—	—	—	W
Floor and wall tile:							
Ceramic	116,953	—	288,770	—	—	20,154	425,877
Quarry tile	W	—	112,788	—	—	—	112,788
Other[2]	28,316	12	—	—	—	22,926	51,254

See footnotes at end of table.

TABLE 20—Continued

CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES[1] IN 1988, BY USE

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Total
Heavy clay products:							
Brick, extruded	W	W	12,652,155	25,169	—	295,075	12,972,399
Brick, other	—	—	3,573,376	13,927	—	115,251	3,702,554
Drain tile	—	—	115,758	—	—	—	115,758
Flower pots	—	—	21,962	—	—	—	21,962
Flue linings	—	—	52,407	20,420	—	7,000	79,827
Portland and other cements	—	20,771	8,098,865	—	33,005	221,578	8,374,219
Roofing tile	—	W	90,902	—	196	—	91,098
Sewer pipe, vitrified	—	—	410,372	4,242	—	7,160	421,774
Structural tile	—	—	92,925	—	—	—	92,925
Terra cotta	—	—	8,166	W	—	—	8,166
Other[2]	W	8,073	1,381,765	2,887	—	20,357	1,413,082
Lightweight aggregate:							
Concrete block	—	—	2,557,099	—	—	—	2,557,099
Highway surfacing	—	—	938,071	—	—	—	938,071
Structural concrete	—	W	523,621	—	—	—	523,621
Other[2]	—	5,363	180,000	—	—	—	185,363
Pelletizing iron ore	—	446,743	88,616	—	—	—	535,359
Refractories:							
Firebrick, blocks and shapes	W	W	133,453	484,233	—	172,764	790,450
Foundry sand	—	770,182	2,000	94,716	—	645	867,543
Grogs and calcines	—	—	—	116,911	—	654,215	771,126
High-alumina brick and specialties	29,426	—	—	74,911	—	18,798	123,135
Kiln furniture	—	W	3,090	—	—	6,676	9,766
Mortar and cement, refractory	—	—	201,049	—	—	—	201,049
Other[2]	W	20,764	—	6,281	—	32,451	59,496
Other[3]	44,373	22,954	2,336	6,302	16,896	8,041	100,902
Exports	152,255	347,472	17,182	8,053	89,655	1,791,571	2,406,188
Total	**1,091,170**	**3,164,703**	**32,036,044**	**874,694**	**2,175,011**	**9,891,135**	**49,232,757**

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Other."
[1] Includes Puerto Rico.
[2] Includes uses indicated by symbol W.
[3] Uses not specified.

TABLE 21

SHIPMENTS OF PRINCIPAL STRUCTURAL CLAY PRODUCTS IN THE UNITED STATES

Product		1984	1985	1986	1987	1988
Unglazed common and face brick:						
Quantity	million standard brick	6,510	6,605	7,204	7,313	7,811
Value	million	$836	$887	$972	$1,060	$1,188
Unglazed structural tile:[1]						
Quantity	thousand short tons	32	55	72	93	58
Value	million	$7	$12	$28	$50	$6
Vitrified clay and sewer pipe fittings:						
Quantity	thousand short tons	397	368	298	325	315
Value	million	$79	$78	$66	$74	$74
Unglazed, salt-glazed, ceramic-glazed structural facing tile including glazed brick:						
Quantity	million standard brick	W	W	W	32	26
Value	million	W	W	W	$11	$18
Clay floor and wall tile including quarry tile:						
Quantity	million square feet	340	370	444	462	488
Value	million	$421	$450	$536	$587	$641
Total value[2]	**do.**	**$1,342**	**$1,428**	**$1,602**	**$1,782**	**$1,927**

W Withheld to avoid disclosing individual company proprietary data.
[1] Includes first 9 months only, 1987.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census Report Form M32-D(88), Current Industrial Reports—Clay Construction Products.

TABLE 22

COMMON CLAY AND SHALE USED IN BUILDING BRICK PRODUCTION IN THE UNITED STATES, BY STATE[1]

State	1987		1988	
	Short tons	Value	Short tons	Value
Alabama	973,878	$4,392,725	966,897	$4,702,268
Arizona[2] and New Mexico[2]	141,992	483,466	72,786	227,741
Arkansas	192,388	447,054	318,266	708,421
California	456,618	8,036,489	422,143	2,536,412
Colorado	289,002	1,551,504	257,439	1,539,154
Connecticut, New Jersey,[2] and New York[2]	403,161	2,759,099	401,131	2,818,649
Georgia	2,104,724	5,919,878	1,971,311	5,580,507
Idaho, Washington, and Wyoming[2]	318,543	1,274,167	339,064	1,557,470
Illinois	131,787	614,170	135,480	559,670
Indiana and Iowa	423,908	1,364,579	467,768	1,803,579
Kansas	191,783	554,907	172,948	526,831
Kentucky[2]	384,692	2,100,514	361,348	1,849,836
Louisiana	73,672	176,499	99,044	286,693
Maine, Massachusetts,[2] and New Hampshire[2]	207,062	1,035,799	149,233	781,821
Maryland and West Virginia[3]	422,113	1,976,791	449,602	2,111,818
Michigan[2] and Minnesota[2]	208,872	586,815	211,623	655,429
Mississippi	479,955	2,429,796	475,954	2,464,209
Missouri	105,823	469,798	107,643	501,835
Nebraska and North Dakota[2]	187,619	493,162	233,495	578,179
North Carolina	2,806,044	10,844,565	2,757,671	10,429,302
Ohio	1,252,827	3,872,507	1,056,344	3,716,068
Oklahoma	374,343	973,542	247,849	796,140
Oregon	21,297	58,521	22,361	64,383
Pennsylvania	967,313	3,212,185	1,148,899	3,678,341
South Carolina	922,223	2,310,141	825,932	1,761,672
Tennessee[2]	442,786	1,053,831	441,001	1,076,601
Texas	1,185,246	4,925,894	1,148,201	5,755,747
Utah[2]	141,625	723,399	152,185	1,069,263
Virginia	870,018	2,681,587	811,913	2,790,901
Total[4]	**16,681,314**	**67,323,384**	**16,225,531**	**62,928,940**

[1] Includes extruded and other brick.
[2] Extruded brick only.
[3] Other brick only.
[4] Includes 1.5 million tons used in other brick production.

TABLE 23

COMMON CLAY AND SHALE USED IN LIGHTWEIGHT AGGREGATE PRODUCTION IN THE UNITED STATES, BY STATE

State	Short tons					Total value
	Concrete block	Structural concrete	Highway surfacing	Other	Total	
1987						
Alabama and Arkansas	743,549	91,433	16,674	25,348	877,004	$6,015,176
California	57,000	57,000	—	—	114,000	592,572
Florida and Indiana	202,832	28,750	—	—	231,582	1,508,486
Kansas, Kentucky, Louisiana	380,563	132,349	26,674	4,019	543,605	10,359,005
Mississippi	50,000	10,000	20,000	—	80,000	277,200
Montana and New York	243,610	163,717	—	—	407,327	2,992,566
North Carolina	270,000	90,000	—	—	[r]360,000	2,836,800
Ohio, Oklahoma, Pennsylvania	295,678	14,759	2,016	—	312,453	754,220
Texas	228,194	134,547	771,568	91,880	1,226,189	5,154,821
Utah and Virginia	321,353	79,809	8,625	1,040	410,827	4,071,305
Total	**2,792,779**	**802,364**	**845,557**	**122,287**	**4,562,987**	**34,562,151**
1988						
Alabama and Arkansas	558,909	101,418	12,219	8,670	681,216	5,293,951
California	80,600	54,000	—	—	134,600	734,916
Florida and Indiana	241,974	28,750	—	—	270,724	1,693,991
Kansas, Kentucky, Louisiana	322,073	113,957	20,704	52,695	509,429	10,342,400
Mississippi and Missouri	65,221	13,609	33,127	118,585	230,542	1,593,374
New York	247,373	169,653	—	—	417,026	3,277,666
North Carolina	270,000	90,000	—	—	360,000	3,390,700
Ohio, Oklahoma, Pennsylvania	268,790	15,296	—	—	284,086	733,770
Texas	191,860	269,275	433,614	—	894,749	3,679,947
Utah and Virginia	310,299	82,113	23,957	50	416,419	4,322,029
Total	**2,557,099**	**938,071**	**523,621**	**180,000**	**4,198,791**	**35,062,744**

[r] Revised.

TABLE 24

SHIPMENTS OF REFRACTORIES IN THE UNITED STATES, BY PRODUCT

Product	Unit of quantity	1986		1987	
		Quantity	Value (thousands)	Quantity	Value (thousands)
CLAY REFRACTORIES					
Superduty fire clay brick and shapes	1,000 9-inch equivalent.	21,968	$26,697	27,070	$27,914
Other fire clay including semisilica brick and shapes, glasshouse pots, tank blocks, feeder parts, upper structure parts used only for glass tanks.	do.	56,685	40,603	62,006	46,126
High-alumina (50% to 60% Al_2O_3) brick and shapes made of calcined diaspore or bauxite.[1]	do.	65,716	118,042	76,004	128,404
Insulating firebrick and shapes	do.	—	—	21,158	20,344
Ladle brick	do.	30,330	9,985	10,302	3,272
Sleeves, nozzles, runner brick, tuyeres	do.	25,279	29,327	9,679	28,315
Hot-top refractories	Short tons	W	W	W	W
Kiln furniture, radiant heater elements, potter's supplies, other miscellaneous-shaped refractory items	do.	27,185	21,965	42,432	33,246
Refractory bonding mortars	do.	79,042	37,156	56,619	29,296
Plastic refractories and ramming mixes, containing up to 87.5% Al_2O_3[2]	do.	75,893	36,669	64,051	32,816
Castable refractories	do.	207,150	78,075	251,808	110,578
Gunning mixes	do.	144,882	37,497	144,940	50,475
Other clay refractory materials sold in lump or ground form.[3 4]	do.	502,625	93,252	885,558	106,707
Total clay refractories		**XX**	**529,268**	**XX**	**617,493**
NONCLAY REFRACTORIES					
Silica brick and shapes	1,000 9-inch equivalent.	4,582	11,825	6,861	19,028
Magnesite and magnesite-chrome brick and shapes	do.	19,467	94,933	21,745	107,987
Chrome and chrome-magnesite brick and shapes	do.	22,914	82,347	27,640	101,124
Shaped refractories containing natural graphite	Short tons	11,548	32,728	17,251	40,117
Zircon and zirconia brick and shapes; other carbon refractories: Forsterite, pyrophyllite, dolomite, dolomite-magnesite molten-cast[5], other brick and shapes.	1,000 9-inch equivalent.	1,557	31,669	1,716	21,924
Other mullite, kyanite, sillimanite, or andalusite brick and shapes	do.	2,825	15,980	2,702	19,108
Other extra-high (over 60%) alumina brick and fused bauxite, fused alumina, dense-sintered alumina shapes.[6]	do.	4,141	63,508	3,287	58,119
Silicon carbide brick, shapes, kiln furniture	do.	979	28,880	1,105	33,936
Refractory bonding mortar	Short tons	21,094	11,539	29,843	16,944
Hydraulic-setting nonclay refractory castables	do.	19,023	18,227	28,837	21,999
Plastic refractories and ramming mixes	do.	120,306	75,922	136,738	89,385
Gunning mixes	do.	364,806	150,950	323,330	111,939
Dead-burned magnesia or magnesite[3 7]	do.	250,990	64,347	141,967	34,374
Dead-burned dolomite	do.	324,691	46,393	331,982	19,682
Other nonclay refractory material sold in lump or ground form.[3]	do.	280,886	74,655	202,486	42,137
Total nonclay refractories		**XX**	**803,903**	**XX**	**737,803**
Grand total refractories		**XX**	**1,333,171**	**XX**	**1,355,296**

W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1] Heat short of fusion; volatile materials are thus driven off in the presence of chemical changes, giving more stable material for refractory use.
[2] More or less plastic brick and materials that, after the addition of any water needed, are rammed into place.
[3] Materials for domestic use as finished refractories and all exported material.
[4] Includes calcined clay, ground brick, and siliceous and other gunning mixes.
[5] Molten cast refractories are made by fusing refractory oxides and pouring the molten material into molds to form finished shapes.
[6] Completely melted and cooled, then crushed and graded for use in a refractory.
[7] Includes shipments to refractory producers for reprocessing in the manufacture of other refractories.

Source: Bureau of Census Report Form MQ 32C(87), Current Industrial Reports—Refractory. Table will be resumed in 1989 Clay chapter.

TABLE 25

U.S. EXPORTS OF CLAYS IN 1988, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	—	—	1	64	([2])	3	—	—	13	3,411	([2])	92	14	3,570
Australia	—	—	35	1,931	31	2,196	—	—	7	1,741	5	2,841	78	8,708
Belgium-Luxembourg	—	—	3	556	50	3,135	1	68	56	9,406	4	763	114	13,928
Brazil	([2])	23	12	1,843	([2])	2	([2])	12	2	754	11	14,715	25	17,349
Canada	33	1,245	262	11,515	23	1,806	93	6,440	465	58,255	60	10,255	936	89,516
Chile	1	40	1	290	—	—	—	—	4	963	3	817	9	2,110
Colombia	—	—	13	670	—	—	—	—	11	2,549	7	5,915	31	9,135
Ecuador	([2])	3	1	118	—	—	—	—	1	326	9	1,466	11	1,913
Finland	1	23	—	—	([2])	10	—	—	206	25,899	1	593	208	26,525
France	—	—	1	275	1	224	([2])	66	15	3,026	5	1,342	22	4,933
Germany, Federal Republic of	([2])	12	13	594	([2])	91	2	120	30	5,218	26	5,122	71	11,157
Hong Kong	([2])	10	([2])	267	([2])	62	—	—	1	173	([2])	53	2	565
Italy	1	18	1	366	4	254	1	124	196	22,239	2	498	205	23,498
Japan	11	777	114	10,564	77	5,153	([2])	72	679	102,485	19	8,726	900	127,776
Korea, Republic of	1	42	5	1,924	([2])	3	([2])	4	96	16,930	4	795	106	19,698
Mexico	144	5,082	5	680	23	1,096	1	74	110	11,931	58	10,256	341	29,118
Netherlands	—	—	5	598	11	915	20	1,271	213	22,472	22	10,111	271	35,367
Peru	—	—	1	68	—	—	—	—	3	1,077	1	106	5	1,251
Philippines	4	394	4	544	([2])	5	([2])	13	3	554	2	842	13	2,351
Saudi Arabia	—	—	—	—	—	—	([2])	78	([2])	37	3	406	4	521
Singapore	—	—	42	2,826	1	37	([2])	34	1	331	1	215	45	3,443
South Africa, Republic of	([2])	23	([2])	78	—	—	2	373	25	4,535	4	1,120	32	6,130
Spain	—	—	([2])	169	([2])	39	—	—	17	2,516	1	106	19	2,830
Sweden	1	47	([2])	7	4	370	([2])	4	44	8,202	9	1,727	58	10,356
Switzerland	—	—	([2])	14	35	2,152	—	—	1	165	([2])	16	36	2,347
Taiwan	([2])	66	22	2,509	7	347	—	—	70	11,315	5	1,445	104	15,682
Thailand	([2])	12	11	996	([2])	14	—	—	9	1,508	2	250	22	2,780
United Kingdom	([2])	17	5	1,807	10	655	1	135	12	2,787	14	8,453	42	13,854
Venezuela	([2])	39	8	587	2	114	([2])	49	26	4,082	5	1,181	42	6,052
Other	5	412	62	6,551	2	192	3	489	46	10,045	16	6,417	134	24,104
Total[1]	**205**	**8,284**	**626**	**48,409**	**280**	**18,874**	**124**	**9,424**	**2,362**	**334,931**	**300**	**96,644**	**3,897**	**516,566**

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Source: U.S. Department of Commerce.

TABLE 26

U.S. IMPORTS FOR CONSUMPTION OF CLAYS IN 1988, BY KIND

Kind	Quantity (short tons)	Value (thousands)
China clay or kaolin:		
France	7	$3
Germany, Federal Republic of	45	22
Guinea	22	6
Netherlands	10	2
Switzerland	3	3
United Kingdom	8,293	1,935
Total	**[1]8,380**	**1,971**
Fuller's earth, beneficated:		
Canada	87	14
United Kingdom	449	15
Total	**536**	**29**
Bentonite:		
Brazil	3	9
Canada	1,425	369
China	44	6
France	22	16
Germany, Federal Republic of	156	269
Japan	3	13
Mexico	1,714	69
United Kingdom	142	60
Venezuela	18	6
Total	**3,527**	**[1]815**
Common blue and other ball clay, not beneficiated:		
United Kingdom	922	80
Total	**922**	**80**
Common blue and other ball clay, wholly or partly beneficiated:		
Germany, Federal Republic of	19	5
Guinea	22	5
United Kingdom	814	195
Total	**[1]856**	**205**
Other clay, not beneficiated:		
Canada	2	2
France	28	8
Germany, Federal Republic of	24	7

TABLE 26—Continued

U.S. IMPORTS FOR CONSUMPTION OF CLAYS IN 1988, BY KIND

Kind	Quantity (short tons)	Value (thousands)
Italy	1	4
Japan	13	14
Korea,Republic of	39	10
Switzerland	3,704	16
Venezuela	2,425	226
United Kingdom	754	206
Total[1]	**6,990**	**493**
Clay, n.e.c., beneficiated:		
Austria	7	5
Belgium	11	15
Canada	215	139
China	7	4
France	175	96
Germany, Federal Republic of	113	52
Italy	22	42
Japan	13	37
Netherlands	13	5
United Kingdom	1,952	799
Total[1]	**[1]2,529**	**1,194**
Artificially activated clay:		
Canada	48	35
China	11	9
France	2	11
Germany, Federal Republic of	374	1,001
Italy	40	84
Japan	6	30
Mexico	11,787	2,390
South Africa, Republic of	155	427
United Kingdom	46	62
Total	**12,469**	**[1]4,048**
Grand total	**36,208**	**8,835**

[1] Data do not add to total shown because of independent rounding.

Source: U.S. Department of Commerce.

WORLD CAPACITY

The data in tables 27, 28, 29, and 30 are rated capacity for mines as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced on a normally sustainable long-term operating rate based on physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for domestic clay production was aggregated from data voluntarily supplied by producers. The rated capacity data for the foreign mines were estimated from previous year's production in cooperation with the Division of International Minerals.

TABLE 27

CLAYS: UNITED STATES ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988, BY KIND AND TYPE

(Thousand short tons)

Kind and type	Rated capacity[1]
Ball clay:	
Air-float	700
Water-slurried	125
Unprocessed	300
Total	**1,125**
Bentonite:	
Non-swelling	1,000
Swelling	4,400
Total	**5,400**
Common clay and shale:	40,000
Fire clay:	1,200
Fuller's earth:	
Attapulgite	730
Montmorillonite	2,180
Total	**2,910**
Kaolin:	
Air-float	2,000
Calcined[2]	600
Calcined[3]	750
Delaminated	1,200
Unprocessed	1,000
Water-washed	4,500
Total	**10,050**
Grand total	**60,685**

[1] Includes capacity at operating plants as well as plants on standby basis.
[2] Low-temperature, filler.
[3] High-temperature, refractory.

TABLE 28

KAOLIN: WORLD ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988, RATED CAPACITY[1]

(Thousand short tons)

Country	Capacity
Algeria	18
Argentina	150
Australia	250
Austria	120
Bangladesh	15
Belgium	80
Brazil	900
Bulgaria	325
Burundi	e6
Chile	60
Colombia	1,500
Costa Rica	1
Czechoslovakia	800
Denmark	15
Ecuador	3
Egypt	150
Ethiopia (including Eritrea)	e5
France	1,600
German Democratic Republic	200
Germany, Federal Republic of	700
Greece	175
Guatemala	5
Hong Kong	10
Hungary	45
India	810
Indonesia	160
Iran	e120
Israel	35
Italy	100
Japan	250
Kenya	e1
Korea, Republic of	1,000
Madagascar	7
Malaysia	125
Mexico	300
Mozambique	e1
Nigeria	1
Pakistan	50
Paraguay	70
Peru	10

TABLE 28—Continued

KAOLIN: WORLD ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988, RATED CAPACITY[1]

(Thousand short tons)

Country	Capacity
Poland	60
Portugal	120
Romania	500
South Africa, Republic of	220
Spain	500
Sri Lanka	12
Sweden	1
Taiwan	100
Tanzania	e2
Thailand	300
Turkey	e250
U.S.S.R.	3,400
United Kingdom	4,000
United States	10,050
Venezuela	30
Vietnam	1
Yugoslavia	300
Zimbabwe	e1
Total	**29,747**

[e] Estimated.
[1] Includes capacity at operating plants as well as at plants on standby basis.

TABLE 29

BENTONITE: WORLD ANNUAL PRODUCTION CAPACITY, DECEMBER 31,1988, RATED CAPACITY[1]

(Short tons)

Country	Capacity
Algeria	40,000
Argentina	165,000
Australia	45,000
Brazil	275,000
Burma	1,000
Cyprus	e80,000
Egypt	6,000
France	15,000
Greece	1,500,000
Guatemala	5,000
Hungary	100,000
Iran	e30,000
Israel	7,000
Italy	400,000
Japan	550,000
Kenya	e200
Mexico	300,000
Morocco	4,500
Mozambique	e1,500
New Zealand	5,000
Pakistan	5,000
Peru	30,000
Philippines	30,000
Poland	85,000
Romania	210,000
South Africa, Republic of	80,000
Spain	150,000
Tanzania	e100
Turkey	e100,000
U.S.S.R.	3,200,000
United States	5,400,000
Zimbabwe	e120,000
Total	**12,940,300**

e Estimated.

1 Includes capacity at operating plants as well as at plants on standby basis.

TABLE 30

FULLER'S EARTH: WORLD ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1989, RATED CAPACITY[1]

(Short tons)

Country	Capacity
Algeria	4,000
Argentina	2,500
Australia (attapulgite)	17,000
Italy	45,000
Mexico	60,000
Morocco (smectite)	60,000
Pakistan	25,000
Senegal (attapulgite)	130,000
Spain (attapulgite)	75,000
United Kingdom	325,000
United States	2,910,000
Total	**3,653,500**

1 Includes capacity at operating plants as well as at plants on standby basis.

WORLD REVIEW

Angola

The Minister of Industry announced an agreement to exploit the kaolin deposits in the hills of Huila Province, which borders on Namibia.[3] Work was scheduled to begin at midyear at an operating rate of about 150,000 tons per year (tpy).

Australia

Construction plans for a kaolin plant capable of producing about 10,000 tpy of high-quality clay by Greenbushes Ltd. reached the final feasibility stage.[4] The $2 million project was to be completed by yearend 1989 and is targeting the high-value end of the southeastern Asian ceramic industry. Greenbushes crude kaolin feed consists of 60% quartz, 40% kaolin, and less than 0.1% combined Fe_2O_3 and TiO_2.

The high cost of domestic shipping has reportedly hindered Comalco Ltd.'s access to the Asian pigments markets, despite the strong international demand for paper-coating quality clays.[5] Comalco's Weipa kaolin was targeted mainly for the Japanese market and European and Asian paper producers. The Asian markets have traditionally used American kaolins. ECC International Ltd. became the sole proprietor of Kaolin Australia Pty. Ltd. by acquiring the remaining 49% shareholding of the group's partners.[6]

A major diversified group, CSR Ltd., agreed to take a 50% stake in a brickmaking and pipemaking venture with Brickworks Ltd. for $52 million.[7] Brickworks is the largest brick producer in New South Wales. CSR has already made several moves into the local brickmaking industries with the most recent being an 18.3% stake in Brick and Pipe Industries Ltd. The British building group, Redland PLC, agreed to buy a 49.99% stake in the clay roof tile business of Monier Ltd., a local building products company.[8] Redland also has roofing tile interest in Indonesia, Japan, Thailand, and the United States.

Belgium

ECC International Ltd. also planned to construct a $15 million technical center for the paper and polymer industries, adjacent to its clay and carbonate processing plant at Lixhe near Liege.[9] The Center will house both a technical service unit and a pilot paper coater and associated equipment. The Center will complement ECC International's extensive research and development facilities in St. Austell, Cornwall, United Kingdom.

Brazil

The Laporte Industries Ltd., United Kingdom, was setting up a joint venture activated bentonite clay plant in Jacarei, Saõ Paulo.[10] The operating company, Fulmont Argilas Ativadas, will be 60% owned by Laporte and 40% owned by its existing partner in Bentonit Uniao Nordeste (BUN) and Barborema Holding Co. Additionally, Laporte had a 40% interest in BUN, which is the largest domestic bentonite producer. Clay for the new $8 million acid-activation plant will come from existing northeastern deposits or from sources in Saõ Paulo. Plant capacity will initially be about 8,000 tpy, increasing to 10,000 if warranted. BUN's imports of activated clay from Laporte's United Kingdom operations will be curtailed when the new unit comes on-stream in the first quarter of 1989. Export markets were targeted for 30% of the plant's output. A mining company owned by the State government of Bahia, Companhia Baiana de Pesquisa Mineral (CBPM) opened a tender for parties interested in a joint exploration of its bentonite mine in Vitoria da Conquista.[11] CBPM estimates its reserves to be 40 million tons and domestic consumption of about 300,000 tpy.

Canada

Esso Minerals Canada sold its 12.5% interest in the Wood Mountain, Saskatchewan, kaolin project back to Ekaton Industries Inc., Calgary, Alberta.[12] The ongoing operation plans to ship upward of 150,000 tpy of premium-quality kaolin paper-filler, 82% to 84% brightness, to markets in the northeastern United States, western Canada, and the Pacific Rim. The Wood Mountain kaolin reserves were claimed to exceed 200 million tons. In another action, Ekaton purchased Canada's only bentonite producer, Avonlea Mineral Industries Ltd., Regina, Saskatchewan, for the company's $1 million debt.[13] Avonlea owned and operated a sodium bentonite mine about 14 miles southwest of Wilcox for the last 9 years. The plant's designed capacity of 100,000 tpy has never been realized. The new management plans to raise the current output from 30,000 to 60,000 tpy in the next 18 months. Bentonite reserves were estimated to be in the vicinity of 7 million tons. Present sales, mostly to the drilling industry, were going to be expanded to include the growing foundry, civil engineering, and agricultural markets.

Chile

The calcium bentonite-diatomite deposits of Arica Province, both underground and open pit, were processed by Sociedad Legal Minera Macarena (SLMM). The calcium-type bentonite was used as a pelletizing agent for the fishmeal industry. SLMM's total bentonite reserves were reported to be nearly 100 million tons of 80% clay. Tests were run by a Swiss-owned company, Colmet S.A., as a possible source for acid-activated bentonites. The low-cost byproduct sulfuric acid from the state-owned Corporación del Cobre de Chile's Chuguicamota plant would be used to acid activate the clay.

China

A large kaolin deposit, between coal horizons, was found in Xuzhou in eastern Jiangsu Province.[14] Kaolin reserves were estimated to be in excess of 200 million tons, of which one-third is said to be of paper quality. China currently spends about $100 million on coating-grade kaolins. A joint venture between the Government and Watts Blake Bearne and Co. PLC was entered into for developing a ball clay processing plant to treat indigenous clay from Guandong Province.[15] Total investment in the project was expected to exceed $1 million.

A contract was signed with Occidental Industries (OCI), Paris, France, to build a state-of-the-art brick plant in Helionjang Province in the northeast.[16] The equipment will be manufactured and supplied by OCI and involve a unique tunnel kiln capable of firing carbonaceous shales without an external energy supply. The 425-foot-long and 30-foot-wide kiln is to be operated at 1,100° C with a 6% shrinking clay body. Finally, the Government, in an attempt to conserve farmland, urged building materials enterprises to refrain from using clays in making bricks.[17] Clay has traditionally been the main raw material in Chinese brickmaking; more than 4 billion bricks are manufactured annually. The Government essentially proposed to prohibit the manufacture of solid bricks by collective and individual kilns on farmland. The ban may not extend to other ownerships.

Japan

Statistics published by the Japan Bentonite Industrial Association show domestic production by major producers to be: Kunimine Industries, 33%; Hojun Kogyo, 29%; Hoyoh, 18%; and others, 20%.[18] Exports in 1987 exceeded $100 million. ECC acquired the remaining 50% share in Fuji Kaolin Co. Ltd. and renamed the subsidiary, ECC Japan Ltd.[19]

Philippines

The U.S. Department of Environmental and Natural Resources reported the discovery of a large bentonite deposit in Rizal Province, Luzon.[20] The Government was looking at the possibilities of a joint venture with private firms to develop the find.

Portugal

The British brickmaker, Ibstock Johnson PLC, acquired an 80% equity share in Fabrics Ceramica de Valadares, one of the country's major sanitary ware producers for $10 million.[21] The company's single manufacturing facility, situated south of Oporto, has a 30% share of the domestic market with 45% of sales destined for exports to France, the United Kingdom, and the United States. Future plans called for eliminating tile production entirely to increase sanitary ware output. Ibstock planned to meet the tight Portuguese demand before addressing export sales.

Spain

In another action, ECC increased its shareholding in Ciá Espanõla de Caolines S.A. to nearly 82% and acquired 75% of the shares in another Spanish kaolin producer, Caosil S.A., with an option to buy the remaining 25%.[22]

Turkey

The lack of success in securing a joint-venture partner for its bentonite properties prompted Etibank, Turkey's mineral company, to lease the mining rights to Urtaslar, a Kayseri-based mining and contracting company.[23]

Uganda

The Government planned to spend upward of $4 million to intensify its exploration program for industrial minerals.[24] Kaolin clay was assigned a top priority by a committee setup to identify deposits and potential markets for allocating the funds made available by the Uganda Development Bank.

U.S.S.R.

The Yermak brickworks in northern Kazakhstan started brick production utilizing coal ash from local powerplants and indigenous clays.[25] The factory planned to produce about 60 million bricks per year made with 30% clay and 70% coal ash. The bricks are relatively inexpensive and exceed local building code specifications.

United Kingdom

Mergers, acquisitions, and divestitures of brickmaking companies were commonplace during the year. Blue Circle Industries PLC, a major worldwide cement manufacturer, purchased Ockley Brick Ltd.'s Swiss parent company, Romag, for $112 million.[26] Romag's other assests included bitumen companies in Austria and the Federal Republic of Germany. Ockley, the principal target in the deal, is strategically situated in the heart of the buoyant southeast Surrey marketplace. Apparently, Blue Circle decided to reduce its dependence on cement and have Ockley complement its smaller brick business based in Sittingbourne, Kent, which produces about 14 million bricks per year. Annual production at Ockley was running at 35 million bricks per year. Blue Circle plans to increase brick capacity, and to improve product quality and manufacturing efficiency, along

TABLE 31

KAOLIN: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria	9	14	16	15	15
Argentina	100	81	129	142	[3]62
Australia[4]	[5]241	[5]183	205	195	200
Austria (marketable)	110	110	41	102	100
Bangladesh[6]	3	5	3	14	[3]11
Belgium	76	41	[e]44	[e]50	50
Brazil (beneficiated)	536	578	688	750	[3]849
Bulgaria	282	283	292	310	315
Burundi	2	5	6	6	[3]4
Chile	54	54	46	49	[3]60
Colombia	1,034	1,148	1,273	1,346	[3]1,413
Costa Rica	[e]1	—	—	—	—
Czechoslovakia	736	[e]720	[e]720	768	[3]756
Denmark	[e]15	[e]14	11	10	11
Ecuador	3	3	[e]2	[e]2	2
Egypt	159	119	141	138	140
Ethiopia (including Eritrea)[e]	10	10	10	6	1
France[7]	338	1,664	1,488	[e]1,540	1,540
German Democratic Republic (marketable)[e]	190	190	180	165	180
Germany, Federal Republic of (marketable)	397	452	564	648	660
Greece	101	97	156	159	160
Guatemala	1	1	2	2	[3]4
Hong Kong	([8])	11	1	—	[3]—
Hungary	43	32	33	37	[3]33
India:					
Salable crude	555	645	808	766	[3]580
Processed	128	121	[e]110	[e]165	165
Indonesia	92	118	138	125	[3]154
Iran[e]	110	110	110	110	110
Israel[e]	30	30	30	30	30
Italy:					
Crude	58	66	39	63	[3]78
Kaolinitic earth	28	29	21	26	[3]21
Japan	248	245	225	190	[3]174
Kenya	([8])	([8])	2	([8])	([3] [8])
Korea, Republic of	795	726	937	695	[3]917
Madagascar	[e]3	7	[e]7	2	([3] [8])
Malaysia	80	91	94	107	[3]129
Mexico	144	311	305	167	[3]236
Mozambique[e]	([8])	([3] [8])	([8])	([8])	([8])
New Zealand	28	27	31	28	28
Nigeria[e]	([3] [8])	([8])	([8])	([8])	([8])

See footnotes at end of table.

TABLE 31—Continued

KAOLIN: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Pakistan	13	7	41	36	35
Paraguay	55	66	[e]66	[e]66	66
Peru	1	([8])	7	([8])	([8])
Poland	50	53	54	[e]54	55
Portugal	115	88	60	63	66
Romania[e]	450	450	450	440	440
South Africa, Republic of	150	142	139	167	[3]203
Spain (marketable)[9]	352	456	413	477	440
Sri Lanka	12	6	7	8	[3]8
Sweden[e]	([3 8])	([8])	([8])	([8])	([8])
Taiwan	88	84	70	74	[3]90
Tanzania	2	2	[e]2	[e]2	2
Thailand	65	118	[7]146	[7]228	[3]297
Turkey	61	76	86	148	[3]231
U.S.S.R.[e]	3,100	3,200	3,300	3,300	3,300
United Kingdom	3,296	3,472	3,211	3,372	3,750
United States[10]	7,953	7,793	8,549	8,827	[3]9,891
Venezuela	24	[e]25	[e]24	28	[3]27
Vietnam[e]	1	1	1	1	1
Yugoslavia[e]	[6]222	225	230	235	275
Zimbabwe	1	1	1	1	([8])
Total	**[r]22,751**	**[r]24,606**	**25,765**	**26,455**	**28,365**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 19, 1989.
[2]In addition to the countries listed, China, Lebanon, and Suriname also produced kaolin, but information is inadequate to make reliable estimates of output levels. Morocco produced less than 500 tons in each of the years covered by this table.
[3]Reported figure.
[4]May include ball clay and other clays grouped for statistical purposes as kaolin.
[5]Excludes Western Australia.
[6]Data for year ending June 30 of that stated.
[7]Includes kaolinitic clay.
[8]Less than 1/2 unit.
[9]Includes crude and washed kaolin and refractory clays not further described.
[10]Kaolin sold or used by producers.

with a more aggressive marketing strategy. The takeover of small- and medium-sized British brickmakers continued with the multinational industrial conglomerate, Hanson Trust PLC, bidding $100 million for George Armitage and Sons PLC.[27] Armitage produced about 104 million bricks per year at its 3 brick factories: Howley Park (57 million) and Swillington (31 million) near Leeds, and Whinney Hill (16 million) at Accrington. The Armitage line also included pavers, hand-thrown, terra cotta, and specialty abrasion-resistant materials. The building materials division of Tarmac PLC agreed to buy the Avonmouth-based Severn Valley Brick Co. (Sevalco), the United Kingdom subsidiary of the American Company Phelps Dodge Corp., for $20 million.[28] In earlier moves, Tarmac purchased Westbrick Ltd. and Hawkins Tiles Ltd., both of which specialized in the high-quality end of the market such as specialty shapes and colored and handmade bricks. In keeping with its restructing program, Alfred McAlpine PLC sold its Scottish brickmaking works, in Errol, Perthshire, to Marley PLC for $5.4 million.[29] This acquisition, Marley's first in Scotland, produces a full line of facing and engineering bricks and tiles. The newly operational Lingl tunnel kilns are currently producing about 10 million bricks per year, all from locally derived clays. Marley plans to expand the market area for the company's bricks into northern England. Finally, the engineering, building, and construction materials firm, Marshalls Halifax PLC, merged with the Wakefield clay brick producer, George Armitage and Sons PLC to form a new diversified construction company.[30]

A major undertaking was instituted at Baggeridge Brick PLC's newly rebuilt brick factory at Hartlebury for the production of slop-molded brick.[31] Slop-molded bricks are relatively uncommon in the United Kingdom and initial output at the factory was to be about 13 million bricks per year. The new bricks closely resemble old handmade bricks and are not surficially sanded. Another new product introduced by Baggeridge was its new line of true blue bricks from the new Lingl tunnel kiln at its Kingsbury factory.[32] Ordinarily, blue bricks are fired batchwise in intermittent kilns. Commissioning of the new tunnel kiln, part of an overall $13 million investment at Kingsbury, strategically fits the company's goal of producing high-quality facing and engineering bricks from the local Etruria marls. The new kiln will be producing upward of 500,000 blue bricks weekly.

ECC's ceramic division invested $11 million to establish a clay plant, claimed to be the most comprehensive and modern centralized unit of its

TABLE 32

BENTONITE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria[3]	27,007	36,376	33,069	[e]33,000	33,000
Argentina	138,564	162,111	161,148	119,705	121,000
Australia[3]	43,180	32,044	27,494	33,501	38,600
Brazil	221,592	260,168	227,099	214,494	220,000
Burma	799	783	938	448	[4]560
Cyprus[5]	35,715	57,320	60,627	87,744	99,500
Egypt[e]	4,200	3,300	5,650	[4]4,219	4,400
France	3,831	16,424	[e]11,000	[e]9,000	9,000
Greece	858,400	977,718	1,452,652	1,433,582	1,322,800
Guatemala	9,570	3,006	4,228	2,932	[4]4,519
Hungary	70,722	65,966	88,061	108,391	[4]72,768
Iran	38,581	29,762	[e]30,000	[e]30,000	30,000
Israel (metabentonite)[e]	[4]6,501	6,600	6,600	6,600	6,600
Italy	335,102	327,239	336,890	345,127	[4]332,274
Japan	452,034	508,749	527,184	458,347	[4]501,702
Kenya[e]	220	220	220	220	220
Mexico	294,700	295,083	150,465	142,859	[4]146,648
Morocco	2,012	3,171	4,226	3,250	[4]3,797
Mozambique	446	398	1,226	[e]1,200	1,200
New Zealand (processed)	7,075	8,157	3,461	([6])	—
Pakistan	1,918	1,776	1,501	2,797	3,100
Peru	14,298	2,223	36,464	20,613	22,000
Philippines	42,162	27,526	1,984	837	[4]2,238
Poland[e]	77,000	83,000	83,000	83,000	83,000
Romania[e]	198,000	198,000	204,000	198,000	198,000
South Africa, Republic of	46,131	47,910	53,203	53,961	[4]77,042
Spain	80,008	99,471	126,935	114,001	110,000
Tanzania[e]	83	83	83	83	83
Turkey	30,967	51,649	61,032	94,631	[4]85,459
U.S.S.R.[e]	3,174,700	3,185,700	3,196,700	3,196,700	3,196,700
United States	3,437,940	3,195,280	2,813,043	2,806,233	[4]3,164,703
Zimbabwe[e]	[r]70,500	[r]75,000	[4]79,352	[r]128,800	124,700
Total	**[r]9,723,958**	**[r]9,762,213**	**9,789,535**	**9,734,275**	**10,015,613**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 19, 1989.
[2]In addition to the countries listed, Canada, China, the Federal Republic of Germany, and Yugoslavia are believed to produce bentonite, but output is not reported and available information is inadequate to make reliable estimates of output levels.
[3]Includes bentonitic clays.
[4]Reported figure.
[5]Includes bleaching earths.
[6]Revised to zero.

kind.[33] Known as the Clay Center, the plant offers four key facilities: clay storage and distribution; china clay milling; clay refining; and the production of bodies with high-quality feldspar, silica, and other materials. The Clay Center is also supported by ECC's Central Research Laboratory.

In specialty clay activities, Watts Blake Bearne and Co. PLC's new kaolin drying plant was scheduled to come on-stream by midyear 1989,[34] and Steetley PLC sold two fire clay refractory operations.[35] The two fire clay operations were judged to be peripheral to Steetly Refractories main business. The plants were the fire clay hollow ware plant at Thomas Wragg Works, Sheffield, and the monolithics operation at Rotherham. In addition, the Refractories Div. also started a new coal-clay operation in Scotland.

TECHNOLOGY

In-depth reviews were published on the industrial minerals of France,[36] Mexico,[37] Nova Scotia,[38] and Newfoundland and Labrador,[39] which included detailed sections on clay, local geology, mineralogy, mining and milling flowsheets, and indigenous mining methods and markets. The French report stressed current production and developments of the attapulgite, bentonite, halloysite, kaolin, and smectite industries. The report also included supply-demand statistics and a map locating the main French kaolin producers. The Mexican study highlighted the individual operating bentonite and refractory clay companies and their long-range goals in the present climate of lower domestic and worldwide demand for their products. The Canadian papers emphasized the commercial opportunities for its clay in the U.S. eastern seaboard marketplace.

Articles on ball clays[40] and bentonite[41] reviewed the world sources of these clays and their major markets. The individual companies in each country, their products, capacities, geology, locations, and plans, and other pertinent data were discussed. The ball clay article stressed the exacting worldwide specifications and demands being made upon the producers by ceramic ware manufacturers. The bentonite paper touched on the overcapacity of the industry—brought about by lower demand levels of the well-drilling, pelletizing, and foundry industries—and stressed the main impact among producers for developing new products and adding value for specialty markets. The bentonite report featured a technical glossary of terms and comprehensive applications lists for natural,

TABLE 33

FULLER'S EARTH: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria[e]	[3]3,858	3,900	3,900	3,900	3,900
Argentina	3,980	1,921	[e]2,200	[e]2,200	2,200
Australia (attapulgite)	[e]16,500	[e]16,500	52,223	12,081	16,500
Italy	[e]33,000	33,500	34,127	42,449	[3]37,919
Mexico	50,372	63,934	57,541	54,123	[3]54,363
Morocco (smectite)	36,824	26,924	38,691	51,005	[3]58,085
Pakistan	21,097	11,736	16,785	19,891	22,000
Senegal (attapulgite)	127,315	105,774	90,232	122,409	[3]119,518
Spain (attapulgite)	48,399	65,805	74,759	[e]58,400	66,100
United Kingdom[4, e]	[r]223,000	[r]238,000	[r]223,000	[r]234,850	276,000
United States[5]	1,899,145	2,059,281	1,909,978	2,056,791	[3]2,175,011
Total	**[r]2,463,490**	**[r]2,627,275**	**2,503,436**	**2,658,099**	**2,831,596**

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Excludes centrally planned economy countries, some of which presumably produce fuller's earth, but for which no information is available. Table includes data available through July 19, 1989.

[2] In addition to the market economy countries listed, France, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

[4] Estimates made by British Geological Survey of marketable production based on reported crude production in short tons, of: 1984—315,000; 1985—322,000; 1986—273,000; 1987—Not available; and 1988—Not available.

[5] Sold or used by producers.

acid-, alkaline-, and organically-activated bentonites.

Three papers dealt with various aspects of kaolin. One paper discussed the kaolin potential in Finland[42] and another was on the diverse requirements of kaolin consumers.[43] The Finnish kaolin paper discussed the geology and mineralogical compositions, along with the economic potential of deposits in the north, northeastern, and southern parts of the country. The Finnish deposits are largely residual-type clays. The second kaolin work delineates the kaolin properties required by the paper coating, paper filling, ceramic, rubber, and catalyst industries. The third paper, while touching briefly on the world's major exporting kaolin companies, emphasized worldwide shipping, trucking, and storage (wet and dry) infrastructure.[44] The sophisticated handling and makedown techniques for these high quality and expensive kaolins are examined. A group of papers dealing with ceramic raw materials suppliers were published. One article on ceramic raw materials from Ecuador outlined the geology of the country and described in detail its reserves and the current status of its industry.[45] A map showing the morphological features and locations of clays and other ceramic raw materials was a feature of the report. The second paper investigates the chemical and physical properties of ceramic raw materials from Greece, including kaolin and plastic clays, and assesses their suitability for the glass and ceramic industries. Tailoring plastic ceramic-quality clays from the Westerwald Region, the Federal Republic of Germany, to meet customer specifications in a rapidly changing marketplace was the topic of another work.[46] Technical case histories are cornerstones of this presentation. The role of chamotte clays in ceramics was examined in the last paper.[47] The use of shredded dry-ground chamottes and ground chamottes, in European ceramic, refractory, and filler markets, was correlated with raw material treatments and its eventual uses in sanitary ware, tiles, and porcelain products. A rapid simple quality-control test based on the measurement of air permeability was developed to assess freeze-thaw resistance of clay bricks.[48] This new test should help in eliminating a major performance problem experienced in cold climates. The lack of a reliable freeze-thaw test method is probably the chief reason for the slow progress made over the years in its elimination. Thermal dilatometry, differential thermal analysis, x-ray diffraction, scanning electron microscopy, and energy dispersive spectroscopy revealed the development of phases and the microstructure on firing bodies containing upward of 50% kaolin.[49] The vitrified anorthite, higher in calcium, produced a superior ware with less shrinkage than observed in conventional higher sodium-bearing porcelains.

The future of mullite refractories in advanced ceramics was correlated with its use as a bonding phase.[50] The crystal structure and the physical and chemical properties of mullites are outlined as well as its interaction with a wide range of added impurities. Another work studied the secondary thermal expansion of mullite refractories containing clays and bauxites as a function of time, temperature, and particle size.[51] The subsequent instrumental study, (see above) of the fired bodies revealed the mechanism for the expansion to an SiO_2 diffusion controlled reaction from the clays to the calcined bauxite or tabular alumina. The expansion was successfully compensated for by regulating the particle size and ratio of the calcined bauxite to tabular alumina. The mullite, which are end products of solid-state reactions involving kaolin, bauxite, and/or fire clays, are widely used in refractory bricks and specialty products. The results of these studies should allow refractory manufacturers to better control the physical properties of the mullite component to optimize the density of the resulting high-performance refractories.

The effects of additives on burnt properties of clay bricks were investigated in great detail, highlighting sawdust and spent lubricating oil.[52] Sawdust was generally found to be beneficial to burnt brick below 2-weight-percent, while no beneficial effect was observed from the engine oil. Sawdust is a popular burnout source for lightweight bricks. The production of consistent high-quality extruded clay bricks were correlated with raw materials handling and clay water absorption.[53] The results of this study appear to agree with theoretical studies relating a ceramic body's ability to absorb water to its exposed surface area and, hence, number of particles.

Two articles reviewed the uses of mineral fillers and extenders in the pharmaceuticals[54] and adhesives and sealants industries.[55] The pharmaceutical paper discussed the main applications of minerals in the manufacture of tablets, as fillers and formulation aids. The article looked at this specialized low-tonnage/high-value use for minerals and the exacting specifications demanded from the industry it supplies. Bentonites, hectorites, kaolins, saponites, and attapulgites were singled out for special attention. Clays are mainly used in suspensions as a suspending agent. Kaolin is also used as a diluent for tablets and capsules and for its adsorptive properties for treating gastro-intestinal conditions. The sealant article technically evaluates the plethora of minerals involved in these industries and discussed their functions and suitabilities. The current state of the market was also reviewed along with new applications yet to make a market impact. The most popular clays used as fillers in adhesive and sealants are attapulgite, bentonite, and kaolin. These clays impart body thixotropy and reinforcing properties. The organophilic bentonites, organic derivatives of hydrous silicate minerals of the smectite-type, are highly efficient gellants for organic liquids of low or intermediate polarity. The uses of industrial minerals as a filler in papermaking was discussed in two works. One paper briefly discussed the less well-known mineral pigments, such as bentonite.[56] It is used primarily as a pitch control agent, but also in new uses as a drainage and pigment enhancer. The other paper cites not only the advantages of paper coating and paper filling but also its shortcomings when papermakers are tempted to go too far in improving quality and profit at the expense of poor strength and contamination of printing presses.[57] The technical evaluation of papers exceeding the usual maximum of one-third inorganics was featured. A novel new filler, solid hollow microspheres were discussed in detail.[58] These newly developed manmade materials compete with industrial mineral fillers. The nature of these valuable materials, compositional and manufacturing details, and outlines of their industrial applications and cost-effectiveness against traditional fillers are assessed. The lighter weight hollow spheres are beginning to make inroads into the plastics industry, replacing glass fibers.

The long established ceramic glaze industry, an integral part of ceramic ware production, was technically examined.[59] The paper reviews recent developments at a new, large, state-of-the-art United Kingdom operation and gives an insight into the manufacturing of frits and glazes. For those unfamiliar with the industry terms and technology, a special section is included on raw materials that is integrated with the network theory of glass-formers and modifiers. Similar works on the trends and developments in prepared ceramic bodies and ceramic manufacturing techniques were also published.[60] The ceramic body paper details the development of the growing prepared body industry from mining, beneficiation, manufacturing, quality control, and applications. Flowsheets for each of these steps were furnished. The second ceramics manufacturing article summarizes the benefits accrued by using infrared radiation in drying ceramics products. A comparison with the more traditional drying methods was offered. A special reference to ceramic tile manufacturing and its shortcomings, using infrared radiation, was also provided.

Special sections on clay processing were included in articles discussing superconducting magnetic separators[61] and hydrocycloning.[62] The development of second generation cryogenically cooled magnetics was detailed along with flowsheets and schematics of equipment and processing steps. A highlight of the report lists estimated operating costs for separator magnets, both conventional and superconducting. The hydrocycloning article discussed some recent developments in grit removal from high quartz-kaolin feeds.

The adsorption of low molecular weight halocarbons by montmorillonite-smectite was investigated.[63] The widely distributed and troublesome organic wastes are the low molecular weight halocarbons—trichloroethylene, perchlorоethylene, and pesticides such as 1,2-dibromo-3-chloropropane. Montmorillonite, pretreated with sodium citrate-bicarbonate-dithionite, was found to be superior in selectively absorbing high levels of halocarbons than equivalent untreated clays in solutions. Another similar study with infrared and Raman spectroscopy was used to determine the adsorption interaction between the organic pollutants, such as pesticides, and soil columns containing preselected amounts of calcium montmorillonites.[64] The uptake and specific interactions between the montmorillonite clay and the pesticides were rapidly ascertained directly with this instrumental approach. If this research proves successful in the field, the problems of hazardous waste disposal and removal of these contaminants from ground waters may be inexpensively available. The structural studies of pillared clays and modified pillared clays were examined by x-ray diffractometry.[65] The structure of clay layers and pillars in pillared interlayered clays (PILC's) is of fundamental importance in understanding their thermal stability and catalytic properties. These catalysts or their derivatives have long been used for cracking liquid hydrocarbons. More recent applications of PILC catalysts and/or supports, along with new clay-related chemistry, have burgeoned in recent years. This paper investigated the integrity of pillared clays, with either Al, Zr, or Cr either alone or in clusters, acid activated with either HCl or H_2SO_4, followed by either air-drying or calcination at 400° C for 4 hours.

Statistical process control (SPC) in the mining and processing of ball clay[66] and air-floated kaolin[67] was detailed. Both papers stressed the point that SPC in clay operations actually begins with a comprehensive testing of crude stocks and reserves. Clays, with the exception of slurried varieties, generally remain constant in their physical properties regardless of processing steps. The ball clay paper demonstrated the extreme consistency of its products by the low standard of deviation in the Al_2O_3 content of the clay samples.

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COBALT

By Kim B. Shedd[1]

U.S. reported consumption of cobalt increased to 16 million pounds, an 8% rise over that of 1987. Industries that reported significant increases in cobalt use included the magnetic alloy, catalyst, paint drier, and pigment industries. U.S. imports of cobalt were 20% lower than imports in 1987. The balance of demand was supplied by consumption from stocks, which had been built up during the previous year.

The producer price of electrolytic cobalt was raised twice during the year. Following the first increase, the market price remained within $1 per pound below the producer price.

DOMESTIC DATA COVERAGE

Domestic data on cobalt processing and consumption are developed by the Bureau of Mines from three separate voluntary surveys of U.S. operations. In the the cobalt processors survey, the eight companies canvassed all responded. Most of the data on cobalt use in chemicals was obtained from this survey. The second survey covers a broad range of metal-consuming companies, such as superalloy producers, magnetic alloy producers, and tungsten carbide producers. The Bureau of Mines also surveys superalloy scrap recyclers to determine the consumption of secondary cobalt in superalloy production. Thirteen recyclers process the vast majority of superalloy scrap. Eight of the recyclers responded to requests concerning the quantity of cobalt contained in scrap processed and sold to superalloy producers. Estimates for nonrespondents on the latter two surveys were based on previous reports.

LEGISLATION AND GOVERNMENT PROGRAMS

On February 25, the U.S. Environmental Protection Agency (EPA) removed cobalt from the "extremely hazardous substances" list that EPA was required to maintain under the Emergency Planning and Community Right-to-Know Act of 1986.[2] In 1986, the agency had identified cobalt as 1 of 40 substances that did not meet its criteria for inclusion on the list. Before the delisting, the final regulations had required any facilities that stored, manufactured, processed, used, or otherwise handled cobalt in quantities greater than 10,000 pounds to notify designated State emergency planning commissions, and to report releases to the environment of cobalt metal powders in quantities greater than 1 pound.

Management and operational responsibilities for the National Defense Stockpile were transferred from the Federal Emergency Management Agency and the General Services Administration to the Secretary of Defense under the authority of Executive Order 12626 of February 25, 1988.[3] The functions of the National Defense Stockpile Manager were delegated to the Assistant Secretary of Defense (Production and Logistics) under the supervision of the Under Secretary of Defense (Acquisition).

The U.S. Department of Defense was authorized to begin a cobalt upgrading program under section 524 of the Treasury, Postal Service, and General Government Appropriations Act of 1988 (Public Law 100-202). The act obligated $1 million to $2 million for a pilot project to upgrade technologically obsolete cobalt in the National Defense Stockpile. The cobalt would be upgraded to meet or exceed Grade B of the National Defense Stockpile Purchase Specification P-13-R6, dated December 18, 1985.

The Minerals Management Service of the U.S. Department of the Interior finalized prelease prospecting regulations for marine minerals on the U.S. Outer Continental Shelf. The regulations apply to all minerals except oil, gas, and sulfur. Separate requirements were established for geological and geo-

TABLE 1

SALIENT COBALT STATISTICS

(Thousand pounds of contained cobalt unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Consumption:					
Reported	12,944	13,541	14,442	r14,892	16,031
Apparent	17,895	15,692	17,373	17,820	17,862
Imports for consumption	25,310	17,708	12,288	19,472	15,545
Stocks, Dec. 31:					
Consumer	1,368	1,131	1,479	2,056	1,726
Processor	1,781	1,557	1,441	2,632	1,989
Price:					
Metal, per pound[1]	$10.40	$11.43	$7.49	$6.56	$7.09
World: Production[2]					
Mine	r90,244	r103,145	110,716	p100,870	e96,781
Refinery	r52,288	r61,118	68,522	p59,188	e55,696

e Estimated. p Preliminary. r Revised.

[1] Market price based on weighted average of Metals Week prices.

[2] In 1986, the units for "World: Production" were changed from short tons to thousand pounds. Some differences between these and previously published data might be encountered owing to differences in conversion methods.

physical prospecting and scientific research.[4]

DOMESTIC PRODUCTION

Blackbird Metals Inc., a New York-based corporation, was formed to purchase and reopen the former Blackbird cobalt mine in Lemhi County, ID, and to build a 5,000-short-ton-per-year refinery. The company entered into an agreement with the State of Idaho under which it would pay $7 million to the State to remedy environmental conditions resulting from past operations. Blackbird Metals rescinded the agreement when the State declined to restrict the use of the funds to the mine. The company then opened negotiations with Noranda Minerals Inc. and with M. A. Hanna Co., coowners of the mine. Blackbird Metals offerred to post security and hold Noranda and Hanna harmless, to the limit of $7 million, against environmental liabilities that might accrue as a result of continuing litigation between the State and the sellers. The negotiations were continuing at yearend.

Although no cobalt was mined or refined in the United States in 1988, secondary cobalt production included the recycling of superalloy and other forms of scrap (magnetic alloy, tungsten carbide, etc.). Cobalt was also recovered from spent petroleum catalysts at the AMAX Inc. plant in Braithwaite, LA, and at Gulf Chemical and Metallurgical Corp. in Freeport, TX. An annual cobalt recovery of between 500,000 and 1 million pounds was estimated, based on 35,000 short tons of spent catalyst processed each year.[5]

TABLE 2

U.S. COBALT PRODUCTS[1] PRODUCED AND SHIPPED BY PROCESSORS

(Thousand pounds of contained cobalt)

	1987		1988	
	Production	Shipments	Production	Shipments
Driers (organic compounds)	1,838	1,751	1,749	1,817
Hydrate (hydroxide)	1,386	1,014	1,115	913
Salts[2] (inorganic compounds)	745	797	1,250	1,275
Total	**3,969**	**3,562**	**4,114**	**4,005**

[1] Figures on oxide withheld to avoid disclosing company proprietary data.
[2] Various salts combined to avoid disclosing company proprietary data.

CONSUMPTION AND USES

U.S. reported consumption of cobalt exceeded 16 million pounds, an 8% increase over consumption reported for 1987. Industries that reported increased cobalt use included magnetic alloy, catalyst, paint drier, and pigment manufacturers. Apparent consumption, calculated from net imports, secondary consumption, and changes in industry stocks, was more or less unchanged at 17.9 million pounds.

PRICES

On January 21, the producer price for cobalt metal was increased from $7.00 per pound to $7.50 per pound. This price was maintained until November 4, when a new producer price of $8.40 per pound was announced following a meeting in Lusaka, Zambia, of representatives from the two major producers, La Générale des Carrières et des Mines (Gécamines) of Zaire and Zambia Consolidated Copper Mines Ltd. (ZCCM). The 12% increase was higher than some market analysts had expected. However, the $8.40 price was established through the end of 1990. This was the first time in the past few years that Gécamines and ZCCM had established the price for more than 1 year. The producers hoped that the 2-year term would provide continued stability to the market.

The market price of electrolytic cobalt began the year at a range of $6.85 to $7.10 per pound. Market prices increased following the November announcement by Gécamines and ZCCM that the producer price would be $8.40 per pound and ended the year with a range of $7.40 to $7.60 per pound. The weighted average market price for the year was $7.09 per pound.

FOREIGN TRADE

As part of the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418) the United States was required to follow the nomenclature of the internationally established Harmonized Tariff Schedule (HTS), effective January 1, 1989. Although tariff numbers and nomenclature for cobalt-containing materials would no longer follow the Tariff Schedules of the United States Annotated (TSUSA), duties would remain the same.

On January 2, the United States entered into the United States-Canada Free Trade Agreement. Duties on certain cobalt materials originating in Canada were scheduled to decrease over a 5-year period beginning January 1, 1989.[6]

U.S. imports of cobalt in 1988 decreased 20% from imports the previous

TABLE 3

U.S. CONSUMPTION OF COBALT, BY END USE

(Thousand pounds of contained cobalt)

End use	1987	1988
Steel:		
Full-alloy	W	W
High-strength, low-alloy	W	W
Stainless and heat-resisting	57	56
Tool	383	397
Superalloys [1]	6,273	6,364
Alloys (excludes alloy steels and superalloys):		
Cutting and wear-resistant materials [2]	1,174	1,197
Magnetic alloys	1,719	1,916
Nonferrous alloys	W	W
Welding materials (structural and hard-facing)	W	W
Other alloys	94	55
Mill products made from metal powder	W	—
Chemical and ceramic uses:		
Catalysts	1,096	1,360
Drier in paint or related usage	[r]1,761	1,966
Feed or nutritive additive	53	58
Glass decolorizer	37	35
Ground coat frit	794	731
Pigments	570	834
Miscellaneous and unspecified	883	1,062
Total	**[r][3]14,892**	**16,031**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] Data not comparable to those prior to 1986 because of the addition of statistical canvass coverage of the superalloy recycling industry.
[2] Cemented and sintered carbides and cast carbide dies or parts.
[3] Data do not add to total shown because of independent rounding.

TABLE 4

U.S. CONSUMPTION OF COBALT, BY FORM

(Thousand pounds of contained cobalt)

	1984	1985	1986	1987	1988
Chemical compounds (organic and inorganic) other than oxide [1]	2,404	1,980	1,977	2,249	2,771
Metal	8,746	9,463	8,594	[r]9,005	9,626
Oxide	915	1,201	1,233	1,129	1,140
Purchased scrap	879	897	2,638	2,509	2,495
Total	**12,944**	**13,541**	**14,442**	**[r]14,892**	**[2]16,031**

[r] Revised.
[1] Includes chemical compounds formerly listed separately as "Other."
[2] Data do not add to total shown because of independent rounding.

year. However, the net import reliance as a percent of apparent consumption remained at 86%. Fifty-nine percent of U.S. cobalt imports were from ores originating in the south-central African countries of Zaire and Zambia, compared with 66% from this area in 1987. This includes significant amounts of cobalt imported from Belgium, where electrolytic Zairian cobalt is processed into metal powder, oxides, and salts by Métallurgie-Hoboken Overpelt S.A. (MHO). Approximately one-third of U.S. cobalt imports in 1988 were from Canada and Norway. About 50% of the cobalt produced in Norway was from Canadian ores, and roughly 30% was from scrap.[7]

The United States exported 1.2 million pounds, gross weight, of unwrought cobalt metal and waste and scrap valued at $10.1 million. Of the cobalt in this category 50% was shipped to Belgium, 13% to France, and 10% to Canada. The remainder was shipped to 32 other countries.

Over 600,000 pounds of wrought cobalt metal, valued at $14 million, was exported to 24 countries. The major recipients were Canada, Japan, and Belgium.

WORLD CAPACITY

The data in table 10 are rated capacity for refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

TABLE 5

YEAREND PUBLISHED PRICES OF COBALT MATERIALS[1]

(Dollars per pound)

Material	1984	1985	1986	1987[2]	1988
Cobalt metal[3]:					
Cathode or shot[4]	11.70	11.70	7.00	7.50	8.40
Fine powder[5]	16.63	19.05	[r]15.40	[r]16.85	17.75
Powder	13.24	14.87	14.47	13.84	14.74
S-grade powder	12.00	11.70	7.50	7.75	8.65
Cobalt oxide:					
Ceramic-grade (70% cobalt)	9.40	9.98	6.08	8.80	9.70
Ceramic-grade (72% cobalt)	9.66	10.26	6.24	9.04	9.94
Metallurgical-grade (76% cobalt)	9.86	10.61	6.51	9.41	10.31

[r] Revised.
[1] Metals Week.
[2] Represents prices as of Jan. 21, 1988.
[3] See table 1 for cathode market price.
[4] 250-kilogram drums.
[5] 50-kilogram drums.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM

(Thousand pounds and thousand dollars)

Form	1986	1987	1988
Metal:[1]			
Gross weight	11,669	18,612	14,715
Cobalt content[e]	11,669	18,612	14,715
Value	$83,295	$122,791	$105,544
Oxide:			
Gross weight	511	795	743
Cobalt content[e]	378	588	550
Value	$4,202	$5,293	$5,692
Salts and compounds:			
Gross weight	805	903	935
Cobalt content[e]	241	271	280
Value	$2,669	$2,004	$2,689
Total content	**12,288**	**[2]19,472**	**15,545**

[e] Estimated.
[1] Includes unwrought metal and waste and scrap.
[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

The United Nations Preparatory Commission of the International Seabed Authority (Prepcom) granted exclusive rights to Japan, France, and the U.S.S.R. to exploit manganese nodules in sites in the deep ocean off Hawaii. Manganese nodules typically contain nickel, copper and cobalt.

Australia

In October 1988, Western Mining Corp. (WMC) purchased BP Australia Ltd.'s 60% share of the Agnew nickel mine in Western Australia, and began negotiations in December to purchase the remaining 40% from MIM Holdings Ltd. WMC planned to reopen the mine, which had been on a care-and-maintenance status since 1986, under the name Leinster Nickel. During past production, nickel-cobalt matte from ores originating at the Agnew Mine contributed to the feedstock at the AMAX nickel-cobalt refinery in Braithwaite, LA.

Queensland Nickel Pty. Ltd. announced plans to increase the capacity of the Yabulu nickel processing plant near Townsville, Queensland. During 1988, cobalt was produced at the plant in a nickel-cobalt sulfide. Projected output after the expansion would be 1,650 short tons of cobalt per year. During the year negotiations were under way with the French Government regarding the importation of feedstock from New Caledonia to the Yabulu plant. Feedstock from New Caledonia would replace ore currently mined at the Greenvale Mine, which was expected to run out of reserves within the next 2 years. Other possible sources of feedstock were Indonesia and the Philippines. At yearend, Dallhold Investments Pty. Ltd. agreed to form a joint venture with the Queensland State government. The State purchased a 12.5% interest in the project.

Anglo American Pacific announced

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY

(Thousand pounds and thousand dollars)

Country of origin	Metal[1]				Oxide				Other forms[2]				Total content[3 4]	
	1987		1988		1987		1988		1987		1988			
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Value	Cobalt content[3]	Value	Cobalt content[3]	Value	1987	1988
Belgium	281	2,618	775	7,508	331	2,414	474	3,744	6	85	34	462	532	1,160
Canada	3,317	20,774	3,486	23,651	73	497	56	397	19	108	41	244	3,390	3,567
Finland	363	4,160	217	3,475	51	349	85	489	9	93	102	558	410	382
France	85	428	47	506	3	80	11	224	([5])	10	—	—	87	56
Germany, Federal Republic of	146	1,726	288	2,623	45	87	—	—	2	99	([5])	11	181	288
Japan	1	75	112	647	([5])	3	—	—	13	373	5	373	14	118
Netherlands	262	1,636	54	152	178	1,142	—	—	—	—	—	—	394	54
Norway	1,551	9,320	1,378	9,257	—	—	—	—	1	3	—	—	1,552	1,378
South Africa, Republic of	1	7	5	46	—	—	18	142	191	799	12	63	192	29
United Kingdom	151	546	69	355	44	266	84	602	27	409	50	479	211	181
Zaire	9,361	63,835	5,384	38,866	49	337	—	—	1	18	—	—	9,398	5,384
Zambia	2,919	17,040	2,663	16,942	—	—	—	—	—	—	—	—	2,919	2,663
Other	174	629	237	1,516	21	115	16	94	1	7	37	499	190	286
Total[4]	**18,612**	**122,791**	**14,715**	**105,544**	**795**	**5,293**	**743**	**5,692**	**271**	**2,004**	**280**	**2,689**	**19,472**	**15,545**

[1] Includes unwrought metal and waste and scrap.
[2] Includes cobalt sulfate, other cobalt salts and other cobalt compounds.
[3] Estimated from gross weights.
[4] Data may not add to total shown because of independent rounding.
[5] Less than 1/2 unit.

Source: Bureau of the Census.

the initiation of a feasibility study on the Salley Malay nickel-copper deposit. The deposit, in the Kimberley region of Western Australia, was believed to contain minor amounts of cobalt.

Botswana

BCL Limited produced a record 52,093 short tons of metal (nickel, copper, and cobalt) in 1988. The company planned to develop a new copper-nickel mine in its existing Selibe-Phikwe district in northeastern Botswana. The new mine would be in the Selibe North deposit. Cobalt-containing nickel-copper matte from BCL's existing mines was refined by Falconbridge in Kristiansand, Norway (74%) and by refineries in Zimbabwe (26%).

Brazil

British Petroleum Mineração S.A. suspended plans to develop a nickel-cobalt-copper deposit at Fortaleza de Minas in Minas Gerais State. The suspension resulted from a Constitutional article passed by Brazil's Congress. The article restricted mineral exploration and mining to Brazilian-capital companies, and required foreign-owned companies to sell their majority interests to Brazilian companies.

Cia. Niquel Tocantins, a Brazilian nickel producer, was scheduled to begin production of electrolytic cobalt at its São Miguel Paulista plant in São Paulo State in late 1989 or 1990. Cobalt concentrate produced by the company was sent to Falconbridge Ltd.'s refinery in Norway for processing.

Canada

Sherritt Gordon Mines Ltd. changed its name to Sherritt Gordon Ltd. to reflect the disposal of its major mining interests. According to the company's annual report, about the same quantity of cobalt was produced in 1988 as in 1987. Research at Sherritt's Special Products Div. included efforts to reduce the cost of making cobalt-samarium magnetic alloys through process improvements.

During the year, Inco Ltd. decided not to renew its 10-year feedstock contract with Sherritt when it expires at the end of 1989. Sherritt pursued alternative sources of feed supplies and announced plans to expand production capacity at the refinery provided that enough feedstock becomes available.

TABLE 8

U.S. IMPORT DUTIES FOR COBALT, EFFECTIVE JANUARY 1, 1987

Item	TSUS No.	Most favored nation (MFN)	Non-MFN
Alloys, unwrought[1]	632.88	5.5% ad valorem	45% ad valorem.
Chemical compounds:			
Oxide	418.60	1.2 cents per pound	20 cents per pound.
Sulfate	418.62	1.4% ad valorem	6.5% ad valorem.
Other	418.68	4.2% ad valorem	30% ad valorem.
Ore and concentrate	601.18	Free	Free.
Unwrought metal, waste and scrap	632.20	do.	Do.

[1] Duty on unwrought alloys of cobalt, containing by weight 76% or more but less than 99% cobalt, temporarily suspended (on or before Dec. 31, 1987).

TABLE 9

U.S. EXPORTS OF COBALT IN 1988, BY COUNTRY OF DESTINATION

(Thousand pounds and thousand dollars)

Country of destination	Unwrought cobalt, waste and scrap		Wrought cobalt	
	Gross weight	Value	Gross weight	Value
Belgium	603	2,615	124	1,789
Canada	121	1,428	179	4,003
France	151	1,706	38	623
Germany, Federal Republic of	100	1,384	4	148
Italy	28	349	14	196
Japan	40	569	124	4,667
Mexico	9	97	63	363
Sweden	27	156	10	197
Switzerland	([1])	3	21	559
United Kingdom	37	627	12	281
Other	80	1,196	35	1,222
Total[2]	**1,197**	**10,131**	**624**	**14,048**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 10

WORLD ANNUAL COBALT PRODUCTION CAPACITY, DECEMBER 31, 1988

(Million pounds of contained cobalt)

Country	Refinery capacity
Canada	6.5
Finland[1]	4
France[2]	1.3
Japan[1 3]	6.2
Norway	4.4
South Africa, Republic of[1]	2
U.S.S.R.[e 4]	15
United States[5]	2
Zaire	39.7
Zambia	12
Total	**93.1**

[e] Estimate.
[1] Includes salts.
[2] Cobalt chloride.
[3] Includes standby capacity of 2.6 million pounds.
[4] Based on estimated production.
[5] Standby capacity.

Inco began a program to consolidate its Sudbury, Ontario, milling and concentrating operations over the next 2 years. All milling and concentrating was to be done at the Clarabelle mill; the Copper Cliff mill was to be used for dewatering concentrates prior to smelting; and the Frood-Stobie mill was to be closed. This consolidation was expected to improve productivity, and to increase the rejection of sulfur-bearing pyrrhotite, which would ultimately reduce emissions of sulfur dioxide to the atmosphere. Also at Sudbury, Inco planned to reopen the Shebandowan Mine in 1989 and had projects under way to reactivate the Crean Hill Mine and to develop the Lower Coleman Mine. Inco also planned several improvements at Thompson, Manitoba. The Birchtree Mine, which had been on standby since 1977, was being redeveloped, and a new mine, to be called Thompson Open Pit South, was being developed to replace Thompson Open Pit North when it runs out of reserves in the next few years.

According to Inco's annual report, 1988 cobalt deliveries, including cobalt contained in alloys and engineering products, were roughly the same as those in 1987.

Falconbridge's 1988 cobalt production from mines in Sudbury showed a 15% increase over production in 1987. The company closed its Falconbridge mill in anticipation of the closure of the Falconbridge Open Pit and East Mine in 1989. Work continued on the Craig Mine, which was projected to account for a substantial portion of nickel production from Sudbury in the future.

China

A large nickel-copper-cobalt deposit was discovered in the western Xinjiang

Uygur Autonomous Region. The deposit, located 8 kilometers from the Lanzhou-Urumqi railway, was believed to be the second largest nickel reserve in China and was estimated to contain 44,000 short tons of cobalt, 882,000 short tons of nickel, and 507,000 short tons of copper. Mining firms in the United Kingdom and Japan were reported to have shown an interest in exploiting the deposit.

Finland

Copper mining continued during 1988 at Outokumpu Oy's Keretti Mine. However, reports stated that cobalt concentrates were no longer being produced.[8] The cobalt content of cobalt products produced by Outokumpu in 1988 was 2.49 million pounds, up from 2.16 million pounds in 1987.

India

A cobalt recovery plant was being installed at the Debari zinc smelter in Udaipur, Rajasthan State. The Hindustan Zinc Ltd. plant was slated to recover approximately 30 short tons of cobalt per year from lead-zinc ore mined in Udaipur. Output from the plant, which was projected to be operating in 1990, would displace an equivalent quantity of imported cobalt.

The Federal Republic of Germany reportedly made an offer of technical and financial assistance to recover nickel and cobalt from lateritic overburden in some of the chromite mines in Sukinda, Orissa State. Recovery of cobalt and nickel was studied by India's Regional Research Laboratory in Bhubaneswar. It was not known at yearend whether India intended to pursue the project.

Reports stated that Sandvik Asia Ltd. of Poona, India, built a chemical pilot plant to recover cobalt from copper, nickel, and zinc scrap. The plant's capacity was listed as 11 short tons per year cobalt. Cobalt powder production began in 1987.

A review of India's position in regard to marine minerals was published during the year. As a result of efforts in the areas of exploration and research and development, India received exclusive rights from Prepcom in 1987 to explore and develop a 58,000-square-mile seafloor mine site in the central Indian Ocean. Deep-sea exploration for polymetallic nodules was described.[9]

Indonesia

Inco announced plans to increase the production capacity of its P.T. International Nickel Indonesia (P.T. Inco) facility. The 30% increase in capacity was expected to be completed in 1990.

Matte production at P.T. Inco reached record levels despite problems during the year. These included earthquake damage to the canal that delivers water to the hydroelectric plant, reduced rainfall resulting in shortages of hydroelectric power, and failure of a transformer late in the year.

Japan

Sumitomo Metal Mining Co. Ltd. remained the sole Japanese producer of refined cobalt; Nippon Mining Co. Ltd. ceased production in 1986. In July, Sumitomo bought a 20% equity interest in P.T. Inco from Inco of Canada. As part of the agreement, Sumitomo was to purchase approximately 20% of the annual output after an expansion of the Indonesian facility. The nickel matte from P.T. Inco was to supplement feed imported from Australia's WMC. In the past, the Nonoc Mine in the Philippines had been a major source of feedstock for Sumitomo.

Morocco

Cie. de Tifnout Tiranimine resumed cobalt mining in the Bou Azzer district in the Anti-Atlas Mountains of central Morocco at the end of 1987. Under a 5-year contract, 2,200 short tons per year of cobalt concentrate were to be sent to China beginning in 1988. Cobalt ore in this district is mostly in the form of cobalt-iron-nickel arsenides associated with altered igneous rocks in an ophiolite complex. Before mining ceased in 1982, Morocco was the only country where cobalt was mined as a primary product.

Norway

Falconbridge Nikkelverk produced at record levels in 1988. Cobalt production was 16% greater than production in 1987. Feedstock for the refinery was in the form of matte, mostly from Sudbury in Canada (60%) and Botswana (30%).

Philippines

The Philippine Government listed the Nonoc Mining and Industrial Corp. as one of the state-owned mining companies it wished to privatize by yearend. Late in the year, the Philippine Government's Asset Privatization Trust made plans to sell the Nonoc nickel production facility at auction. The facility, in Surigao del Norte, Nonoc Island, was closed in 1986 after financial and labor difficulties. The former owners, Marinduque Mining & Industrial Corp., reported that past cobalt production from the mine reached a high of 1,500 short tons cobalt content in mixed sulfides in 1979.

Uganda

A preliminary agreement was signed under which North Korea would supply technical assistance to the Government of Uganda for the rehabilitation of the Kilembe copper mines.[10] The mines, located in southwest Uganda, ceased operation in 1979 and were on a care-and-maintenance basis from 1980 through 1988. Plans for the rehabilitation included repairs to the concentrator, construction of a new smelter, a cobalt plant, a sulfuric acid plant, and a new refinery. No projected startup date was announced.

Zaire

Gécamines was the world's largest producer and exporter of cobalt. Cobalt sales in 1988 increased 47% to 17,314 short tons valued at $223 mil-

TABLE 11

COBALT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand pounds)

Country	Mine output, metal content[2]					Metal[3]				
	1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987[p]	1988[e]
Albania[e 4]	1,300	1,300	1,300	1,300	1,300	—	—	—	—	—
Australia[5]	2,064	[r]2,500	[e]2,680	[r e]2,640	2,420	—	—	—	—	—
Botswana[6]	570	489	357	401	[7]642	—	—	—	—	—
Brazil[e]	220	220	330	330	330	—	—	—	—	—
Canada[8]	5,125	4,556	5,481	5,490	[7]6,094	[r]4,879	4,460	4,387	[e]4,850	4,850
Cuba[e 9]	3,079	3,280	3,300	3,500	4,400	—	—	—	—	—
Finland	1,896	[r]2,407	1,382	419	400	3,203	[r]4,916	2,972	1,096	[7]485
France	—	—	—	—	—	255	271	[e]220	[e]240	110
Japan	—	—	—	—	—	1,995	2,813	2,949	273	[7]240
Morocco	—	—	—	—	[7]557	—	—	—	—	—
New Caledonia[e 10]	1,100	1,490	1,540	1,650	1,760	—	—	—	—	—
Norway	—	—	—	—	—	2,625	3,608	3,483	3,527	3,530
Philippines	141	2,008	203	—	—	—	—	—	—	—
South Africa, Republic of[e]	1,500	1,500	1,500	1,600	1,600	1,100	1,100	1,100	1,150	1,150
U.S.S.R.[e]	5,700	6,000	6,200	6,200	6,300	10,400	10,600	[r]11,700	[r]11,700	11,700
Zaire	57,194	64,375	73,575	[e]64,000	56,000	20,006	23,539	31,967	26,235	[7]22,353
Zambia[11]	10,185	[e]12,800	[e]12,700	[r e]13,100	14,700	7,654	9,609	9,576	9,874	11,000
Zimbabwe[12]	[r e]170	[e]220	[r e]168	[r e]240	278	171	202	168	243	[7]278
Total	**[r]90,244**	**[r]103,145**	**110,716**	**100,870**	**96,781**	**[r]52,288**	**[r]61,118**	**68,522**	**59,188**	**55,696**

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 21, 1989. In 1986, the units in this table were changed from short tons to thousand pounds. Some differences between these and previously published data might be encountered owing to differences in conversion methods.

[2] Figures represent recoverable cobalt content. In addition to the countries listed, Bulgaria, the German Democratic Republic, Greece, Indonesia, Poland, Spain, and Uganda are known to produce ores that contain cobalt. Information is inadequate for reliable estimates of output levels. Other copper and/or nickel producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

[3] Figures represent elemental cobalt recovered unless otherwise specified. In addition to the countries listed, Czechoslovakia presumably recovers cobalt from Cuban nickel-cobalt oxide and oxide sinter; Belgium has imported small quantities of partly processed materials containing cobalt, but available information is inadequate to make reliable estimates of cobalt recovery from these materials.

[4] Calculated from reported and estimated weight of nickeliferous ore; the amount of cobalt recovered, if any, is conjectural.

[5] Australia does not refine cobalt. Figures represent quantities of cobalt contained in intermediate metallurgical products (cobalt oxide and nickel-cobalt sulfide). Actual quantities of cobalt mined were as follows, in thousand pounds: 1984—4,685; 1985—6,693; 1986—6,424; 1987—5,986; and 1988—6,120 (estimated).

[6] Reported cobalt content of pelletized nickel-copper matte.

[7] Reported figure.

[8] Actual output is not reported. Data for mine output are total cobalt content of all products derived from ores of Canadian origin, including cobalt oxide shipped to the United Kingdom for further processing, and nickel-copper-cobalt matte shipped to Norway for further processing. Data presented for metal output represent the output within Canada of metallic cobalt from ores of both Canadian and non-Canadian origin.

[9] Estimated from reported nickel-cobalt content of granular and powder oxide, oxide sinter, and sulfide production.

[10] Series reflects recovery from ores and intermediate metallurgical products exported from New Caledonia to France and Japan. The estimated cobalt content of total ores mined is as follows, in thousand pounds: 1984—9,025; 1985—11,433; 1986—11,000; 1987—12,787; and 1988—13,200.

[11] Mine output is cobalt content in concentrate estimated from reported metal production assuming 75% recovery from concentrate to metal. Cobalt content of mined ore is estimated to be twice the reported metal production.

[12] Data under "Metal" may include cobalt content of salts or compounds, and cobalt recovered from nickel-copper matte imported from Botswana. Mine output figures are estimates calculated from metal production.

lion. Sales in 1987 were 11,795 short tons valued at $147 million. However, cobalt production decreased in 1988 partly because copper recovery was emphasized over cobalt recovery at the metallurgical plants. This shift was the result of more favorable prices for copper and a desire to draw down the level of the company's cobalt stocks.

Zambia

ZCCM and its sales agent, Metal Marketing of Zambia (Memaco), announced the opening of a U.S. sales office for cobalt in April. Sale of cobalt from the Memaco Trading Inc. office outside Cleveland in Westlake, OH, was expected to give ZCCM several advantages over selling cobalt to the United States from its London office. ZCCM planned to hold warehouse stocks in the United States and hoped to reach more of the smaller cobalt consumers.

TECHNOLOGY

Cobalt producers in Zaire and Zambia worked together to develop standard cobalt quality specifications because there were no internationally recognized specifications for primary cobalt metal. Specifications proposed by ZCCM and Gécamines of Zaire were based on minimum levels of cobalt, or cobalt plus nickel, maximum levels of nickel, and maximum allowable levels of 22 other impurities. The producers emphasized the importance of defining specifications that take into account the needs of consumers. A major problem area related to defining specifications was the heterogeneity of the broken cathode. The need for standardized sampling by both producers and consumers was emphasized.[11]

The Metallurgical Society of of the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) held a symposium on the extractive metallurgy of nickel and cobalt. Several comprehensive overviews of the cobalt industry were presented. These covered the supply of cobalt from various ore types, reserves, production methods, capacity, and composition of cobalt products. Flow sheets of processing methods were provided for most producers. Detailed discussions on cobalt processing were also presented. Representatives from MHO discussed two solvent-extraction processes to remove iron and zinc from concentrated cobalt chloride solutions. Gécamines representatives discussed the hydrometallurgical processes at Gécamines' Shituru and Luilu plants, with emphasis on impurity removal. They also discussed the conditions necessary to electrodeposit malleable cobalt. An X-ray diffraction study of the malleable cobalt, which could be used in the production of cobalt foils, was presented. A ZCCM spokesperson discussed the vacuum-induction refining plant at ZCCM's Chambishi Mine for the production of high-purity cobalt metal. Other presentations covered the production of electrolytic cobalt "rounds" at Inco's Port Colborne plant, and a review of cobalt health effects.[12]

The Bureau of Mines published a summary of cobalt processing technologies for major domestic resources. Included in the review were the Blackbird deposit in Idaho, the Madison Mine in Missouri, the Missouri lead belt deposits, the Duluth Gabbro in Minnesota, spent copper leach solutions, laterite deposits, and ocean floor manganese nodules and crusts.[13]

A process for the recovery of cobalt from heap or dump leaching of low-grade copper ores was improved by the Bureau of Mines. In the process, cobalt was recovered from spent copper leach solutions by ion exchange, followed by solvent extraction, then electrowinning. The net operating cost was reduced to $5.10 per pound of electrolytic cobalt by using improved methods of elution (removal of ions from ion-exchange resins) and impurity removal.[14]

The Bureau of Mines investigated the commercial recovery of superalloy scrap at the request of the U.S. Air Force. The study indicated that approximately 55 million pounds of superalloy scrap with an estimated 5% cobalt content was processed in 1986. Of the 40 million pounds that went to domestic buyers, about 70% was recycled to the same superalloy, 20% was downgraded, and the remainder was sold to refineries.[15]

Neodymium-iron-boron magnets represent an important class of permanent magnets. However, they have some disadvantages when compared with cobalt-rare earth based magnets. These include a lower Curie temperature (temperature at which there is a change in magnetic properties) and a greater tendency for corrosion. Cobalt was found to be the most effective elemental addition for raising the Curie temperature of neodymium-iron-boron magnets, but it caused some adverse side effects on other magnetic properties. A balance of cobalt and dysprosium provided the best properties at elevated temperatures.[16]

A market research study on cobalt was published by the Cobalt Development Institute, Slough, United Kingdom. The study was based on data surveyed from cobalt producers, processors, consumers, and traders, with additional information obtained from individuals, companies, organizations, the Institute archives. The study covered cobalt production, sales, consumption, properties, uses, with emphasis on data for 1987. A major finding of the study was that there was a balance between supply and demand during 1987.[17]

The Cobalt Development Institute also published articles on selected cobalt uses, data on cobalt production by Institute members, and abstracts on cobalt technology in quarterly issues of Cobalt News.

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COLUMBIUM AND TANTALUM

By Larry D. Cunningham[1]

As there was no domestic mine production of either columbium or tantalum minerals, the United States continued to be dependent on imports. Imports for consumption of columbium mineral concentrates were lower than those of 1987, whereas imports for tantalum mineral concentrates more than doubled to the highest level since 1984. Demand for tantalum feed material rose owing to the drawdown of inventory that had been built up in the early 1980's.

Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium was at the highest level since 1985. Reported shipments of tantalum products and the sales of tantalum capacitors were at their highest levels since 1984.

Columbium price quotations remained stable, whereas the tantalum mineral concentrate price nearly doubled to the highest level since the third quarter of 1981. Net U.S. trade for both columbium and tantalum remained in deficit.

In February, the President issued an Executive Order designating the Secretary of the U.S. Department of Defense as the manager of the National Defense Stockpile (NDS). In November, the U.S. Department of Energy (DOE) announced that Texas had been selected as the location to build the world's largest Superconducting Super Collider (SSC).

Tantalum supply got a boost in September with the startup of tantalite production by the Tantalum Mining Corp. of Canada Ltd. (TANCO). The mine operation had been suspended since yearend 1982.

DOMESTIC DATA COVERAGE

Domestic production data for ferrocolumbium are developed by the Bureau of Mines from the annual voluntary domestic survey for ferroalloys. Of the four operations to which a survey request was sent, three responded. Thus, ferrocolumbium production data for 1988 were incomplete at the time this chapter was prepared.

LEGISLATION AND GOVERNMENT PROGRAMS

Under the offset concept for the NDS, 57% of the goal for columbium concentrates and 37% of the goal for tantalum materials were met (table 3). On February 25, the President issued Executive Order 12626 designating the Secretary of Defense as NDS Manager. On July 3, the Defense Logistics Agency officially assumed all stockpile management duties, taking over roles previously divided between the Federal Emergency Management Agency and the General Services Administration. Late in the year, the Department of Defense submitted to Congress a $30 million proposed plan which included the upgrade columbium and tantalum from the NDS in fiscal year 1989. The plan called for conversion of an estimated 45,000 pounds of columbium metal powder to high-purity columbium metal ingot and 45,000 pounds of tantalum metal powder to high-purity tantalum metal ingot. The materials would be for emergency use in superalloys for jet engine production. The Congress had 30 legislative days after receiving the proposal to object to the plan.

In November, the DOE announced that it had selected Texas as the location to build the world's largest SSC, particle accelerator, if funding is approved by Congress. The Texas site, about 30 miles south of Dallas, won over sites in Arizona, Colorado, Illinois, Michigan, North Carolina, and Tennessee. If built, the $4 billion-plus

TABLE 1

SALIENT COLUMBIUM STATISTICS

(Thousand pounds of columbium content unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Mine production of columbium-tantalum concentrates	—	—	—	—	—
Releases from Government excesses	—	—	—	—	—
Consumption of raw materials[e]	2,600	2,000	W	W	NA
Production of ferrocolumbium	W	W	W	W	NA
Consumption of primary products: Ferrocolumbium and nickel columbium[e]	5,399	5,968	4,995	5,179	5,876
Exports: Columbium metal, compounds, alloys (gross weight)[e]	100	120	120	130	120
Imports for consumption:					
Mineral concentrates[e]	1,790	1,290	1,320	2,010	1,750
Columbium metal and columbium-bearing alloys[e]	10	1	5	42	32
Ferrocolumbium[e]	4,343	4,699	3,432	4,016	4,238
Tin slags[e 1]	W	W	W	W	NA
World: Production of columbium-tantalum concentrates[e]	[r]30,674	[r]32,708	[r]32,149	20,535	35,818

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1] Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

TABLE 2

SALIENT TANTALUM STATISTICS

(Thousand pounds of tantalum content unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Mine production of columbium-tantalum concentrates	—	—	—	—	—
Releases from Government excesses	—	—	—	—	—
Consumption of raw materials[e]	1,300	1,100	W	W	NA
Exports:					
Tantalum ores and concentrates (gross weight)[1]	156	122	71	103	214
Tantalum metal, compounds, alloys (gross weight)	352	369	392	413	487
Tantalum and tantalum alloy powder (gross weight)	151	143	160	193	278
Imports for consumption:					
Mineral concentrates[e]	680	230	280	220	400
Tantalum metal and tantalum-bearing alloys[2]	47	32	46	60	128
Tin slags[e 3]	W	W	W	W	NA
World: Production of columbium-tantalum concentrates[e]	[r]694	[r]695	[r]473	[r]544	637

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
W Withheld to avoid disclosing company proprietary data.
[1]Includes reexports.
[2]Exclusive of waste and scrap.
[3]Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

TABLE 3

COLUMBIUM AND TANTALUM MATERIALS IN GOVERNMENT INVENTORIES AS OF DECEMBER 31, 1988

(Thousand pounds of columbium or tantalum content)

Material	Stockpile goals	National Defense Stockpile Inventory		
		Stockpile-grade	Nonstockpile-grade	Total
Columbium:				
Concentrates	5,600	1,150	869	[1]2,019
Carbide powder	100	21	—	21
Ferrocolumbium	—	598	333	[1]931
Metal	—	45	—	[1]45
Total	**([2])**	**1,814**	**1,202**	**3,016**
Tantalum:				
Minerals	8,400	1,686	1,152	[3]2,838
Carbide powder	—	29	—	[3]29
Metal	—	201	([4])	[3]201
Total	**([2])**	**1,916**	**1,152**	**3,068**

[1]All surplus ferrocolumbium and columbium metal were used to offset columbium concentrates shortfall. Total offset was 1,148,000 pounds.
[2]Overall goals, on a recoverable basis, total 4,850,000 pounds for the columbium metal group and 7,160,000 pounds for the tantalum metal group.
[3]All surplus tantalum carbide powder and tantalum metal were used to offset the tantalum minerals shortfall. Total offset was 271,000 pounds.
[4]100 pounds.

Source: U.S. Department of Defense, Defense Logistics Agency.

facility would have a permanent work force of about 3,500 people, including a visiting contingent of scientists, with an expected annual operating budget of about $270 million. Congress provided $100 million for continued research and development and design studies. Superconducting magnets reportedly using about 1 million pounds of a 50% to 50% columbium-titanium alloy will be needed for the project.

The National Superconductivity and Competitiveness Act of 1988 (Public Law 100-697) promotes an agenda for Government support of research and development into high-temperature superconducting materials. The new law required the President's Office of Science and Technology Policy (OSTP) to establish a 5-year national action plan on superconductivity, with the cooperation of the National Critical Materials Council. The OSTP had 9 months in which to develop the action plan. In addition, the legislation mandated that the National Institute of Standards and Technology, and the Departments of Defense and Energy would play an active role in supporting the United States research and development efforts into superconducting materials.

The Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418) required, among other things, that the United States adopt the tariff schedules nomenclature of the internationally established Harmonized System, effective January 1, 1989. In January 1988, a number of U.S. trading partners implemented the Harmonized System. The new tariff schedules provided a universally accepted tariff nomenclature for foreign trade statistics.

On March 31, the President issued Proclamation 5787 "Amending the Generalized System of Preferences (GSP)." The Proclamation included the suspension of designated specified articles provided for in the Tariff Schedules of the United States as eligible for preferential tariff treatment under the GSP when imported from designated beneficiary developing countries. As of July 1, columbium oxide imported from Brazil no longer received duty-free preferential tariff treatment under the GSP.

DOMESTIC PRODUCTION

Although there was no domestic mineral production of either columbium or tantalum in 1988, there were three processors of imported columbium- and tantalum-bearing source materials that were integrated from material processing through to columbium and tantalum end products. They were Cabot Corp. and Fansteel Metals for columbium and tantalum processing, and Shieldalloy Metallurgical Corp. dedicated solely to columbium processing. NRC Inc. continued to be a major producer of tantalum products. Reading Alloys Inc. and Teledyne Wah Chang Albany were major producers of high-purity columbium products, and Kennametal Inc. was a producer of columbium and tantalum carbides.

CONSUMPTION, USES, AND STOCKS

Overall reported consumption of columbium as ferrocolumbium and nickel columbium rose by 13% to the highest total since 1985. Consumption of columbium by the steelmaking industry increased by 17%, in line with a 13% increase in raw steel production and a 5% increase in the percent of columbium usage per ton of steel produced. Columbium consumption in carbon steel increased by more than 20%, influenced by a 12% production increase in that steel end-use category. Columbium demand in high-strength low-alloy steels advanced by more than 20%, boosted by a strong demand from the automotive industry.

Demand for columbium in superalloys was up by 4%, ending a 3-year decline for columbium consumption in this end-use category. That portion used in the form of nickel columbium rose by more than 20% to about 370,000 pounds. Columbium usage in superalloys reportedly was being influenced by a boom in the commercial aerospace market.

Tantalum consumption continued to improve, as reflected in the 8% increase in overall shipments reported by the Tantalum Producers Association. This was the highest level of tantalum shipments since 1984. The powder and anodes and the mill products segments continued to show significant improvements, with both segments up by more than 20%. However, contrary to tantalum's growing usage in superalloys during the 1980's and the sustained good health of the aerospace market, shipments of tantalum for the alloy additive segment were down by more than 50%.

Factory sales of tantalum capacitors were up about 15% as reported by the Electronic Industries Association. With emphasis being placed on higher capacitance powders and miniaturization, the production of tantalum chip capacitors for surface-mount applications reportedly accelerated.

TABLE 4

MAJOR DOMESTIC COLUMBIUM AND TANTALUM PROCESSING AND PRODUCING COMPANIES IN 1988

Company	Plant location	Products[1] Metal[2] Cb	Products[1] Metal[2] Ta	Products[1] Carbide Cb	Products[1] Carbide Ta	Products[1] Oxide and/or salts Cb	Products[1] Oxide and/or salts Ta	FeCb and/or NiCb
Cabot Corp.	Boyertown, PA	X	X	—	—	X	X	—
Do.	Revere, PA	—	—	—	—	—	—	X
Fansteel Metals	Muskogee, OK	X	X	—	—	X	X	—
Do.	North Chicago, IL	—	X	—	—	—	—	—
Kennametal Inc.	Latrobe, PA	—	—	X	X	—	—	—
NRC Inc.[3]	Newton, MA	X	X	—	—	—	—	—
Reading Alloys Inc.	Robesonia, PA	—	—	—	—	—	—	X
Shieldalloy Metallurgical Corp.	Newfield, NJ	—	—	—	—	—	—	X
Teledyne Inc.: Teledyne Wah Chang Albany Div.	Albany, OR	X	—	—	—	X	—	X

X Indicates processor and/or producer.
[1] Cb, columbium; Ta, tantalum; FeCb, ferrocolumbium; NiCb, nickel columbium.
[2] Includes miscellaneous alloys.
[3] Jointly owned by Bayer U.S.A. and Hermann C. Starck Berlin A.G.

TABLE 5

REPORTED SHIPMENTS OF COLUMBIUM AND TANTALUM MATERIALS

(Pounds of metal content)

Material	1987	1988
Columbium products:		
Compounds including alloys	914,900	995,880
Metal including worked products	399,800	418,700
Other	600	(1)
Total	**1,315,300**	**1,414,580**
Tantalum products:		
Oxides and salts	20,120	16,640
Alloy additive	174,200	76,910
Carbide	69,500	2 46,250
Powder and anodes	556,300	711,990
Ingot (unworked consolidated metal)	100	2,300
Mill products	282,500	345,100
Scrap	13,400	5,300
Other	—	—
Total	**1,116,120**	**1,204,490**

[1] Included with "Compounds including alloys."
[2] Partial year data.

Source: Tantalum Producers Association.

PRICES

Published prices remained stable for pyrochlore concentrates and for columbium products based on them. The price for pyrochlore concentrates produced in Canada continued to be quoted at $2.60 per pound of contained columbium pentoxide (Cb_2O_5), f.o.b. Canada,.for concentrates with a nominal content of 57% to 62% Cb_2O_5. A published list price for Brazilian-produced pyrochlore concentrates was not available. In April, the quoted spot price of regular-grade ferrocolumbium containing 63% to 68% columbium rose from $5.66 to $6.00 per pound of contained columbium, f.o.b. shipping port. Rising production costs, especially the price for the subsidiary material aluminum, was cited by industry sources as the main reason for the price increase.

The quoted price for high-purity ferrocolumbium containing 62% to 68% columbium widened in June from a range of $17.00 to $17.50 to a range of $16.00 to $17.50 per pound of contained columbium, f.o.b. shipping point. The quoted spot price for columbite concentrates was unchanged, as in 1987, at $2.00 to $2.50 per pound of contained Cb_2O_5 and tantalum pentoxide (Ta_2O_5), c.i.f. U.S. ports. At yearend, the price for nickel columbium was being quoted at $17.50 to $19.50 per pound of contained columbium, and the price for columbium oxide was being quoted at $7.14 per pound of oxide.

The price increase for tantalum feed materials was a major concern in the tantalum industry, because the price for tantalite nearly doubled during 1988. The published spot-market price for tantalite, on the basis of 60% combined Cb_2O_5 and Ta_2O_5, c.i.f. U.S. ports, started the year at $24 to $28 per pound, increased to $37 to $40 at midyear, and continued to advance in the fourth quarter to finish the year at $49 to $51, the highest level since the third quarter of 1981. Industry sources attributed the price escalation to increased demand for tantalum feed materials, following the drawdown of tantalum material stockpiles built up

TABLE 6

CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF FERROCOLUMBIUM AND NICKEL COLUMBIUM IN THE UNITED STATES

(Pounds of contained columbium)[1]

	1987	1988
END USE		
Steel:		
Carbon	1,613,710	2,000,855
Stainless and heat-resisting	919,807	909,173
Full alloy	(2)	(2)
High-strength low-alloy	1,653,853	1,995,702
Electric	—	—
Tool	(3)	(3)
Unspecified	12,803	27,376
Total	**4,200,173**	**4,933,106**
Superalloys	883,149	917,716
Alloys (excluding alloy steels and superalloys)	90,974	(4)
Miscellaneous and unspecified	4,500	24,778
Total consumption	**5,178,796**	**5,875,600**
STOCKS		
Dec. 31:		
Consumer	W	NA
Producer[5]	W	NA
Total stocks[e]	**710,000**	**NA**

[e] Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Total stocks."
[1] Includes columbium and tantalum in ferrotantalum-columbium, if any.
[2] Small; included with "Steel: High-strength, low-alloy."
[3] Included with "Steel: Unspecified."
[4] Included with "Miscellaneous and unspecified."
[5] Ferrocolumbium only.

during the early 1980's. A published contract price for tantalite from the Canadian producer, TANCO, remained suspended. For the first time since 1981, a published contract price was in effect for tantalite produced by Greenbushes Ltd. of Australia. The Greenbushes tantalite price, on the basis of 40% contained Ta_2O_5, was revived in February and listed at $32 per pound, rose to $40 in May, and ended the year at $47.50. Depending on the size of the order-contract and material specification, industry sources indicated that tantalum mill products and powders continued to sell in the range of $100 to $160 per pound. A published price for columbium and tantalum carbide was not available.

FOREIGN TRADE

Net trade for columbium and tantalum remained in deficit and was at the highest level since 1985. Overall trade volume and value for exports were up by about 40%. For imports, overall trade volume was relatively unchanged with total value up by more than 30%. Exports and reexports of tantalum ore and concentrates increased substantially to 214,000 pounds valued at $536,000. The Federal Republic of Germany was the principal recipient with more than 90% of total shipments.

The value of imports of raw materials and intermediates, such as ferrocolumbium and columbium oxide, continued to exceed the value of reported columbium and tantalum exports by more than 40%. Imports for consumption from Brazil included about 6.5 million pounds of ferrocolumbium with a value of $22.4 million compared with 6.2 million pounds valued at $20.4 million in 1987. Imports for consumption of columbium oxide from Brazil decreased to 840,000 pounds valued at $4.8 million compared with 1.6 million pounds valued at $9.5 million in 1987. Overall imports for consumption of columbium oxide were estimated at 1.2 million pounds valued at $6.0 million. The Federal Republic of Germany accounted for about 290,000 pounds of the total valued at $1.1 million. Estimated data for ferrocolumbium and columbium oxide were based on entries in nonspecific classes.

Imports for consumption of columbium mineral concentrates declined by 19% from those of 1987. Average unit value for overall imports rose by 40% owing to the higher unit value of concentrates from Canada, which was 98% of the total quantity. Imports were estimated to contain 1.51 million pounds of columbium and 15,000 pounds of tantalum at an average grade of approximately 58% Cb_2O_5 and less than 1% Ta_2O_5.

Imports for consumption of tantalum mineral concentrates more than doubled to the highest level since 1984, with the average unit value for overall imports increasing by more than 40%. Demand for tantalum feed materials was on the rise owing to the decline in stocks built up in the early 1980's. Imports from the Federal Republic of Germany, Hong Kong, the Netherlands, and the United Kingdom, all nonproducing countries, together provided about 50% of total quantity and total value. Imports were estimated to contain 385,000 pounds of tantalum and 240,000 pounds of columbium at an average grade of approximately 33% Ta_2O_5 and 17% Cb_2O_5.

Imports for consumption of columbium-tantalum synthetic concentrates declined significantly: 263,000 pounds valued at $1.5 million compared with 457,000 pounds valued at $2.6 million in 1987. These figures are not included in the salient statistics data.

WORLD CAPACITY

The data in table 10 are rated capacity for mines and mills as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Mine capacity for columbium and tantalum is based on published reports, maximum production statistics, and estimates by the Bureau of Mines.

WORLD REVIEW

Australia

For its fiscal year, Greenbushes reported that the company's mine operation changed from the mining of high-grade alluvial tin ore bodies to high-grade pegmatite ore bodies, owing to the improvement of tantalite concentrate prices in the international marketplace. Ore treated increased almost 30% to 1.8 million tons, with tantalum oxide produced in tantalite concentrates increasing to 204,800 pounds. Greenbushes' chemical plant produced 48,300 pounds of Ta_2O_5 and 16,400 pounds of Cb_2O_5. Tantalum oxide contained in tantalum glass (slag) production decreased almost 15% to 48,400 pounds.

Greenbushes reportedly shipped over 200,000 pounds of Ta_2O_5 contained in tantalum concentrates and tantalum glass and some 60,000 pounds of Ta_2O_5 contained in upgraded forms of tantalum oxide, carbide, and metal. Greenbushes planned to operate its tailings retreatment plant on a one-shift basis, with full production dependent on the tantalite market. Operating at full production, the plant had an annual throughput capacity of 1.65 million tons of tailings producing 110 tons of

TABLE 7

U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS

(Thousand pounds, gross weight, and thousand dollars)

Class	1987 Quantity	1987 Value	1988 Quantity	1988 Value	Principal destinations and sources, 1988
EXPORTS[1]					
Tantalum:					
Powder	193	16,129	278	23,758	Japan 87, $6,957; France 68, $5,680; West Germany 60, $4,687; United Kingdom 27, $2,588; Spain 23, $2,488.
Unwrought and waste and scrap	322	5,012	328	5,260	West Germany 183, $2,629; Canada 16, $751; Belgium-Luxembourg 21, $608; Japan 10, $367.
Wrought	91	12,842	159	20,076	Japan 65, $8,641; United Kingdom 31, $3,693; West Germany 19, $2,786; France 20, $2,229.
Total	**XX**	**33,983**	**XX**	**49,094**	**Japan $16,000; West Germany $10,100; France $7,800; United Kingdom $6,400.[2]**
IMPORTS FOR CONSUMPTION					
Columbium:					
Ferrocolumbium[e]	6,179	20,434	6,520	22,424	All from Brazil.
Unwrought metal and waste and scrap	28	399	11	154	West Germany 4, $69; Brazil 1, $45; United Kingdom 5, $32; Japan 1, $7.
Unwrought alloys	19	186	30	199	West Germany 30, $194; Taiwan ([3]), $5.
Wrought	2	102	2	108	Japan ([3]), $44; West Germany 1, $26; United Kingdom ([3]), $24; Canada ([3]), $14.
Tantalum:					
Waste and scrap	176	4,891	309	10,341	Japan 175, $5,155; West Germany 48, $2,487; Taiwan 26, $1,202; United Kingdom 19, $540.
Unwrought metal	57	3,236	121	7,028	West Germany 53, $3,943; Australia 30, $1,217; Hong Kong 14, $847; Belgium-Luxembourg 8, $392.
Unwrought alloys	([3])	29	3	168	Canada 2, $155; West Germany ([3]), $11; Japan ([3]), $2.
Wrought	2	214	5	485	Japan 2, $216; Canada 2, $181; West Germany ([3]), $75; Austria ([3]), $13.
Total	**XX**	**29,491**	**XX**	**40,907**	**Brazil $22,400; West Germany $6,800; Japan $5,400; Australia $1,200; Taiwan $1,200.[2]**

[e] Estimated. XX Not applicable.

[1] For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in basket category.

[2] Rounded.

[3] Less than 1/2 unit.

Sources: Bureau of the Census and Bureau of Mines.

tin metal and over 130,000 pounds of Ta_2O_5 contained in combined tantalum concentrates and tantalum glass. The company's proposed tantalum oxide production schedule, which included production from soft and hard rock mining and tailings retreatment, in fiscal years 1989, 1990, 1991, and 1992 is, in thousand pounds, 300, 440, 640, and 640, respectively.

West Coast Holdings Ltd. reportedly built a 2.2-ton-per-day ore pilot processing plant in Stevenage, United Kingdom, at the British Government's Warren Spring Laboratory, where work will be carried out to confirm laboratory test process parameters. Commissioned in April 1988, the plant was to treat ore from the Brockman multimineral project in the Kimberly region of Western Australia. The Brockman deposit was believed to contain recoverable values of columbium, tantalum, and rare-earth minerals.

Austria

Treibacher Chemische Werke AG formed a joint venture with Greenbushes of Australia for the production and marketing of columbium and tantalum carbide products at Treibacher's Seebach plant. The new venture, which was to market its products under the brand name of Treibacher-Greenbushes, reportedly was to produce up to 55 tons of carbide products for sale worldwide. Treibacher was to market the products

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM MINERAL CONCENTRATES, BY COUNTRY

(Thousand pounds and thousand dollars)

Country	1987 Gross weight	1987 Value	1988 Gross weight	1988 Value
Brazil	4	16	5	14
Canada	4,488	6,480	3,665	7,200
Hong Kong [1]	—	—	53	347
Nigeria	89	116	—	—
Total	**4,581**	**6,612**	**3,723**	**7,561**

[1] Presumably country of transshipment rather than original source.

Sources: Bureau of the Census and Bureau of Mines.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF TANTALUM MINERAL CONCENTRATES, BY COUNTRY

(Thousand pounds and thousand dollars)

Country	1987 Gross weight	1987 Value	1988 Gross weight	1988 Value
Australia	45	293	34	439
Brazil	54	337	169	1,829
Canada	—	—	36	455
China	—	—	133	1,483
Germany, Federal Republic of [1]	378	2,250	86	1,190
Hong Kong [1]	—	—	304	3,603
Netherlands [1]	113	1,099	140	936
South Africa, Republic of	27	254	—	—
Thailand	—	—	255	3,425
United Kingdom [1]	—	—	199	1,113
Zaire	81	953	54	555
Total [2]	**697**	**5,186**	**1,410**	**15,027**

[1] Presumably country of transshipment rather than original source.
[2] Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and Bureau of Mines.

for the joint venture. The venture combined Greenbushes columbium and tantalum source material production activity with Treibacher's know-how in the manufacture of columbium and tantalum carbide.

Brazil

Cia. Brasileira de Metalúrgia e Mineração's (CBMM), was the world's largest columbium producer. Production output reportedly included about 31,100 tons of pyrochlore concentrates, containing 18,700 tons of Cb_2O_5, 17,900 tons of steelmaking-grade ferrocolumbium, 141 tons of high-purity ferrocolumbium, 1,240 tons of columbium oxide, 33 tons of nickel columbium, and 12 tons of columbium metal.

In late August, the Brazilian Constitutional Assembly confirmed an earlier decision to include in its new constitution a clause restricting mining and mineral development to Brazilian-owned companies. The new resolution restricted the participation of foreign capital in mineral exploration, development, and mining projects to 49%. Those companies that were already in operation and were vertically integrated into mineral-processing would retain their control over such projects. However, no new foreign-controlled exploration or development projects would be authorized.

Canada

As reported by Teck Corp. for the 12 months ending December 31, production of Cb_2O_5 at the Niobec Mine at St. Honoré, Quebec, was 7.4 million pounds. Ore milled was 868,000 tons, as the mill operated on the average of 2,379 tons of ore per day. Average recovery was 61% with Cb_2O_5 grade of concentrate at 71%. Yearend ore reserves were about 12 million tons assaying 0.65% Cb_2O_5. Owing to increased demand from the specialty steel market, mine inventories reportedly decreased from 1.6 million pounds of Cb_2O_5 contained in concentrate to 182,000 pounds of Cb_2O_5 contained in concentrate.

The Hudson Bay Mining and Smelting Co. Ltd. (HBMS) reported that tantalum mining had resumed at the Bernic Lake, Manitoba, tantalum operation of TANCO, ending about a 6-year shutdown. HBMS, which managed the TANCO operation, attributed the startup to improved tantalum markets. Production was planned to be about 200,000 pounds of contained tantalum annually, with most of the production slated for the United States. TANCO's owners, HBMS (37.5%), Cabot Corp. (37.5%), and the Province of Manitoba (25%), reportedly spent about $4 million to refurbish the mine and mill site.

TABLE 10

WORLD COLUMBIUM AND TANTALUM ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand pounds of columbium or tantalum content)

Country	Rated capacity [1 2] Columbium	Rated capacity [1 2] Tantalum
North America:		
United States	—	—
Canada	5,000	200
Total	**5,000**	**200**
South America: Brazil	40,000	300
Africa:		
Nigeria	400	100
Zaire	100	100
Other	200	200
Total	**700**	**400**
Asia:		
Malaysia	200	200
Thailand	600	800
Total	**800**	**1,000**
Oceania: Australia	200	300
World total (may be rounded) [3]	**47,000**	**2,200**

[1] Includes capacity at operating facilities as well as facilities on standby basis.
[2] Includes estimated byproduct recovery as tin slag.
[3] Excludes centrally planned economies.

Ethiopia

Ethiopian authorities announced the discovery of a tantalum deposit near Shakiso. The deposit was considered to be economic, with potential for development at a rate of over 200 tons of ore annually.

Japan

Production of ferrocolumbium totaled 715 tons compared with 787 tons produced in 1987. Columbium ore imported for ferrocolumbium production was 1,113 tons with Canada providing 80% of the total. Ferrocolumbium imports rose to 3,704 tons from the 1,961 tons imported in 1987. The bulk of the imports came from Brazil.

Rwanda

Rwanda reportedly was to create a state mining corporation to manage 20 mines that had been closed since 1985. The new company was to be called Regie d'Exploitation et de Development des Mines, and would be charged with the mining, processing, and marketing of ores. The mines, previously owned by Société Minière du Rwanda (SOMIRWA), principally produced tin, tungsten, and tantalum. SOMIRWA, owned 49% by the Rwandan Government and 51% by the Belgian Compagnie Geologique et Minière des Ingenieurs et Industriels Belges, went into receivership in late 1985 owing to a heavy debt burden, low prices, and currency difficulties. A schedule for startup of the mine operations had not been established.

Thailand

Columbite-tantalite production was down by more than 30%, and struverite production was up to 769 tons from 467 tons in 1987. Tantalum-bearing tin slags ranked behind tin metal and gypsum in value of exports of metals and minerals.

The Thailand Smelting and Refining Co. Ltd. (Thaisarco) tin smelter, with an annual capacity to produce about 700,000 pounds of tantalum contained in tin slags, reportedly operated significantly under capacity owing to an inadequate supply of tin concentrates. Thaisarco, for the first time in the company's history, toll-smelted foreign concentrates on a trial basis. However, Thailand failed to meet its tin metal export quota as set by the Association of Tin Producing Countries, and the Thai Mining Industry Council was concerned that the country's allocation would be reduced.

In June, a West German arbitration board ruled that Hermann C. Starck Berlin A.G, a subsidiary of Bayer AG of the Federal Republic of Germany, must fulfill its commitment to provide Thailand Tantalum Industry Corp. Ltd. (TTIC) with the extraction technology needed to rebuild TTIC's columbium and tantalum processing plant at the Mab Ta Pud Industrial Estate in Rayong Province east of Bangkok. Starck and TTIC were two major partners of the Phuket Island processing plant that was destroyed by fire in 1986. Despite the favorable ruling, construction of the $36 million plant with a capacity to produce about 300 tons each of columbium and tantalum oxides remained uncertain. The Thai Government was said to be committed to the project and reportedly had pledged a loan of around $18 million for its construction, anticipated to be completed by late 1990. Thaisarco-produced columbium- and tantalum-bearing tin slags would be the major feed material for the plant when and if it becomes operational.

TECHNOLOGY

An overview of the tantalum and columbium (niobium) industries was presented in the proceedings from the "International Symposium on Tantalum and Niobium."[2] The overview placed emphasis on the marketing aspects, production of raw materials, processing technology, and the applications for tantalum and columbium.

[1] Physical scientist, Branch of Ferrous Metals.

[2] Proceedings. International Symposium on Tantalum and Niobium, Orlando, FL, Nov. 7-9, 1988. Tantalum-Niobium International Study Center, Brussels, Belgium, 759 pp.

TABLE 11

COLUMBIUM AND TANTALUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1]

(Thousand pounds)

Country[2]	Gross weight[3]					Columbium content[e 4]					Tantalum content[e 4]				
	1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987	1988	1984	1985	1986	1987	1988
Australia: Columbite-tantalite	309	242	309	[e]351	498	64	50	64	60	70	109	85	109	115	164
Brazil:															
Columbite-tantalite	375	589	604	774	840	86	135	139	177	190	110	170	175	224	240
Pyrochlore	61,233	64,816	63,354	37,699	71,870	25,719	27,223	26,610	15,800	30,203	—	—	—	—	—
Canada:[e]															
Pyrochlore	9,700	10,900	11,500	9,490	11,730	4,380	4,900	5,160	4,270	5,200	—	—	—	—	—
Tantalite	—	—	—	—	200	—	—	—	—	8	—	—	—	—	60
Malaysia: Columbite-tantalite	[r]51	[r]168	474	503	—	5	25	71	75	—	4	12	33	35	—
Mozambique:															
Microlite	22	14	[e]13	([5])	—	NA	NA	NA	—	—	8	7	7	—	—
Tantalite	15	9	[e]9	([5])	—	NA	NA	NA	—	—	5	3	3	—	—
Namibia: Tantalite	[r]11	[r]7	18	30	33	4	3	3	3	3	2	1	3	5	5
Nigeria:															
Columbite	278	223	29	106	110	120	90	12	45	46	16	13	2	6	6
Tantalite	[e]2	[e]2	—	—	—	([6])	([6])	—	—	—	1	1	—	—	—
Portugal: Tantalite	7	4	13	—	—	2	1	3	—	—	2	1	4	—	—
Rwanda: Columbite-tantalite	115	61	—	—	—	34	18	—	—	—	25	13	—	—	—
South Africa, Republic of:															
Columbite-tantalite	1	([6])	—	([6])	—	([6])	([6])	—	([6])	—	([6])	([6])	—	([6])	—
Spain: Tantalite	70	40	[e]26	[e]22	24	NA	NA	NA	NA	NA	[7]21	[7]10	7	6	6
Thailand: Columbite-tantalite	1,052	952	267	403	[7]273	180	162	46	69	46	284	257	73	109	74
Zaire: Columbite-tantalite	220	324	[e]110	[e]110	110	60	88	30	30	30	62	91	31	31	31
Zimbabwe: Columbite-tantalite	130	88	73	82	[7]146	[5]20	13	11	6	22	[5]45	31	26	13	51
Total	**[r]73,591**	**[r]78,439**	**76,799**	**49,570**	**85,834**	**30,674**	**32,708**	**32,149**	**20,535**	**35,818**	**694**	**695**	**473**	**544**	**637**

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1] Excludes columbium- and tantalum-bearing tin slags. Production of tantalum contained in tin slags was, in thousand pounds: 1984—827; 1985—877; 1986—622; 1987—543; and 1988—1,145, according to data from the Tantalum-Niobium International Study Center. Table includes data available through June 28, 1989.

[2] In addition to the countries listed, China, the U.S.S.R., and Zambia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[3] Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups such as columbite and tantalite where it is not.

[4] Unless otherwise specified, data presented for metal content are Bureau of Mines estimates based, in most part, on reported gross weight. Metal content estimates are revised as necessary to reflect changes in gross weight data.

[5] Revised to zero.

[6] Less than 1/2 unit.

[7] Reported in official country sources.

COPPER

By Janice L. W. Jolly and Daniel Edelstein[1]

The market for copper was strong throughout 1988. Production of refined copper in the Market Economy Countries (MEC) exceeded previous records, and consumption increased for the fifth consecutive year. Since 1983, total world consumption grew at an annual rate of 3.5%, reaching 10.7 million tons[2] in 1988. Despite significantly increased U.S. production during the year, world production shortfalls and a relatively high rate of world consumption and low refined inventories kept the balance between supply and demand tight throughout the year. Temporary supply constraints included strikes in Papua New Guinea and Peru and production difficulties in Chile and Zambia. The year ended with a slight increase of 43,000 tons in visible world refined copper stocks, indicating the delicate balance between supply and demand. At yearend, total visible world stocks were about 550,000 tons. This was less than 4 weeks of MEC consumption, a remarkably low level by historical standards.

U.S. copper prices remained well above $1 per pound with copper stocks near record-low levels. U.S. commercial refined stocks had not been at such low levels since the 1960's when Government stockpile releases were used to relieve supply shortages. Limited scrap supplies, record levels of world consumption, and production problems at some foreign producers at midyear prompted firm prices for copper through the remainder of the year, and the price reached a record peak in December.

As a result of higher prices, the U.S. industry experienced record profits and was making plans for further production increases and improvements. U.S. industry achievements during the year included a significant increase in mine and refined production compared with those of 1987. The industry also reported a record refined consumption. At the same time, the industry continued to be concerned with new regulatory requirements being proposed by the Occupational Safety and Health Administration (OSHA) and the various Federal and State environmental agencies and their impact on its future competitiveness.

DOMESTIC DATA COVERAGE

Domestic production data for copper were developed by the Bureau of Mines from seven separate surveys of U.S. operations. Typical of these surveys is the mine production survey. Of 108 operations to which a survey request was sent in 1988, 90% responded and 65 mines reported copper production, representing an estimated 99.9% of the recoverable copper content in the total mine production shown in tables 9, 11, 12, and 34. Production for the remainder was estimated using other surveys.

LEGISLATION AND GOVERNMENT PROGRAMS

Copper Study Group

Representatives of countries interested in copper met in Geneva, Switzerland, June 13–14, to negotiate the formation of an international copper study group (ICSG). An understanding was reached for a nonpromotional role in copper product market development for the proposed study group, which would be formed as an autonomous organization. The ICSG, first proposed by the United States, was intended to promote a healthy world copper industry by providing an accurate, comprehensive, and current information base for analysis and better understanding of the world copper market. The group also could provide a producer and consumer forum to discuss issues of common concern, coordinate development projects between existing market development organizations, and sponsor market studies, including studies to be financed by the United Nations Common Fund. Negotiations were scheduled to resume in February 1989 on the remaining terms of reference and rules of procedure.

Environmental Programs

In July, in what industry sources described as a major victory, the U.S. Circuit Court of Appeals for the District of Columbia upheld the 1986 Environmental Protection Agency (EPA) decision that mine waste generated in the mining and milling of nonfuel minerals did not constitute hazardous waste under the terms of the Resource Conservation and Recovery Act (RCRA). A spokesperson for the American Mining Congress indicated that the ruling covered more than 80% of the country's mining waste. However, in a related decision in July 1988, the same court overruled EPA's July 1986 decision not to reinterpret the inclusion of mineral processing wastes in the mine waste exclusion. The court ordered EPA to list six mineral processing wastes, including acid plant blowdown at copper smelters as hazardous and subject to regulation under subtitle C of RCRA. The court also ordered EPA to propose, by October 15, 1988, guidelines for exclusion of smelting and refining wastes from regulation as hazardous wastes.

On October 20, EPA issued a Notice of Proposed Rulemaking for placing of certain mineral processing wastes under the Bevill Amendment to RCRA. The amendment provided for the exclusion and further study of mining wastes from the hazardous waste category as defined in RCRA. EPA proposed including under Bevill, 15 waste streams that met its criteria for high volume and low hazard.

In November, metal industry representatives urged EPA not only to expand the list of mining wastes to be exempted from hazardous waste treatment procedures established under RCRA but also to set clear criteria for exemptions. U.S. copper

TABLE 1

SALIENT COPPER STATISTICS

(Metric tons unless otherwise specified)

		1984	1985	1986	1987	1988
United States:						
Ore produced	thousand metric tons	171,814	[r]165,190	[r]172,476	202,632	223,515
Average yield of copper	percent	0.58	[r]0.61	[r]0.60	[r]0.57	0.60
Primary (new) copper produced:						
From domestic ores, as reported by:						
Mines		1,102,613	[r]1,104,823	[r]1,144,213	[r]1,243,638	1,419,645
Value	millions	$1,625	[r]$1,631	[r]$1,666	[r]$2,262	$3,772
Smelters		989,924	939,257	[1]908,087	[1]972,141	[1]1,042,954
Percent of world total		12	11	10	11	12
Refineries		[r]1,079,062	[r]1,003,713	[r 2]1,073,982	[r 2]1,126,908	[2]1,406,020
From foreign ores, matte, etc., as reported by refineries		[r]95,016	[r]53,528	W	W	W
Total new refined, domestic and foreign		[r]1,174,078	[r]1,057,241	[r]1,073,982	[r]1,126,708	1,406,020
Refined copper from scrap (new and old)		[r]306,537	[r]371,787	405,944	414,738	451,178
Secondary copper recovered from old scrap only		460,695	503,407	477,469	[r]497,937	519,230
Exports:						
Refined		91,414	37,937	12,452	9,197	58,325
Unmanufactured[r 3]		317,000	435,000	442,000	387,000	557,000
Imports for consumption:						
Refined		444,699	377,725	501,984	469,159	331,671
Unmanufactured[3]		551,802	443,932	597,523	[r]568,448	511,360
Stocks, Dec. 31: Total industry and COMEX:						
Refined		564,000	320,000	225,000	113,000	98,000
Blister and materials in solution		245,000	146,000	135,000	150,000	119,000
Consumption:						
Refined copper (reported)		2,122,732	1,976,038	2,102,625	[r]2,125,699	2,210,498
Apparent consumption, primary and old copper (old scrap only)		[r]2,116,058	[r]2,144,436	[r]2,135,983	[r]2,196,807	2,213,596
Price: Weighted average, cathode, cents per pound, producers		66.85	66.97	66.05	82.50	120.51
World:						
Production:						
Mine	thousand metric tons	[r]7,879	[r]7,969	8,001	[p]8,328	[e]8,453
Smelter	do.	[r]8,455	[r]8,655	8,817	[p]8,914	[e]9,023
Refineries	do.	[r]9,148	[r]9,473	9,661	[p]9,815	[e]10,072
Price: London, Grade A, average cents per pound[4]		62.45	64.27	62.28	80.88	117.92

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes production from foreign ores and concentrates.
[2]Includes primary copper produced from foreign ores, matte, etc., to avoid disclosing company proprietary data.
[3]Includes copper content of alloy scrap.
[4]High-grade prior to 1988.

producers hoped to lessen the effects of a Supreme Court decision that denied an American Mining Congress suit to overturn the EPA's classification of acid plant blowdown from copper smelting—among other ore and mineral mining wastes—as hazardous.

In December, EPA revised the list of mineral processing wastes that it proposed to exclude as "Bevill wastes" from the strict regulatory guidelines of subtitle C of RCRA. The expanded list of 46 items specified most waste streams from the smelting and refining of copper, including slag, acid plant blowdown, process wastewater, bleed electrolyte, roast-leach acid plant residue, and wastewater treatment plant sludge. The proposed exemption list was based on two factors: namely, whether the wastes were processing wastes and whether they met the volume criterion. A final list was to be prepared by the court-imposed deadline of February 15, 1989.[3]

Labor Health and Safety

In September, the Mine Safety and Health Administration (MSHA) in the U.S. Department of Labor issued a more stringent machinery usage ruling for metal mines. One reason for the new rules was the growing presence of automated processing in domestic metal mining. The revisions took effect on October 24 and included stricter rules for loading heavy machinery, a provision requiring seat belts to be worn when operating all hauling equipment, and a safer procedure to test adequacy of brakes for large hauling vehicles.

Arizona and Utah adopted the OSHA respirable fiber regulations in March 1988, which postulated the regulation of the amphiboles actinolite, tremolite, and anthophyllite (ATA). The mining industry estimated that between 70% and 90% of all mining operations in the United States could be affected by the legal ramifications and liabilities of mining associated with these amphiboles, especially if these minerals were regulated like asbestos. Although OSHA studies had determined that the death rate from exposure to ATA was so low that medical studies could not separate it as an independent cause, the agency decided that many common amphiboles—which occur in the gangue or host-rock of many ore deposits, including some copper deposits—should be defined as asbestos. In addition, the International Agency for Research of Cancer, part of the World Health Organization, placed silica on the list of suspected carcinogens. Silica occurs in great abundance at copper and other mines. OSHA was also working on a silica standard.

State Legislation

U.S. mining companies appealed to the U.S. Supreme Court about the Arizona Supreme Court ruling that Arizona must appraise the value of mineral lands on State trust lands before they can be leased to mining companies, and that royalties paid by the mining companies should be based on the appraised value. The ruling would increase the royalties paid by ASARCO Incorporated, Magma Copper Co., and other companies that mine on State trust lands. Arizona law had previously required companies holding mineral leases on State school trust lands to pay a 5% royalty on minerals extracted, irrespective of the land valuation.

Some statutory changes were expected to occur on the Arizona decision regardless of the outcome of the appeal to the U.S. Supreme Court. In response to charges that the current methods of royalty determination caused the trust to lose millions of dollars, the Governor of Arizona appointed an oversight committee to examine Land Department statutes and operations. The committee recommended that a new royalty system be instituted: the minimum rate would be 1% of gross value; land appraisals would set rates for individual mines; land rental would be appraised for mineral leases; prospecting permits that are not in the interest of the trust would be denied; and, an authority would be established to audit company records. There was a moratorium on issuing new mineral leases or renewing existing ones throughout 1988 because of the uncertainty arising from this issue.

In recent years, 98% of royalties from mineral leases in Arizona were generated by two copper mines: Magma's operation at San Manuel and Asarco's Mission Pit south of Tucson, both of which are within State trust lands. Over the past 5 years, royalties from mineral leasing on State trust lands in Arizona steadily increased, from $879,000 in fiscal year 1983–84, to more than $3.9 million in fiscal year 1987–88, as the copper industry recovered from a serious economic slump. Prospecting permit applications and exploration budgets were also low during the period of low copper prices. This lack of confidence in the investment of exploration funds on State trust lands was compounded in late 1987, after the Arizona Supreme Court declared the mineral royalty fixed rate for State mineral leases unconstitutional.[4]

Stockpile Issues

Until February 25, 1988, the National Defense Stockpile (NDS) was guided by the Federal Emergency Management Agency and administered by the General Services Administration. On that date, Executive Order 12626 transferred management responsibility for the stockpile to the U.S. Department of Defense.

In July, the critical materials staff at Defense recommended streamlining the NDS by placing more emphasis on defense needs and on materials that could quickly be manufactured into end products. A full report on the future of the stockpile was to be released by Defense on February 15, 1989. The report would be prepared by the Office of the Secretary of Defense with the advice and assistance of the Joint Chiefs of Staff and civilian agencies in the executive branch concerned with strategic and critical materials.

The military requirements for strategic and critical materials needed to support current military strategies for conventional global conflict and modern military technology systems were viewed as having changed significantly since the 1970's. While the need for some traditional materials remained substantial, some weapon systems would require advanced forms of industrial materials. Changes in the needs of the civilian sector also were anticipated. Critical material requirements also had been affected by shifts in sources and supply, such as the reduction in domestic smelting, refining, and processing capacity for a number of the older stockpiled materials, such as copper. Standards for some materials also have become more stringent to meet increased performance requirements.

Trade Legislation and Actions

Several trade actions were important issues for the copper industry during the year. The most important were the Omnibus Trade and Competitiveness Act of 1988, Public Law 100–418, the United States-Canada Free Trade Agreement Act of 1988 (FTA), Public Law 100–449, and several antidumping and countervailing duty cases on brass mill products.

Two decisions on dumping in 1988, against Japan and the Netherlands, made a total of 11 countries that have had their exports to the United States similarly curbed over the past 3 years. The International Trade Administration (ITA) made a final determination in June that imports of brass sheet and strip from Japan and the Netherlands were being dumped in the United States at prices as much as 58% below their domestic prices. As a result, brass sheet and strip producers in those countries were required to deposit cash in the amount determined by multiplying the value of each customs entry by percentages that varied with each company.

The Omnibus Trade Act included modifications of statutes and new strategies for improving U.S. industrial competitiveness. The act's strengthened section 301 provision was aimed at forcing U.S. trading partners to open their markets through increased discretionary powers of the Office of the U.S. Trade Representative (USTR). The new law increased the possibility of action against countries trading unfairly with the United States, adding to the possible forms of retaliation and adding to the list of actionable and unreasonable practices that might contribute to global oversupply through a foreign country's subsidization of a metals industry. The revised section 201 would require petitioners to submit a plan to carry out import competition adjustment. Action recommended to the ITC could include tariffs, tariff-rate quotas, and quantitative restrictions.

The Omnibus Trade Act also required that U.S. tariff schedules adopt the nomenclature of the internationally established Harmonized System, to become effective January 1, 1989. In an attempt to standardize tariff systems throughout the world, the Harmonized System is to be adopted by about 55 countries, including Canada, Japan, and members of the European Community (EC).

On November 24, the Copper and Brass Fabricators Council Inc. (CBFC) filed a petition with the USTR seeking relief under section 301 of the Trade Act of 1974, as amended, regarding restrictions on exports of copper scrap, copper-alloy scrap, and zinc scrap from the EC countries and Brazil. At yearend, the USTR agreed to investigate the allegations concerning EC scrap. The petitioners claimed that export controls imposed on copper scrap by EC countries were unjustifiable, a violation of the General Agreement on Tariffs and Trade (GATT), and a burden to the U.S. brass mill industry. The petitioners claimed that the restrictions, coupled with an open U.S. market, tended to depress scrap prices in countries that restrict exports and, conversely, to elevate the price of U.S. scrap. The semifabricating industry of the restrictive countries, thereby, had a raw materials cost advantage that permitted them to export their products to the United States at prices below those of the U.S. brass mills. The CBFC later withdrew a complaint with regard to zinc scrap and Brazil and dropped specific allegations against the United Kingdom.

In rebuttal, the European copper and brass industries argued that since minable copper resources in Europe were negligible, scrap was an essential copper raw material there; that export restrictions were consistent with the principle that all parties to the GATT are entitled to an equitable share in the international supply of products in short supply, as set forth in Article 20 (j) of GATT; that the EC restrictions, which were renewed annually, were intended to prevent the trade policies of Japan and the newly industrialized countries from depriving the EC of an adequate supply of copper raw materials; and that the EC was committed to eventually removing the export controls.

The FTA is to be implemented on January 1, 1989, at which time tariffs are to be gradually decreased, according to an agreed upon schedule of 5 to 10 years. The U.S. nonferrous industry was concerned with Canadian advantages obtained through alleged subsidization of their copper industry. The U.S. industry worried that in difficult times the Canadian smelters and refineries, if subsidized, would have the financial ability to support the continued operation of marginal mines, thus putting additional pressure on otherwise economic mines and plants elsewhere. The U.S. copper industry has had to bear the full costs of operating mines and upgrading plants in the effort to comply with environmental and other regulatory laws. According to preliminary estimates by the Bureau of Mines, this has amounted to as much as 7.5 cents per pound of copper produced at U.S. smelters, after deducting 1.3 cents per pound for sulfuric acid "credits." Existing tariffs on copper products were generally low, but were thought by the industry to have a utility in the context of multilateral negotiations where reciprocal reductions in trade barriers could be sought. The most important was thought to be the 4% ad valorem tariff on copper rod.

U.S. trade officials were to begin reviewing the FTA accelerated tariff reduction requests from about 200 companies after April 15, 1989, and would have until January 1, 1990, to announce any changes in the elaborate tariff phaseout schedule. The primary copper-producing industry did not request or support acceleration of the tariff reduction schedule.[5]

PRODUCTION

Mine and Plant Labor

Productivity, in terms of average hours worked per metric ton of copper produced, was 18.5 hours per ton of recoverable copper by open pit, underground, and leach methods. This was an improvement compared with 18.9 hours per ton in 1987. Average productivity for five operating underground mines was 36.2 hours per ton and for 16 open pit mines was 13.4 hours per ton of recoverable copper produced. Mines that produce copper as a byproduct of another metal, such as the Asarco Troy Mine in Montana, were not included in this analysis.

Productivity at copper smelters and electrolytic refineries was 8.2 hours per ton of copper, compared with 9.5 hours per ton required in 1987 and 15.7 hours per ton in 1983. Average hourly earnings for production and nonsupervisory workers at smelters and refineries, according to unpublished preliminary data by the U.S. Department of Labor, was $11.70 per hour, an increase over the $11.37 per hour for 1987, but a decrease from the average hourly wage of $12.88 per hour in 1983.

Total workers in the U.S. copper industry averaged 17,300 in 1988. Copper mine, mill, leach plant, and office workers in Arizona totaled 8,030, according to MSHA data for 1988. New Mexico (1,387 workers) and Utah (1,303 workers) were second and third in the Nation in terms of the number of copper mineworkers. Copper Range Co. employed 963 people from eight counties in Michigan and Wisconsin at the White Pine Mine in Michigan.

The 250 workers at Asarco's Troy, MT, copper and silver mine voted to be represented by the United Mine Workers of America (UMWA) in late 1987, after previously rejecting such representation in July 1986, by a wide margin.

TABLE 2

PRODUCTIVITY[1] IN THE U.S. COPPER INDUSTRY, BY ACTIVITY

		1983	1984	1985	1986	1987	1988
Copper mine production:							
Ore concentrated and leached	metric tons	177,930,000	171,814,000	165,190,000	172,476,000	202,632,000	223,515,000
Copper recovered	do.	915,081	989,935	1,003,990	1,041,520	1,154,222	1,342,014
Average yield of copper	percent	0.51	0.58	0.61	0.60	0.57	0.60
Copper from dump leach	metric tons	89,274	80,845	82,948	79,031	70,136	50,284
Total production[2]	**do.**	**1,004,355**	**1,070,780**	**1,086,938**	**1,120,551**	**1,224,358**	**1,392,298**
Mine and SX-EW plant labor:							
Average annual workers[3]		14,700	12,461	9,854	10,154	11,924	11,873
Employee hours worked		28,400,000	22,587,340	18,831,046	20,326,091	23,197,110	25,707,013
Productivity at mines, hours per ton		**28.28**	**21.09**	**17.32**	**18.14**	**18.95**	**18.46**
Refined copper production:							
Electrolytic copper[4]	metric tons	1,304,915	1,235,101	1,231,612	1,241,309	1,276,933	1,525,470
Smelter and refinery labor:							
Average annual workers[5]		9,700	8,600	6,100	5,400	5,500	5,400
Employee hours worked		20,529,000	18,146,000	11,263,200	12,753,000	12,100,000	12,500,000
Productivity at plants, hours per ton		**15.73**	**14.69**	**9.15**	**10.27**	**9.48**	**8.19**
Industry productivity, hours per ton		**44.01**	**35.79**	**26.47**	**28.41**	**28.42**	**26.64**

[1] Employee hours per metric ton mined and processed.
[2] Production from byproduct mines not included.
[3] Includes mine, mill, SX-EW plant, and administrative workers at copper open pit and underground mines. Includes construction and workers at mines on standby or care and maintenance; excludes mines producing copper as a byproduct.
[4] Excludes electrowon or secondary fire-refined material.
[5] U.S. Department of Labor, unpublished data.

Sources: Mine Safety and Health Administration, U.S. Department of Labor; production statistics from the Bureau of Mines.

Talks began immediately regarding restoration of wage cuts made earlier and preferential hiring rights for Asarco's Rock Creek Mine project near Noxon, MT. Mine safety was also an issue with the union. In September, miners unhappy with the union's failure to reach a contract settlement at the Troy Mine filed a petition with the company and the National Labor Relations Board (NLRB) seeking decertification of the UMWA. Based on this petition, Asarco officials reportedly declared the union no longer representative of the majority of workers and refused to negotiate further. At the same time, they posted a new wage scale increasing miners' pay.

Magma laid off 200 workers in late 1988 as a result of company plans to reorient its mine production at San Manuel, AZ, by cutting underground sulfide production by about 9% and increasing production from its open pit and in situ oxide leach operations by a commensurate amount. The shift in production, which was complete by the end of October, was expected to reduce cash costs. In addition, underground development work on the Kalamazoo ore body was curtailed for at least 1 year. Production from the underground mine was to be reduced from 39,900 to 36,300 tons of ore per day.

In mid-December, Montana Resources Inc. distributed $4.5 million in bonuses to approximately 330 nonunion employees at its Continental East Mine in Montana. The bonuses, along with quarterly profit-sharing payments, reportedly were estimated to have more than doubled the employees' average base salary of $20,000. In 1950, 6,006 persons were employed in mining at Butte, MT, comprising 12.4% of total employed persons in Montana, but by 1980, the Butte mining work force had been reduced to 1,850 persons (4.9% of the total State work force) and by 1988 to 320, or 2.5% of the total State working population.

Cost of Production

The weighted-average cash cost, including byproduct credits and taxes but excluding depreciation, of producing refined copper in the United States was estimated to have decreased to about 50 cents per pound in 1988, according to Bureau of Mines Minerals Availability System estimates. Including recovery of capital, the average production cost was 58 cents per pound.

Montana Resources estimated that it had lowered operating costs to about 50 to 60 cents per pound. A 12-cent savings was realized by renegotiating transportation and refining contracts. Additional savings came from a reduction in the labor force.

Unit costs at Phelps Dodge Corp.'s operations continued to reflect high levels of production and cost-cutting efforts made over the past several years. Phelps Dodge had reduced production costs to about 55 cents per pound by 1987, from a high of more than 80 cents per pound of copper in 1981. A $365 million investment was planned to further reduce costs over the next 3 years, including a $48 million in-pit crushing and conveying program at Morenci, AZ, which was expected to be operational in 1989. Construction of the $55 million Chino, NM, solvent extraction and electrowinning (SX-EW) plant was completed in August 1988. Incremental production costs at the Tyrone, NM, SX-EW plant were below 30 cents per pound for cathode copper, and similar production costs were experienced at the Morenci plant. Expansions were continuing at Morenci and Tyrone SX-EW plants. Even so, Phelps Dodge's unit production costs of copper in 1988 were marginally higher owing to increases in special labor costs and State severance taxes that were set to vary with copper prices.

Company Earnings and Ownership Changes

All U.S. copper mining companies were profitable during the year as prices for copper and other nonferrous metals rose in late 1987 and 1988, with some companies registering record profits. Some, however, were still repaying extensive debts that had been acquired for the necessary regulatory compliance and productivity improvements of the past several years. Ownership changes continued as the copper industry attempted to complete restructuring.

Asarco experienced one of its best years in terms of net reported earnings; the 1988 operating income of $269.3 million was exceeded only by that of 1979 and 1980. Structural changes over the past 3 years had been directed toward deriving more of the company's income from its own operations than from its investments in other companies. These changes included a substantial lowering of all costs and an increase in mine capacity, which would enable Asarco to supply more of its own ore and concentrate requirements for its smelters and refineries. In 1988, Asarco spent over $250 million on capital projects, acquisitions, and investments. In addition, an expenditure of about $260 million was to be spent over the next 3 years to expand copper production further at the Mission and Ray Mines in Arizona and to install a modern smelting process at the El Paso, TX, copper smelter.

The improved ($541 million) earnings of British Petroleum PLC's (BP) minerals group were attributed to the modernization at the Bingham Canyon copper mine in Utah, as well as to the high price of copper during 1988. Capital expenditures were down during 1988, being only $561 million in 1988 compared with $707 million in 1987. Late in 1988, BP announced an agreement in principle to sell its minerals business, excluding a couple of small Canadian operations, to Rio Tinto Zinc PLC (RTZ) of the United Kingdom, for $4.3 billion. The sale, to be completed in 1989, would be the largest in United Kingdom corporate history and would remove BP from the nonfuel minerals business. Bingham Canyon comprised about 40% of the total value. Total copper output, including Olympic Dam, Australia; Bougainville, Papua New Guinea; Highland Valley, Canada; Palabora, Republic of South

Africa; Escondida, Chile; Neves-Corvo, Portugal; and various Spanish mines would give RTZ about 6.5% of world copper production. Through its subsidiary, the Standard Oil Co. of Ohio (Sohio), BP paid $1.77 billion in 1981 for Kennecott, which owned and operated the Bingham Canyon Mine, UT.

Copper Range's plans for a $35 million public stock offering were put on hold following the collapse of one part of the mine in February. At yearend, Copper Range arranged to purchase the refinery it leased from Louisiana Land and Exploration Co. for $14.3 million.

Metall Mining Corp., Toronto, Canada, a subsidiary of the West German company, Metallgesellschaft AG, agreed in principle to purchase, early in 1989, the assets of Copper Range, owner of the White Pine Mine and an associated smelter and refinery in Michigan. In conjunction with the proposed acquisition, Metall Mining negotiated an agreement for a new collective bargaining agreement between Copper Range and the United Steel Workers of America. Union workers of the 70% employee-owned Copper Range overwhelmingly approved a labor contract with the prospective new owners. Metall Mining was expected to pay between $85 million and $98 million for the operations, depending upon operating profits achieved over the next 4 years. Metall Mining reportedly intended to boost White Pine's projected 1989 production of 43,000 tons by 25% over the next 3 years.

Cyprus Minerals Co. announced sharply higher earnings ($170 million) as a result of higher copper prices, coupled with increased sales volume from copper-producing acquisitions. Cyprus also benefited from higher molybdenum sales, which were largely associated with its copper production. Cyprus acquired three copper-producing properties during the year, the Anaconda Minerals Co., Tonapah, NV, molybdenum-copper property; the Inspiration Consolidated Copper Co.(ICC) properties in Miami, AZ, and the Anamax Co. Twin Buttes, AZ, open pit mine and facilities. The Twin Buttes Mine and associated SX-EW plants were acquired under a 15-year lease in March. Cyprus purchased the ICC properties, including mines, a smelter, a refinery, and a rod mill, in July 1988 for $122 million.

Cyprus also announced that it would purchase Warrenton Refining Co. early in 1989. By integrating the Warrenton refinery and its recently acquired ICC refinery, the company anticipated being able to recover precious metals from scrap operations that Warrenton could not do in the past.

In October, Magma filed with the Securities and Exchange Commission (SEC) regarding its proposed offering of four issues of subordinated notes with aggregate principal of about $210 million. The company said proceeds would be used for its recapitalization plan, under which Magma took an option to buy back the 15% of its common stock and preferred shares retained by Newmont Mining Corp. when it spun off the copper operations last year. To obtain the cash needed to repurchase options held on shares of its stock still owned by Newmont before a November 30 deadline, Magma put $210 million of debt on the market, to mature in 1998. The bonds were interest-indexed on the basis of quarterly averaged copper prices, paying 18% per year interest for the first two quarters; thereafter, the payments were to be based quarterly on Commodity Exchange of New York (COMEX) prices. Investors would receive 12%, when copper was 80 cents per pound and up to 21%, if the average price of copper went to $2 per pound or higher. Magma stood to gain by the refinancing plan because existing debt covenants, which the company considered a hindrance to operational decisions, would be eliminated.

Phelps Dodge's net income ($420 million) was a record. The company credited the improved earnings to record high spot prices for copper in the fourth quarter, record high copper production and sales, and a continuing commitment to reduce costs. In September, the corporation created two operating divisions, Phelps Dodge Mining Co., which comprised the operating, marketing, mineral exploration and development functions, and Phelps Dodge Industries, which comprised the manufacturing and specialty chemicals functions of the company. Phelps Dodge Industries, the nonmining business, contributed earnings of $150 million for the year.

Mine Production and Reserves

Copper was mined in 13 States during 1988, with Arizona yielding 60% of the total, followed by New Mexico and Utah. There were 65 copper-producing mines, up from a total of 52 mines in 1987. Of these, 35 were producing copper mines and 30 were mines from which copper was produced as a byproduct or coproduct of gold, lead, silver, or zinc. Total U.S. operating mine capacity, in terms of recoverable copper per year, was estimated to be 1.69 million tons in 1988 compared with 1.51 million tons in 1987. The increased capacity was largely a result of new SX-EW capacity at several mines, although some mines, such as Mission and Bingham Canyon, also increased concentrate throughput. Mine capacity for the three largest producing States was Arizona, nearly 1.1 million tons; New Mexico, 285,000 tons; and Utah 210,000 tons of recoverable copper.

Arizona produced nearly two-thirds of the Nation's copper from 27 mine and leach operations. The value of Arizona's nonfuel mineral production rose sharply during the year to an estimated $2.83 billion, representing an increase of more than $1 billion over the 1987 value. The bulk of this increase was due to the strong price received during the year for copper, which accounted for more than three-fourths of the State's nonfuel mineral value. Most exploration efforts in the

United States continued to be focused on precious metals and leachable copper. Arizona ranked third among the States in the number of active claims for all mineral commodities.

Asarco and its associated companies accounted for 9% of MEC mine production of copper in 1988, according to the company annual report.[6] By yearend, Asarco nearly had completed the $13 million expansion of the Mission Mine complex, which would increase the mine's annual production capacity by 46%. The Mission mill output in 1988 was increased to a rate of 37,000 tons of ore per day from 25,400 tons per day. Mission Mine capacity was 191,000 tons per year of concentrates or 60,000 tons of copper. A project was also started in late 1988 at the Ray Mine to expand mill capacity in an effort to offset anticipated effects of increasing hardness of ore as the pit deepens. The expansion at Ray Mine would cost about $12 million to maintain a capacity of 68,000 tons per year of copper in concentrates and was expected to be completed by early 1990. These efforts were part of a $260 million program to expand Asarco's mine output to 263,000 tons of copper; it included a new mill and concentrator and an in-pit crusher at the Ray Mine, purchase and renovation of the idle Pima mill and concentrator for use at the Mission Mine, and a new smelting process at the El Paso smelter.

Mine	State	Ore milled (thousand metric tons)	Copper produced (thousand metric tons)	Reserves (thousand metric tons)	Grade (percent of copper)
Coeur	Idaho	130	1	398	0.70
Galena	do.	183	1	1,124	.57
Troy	Montana	2,560	15	32,365	.74
Mission	Arizona	9,236	59	324,898	.64
Ray	do.	8,598	106	598,793	.70
Silver Bell	do.	—	4	19,010	.68
Total[1] or average		**20,709**	**186**	**976,589**	**.68**

[1] Data may not add to totals shown because of independent rounding.

Source: ASARCO Incorportated 1988 Annual Report.

Several lawsuits brought during the year by Indian tribes and some other Arizona water users in the Federal and State courts had the potential to affect Asarco's use of water at its Ray Unit, Hayden plant, Mission Complex, and other Arizona operations. Asarco was a defendant in lawsuits contesting the right of Asarco and numerous other individuals and entities to use water and, in some cases, seeking damages for water usage.[7]

Asarco purchased the Helvetia property, a large undeveloped copper reserve 15 miles west of the Mission Mine, for possible future development. Helvetia had estimated sulfide reserves of 254 million tons of 0.62% copper and oxide reserves of 21 million tons of 0.78% copper. The property was purchased for $1 million plus 1,200 acres of land that reportedly had no mineral potential. In December, Asarco and Freeport-McMoRan Gold Co. jointly acquired the Santa Cruz porphyry copper deposit 7 miles west of Casa Grande, AZ, for $7 million, and were viewing the venture as a long-range project. The deposit, which the partners acquired for $14 million, includes both oxide and sulfide copper in an estimated 350 million tons of ore with an average grade of 1.05% copper within a larger resource of 726 million tons with an average copper content of 0.43%. Part of the newly acquired property had been extensively drilled about 10 years ago by a joint venture of Getty Minerals Co. and M. A. Hanna Co. Asarco and Freeport-McMoRan were participating with the U.S. Bureau of Mines in an in situ leaching experiment at the property. This large, deep-seated deposit would be used to determine the feasibility of in situ leaching in undisturbed virgin ground, as well as to develop a data base for application to other deposits. Hydrologic studies would follow design and development of the leach field and the design of the pilot SX-EW plant. About $20 million was budgeted to be spent on the 5-year research project. In late 1988, the joint venture purchased an adjoining ore reserve that could be mined with this technology if it proves feasible.

Asarco's copper production and reserves are reported in the text table.

Asarco estimated that a capital expenditure of about $130 million would be required to bring its Rock Creek, MT, project into production. Operational expenses would include about $26 million per year for salaries, wages, and purchases and $3 million for Montana taxes. Access to the ore deposit would be made with two parallel adits opening outside the wilderness area. About 46,300 tons of concentrate per year would be transported by truck to Noxon for rail shipment.

According to news reports, Copper Range produced 44,600 tons of copper in 1988 from its White Pine Mine in the Upper Peninsula of Michigan.[8] This contrasted with a production of about 48,350 tons in 1987 and 27,500 tons in 1986. A major ground collapse at the White Pine Mine in February closed the main belt line servicing about 75% of the mine production. Mining was shifted to another area, which held the long-range ore reserves of the mine, while the company constructed a new conveyor system. The new system was put into service by May and production began to return to normal. With a $40 million line of credit from Chemical Bank of New York, Copper Range planned to expand the operation further through purchasing new equipment, adding columnar flotation cells in the mill and acquiring the electrolytic refinery for $14.3 million, which it had been leasing from Louisiana Land and Exploration Co.

Cyprus announced that it would increase capacity at the Bagdad Mine by about 18,000 tons of copper per year. Expansion would result in the ore throughput increasing from 52,000 to 64,000 tons per day. The $21 million expansion of the mill would also reduce production costs through added capacity and improved productivity. Construction was to be completed by June 1, 1990. According to a company press release, about 82,000 tons of copper was produced at Bagdad in 1988, and the company planned to increase production to nearly 100,000 tons after the expansion. Cyprus produced nearly 212,000 tons of copper in 1988 and expected to produce more than 272,000 tons in 1989.[9]

Most of the company's growth from 1983 to 1988 was from acquisitions, which added about 123,000 tons of copper to its production. The purchase of Sierrita added about 82,000 tons of copper and 18 million pounds of molybdenum. Acquisition of Casa Grande and ICC's Miami, AZ, properties, made possible smelting and refining of some of the company's own concentrates. The Miami deposits added 57,000 tons of copper from low-cost oxide leaching. The facilities were on a combination of fee property, patented and unpatented mining and millsite claims, and private and State leases. Proven reserves for leaching operations were 151 million tons of ferric cure ore with an average grade of 0.60% copper and 74.8 million tons of dump leach ore with an average grade of 0.21% copper. Cyprus acquired crushing equipment, an SX-EW plant, and some mining equipment along with its 15-year lease of the Twin Buttes copper open pit. Proven reserves at Twin Buttes totaled 32 million tons of sulfides containing 1% copper and 6.4 million tons of oxide ore containing 0.67% copper. Cyprus began mining at Twin Buttes in June 1988. The ore was being milled at Sierrita.

	1983	1984	1985	1986	1987	1988
Copper ore reserves thousand metric tons	461.21	395.53	378.30	360.42	401.52	835.90
Grade percent copper	0.47	0.44	0.44	0.44	0.47	0.45
Copper/molybdenum ore reserves[1] thousand metric tons	—	—	—	311.44	295.47	311.20
Grade percent copper	—	—	—	0.31	0.30	0.29
Copper production thousand metric tons	77.93	25.67	78.70	133.40	157.44	211.60

[1] Molybdenum grade was .036% (1986) and .037% (1987); represents Sierrita reserves acquired Mar. 1986.

Source: Cyprus Minerals Co., 1987 and 1988 10K report.

Cyprus' copper reserve revisions, shown in the text table, reflect changes at the Bagdad Mine in 1987, which added about 50 million tons and the addition of the Casa Grande and Pinos Altos Mines. In 1984, copper reserves of 112 million tons were eliminated owing to discontinued operations at the Johnson and Pima Mines.

The modernization project started in February 1986 at Kennecott's Bingham Canyon open pit and was completed 33 months later in 1988. Planned capacity for the modernized section was 186,000 tons of copper per year. The new Copperton concentrator was on the eastern foothills of the Oquirrh Mountain Range, about 26 miles southwest of Salt Lake City. The concentrator received ore from the Bingham Canyon Mine by way of a 5-mile conveyor system. The concentrate was pumped to the Garfield smelter through a 17-mile pipeline. Waste materials flowed through a pipeline by gravity to the Magna tailings pond. Except for the molybdenite recovery plant, most plant operations were controlled from a central room by a microprocessor-based system. The major source of process water was reclaimed water from the Magna tailings pond. Makeup water was obtained from deep wells, surface drainage, springs, and the North Jordan Canal.

The Copperton concentrator was operating at a capacity of 69,800 tons per day of ore. Copperton combined with the Bonneville-Magna concentrator, which operated at 27,200 tons of ore per day, provided Kennecott with a total milling capacity for 1988 of 97,000 tons per day of ore. At midyear, BP Minerals announced that it had tendered 90,700 to 181,000 tons of concentrates, containing roughly 23,000 to 45,000 tons of copper, for delivery to other smelters through yearend 1989. The excess copper over its smelter capacity was the result of the company's decision to run the old concentrators at Bingham Canyon, instead of shutting them in June when the new concentrator and ore-processing system began operation. With prices strong, Kennecott anticipated maximizing its output. Several Japanese smelters were approached with the possibility of 3-year contracts for the excess concentrates.

A tentative agreement was reached among three Rusk County, WI, cities and BP Minerals in the company's efforts to start mining near Ladysmith. The parties had met more than 12 times by March 1988 to discuss Kennecott's proposal to construct an open pit between the Flambeau River and Highway 27, north of Ladysmith in the town of Grant. Negotiations included project monitoring, zoning and related controls along with environmental guarantees. BP Minerals was to assume responsibility for supplying water to areas where a well failure might occur because of the mine. BP Minerals also agreed to hire a majority of its personnel, except technical and managerial, from the local area. The company hoped to obtain all permits by January 1990 and begin operation later that year.

Preparatory work was completed for an in situ solution mining project at the Nacimiento chalcocite ore body near Cuba, NM, 80 miles northwest of Albuquerque. Leaching Technology Inc. (LTI) planned to start operations in late 1989 or early 1990. A pilot leach program using ferric ion, sulfuric acid and a surface bio-leach pile achieved some early success. The SX-EW plant being utilized was a former Cyprus Bagdad pilot plant that was repositioned at the Nacimiento minesite and upgraded to meet a higher production goal. The new design was for 7,500 tons of copper per year. The ore body was within a down-dropped fault block (graben) east of the Nacimiento thrust fault. The copper-bearing, Aqua Zarca sandstone member consisted of quartz pebble and cobble conglomerate with lenses of sandstone and shaley material. Biological oxidation of contained iron was used to accelerate ferrous to ferric conversion. Bacteria, *Thiobacillus ferrooxidans*, were used to oxidize the chalcocite ore body. Only the copper in the ore below the water table was available for leaching. Since the water table had risen since the calculation of reserves, the amount of copper available for leaching was estimated to be greater than the original 45,000 tons reported in 1977. Total in-place reserve was estimated at 59,000 tons of copper.

The copper deposit at Nacimiento previously had been the subject of extensive geologic evaluations and an attempt at open pit mining, which had been started in 1971, suspended in 1975 owing to low copper prices, and never resumed by the former owner, Earth Resources Co. The mill structure was removed. Ore grading 0.70% copper had been mined at the rate of about 4,000 tons per day. A high waste-to-ore ratio of 5:1 contributed to the high cost of mining.[10]

At Magma's San Manuel Mine, the oxide open pit in the subsidence zone of the underground mine was operating at the rate of 18,000 tons of ore per day and 22,000 tons of waste per day. Mining was planned to last about 9 years. An ore reserve of about 247 million tons of chrysocolla-bearing ore, lying under the pit area, had been identified for in situ leaching. Injection wells were drilled into this zone to a depth of 1,000 feet. The wells were cased with PVC pipe, and a weak sulfuric acid solution was injected at a rate that depended upon the zone permeability. The copper-bearing solution was pumped to the surface where it joined the leach dump solution system for processing in the electrowinning plant, which had been enlarged in preparation for the new production.

At the San Manuel underground mine, ore was mined from an elliptical-shaped porphyry ore body that measured about 8,000 feet long and 2,500 feet across, lying 700 to 3,000 feet below the surface. A faulted segment, the Kalamazoo, or "K" ore body, was similar in size and composition and lay to the west, 2,500 to 4,000 feet below the surface. The disseminated copper ore of the underground mine averaged about 0.65% copper. A modernized concentrator processed ore as well as returned slag from the smelter.

The Pinto Valley Div. of Magma operated a large, open pit sulfide mine and flotation concentrator, a sulfide-waste dump leach site, an in situ leach site, a tailings leach site, and two SX-EW plants. An annual average of 562 workers (mine, mill, plants, and administration) were employed at the division. Pinto Valley had a production capacity of about 250,000 tons per year of copper concentrates, or about 70,000 tons per year of copper, in addition to about 15,000 tons per year of SX-EW copper capacity. The Miami Unit in situ leaching operation had been in operation since 1942. This operation leached the rubblized ore of the former Miami underground mine, which was mined by block caving from the early 1900's through 1959. A new tailings leach project was under construction and was to start production of electrowon cathode at the rate of 7,500 tons per year in May 1989 through a system of hydraulic mining, leaching, and SX-EW. Sulfuric acid for the leach projects was supplied by the San Manuel acid plant associated with the smelter.

Phelps Dodge Mining Co., Phelps Dodge Corp.'s mining and metals subsidiary, was the largest U.S. producer of copper. The company's mines at Morenci, AZ (15% owned by Sumitomo Metal Mining Corp.), Chino, NM (one-third owned by Mitsubishi Corp.), and Tyrone, NM, produced 527,620 tons of copper in concentrates during the year, according to the company annual report.[11] Of the total, 80,200 tons was electrowon cathode from Chino, Morenci, and Tyrone Mines. A substantial tonnage of concentrates was in excess of the company's smelter capacity and was either toll smelted or sold. A $48 million in-pit crushing and conveying system was under construction at Morenci, which would allow phasing out of rail haulage to the mill; operation was to begin in 1990. Concentrate capacity at Tyrone, about 110,000 tons of copper annually, was expected to cease in the early 1990's. Burro Chief Copper Co. would continue leaching at the mine for another 15 years. Copper ore reserves and reserve base at Phelps Dodge's U.S. properties including partner's shares, are shown in the text table.

Drilling continued at the Phelps Dodge Cochise copper project near Bisbee, AZ, to further delineate grade and tonnage. Engineering studies and costs estimates were being prepared to determine the potential for heap leaching and recovery of copper by SX-EW methods. The company did not foresee reopening the Ajo Mine, which had been shut since August 1984, until market conditions warrant.

Several proposed mines were receiving attention during the year owing to higher prices. The Rock Lake and Rock Creek Mines in Montana were considered highly probable for development. In addition, higher prices could also increase

Mine	State	Ore mined: Quantity (thousand metric tons)	Ore mined: Grade (percent copper)	Precipitates recovered (metric tons)	Ore reserves: Quantity (thousand metric tons)	Ore reserves: Grade (percent copper)
Morenci	Arizona	31,556	0.83	3,084	621,300	0.76
Copper Basin	do.	—	—	4,990	158,800	.55
Tyrone	New Mexico	14,734	.87	6,622	72,400	.77
Chino (Santa Rita)	do.	10,111	.72	13,426	306,100	.71
Total[1] or average		**56,402**	**.82**	**28,123**	**1,158,500**	**.72**

[1]Data may not add to totals shown because of independent rounding.

Source: Phelps Dodge Corp. 1988 Annual Report.

interest in the proposed Sheep Creek Mine near White Sulphur Springs, MT. Cominco Resources International Inc. reported that ongoing exploration at its Sheep Creek property had intersected a new zone of high-grade copper mineralization in a drill hole located southeast of previous testsites in the lower part of the ore body. Analysis of the drill core indicated that 7.4% copper was contained over a 24-foot interval and 5.7% copper over a 41-foot interval. The upper zone of the deposit reportedly comprised 5 million tons of ore containing 2.5% copper and 0.1% cobalt. BHP-Utah International Inc. was a partner in the Sheep Creek property.

Montana Reserves Co., a privately held partnership, announced that it had signed an agreement to purchase a silver-copper property from United States Borax & Chemical Co. and two Canadian companies for a total of $94 million. The property was in the Cabinet Mountains of northwestern Montana, about 30 miles south of Asarco's Troy Mine. It was expected that the new owners would proceed with plans for developing the property, which called for production of about 10,000 tons of ore per day, yielding 6 million ounces of silver and 20,000 tons of copper per year.

The Sanchez copper oxide deposit, in the Lone Star mining district of Graham County, AZ, was under investigation for development by the Arizona Copper Co. (AZCO). The established reserves at the porphyry copper deposit totaled more than 227 million tons of copper oxide ore, with an average of 0.28% copper and 91 million tons of sulfide ore, with a grade that ranged between 0.37% to 0.50% copper. A stripping ratio of 1.78:1 indicated that a small open pit would be feasible. A block minable by open pit contained about 109 million tons of ore averaging 0.37% copper, including a central portion of 27 million tons averaging 0.50% copper and 67 million tons containing between 0.40% to 0.50% copper. Capital costs for development were estimated at $18 million for the SX–EW plant, $10 to $12 million for mining equipment and $4 million for support facilities and other capital costs. Mining plans centered about a 4.8-million-ton-per-year ore operation, with the potential for recovery of 16,000 tons of copper per year from leaching and an SX–EW plant. Production costs were estimated to be about 55 cents per pound of copper. Kennecott, Harpoon (United Nuclear Co.), and ICC had all held the property since the 1950's, doing extensive drilling and metallurgical testing.

Mine Environmental Issues

The Berkeley Pit was started in 1955 as an extension of the historic mining activity in Butte, MT. Over 500 million tons of earth was removed at the north end of Butte. In 1983, when mining ceased, the pit measured 7,000 feet long, 5,600 feet wide, and about 1,800 feet deep; it was filling with water. Water from the pit also drained into the mine shafts, covering the pumping stations that were no longer active. The water in the Berkeley Pit was rising about 71 feet per year, and by yearend 1988 was about 200 feet deep, polluted with various metals, and was of concern to EPA and local citizens. EPA had spent more than $5 million to investigate the mine flooding, which was not occurring uniformly. EPA officials speculated that the contaminated water eventually could flow over the pit's rim, resulting in contamination of the alluvial aquifer during the mid-1990's. The agency planned to spend at least 2 more years gathering data to determine the full extent of any potential or actual ground water pollution. An 18-month hydrological study was expected to start in early 1989. EPA planned to determine, among other things, at what level water will begin flowing out of the aquifer into Silver Bow Creek. Remedial options under consideration included installing a water treatment plant, releasing cleaned water into Silver Bow Creek, treating the water at Metro Sewer, or piping it to the active Continental East Pit area for use at Montana Resources concentrator.[12]

Smelter Production

Primary and secondary copper smelting capacity increased during the year, with increases noted at two primary and two secondary smelters. Eight primary smelters operated during the year with a capacity of 1.3 million tons of copper in blister or anode. Five secondary smelters operated with a combined capacity of 359,000 tons of copper anode. Total U.S. smelting capacity was 1.7 million tons, a slight increase over that of 1987.

Asarco announced plans to provide all of the feed required for its copper smelters from its own mines compared with less than 25% in 1985. Asarco planned to install a modern smelting process at the El Paso reverberatory copper smelter and construction of a holding furnace at its Hayden flash copper smelter to improve the operating rate. Under normal operating conditions and allowing for normal downtime for repairs and maintenance, which are determined by the company, smelter capacities, in tons per year of blister, were as follows: El Paso, 104,000 tons; Hayden, 168,000 tons; and Hayden-Ray, 100,000 tons.

Of the seven smelters in Arizona in 1988, only three were operated. All operating smelters were in compliance with regulatory requirements. The Ray smelter that Asarco acquired from Kennecott met all significant environmental constraints when last operated in 1982 and was available if needed, but Phelps Dodge's closed smelters at Ajo, Douglas, and Morenci would have required extensive retrofitting before they could be operated. As an alternative to smelting, Cyprus Casa Grande had reactivated the roast-leach-electrowinning (RLE) plant built by Hecla Mining Co. at the Lakeshore property. In this process, sulfide-bearing concentrates were roasted to make them soluble for vat-leaching with sulfuric acid; cathode copper was then produced at the company's SX-EW plant. Acid was produced from the roaster gases, and thus, the process was essentially pollution-free. A portion of Sierrita concentrates was to be processed at this plant.

The Cyprus Miami smelter, purchased from ICC, had an input capacity of 408,000 tons of concentrates per year. As a result of its Miami acquisition, Cyprus expected to process about 50% of its concentrate production there. The company's Bagdad, Sierrita, and Twin Buttes Mines were expected to provide up to 318,000 tons per year of concentrates to the smelter. The remainder would be purchased or toll concentrates from other producers. In addition, the company also had toll smelting and refining contracts with two other custom smelters for the remainder of 1988. Cyprus concentrates were to be processed at the Magma smelter under contract through 1997.

The Copper Range White Pine smelter had two reverberatory furnaces, two converter furnaces, two refining furnaces, and an anode caster. Blister was cast continuously into 630-pound anodes for the refinery. Annual smelter capacity was about 64,000 tons per year of copper.

At BP Minerals Garfield smelter, a new pressure filtration plant received concentrate from the slurry pipeline from the new mill, eliminating the need for rail transport of the concentrate. The plant was part of the modernization project at the Bingham Canyon Mine.

Magma's Outokumpu flash furnace started up in late 1988. The furnace incorporated the latest Outokumpu technology and had a design input capacity of 2,700 tons per day of concentrates or 910,000 tons per year, making it the highest capacity smelting furnace in the world. The furnace was the first Outokumpu retrofit of an existing smelter. Construction had begun in October 1986 and smelting started in July 1988. Following numerous startup problems, tons of concentrate smelted increased from about 19,000 in July to 69,000 in November. Production in December dropped to about 35,000 tons, however, as a result of a temporary shutdown. On December 19, an explosion at the flash smelter resulted in the death of one worker and the declaration of a force majeure by Magma on receipts of raw materials and deliveries of refined copper. Prior to the smelter's problems, the company expected to produce 202,000 tons of copper in 1988, a 13% increase over that of 1987. The smelter never reached full capacity in 1988, largely because of flue dust buildup in the waste heat boiler. The retrofit applied to all areas of the Magma smelter, including the converter section, where the four operational converters were fitted with four Lurgi radial flow scrubbers to cool and clean the gas streams. Magma's use of the Lurgi scrubbing system was the first application in the copper industry.

Both furnace and converter slags were treated in an existing slag concentration circuit at the San Manuel Mine mill. Magma had practiced slag concentration for a number of years under the old configuration, with concentration costs being charged to the smelter. With the new furnace, copper content of the slag was high, running between 2% and 10%. Average slag grade to the mill was 2.4% copper. About 88% of the copper content in the reprocessed slag was recovered.

The strong sulfur dioxide gas streams from the converters and from the flash furnace were combined in a humidifying tower, passed through a cooling tower, and then processed through the acid plant. Blowdown from the gas-cooling tower was sent to mill tailings without concentration for neutralization and disposal, exempting the solution from regulatory control.

Primary feed for Magma's new San Manuel flash smelter was to come from the company's San Manuel and Pinto Valley Mines as well as from Cyprus. Some of the excess concentrates from the Bingham Canyon Mine were also processed there. Flux was from company-owned mines, principally the Camp Grant Mine. Nitrogen from the air separation plant was being used in place of secondary air to reduce possible combustion problems at the new flash furnace.

Phelps Dodge Mining smelted much of its own mine production at its smelters in Hidalgo and Chino, NM. According to its annual report, the company produced only 245,900 tons of blister, up from the 241,000 tons produced in 1987, but still down from the 325,200 tons produced in 1985 when the company's smelter at Douglas, AZ, was still operational.

Smelter Environmental Issues

Three Arizona smelters, Asarco's Hayden, Magma's San Manuel, and Cyprus' Miami, were all operating under Arizona regulations with respect to smelter emissions. All were required to complete fugitive gas surveys of the areas surrounding their operations under the Arizona rules.

RCRA compliance was a major concern, not only for current operations, but from the Superfund aspects that applied to many old operations. Arizona ground water regulations also continued to be of concern as the program for implementation progressed. By 1990, the Best Available Demonstrated Control Technology, affecting waste water, leaching operations, and tailings disposal had to be in place.

A wide range of solid waste treatment operations were in practice at U.S. smelters. Solid wastes identified by EPA as concerns for the future were acid plant blowdown, slag, refinery tankhouse slimes, leach liquor, furnace brick, and water treatment sludge. Recycling of dusts, sludges, and other materials through the smelter system was widely practiced, but could eventually result in the concentration of some elements in the process streams that could later cause a deterioration in anode quality. Each site handled waste treatment differently. For example, at one site, acid plant blowdown solids were thickened, filtered, and recycled to the smelter while the liquid was sent to leach dumps; at another site, solids were separated, air dried, and recycled to the smelter and the liquid sent through a treatment cycle. At a third site, acid plant blowdown was mixed with mill tailings and disposed of in a tailings pond.

Magma recycled solid waste within its facility. Slag from the flash furnace was cooled in slag pits, crushed, and then sent to the concentrator for recovery of the copper contained in it. Magma's acid plant blowdown disposal was unique in that after dust removal and electrostatic precipitation, the primary blowdown was combined with mill tailings and sent to the tailings pond. The acidic liquor was mixed with large volume alkaline tailings from the concentrator, resulting in its neutralization. The Lurgi scrubber effluent underflow was reprocessed through the concentrator to recapture copper values while the overflow was recycled through the scrubber. Magma petitioned EPA to exempt Lurgi scrubber effluent from RCRA, subtitle C regulation.

Asarco's Hayden smelter combined several process streams from the acid plant gas-cleaning treatment steps. The solids were removed from the blowdown liquor before sending the liquor to a water treatment unit, where it was heated and lime-neutralized. The blowdown solids were thickened, dried, and recycled to the smelter. When furnaces were relined, the used refractory brick was stockpiled for recycling to recover the valuable metal content. However, the concentration of minor elements in the smelting process increases when dusts and other process streams are recycled to the smelter. This could be a concern for the future; for example, since bismuth tends to concentrate in dusts, procedures may be necessary in the future for bleeding off the bismuth, since the refinery cannot process anode copper with a high bismuth content. Trace amounts of bismuth occur in Asarco's Mission Mine concentrate.

Asarco had received notices from the EPA that it and numerous other parties were potentially responsible for the correction of hazardous substance releases under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) at several areas. These included the company's former smelter (1984) and Commencement Bay sites in Tacoma, WA (1982) and the Ruston, WA (1988) area. Remedial action was being undertaken at several of the sites. At Tacoma, Asarco still owned what was considered to be a valuable industrial site with a deepwater dock. Even so, the smelter area was a Federal Superfund site under control of the EPA, which was overseeing the cleanup of arsenic and other chemicals in the area. The work might require as long as 5 years and millions of dollars.

The 572-foot, arsenic-contaminated smokestack at Asarco's closed Tacoma, WA, smelter, which had operated for nearly 70 years, was to be demolished. Asarco submitted a proposal in June to remove the stack and other buildings of its closed smelter to the EPA. Studies have traced arsenic emissions as far from the stack as British Columbia, Canada, while others reportedly have found areas of north Tacoma with arsenic levels 27 times higher than normal.[13] The smelter was in Ruston, a city bordering Tacoma and Puget Sound, where Asarco was the main employer until the smelter closed in 1985. The entire cleanup project was expected to cost millions. The cost of cleaning just the Puget Sound sediments adjacent to the property was estimated at about $30 million. About 80 acres of the property was seriously contaminated by hazardous materials. An adjacent 30 acres may undergo an environmental facelift to remove or cover up hazardous materials from the smelter. Since the stack contains high levels of arsenic, it must be removed in a way that would minimize the release of hazardous materials.

Asarco and two other copper producers were asked to pay cleanup bills in the State of Washington that reportedly could exceed $7 million. A suit filed by Louisiana-Pacific Corp. sought payment for removal of smelter slag said to be contaminating the timber company's log-sorting yard in Milton, WA, with arsenic and other toxic materials. Other copper company defendants reportedly named were Atlantic Richfield Co. (ARCO) and Kennecott. The suit was filed May 16 under the Superfund law, which allows companies facing cleanup orders to recover costs from the companies that produced the hazards.

Refinery Production

Refinery production exceeded that of 1987, in part owing to startup of new electrowinning capacity, which expanded by about 100,000 tons. Total U.S. refinery capacity at 8 primary electrolytic plants, 2 secondary electrolytic plants, 7 secondary fire-refining plants, and 11 electrowinning plants was 2.2 million tons of refined copper.

Asarco reported normal operating capacity for its refineries as follows: Amarillo, TX, 414,000 tons of refined copper per year and the Hayden-Ray SX-EW plant, 40,000 tons per year. Asarco's refined metal production was derived 30% from its own mines, 56% from custom refining, and 14% from toll refining.

The White Pine refinery, built in 1982, was designed to produce high-grade cathode at an annual rate of 65,000 tons per year. The refinery included an anode charging section, an electrolytic tankhouse, a cathode stripping section, an electrolyte purification section, and a fine casting section. The fine casting plant, however, remained idle in 1988. Copper and silver produced by Copper Range were sold under an exclusive contract with Philipp Bros. Inc. Copper products were shipped via the Escanaba & Lake Superior Railroad from a loading point in Ontonagon. White Pine was also serviced directly by Wisconsin Central Railroad.

Early in the year, Cox Creek Refining Co. began production from its copper refinery in Baltimore, MD. The 145,000-ton-per-year tankhouse utilized purchased anode as well as anode from purchased blister and No. 2 scrap cast from the company's own anode furnace. Most primary material was imported. Cox Creek reportedly had an agreement to produce 18,000 to 27,000 tons of refined metal per year for Mitsubishi of Japan from imported anode. Cox Creek produced copper rod from a combination of purchased cathode and cathode produced in its own tankhouse. About 250 workers were employed at the tankhouse and rod mill.

On September 17, Cox Creek declared a force majeure on receipts of raw materials for its anode casting operations after a molten copper spill at its anode furnace. Anode casting was renewed by November 7, and normal production levels were regained by December. Rod mill operations at the refinery were not affected by the spill.

The London Metal Exchange (LME) reinstated the KE brand of copper cathode as deliverable against LME Grade-A contracts. The reinstatement was made after Cox Creek made certain guarantees as to the quality of material produced at its refinery. The KE brand had originally been registered by Kennecott, the previous owner of the Baltimore refinery.

Cyprus purchased the ICC refinery in July 1988. The Miami refinery's annual production was projected to reach full capacity of 57,000 tons in 1989. The rod mill had a capacity of 123,000 tons per year. Cyprus planned to convert all of Miami's copper cathode production at the rod mill, as well as a portion of the production that was derived from Cyprus' other mines.

Cyprus announced it would acquire Warrenton Refining Co., a producer of copper ingot and wirebar from scrap. The refinery was in Truesdale, MO, with headquarters in New Canaan, CT, and was a subsidiary of Anschutz Corp. of Denver, CO., which acquired the company in 1982 from General Cable Co. Warrenton employed 70 people and operated a 300,000-square-foot, secondary fire-refining plant with two reverberatory furnaces. Its products were sold to brass mills, foundries, and hot-rolling mills. The company processed about 2,700 tons of copper scrap per month.

Magma's principal product was premium-quality continuous cast, 5/16-inch wire rod, shipped to customers in the wire and cable industry. Magma's San Manuel and MCR Products Co. (Chicago) rod plants utilized the Southwire casting system and the 12-strand Morgan nontwist rolling mill. Rod plant production capacity was 163,000 tons per year at San Manuel and 127,000 tons per year at MCR.

In addition to its large 195,000-ton-per-year electrolytic refinery at San Manuel, Magma operated three SX-EW plants at San Manuel (45,000 tons per year), Pinto Valley (6,800 tons per year), and the Miami in situ unit (6,000 tons per year). Production at the Pinto Valley unit was to be doubled as part of the tailings reprocessing project, to start production in May 1989.

Most of Phelps Dodge's refined production from its El Paso refinery and its SX-EW plants at the Chino, Morenci, and Tyrone Mines was cast into rod. Phelps Dodge was the largest domestic producer of copper rod, with continuous cast rod facilities in El Paso, TX, and Norwich, CT. Rod sales comprised about 50% of the company's primary copper sales in 1988; the remainder was sold as refined cathode. According to the company's annual report, refined copper production was 387,300 tons.

Phelps Dodge continued to expand its use of SX-EW technology. The Burro Chief copper plant at the Tyrone Mine in New Mexico had been expanded three times since 1984; the third expansion, completed in 1988, raised capacity to 50,000 tons per year. The new $55 million facility at Chino began production in the third quarter of 1988, but it was not expected to reach its peak capacity of 41,000 tons per year until 1989. The company planned to further expand the Morenci SX-EW plant to double its annual capacity to 91,000 tons by 1990. A $9 million modernization program was also underway at the El Paso refinery. SX-EW production was to continue at the Tyrone Mine for about 15 years beyond cessation of mining in the early 1990's.

Electrowon Copper Production

The Bureau of Mines revised its figures for electrowon copper production at U.S. mines and refineries for 1968–88. In 1968, U.S. electrowinning production was 10,123 tons, but by 1988, production had increased to 227,654 tons as companies moved to cut costs through what had become a low-cost alternative for producing copper from certain ores. Electrowinning capacity was estimated to be 300,000 tons in 1988 and was anticipated to increase to a peak of about 430,000 tons by 1995. Production costs were estimated to range from 20 to 45 cents per pound, depending upon whether or not any mining costs were ascribed to electrowinning operations. This compared with an average mining, milling, smelting, and refining cost of 53 cents per pound of refined copper extracted through the normal copper sulfide processing.

Electrowinning began in the United States at two mines in 1968, the Bluebird and Inspiration, and at a third, the Ray Mine, in 1969. Cyprus' Bagdad plant began in 1970, while other Arizona plants started later in the 1970's, including Anamax Co.'s Twin Buttes plant (1975), Cyprus' Johnson plant (1975), Hecla Mining Co.'s Casa Grande plant (1976), Duval Corp.'s Sierrita Clear-process plant (1979), and City Service Co.'s Miami plant (1978). Anaconda's Arbiter, MT, plant began in 1974 and Duval's Battle Mountain, CA, plant began copper production in 1979. In the 1980's, several new plants were commissoned: Magma's Pinto Valley plant (1981), Phelps Dodge's Burro Chief plant at the Tyrone Mine (1984), Magma's San Manuel oxide pad leach (1986) and in situ (1988) leach operations, Cyprus' Sierrita plant (1987), Phelps Dodge's Morenci plant (1987) and, most recently, Chino Mines' plant (1988) at the Santa Rita Mine in New Mexico. Although expansions and renovations continued at several of the operating electrowinning plants during the 1980's, some were shut permanently, including the Ranchers' Bluebird plant (1982), the Cyprus Johnson plant (1986), the Arbiter plant (1977), the Sierrita Clear-process plant (1982), and the Battle Mountain plant (1984). Kennecott's Ray Mine plant was renovated several times to improve the quality of its output. Shut down in 1982, the Ray plant was renovated and reactivated by Asarco after it purchased the plant in 1984. Duval's Clear-process plant at Sierrita, which produced a high-grade precipitate, was never economical to operate. A new SX-EW plant was constructed at the Sierrita Mine in 1987 to recover copper from heap-leached oxide ores.

TABLE 3

COPPER ELECTROWON AT U.S. MINES AND PLANTS[1]

(Metric tons, copper in cathode)

Year	Mine production	SX-EW plant, refined production[2]
1968	10,123	10,123
1969	21,863	12,980
1970	32,833	18,155
1971	32,700	17,852
1972	28,467	18,500
1973	37,068	22,037
1974	31,196	20,980
1975	36,416	28,042
1976	78,206	94,070
1977	103,652	125,134
1978	95,028	98,547
1979	97,248	100,132
1980	116,053	117,549
1981	159,029	161,086
1982	130,417	131,541
1983	101,936	101,936
1984	100,180	100,180
1985	90,438	90,463
1986	125,359	125,359
1987	161,131	161,287
1988	227,992	227,992

[1] Revised series.

[2] Only refinery-grade cathode production is indicated. Smelter-grade was reprocessed by fire- or electrolytic-refining and became a product of these plants.

Source: U.S. Bureau of Mines, July 1989.

Most SX-EW production was derived from leaching processes that were applied to oxide or soluble chalcocite dump, waste, or in situ ores. A notable exception was the Lakeshore or Casa Grande operation, which utilized a roast-leach process that was successful in processing concentrates from sulfide ore. Only when sulfide ore mining at the Lakeshore Mine became uneconomical did this operation close in 1984. However, the roast-leach process was renewed in 1988 after the plant was acquired by Cyprus, who planned to import sulfide concentrates from its other mines for use in the roast-leach process. In situ leaching was started in 1984 at the Lakeshore Mine and continued through 1988.

Mine and refinery electrowon production were reported separately for the 1968-88 period in the Bureau of Mines revised data. Some of the differences between production numbers recorded at the mine and those recorded for refinery-grade cathode can be accounted for by the purchase of sulfide-bearing concentrates in the 1970's for processing through the Lakeshore roaster. This resulted in a higher production at the refinery than at the mine level. This material was counted as copper in concentrates by the mine from which it was extracted, and therefore, it was not attributed to leaching at the mine level. Some plants also used purchased anode to make starter sheets during this period, creating another numerical disparity between mine and refinery products. In addition, some of the early U.S. electrowon production was smelter grade, requiring further refining. The rerefined production was attributed to fire-refining or electrolytic refining production at the refinery level. By 1977, however, the SX-EW process had been improved to the extent that most production resulted in a very high-quality cathode that could be used directly by wire rod plants. In addition to the mine-derived, domestic electrowinning production, a plant operated by AMAX Nickel Inc. in Braithewaite, LA, produced electrowon copper from imported copper matte from Botswana. This production, however, does not appear in the U.S. electrowon production statistics of the revised data table.

Copper Sulfate

Copper sulfate was produced from copper scrap, blister copper, copper precipitates, electrolytic refinery solutions, and spent electroplating solutions. Imports of copper sulfate reached record levels, increasing almost fivefold compared with imports in 1987 and accounting for 25% of domestic demand. Export data were not available. By yearend, Kocide Chemical Corp. was producing copper precipitates for use in copper sulfate production from its in situ copper

TABLE 4

COPPER SULFATE PRODUCERS IN THE UNITED STATES IN 1988

Company	Plant location
CP Chemicals Inc.	Sewaren, NJ, and Sumpter, SC.
Kocide Chemical Corp.	Casa Grande, AZ.
Madison Industries Inc.	Old Bridge, NJ.
Phelps Dodge Corp.	El Paso, TX.
Southern California Chemical Co.	Santa Fe Springs, CA, Union, IL, Garland, TX.
Tennessee Chemical Co.	Copperhill, TN.

leach program at the Van Dyke Mine in Miami, AZ. Data supplied by domestic producers for 1988 indicated that 64% of their shipments went for agricultural uses, 24% for industrial uses including wood preservatives, and 12% for water treatment. In agriculture, copper sulfate was principally used as a fungicide for treatment of citrus and vegetable crops.

CONSUMPTION

The upward trend in apparent consumption of copper that began in 1983 continued in 1988. However, consumption in 1988 was about the same as in 1981, the year prior to the 1982 recession. Domestic demand was increasingly met by domestic production, which rose by about 20% and was equivalent to 87% of domestic consumption. Nearly all of the remaining demand was met by imports of refined copper.

Refined copper and copper-base scrap were consumed directly in the manufacture of semifabricated metal shapes and copper chemicals at approximately 20 domestic wire-rod mills, 40 brass mills, and more than 1,000 foundries, chemical plants, and miscellaneous consumers. According to Bureau of Mines estimates, 69% of the copper was used in electrical wiring and devices. Copper used for electrical applications in all the end-use categories, except ordnance, was included under electrical applications. As shown in table 5, electrical uses of copper have accounted for an increasing market share over the past 20 years. Growth in demand for consumer and business electronics and building wire has contributed to growth in domestic copper demand. U.S. demand in other markets has remained stable or declined owing to materials substitution in plumbing, automotive radiators, coinage, etc. and increased imports of copper-containing manufactured goods such as automobiles, machinery, and air conditioning units. The growth in electrical demand has occurred despite the substitution of aluminum in overhead power transmission lines, the development of microwave, digital and fiber optic technologies for telecommunications, and the downsizing of motors and switch gear.

According to the Copper Development Association (CDA) estimates based on the gross weight of domestic mill shipments and net imports of mill products, domestic consumption by sector of copper and copper alloy products in 1988 was construction, 41%; electrical and electronic products, 22%; industrial machinery, 14%; transportation equipment, 13%; and consumer and general products, 10%. Electrical uses of copper were included in the estimates of end-use markets. According to CDA, total shipments were about the same level as in 1987, with declines in the construction industry being balanced by increases in other sectors. In construction, estimates of a decline in building wire and plumbing and heating applications correlated with an 8% decline in housing starts. Industry reports during the first half of the year indicated slack demand and excess building wire inventories in addition to price-driven substitution of plastics in the water tube market. According to CDA estimates for transportation uses of copper, a decline in automotive nonelectrical uses was overshadowed by a 9% increase in electrical uses. Since the Federal Reserve Board Index for automotive production increased by 5% in 1988, the rising copper shipments to this sector showed that the substitution of aluminum for copper in radiators was offset by increasing intensity of copper use for automotive electronics.

In response to increasing demand for thin-walled copper tubing, principally for air conditioning and refrigeration, Cerro Copper Products announced a further expansion of its Shelbina, MO, plant, to begin after the completion of its current expansion project. When completed, Cerro will have tripled its drawing capacity. Similarly, following a $15 million investment in its beryllium copper strip plant in Pennsylvania, NGK Metals Corp. announced its intention to invest another $15 million to expand its production of rod, bar, and plate. Beryllium copper offers superior heat resistance, conductivity, and durability to the traditional phosphor bronze and was finding increasing use in small electronic components and welding tips for welding robots in the automotive industry. Olin Specialty Metals Corp., a division of Olin Brass, East Alton, IL, announced its intent to produce beryllium copper strip beginning in 1989, making it the third domestic producer. Olin had already expanded its flat-rolled product capacity by 30% by acquiring Bridgeport Brass in September.

Domestic production and consumption of brass and bronze ingot declined markedly between the late 1960's and early 1980's owing to the substitution of aluminum and plastics for brass and bronze castings, increased import penetration, and the imposition of pollution

TABLE 5

APPARENT CONSUMPTION OF COPPER, BY END-USE SECTOR[1]

(Quantities in thousand metric tons of copper and percent of consumption)

Year	Electrical[2]		Construction		Machinery		Transportation		Ordnance		Other uses		Apparent consumption (quantity)
	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	
1960	755	52	261	18	203	14	102	7	29	2	102	7	1,452
1961	728	48	303	20	228	15	106	7	30	2	121	8	1,517
1962	820	50	328	20	246	15	115	7	33	2	98	6	1,640
1963	822	48	377	22	274	16	120	7	34	2	86	5	1,712
1964	870	49	409	23	231	13	124	7	36	2	107	6	1,776
1965	1,031	52	416	21	238	12	139	7	40	2	119	6	1,982
1966	1,064	48	465	21	266	12	177	8	155	7	89	4	2,216
1967	918	50	367	20	220	12	129	7	147	8	55	3	1,836
1968	974	51	382	20	210	11	134	7	134	7	76	4	1,909
1969	1,009	49	432	21	247	12	144	7	144	7	82	4	2,058
1970	1,000	55	346	19	182	10	127	7	91	5	73	4	1,819
1971	1,038	55	377	20	189	10	132	7	57	3	94	5	1,886
1972	1,264	59	386	18	193	9	129	6	64	3	107	5	2,142
1973	1,378	62	378	17	178	8	133	6	44	2	111	5	2,223
1974	1,287	60	365	17	214	10	129	6	43	2	107	5	2,145
1975	914	62	236	16	118	8	88	6	44	3	74	5	1,473
1976	1,154	60	327	17	154	8	154	8	19	1	115	6	1,924
1977	1,242	60	373	18	186	9	145	7	21	1	103	5	2,070
1978	1,422	60	427	18	190	8	166	7	47	2	118	5	2,370
1979	1,412	58	463	19	219	9	170	7	24	1	146	6	2,434
1980	1,438	66	327	15	174	8	109	5	22	1	109	5	2,179
1981	1,590	70	273	12	159	7	136	6	23	1	91	4	2,271
1982	1,251	71	229	13	123	7	70	4	18	1	70	4	1,762
1983	1,368	68	322	16	161	8	80	4	20	1	60	3	2,012
1984	1,397	66	359	17	148	7	106	5	21	1	85	4	2,116
1985	1,480	69	343	16	150	7	86	4	21	1	64	3	2,144
1986	1,410	66	384	18	150	7	107	5	21	1	64	3	2,136
1987	1,494	68	395	18	132	6	88	4	22	1	66	3	2,197
1988	1,550	70	376	17	133	6	67	3	22	1	66	3	2,214

[1] Data are revised from previous data published in various issues of Mineral Facts and Problems, U.S. Bureau of Mines. Copper Development Association (CDA) categories have been redistributed on a copper content basis (the alloy component has been subtracted). The electrical component has been extracted from all end-use categories except electrical and ordnance. Adjustments were also made for the new scrap component, which was subtracted. Ordnance data reflect U.S. Department of Commerce ACM military shipments to 1983; estimated data, thereafter, reflect June 1988 CDA data for 1980-86.

[2] Includes wire and other forms used in electrical, communications, and other special uses.

control regulations on ingot makers and foundries. Over that time period, domestic production of alloy ingot fell by 40%, and more than one-half of the approximately 40 ingot makers were closed. The foundry industry underwent a similar contraction, with alloy ingot consumption falling by a commensurate amount. However, over the past 5 years, production and consumption of alloy ingot have stabilized at about 180,000 tons per year.

PRICES AND STOCKS

Prices fell sharply in January, declining by more than 35 cents per pound, following a price rise at yearend 1987 when the domestic producer price for copper reached $1.51 per pound and industry stocks of refined copper dropped to their lowest level since the end of the Korean war. The price drop was viewed as a "correction" in the market following an apparent end-of-the-year scramble by consumers, and perhaps speculators, to secure supplies for the first quarter of 1988. The price decline coincided with a slight increase in industry stocks and with reports that consumers had secured adequate supplies for the first quarter and that manufacturers of building wire were overstocked and cutting back on production. However, in February and March, prices fluctuated with spot prices on COMEX ranging from $ 0.93 to $1.14 per pound, indicating the delicate balance between supply and demand. Total industry stocks, which were at their 1988 peak in March, represented less than a 3-week supply at the prevailing rate of consumption. By April, prices had stabilized, with monthly producer prices from April through August averaging $1.065 per pound.

After the summer slowdown in August, supplies began to tighten, stocks fell from their already low levels, and prices soared. The COMEX spot price reached a record high of $1.63 per pound on December 8. Domestic industry stocks at the end of October were 83,000 tons, equivalent to about a 10-day supply, and inventories held in COMEX warehouses were 5,000 tons. Stocks held in LME warehouses, which had risen by 47,000 tons during the first three quarters of the year, fell by 35,000 tons during the fourth quarter. Yearend prices were pushed up by several international events, including strikes in Papua New Guinea and Peru, a fire at the Nkana acid plant in Zambia, and announced plans for temporary smelter shutdowns early in 1989 in the United States and Chile. Changes in the ratio of supply to apparent consumption, shown in figure 1, indicate that copper availability reached a minimum in October, coinciding with the upturn in prices.

Pricing on COMEX remained in backwardation throughout the year, with forward sales contracts selling at a discount to spot purchases. The discount on contracts trading 3 months forward, which began the year at 55 cents per pound, generally narrowed as prices fell. The discount reached a minimum of only 6 cents per pound during August, when prices fell to the lowest level of the year. However, as spot prices increased again in the latter part of the year, the discount on 3-month forward contracts increased, reaching 45 cents per pound at the peak spot price.

Domestic producers continued to maintain aggressive marketing schemes. All domestic producers retained COMEX-based pricing mechanisms, using average COMEX prices during the month of shipment plus a fixed premium. Alternative pricing mechanisms offered by producers included known pricing based on average COMEX prices for the month prior to shipment and unknown pricing based on the average for the month following shipment. Premiums for at least three of the domestic producers were freight-related and varied depending on the delivery point. Producer premiums, which were generally capped at 6 cents per pound in January, declined by midyear to about 4 cents, as COMEX prices softened. Warrenton Refining, the only domestic producer of fire-refined wirebar, set its wirebar premium about 6 cents per pound above prevailing cathode premiums. Premiums for copper rod averaged about 4.5 cents per pound over producer cathode prices.

On January 1, 1989, COMEX trading began on a new high-grade contract as well as on the existing standard-grade. The new contract, which began forward trading in July 1988, only accepted grade-1 electrolytic cathode and was intended to supplant the standard-grade contract by the end of 1989. However, by yearend, forward trading volume for the new contract remained low. The standard-grade contract accepted both grade-1 and grade-2 material, but charged a 1.5-cent-per-pound premium for grade-1 material.

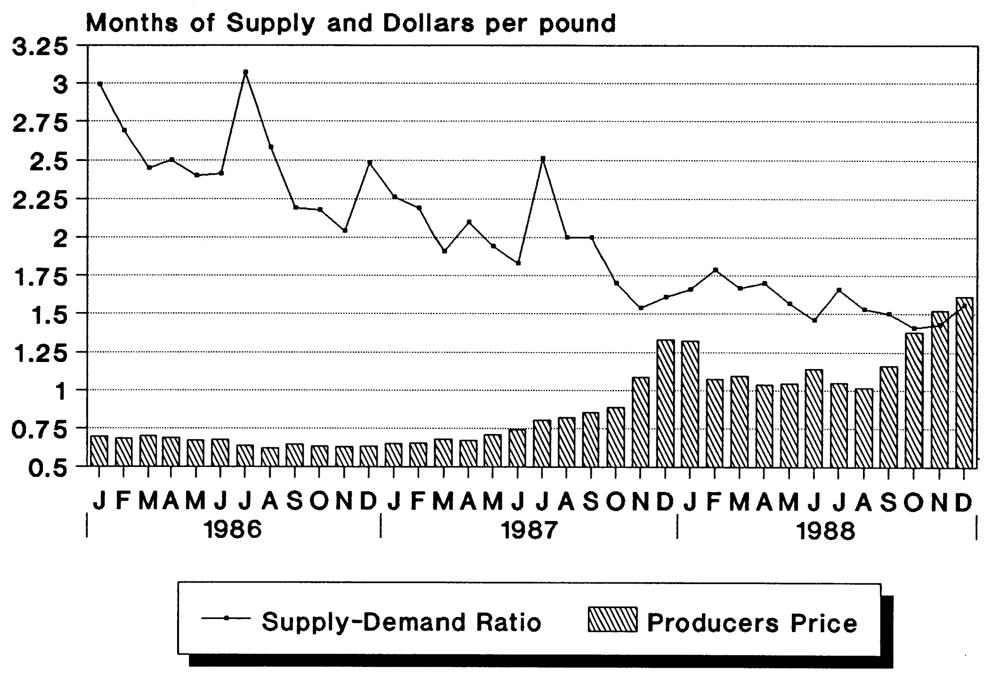
While refined copper supplies were generally tight throughout the year, high copper prices stimulated the collection of copper scrap. Consequently, the margin widened between the price of copper scrap, on a contained copper basis, and the price of refined copper as the price of refined copper rose. While the average producer price for refined copper rose about 60 cents per pound from August to December, the consumer buying price of No. 1 copper scrap rose only about 20 cents and the price for No. 2 scrap, a major feed source to the secondary smelting industry, rose only 18 cents. As a result, processing margins increased for secondary smelters and for brass mills, who adjust product prices to reflect the refined price of contained copper.

WORLD CAPACITY

Production capacity at copper mines, smelters and refineries increased during the year. Compared with that of 1987, world mine capacity increased by 4.4%, smelter capacity by 1.9%, and refinery

FIGURE 1

U.S. COPPER AVAILABILITY [1] AND PRICE



1 Copper supply(beginning stocks+primary refined production +net imports of refined copper+copper recovered from old scrap) divided by apparent consumption.

capacity by 4.6%. The most significant increase in copper mine capacity was in the United States, which experienced a 12% increase compared with that of 1987, owing to new electrowinning capacity as well as to increased activity at established mines. World capacity utilization during 1988, was 81% for mines, 77% for smelters, and 83% for refineries, owing to occasional production losses caused by labor strikes and accidents at some facilities in Canada, Papua New Guinea, Peru, United States, and Zambia.

	Production (thousand metric tons)	Capacity (thousand metric tons)	Capacity utilization (percent)
Mine:			
Centrally planned economy countries	1,669	1,831	91
Market economy countries	6,785	8,379	81
Total	**8,454**	**10,210**	**83**
Smelter:			
Centrally planned economy countries	1,834	2,294	80
Market economy countries	7,189	9,359	77
Total	**9,023**	**11,653**	**77**
Refinery:			
Centrally planned economy countries	2,115	2,325	91
Market economy countries	7,957	9,844	81
Total	**10,072**	**12,169**	**83**

Source: U.S. Bureau of Mines.

The data in table 6 are rated annual production capacity for mines, smelters, and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Capacity at mines generally represents the potential copper production contained in concentrates, but for some, such as those in the United States, it represents copper recoverable at the smelter level, based upon known recovery factors. SX–EW capacity is counted as smelter-level capacity only when the material must be rerefined. It is otherwise counted as mine and refinery capacity bypassing smelter-level production. Past and present production potential are taken into consideration when rating a mine or plant capacity, especially where an engineering estimation is not available. Generally, the rated capacity is based upon 360 days per year and 2 to 3 shifts per day. For new facilities, capacity is prorated for the year in which it started, but the full capacity is used for the year in which a facility closes. Mines and plants generally are not counted if they are not operating at any time during the year, except where it may be reasonably expected that a shutdown may be temporary, i.e., usually less than 2 years.

WORLD REVIEW

The world supply and demand for refined copper were in close balance throughout the year, with total estimated MEC stocks of refined copper changing only marginally throughout the year. However, stocks of refined copper were at, or near, the low level established during 1987, representing only about a 4-week supply. Consequently, prices were sensitive to even the relatively small changes in availability that occurred. Following the price surge and stock drawdown in late 1987, copper prices fell sharply in the first quarter of 1988. This coincided with a significant increase in consumer inventories. Despite an overall decline in inventories during the second and third quarters, prices remained at a lower level, while inventories shifted from industry to the more visible LME. With renewed drawdown of LME stocks and a surge in consumer buying during the fourth quarter, prices again rose rapidly, reaching record-high levels in December.

The anticipated large increase in world mine production from both new and expanded mines failed to materialize in 1988, and mine production in market economy countries remained at about the same level as in 1987. In Peru, labor strikes reduced production by more than 100,000 tons; Zambian production fell owing to shortages of sulfuric acid, skilled labor, and equipment; and Canadian production declined owing to closure or cutbacks at several mines due to depletion of ore reserves. Although production increased in Chile and was unchanged in Papua New Guinea, both fell short of expectations. However, several major new copper projects came into production as scheduled, including the Olympic Dam project in Australia in the second quarter and the Neves Corvo underground mine in Portugal in the fourth quarter. In Indonesia, Freeport-McMoRan completed the first stage of a mill-expansion program and development of a second underground mine. Perhaps the brightest spot was the United States, where production increased by 14% owing to numerous

TABLE 6

WORLD MINE, SMELTER AND REFINERY CAPACITIES IN 1988

(Thousand metric tons, primary and secondary copper)

Continent and country	Rated capacity: Mine	Smelter	Refinery
North America:			
Canada	929	629	610
Mexico	329	274	174
United States	1,690	1,691	2,202
Total	**2,948**	**2,594**	**2,986**
Central and South America:			
Brazil	53	160	195
Chile	1,580	1,304	1,208
Peru	457	362	252
Other[2]	9	7	6
Total	**2,099**	**1,833**	**1,661**
Europe:			
Albania	19	15	14
Austria	—	45	45
Belgium	—	172	495
Bulgaria	103	140	140
Czechoslovakia	11	25	30
Finland	21	100	70
France	([3])	17	47
German Democratic Republic	12	45	105
Germany, Federal Republic of	2	389	462
Italy	1	72	95
Norway	22	35	40
Poland	465	420	432
Romania	30	60	50
Spain	46	236	242
Sweden	94	110	107
Turkey	65	81	110
U.S.S.R.	750	980	1,040
United Kingdom	1	75	155
Yugoslavia	168	180	165
Other	9	27	29
Total	**1,819**	**3,224**	**3,873**
Of which:			
Centrally planned economies	1,390	1,689	1,825
Market economy countries	429	1,535	2,048
Africa:			
Botswana	25	22	—
Morocco	24	—	—
Namibia	45	60	—
South Africa, Republic of	196	256	163
Zaire	780	525	250
Zambia	637	464	625
Zimbabwe	22	35	33
Other[1]	2	2	3
Total	**1,731**	**1,364**	**1,074**
Asia:			
Burma	18	—	—
China	240	585	475
India	75	92	48
Indonesia	130	—	—
Iran	87	70	145
Japan	26	1,212	1,244
Korea, North	15	20	25
Korea, Republic of	3	185	175
Malaysia	30	—	—
Mongolia	180	—	—
Oman	20	22	20
Philippines	247	138	138
Taiwan	—	60	62
Other	4	—	—
Total	**1,075**	**2,384**	**2,332**
Of which:			
Centrally planned economies	435	605	500
Market economy countries	640	1,779	1,832
Oceania:			
Australia	288	254	243
Papua New Guinea	250	—	—
Total	**538**	**254**	**243**
World total	**10,210**	**11,653**	**12,169**
Of which:			
Centrally planned economies	1,831	2,294	2,325
Market economy countries	8,379	9,359	9,844

[1] Includes mine capacity of 1,000 tons for the Congo, a centrally planned economy.
[2] Includes mine capacity of 5,000 tons for Cuba, a centrally planned economy.
[3] Less than 1/2 unit.

expansions and a full year of operation at the Bingham Canyon Mine.

In centrally planned economy countries, estimated production increased by about 5%: production increased at the Sieroszowice Mine in Poland, at the expanded Dexing Mine in China, and at the Erdenet copper-molybdenum mine in Mongolia where a fifth-phase expansion project had begun in 1987.

Although mine production was stagnant in the market economy countries, consumption of refined copper increased by 3% according to data from the World Bureau of Metal Statistics. In Japan, brass and wire mill production reached record levels, and smelters and refiners increased production at yearend. In the Republic of Korea, consumption rose by an estimated 15%; the large Onsan copper and copper alloy fabrication complex was completed in 1987. In the United States, demand was buoyed by a lower exchange rate for the dollar. Exports of brass mill products increased by 45% according to the Copper and Brass Fabricators Council Inc.

Production of refined copper increased despite the stagnant mine production; stocks of blister and concentrate became depleted and production of secondary refined copper increased. Production increased at Norddeutsche Affinerie in the Federal Republic of Germany, Europe's largest smelter-refinery, and at Noranda Inc.'s Montreal East refinery in Canada. In the United States, increases in mine output, imports of blister, and recovery from scrap, led to a 21% increase in refined production. Production in Belgium and Japan fell owing to shortfalls of concentrates.

The tight world market for custom concentrates over the past several years, which led to low treatment and refining charges at custom smelters, continued through most of the year. Despite the high price for refined copper, according to estimates by the Commodity Research Unit Ltd. of London, United Kingdom, spot treatment and refining charges in Japan rose only slightly during the year; these averaged about 19 cents per pound of copper, up about 3 cents from 1987. However, at yearend, concentrate markets were easing. In the United States, property acquisitions were prompted by companies seeking to ensure an adequate supply of concentrates, and in Europe and Asia custom smelters continued to invest in mining properties. Outokumpu Oy of Finland was reported to be negotiating a barter trade agreement with Mongolia to supply equipment to modernize the concentrator at the Erdenet copper project in exchange for a long-term concentrate supply contract. Chile's Escondida project was being partially funded by Finnish, West German, and Japanese financial institutions in exchange for concentrate supply contracts for smelters in those countries.

International concern over acid rain was placing increased pressure on Canadian and Chilean smelters to control smelter emissions. Significant trade issues in 1988 included the longstanding dispute between the EC and Japan over Japanese tariffs on imports of refined copper. This dispute, first brought before GATT in 1982, came closer to resolution in December 1987, when both parties requested the Director General of the GATT Council to mediate the dispute. The EC contended that the high Japanese tariff harmed EC smelters by establishing a higher refined copper price in Japan and allowed Japanese smelters to dominate the concentrate market. As a first step in the resolution, the Director General appointed an independent investigator to establish the factual situation. Similar, but higher, tariffs were applied in the Republic of Korea and Taiwan. However, those two countries were moving toward elimination of the high tariffs. The tariff in Taiwan was reduced in stages from 17.5% to 6.5% over the 1987-88 period, and in the Republic of Korea, the tariff was being reduced from 20% to 10% over the 1988-89 period.

The average production cost for 112 of the world's producing copper mines, including smelter and refinery charges and recovery of capital, was estimated to be 56 cents per pound, when based on annual production rates and ore grades for 1988. When the same mines were evaluated using parameters based on life-of-mine production rates and ore grades, the production cost was slightly higher at 58 cents per pound. The life-of-the-mine methodology was the basis for all production cost estimates published in previous issues of the Minerals Yearbook. Results from both methodologies are presented in table 7.

Australia

Despite continued production declines at two of Australia's largest mines, Mount Isa in Queensland and Mount Lyell in Tasmania, and at the smaller Woodlawn Mine in New South Wales, copper mine production increased, reversing the downward trend of 1986 and 1987. Initial production was reported from Olympic Dam, South Australia; Horseshoe Lights, Western Australia; Selwyn, Queensland; and Telfer, Western Australia. The Warrego Mine, Northern Territory, which had closed in early 1987, was reactivated. Dewatering began at the Gecko Mine in preparation for production in 1989.

The large Olympic Dam copper-gold-silver-uranium project, owned by Western Mining Corp. Holdings Ltd. (51%) and BP Australia (49%) and operated by Roxby Mining Corp. Pty. Ltd., began ore production in June. The on site smelter and refinery started during the third quarter and were expected to produce 45,000 tons of refined copper per year at full capacity.

Initial production of byproduct copper was reported at several mines. At the polymetallic Horseshoe Lights Mine, operated by Barrack Mines Ltd., production of copper began early in the year and was expected to reach 17,000 tons of copper in concentrate per year.

At the Selwyn gold mine, a joint venture between Cyprus Minerals Australia Co., Arimco NL, and Elders Resources Ltd., production at yearend had reached the annual projected rate of 10,000 tons of copper in concentrate. At the Telfer gold mine, a joint venture between Newmont Holdings Pty. Ltd. (70%) and BHP Gold Mines Ltd. (30%), production began on a campaign basis late in the year.

The higher output of refined copper resulted primarily from increased production from Copper Refiners Pty. Ltd.'s Townsville refinery, where a secondary refinery was added to the existing primary refinery. Late in the year, CRA Ltd. agreed to sell 40% of its subsidiary, Electrolytic Refining and Smelting Co. of Australia Ltd., operator of the Port Kembla smelter and refinery, to a Japanese group led by Furukawa Co. Ltd. In conjunction with the sale, CRA announced plans to double the size of the smelter and refinery to 80,000 tons of refined copper per year. Included in the development, scheduled for completion in 1990, were a new flash smelter and an acid plant.

Canada

Several mines, with economic reserves, which were expected to be exhausted by 1988, continued to operate because of the high price for copper. Copper was produced at about 25 mines, mostly in Quebec, Ontario, Manitoba, and British Columbia. Several of the operations consisted of multiple mines within a single geologic formation, such as those of Falconbridge Ltd. and Inco Ltd. in the Sudbury Basin. Five smelters and four refineries operated during the year.

In Quebec, Minnova Inc. was completing development of its Ansil Mine, with startup scheduled for the first quarter of 1989. The mine was expected to produce 30,000 tons of copper in concentrate per year. Noranda announced plans to invest about $17 million to repair and reopen the Gaspé Mine early in 1989. The Gaspé Mine closed in April 1987 because of a fire. In Sudbury, Ontario, Inco announced plans to renovate its Clarabelle mill, at a cost of $60 million, and then close its Frood-Stobie mill. Falconbridge, which operated five underground mines and one open pit in the Sudbury Basin, closed the Falconbridge mill in February. The company planned to close the open pit and the East Mine in 1989. In British Columbia, exploration activities allowed Noranda to extend the lives of its Brenda and Bell Mines through 1990 and 1992, respectively. In January, Highland Valley Copper Co. (HVC), Canada's largest and lowest cost copper producer with operations in British Columbia, agreed to acquire the Highmont Mine and facilities. The Highmont mill, which HVC planned to move to the Lornex millsite by May 1989, was to replace the Bethlehem mill, scheduled for closure in mid-1989. At that time, HVC was expected to have a milling capacity of 130,000 tons of ore per day. In May, Cassiar Mining Corp. purchased the assets of Newmont's Similkameen operations. The new operating company, Similco Mines Ltd., expected the mine to have a life of 7 years.

During 1988, exploration activity flourished. A drilling program at Geddes Resources Ltd.'s Windy Craggy property in British Columbia outlined ore reserves in excess of 90 million tons grading between 2% and 3.5% copper. Exploration of the property, about 40 miles from a paved road, was expected to continue during 1989.

In response to an overall Canadian Government commitment to reduce sulfur dioxide emissions, Noranda began work on a $104 million acid plant at its Horne smelter, expected to be operational by yearend 1989, and planned to close its reverberatory furnaces early in 1989. Noranda also announced plans to invest $37.7 million to modernize its Montreal East refinery and to increase by 20,000 tons its annual capacity of 350,000 tons. Inco announced plans to spend $414 million to reduce emissions at its Sudbury smelter, including $57 million to improve mill circuits to increase rejection of pyrrhotite, and $357 million for new flash smelting furnaces and associated acid and oxygen plants. Hudson Bay Mining & Smelting Co. Ltd. was seeking Federal and Provincial Government loans to help finance a proposed $110 million program to modernize and reduce sulfur emissions at its Flin Flon, Manitoba, smelter.

Chile

The increase in mine output to a record-high level was accounted for by the small and medium-size mining sectors, with production by the state-owned Corporación Nacional del Cobre de Chile (CODELCO-Chile), the world's largest copper producer, increased only nominally to 1.1 million tons. Total production by CODELCO-Chile fell short of the production target of 1.17 million tons owing to a series of events, including rock bursts and lead contamination at the El Teniente Div. (the world's largest underground copper mine), rapidly declining ore grades at the El Salvador Div., a fire at the Andina Div., and arsenic contamination and startup problems at the new Outokumpu flash furnace at the Chuquicamata Div.. Sulfuric acid production from the new smelter was to relieve Chile's shortage of low-cost sulfuric acid and promote development of oxide-leach projects. Production declines of 11% and 4% were reported at El Salvador and El Teniente, respectively, while increases of 3.2% and 8.2% were reported at Chuquicamata and Andina, respectively.

Production by Empresa Nacional de Minería (ENAMI), the state-owned custom mineral processor, decreased by 4.5%, to 109,000 tons owing to lower ore grades and ore receipts. ENAMI served the small- and medium-size mining sectors with its four concentrators, two smelters, and refinery. Production declines were also reported by Anglo-American Corp., which operates the

Mantos Blancos Mine, and by Sociedad Minera Puduel, which operates the Lo Aquirre and the La Cascada mines. Cía. Disputada de las Condes S.A., owned by Exxon Minerals Corp., increased production 35% to 125,000 tons, owing to a major expansion of its El Soldado Mine in 1987. Byproduct copper production increased at Cía. Minera El Indio S.A., a gold producer, to about 30,000 tons, a 50% increase from 1987 production.

CODELCO-Chile announced a $1.25 billion, 5-year investment program for the 1988–92 period, which included capacity increases and cost reduction measures. The company projected production to reach 1.38 million tons in 1992. Expenditures in 1988 were reported to be $324 million, with 58% for Chuquicamata, 28% for El Teniente, and 5% each for Andina and El Salvador. Chuquicamata was expanding its mine, smelter, and concentrator to handle 153,000 tons of ore per day and was developing several heap-leach and in situ leach projects. The expansion was reported to be 6 months behind schedule owing to smelter startup problems and delays in the construction of its semiautogenous grinding mill. At El Salvador, underground expansions and continued development of an open pit in the Quebrada "M" ore body and associated oxide leach were planned. High-grade ore pockets, extracted during development of the new open pit, helped minimize the production decline at El Salvador. At Andina, the concentrator was being expanded to compensate for lower ore grades and improvements to infrastructure were being made. At El Teniente, the underground mine and the concentrator were being expanded to compensate for lower grade and harder ore, and the smelter was being retrofitted with additional El Teniente-type converters.

In July, Minera Escondida, 60% owned by The Broken Hill Pty. Co. Ltd. (BHP) of Australia, 30% by RTZ, and 10% by a Japanese consortium, announced the final go-ahead for its $1.1 billion La Escondida Mine, slated to begin production by mid-1991. The long-term production rate was projected at 320,000 tons of copper in concentrate per year. In March, a letter of intent was signed with Japanese, West German, and Finnish smelters for 12-year supply contracts, beginning in 1991, which will account for 72% of Escondida's projected concentrate output. In July, a $680 million financing package was announced, which included $350 million from the Export-Import Bank of Japan, $140 million from the Federal Republic of Germany, $47 million from Finland, and $70 million from the International Finance Corp. (IFC), for which the IFC will acquire a 2.5% equity share from BHP.

Phelps Dodge's Cía. Minera Ojos del Salado announced a potentially significant copper-gold discovery, the Geolar project, near its existing Copiapo mining operations in the Atacama Desert. About 65 million tons of proven and indicated ore reserves, with an average grade of 1.13% copper, had been delineated.

Indonesia

Freeport Indonesia Inc., 85% owned by Freeport-McMoRan of the United States, began production from a second underground mine, The Deep Ore Zone, at its Ertsberg copper-gold-silver operations in Irian Jaya. Freeport Indonesia also operated the Ertsberg East underground mine and the Ertsberg open pit, whose reserves were nearing depletion. Freeport Indonesia also completed an expansion of its mill capacity from 16,000 to 22,000 tons of ore per day and initiated a second stage expansion, which was expected to increase mill capacity to 32,000 tons per day by mid-1990.

Freeport Indonesia announced the discovery of a significant copper-gold ore body in the Grasberg area, 2.5 kilometers from the existing Ertsberg operations. As a result of new drilling at Grasberg during 1988, Freeport Indonesia increased its reserve estimates by 1.3 million tons to a total of 2.9 million tons of recoverable copper.

Mexico

The two state-controlled mining companies, Mexicana de Cobre S.A., which operated the La Caridad Mine, and Cía Minera de Cananea S.A., which operated the Cananea Mine, accounted for 98% of Mexico's copper production. Cananea, which had expanded its concentrator and leach facilities over the past several years, accounted for the increase in Mexican mine production. In March, the Government, as part of its program to reduce debt by selling nonstrategic assets, announced the solicitation of bids for sale of its 90% interest in Cananea and 95% interest in La Caridad. In November, the Government announced that it had accepted an offer from Fomente Industrial del Norte de México (Fidenome), a branch of Industrial Minera de México, for Mexicana de Cobre and its subsidiary, Mexicana de Acido Sulfúrico. The transaction involved swapping public-sector debt for debt backed by Mexicana de Cobre. Mexico's mineworkers union retained a 5% interest. An offer in April to buy Cananea by Grupo Protexa S.A., a mining, construction, and real estate company, for $900 million in Mexican foreign debt was abandoned when financing of the purchase could not be obtained.

Papua New Guinea

Mine production remained at about the same level as in 1987, falling short of the company's projected increase. Miners struck at Ok Tedi Mining Ltd. in August and September over housing allowances and job classification structure. As a result of the work stoppages, Ok Tedi ceased processing gold ores prematurely in September, hastening the projected yearend conversion from a gold- and copper-concentrate producer to a producer of copper concentrates having a high gold value. By yearend, Ok Tedi had completed the final stage of its development plan to raise ore processing capacity from 45,000 to 70,000 tons per day. The production rate at yearend was reported to be at about 250,000 tons of concentrate per year, about 65% of the target rate of 400,000 tons per year.

At Bougainville Copper Ltd.'s Panguna Mine, work stoppages were caused by sabotage from local landowners demanding compensation for the environmental effects of mining activity in the area and loss of their lands. This resulted in a decline in production of about 12,000 tons of copper contained in concentrate. During the year, Bougainville expanded its concentrator capacity; the preconcentration screening plant, installed during 1987, achieved design capacity, and an additional ball mill was installed. The new screening plant expanded economic reserves by 200 million tons of ore grading 0.34% copper, bringing the total reserve estimate to 710 million tons grading 0.4% copper.

Peru

The sharp decline in mine production in Peru was caused principally by mining industry strikes. A 30-day nationwide mineworkers' strike in July and August affected most copper operations and led to declarations of force majeure on copper shipments by state-owned Empresa Minera del Centro del Perú (Centromín Perú) and by state-owned Empresa Minera Especial Tintaya S.A. (Tintaya). A second strike, beginning mid-October and lasting for 54 days, was reportedly called because the Government failed to fulfill commitments reached in August. The nationwide agreement reached in August between the Government and the National Federation of Miners was a precedent for Peru; previously wages and working conditions had been negotiated locally. In addition to the nationwide strikes, a strike in January temporarily closed three of Centromín Perú's largest mines, including the Cobriza Mine; there was a second strike at the end of June at Cobriza and a 6-day strike at Southern Peru Copper Corp.'s Toquepala Mine.

The national mining strikes were reported to be symptomatic of national discontent with an economy with a mounting national debt and nearing collapse. Mine production was hampered by a lack of foreign exchange for capital purchases. At Tintaya, concentrate shipments were delayed because of a shortage of trucks to transport the concentrate to the railhead and to transport ore to the concentrator. The other state-owned copper producers, Centromín Perú and Empresa Minera del Perú, also were reported to be facing a shortage of equipment and spare parts, which reduced production from that of 1987.

Philippines

A production increase by Atlas Consolidated Mining Development Corp. balanced declines by other producers. At its Toledo Mine on Cebu Island, Atlas completed installation of a belt conveyor for ore from its high-grade underground section and was developing underground operations to the south, where reserves of 78 million tons had been delineated. A second open pit was being planned to offset nearly depleted reserves at the Toledo Mine.

After sustaining heavy losses since 1984, Marcopper Mining Corp., the Philippines third largest copper producer, returned to profitability during the first quarter of the year. Marcopper's Taipan Mine and mill at Santa Cruz, Marinduque Island, was closed for about a month following a Government order to develop a new disposal system for tailings being discharged into Calancan Bay. The new system was to deposit tailings further out to sea. Following resumption of mining at Taipan, Marcopper announced plans to restart development at its San Antonio ore body, curtailed since 1983. With reserves estimated at 200 million tons of ore grading 0.475% copper, it was expected that production from San Antonio would replace that from Taipan when the latter's reserves are exhausted in 1989.

Far South East Gold Resources Inc., a joint venture formed in July between Lepanto Consolidated Mining Co. (60%) of the Philippines, Galactic Resources of Canada (30%), and the IFC (10%), announced plans to develop the Far South East porphyry copper-gold deposit in Benguet Province. Reserves were estimated at 163 million tons of ore grading 0.81% copper. It was projected that development of the 32,000-ton-per-year mine could take 5 years.

The Philippine Associated Smelting and Refining Corp. was proceeding with the planned expansion of its 138,000-ton-per-year smelter and refinery on Leyte. The 25% expansion was projected to cost $51 million.

Zaire

Copper production in Zaire was from the state-owned company, La Générale des Carrières et des Mines du Zaire (Gécamines), which operated about a dozen mines in three geographic provinces. Gécamines was proceeding with a 5-year, $870 million investment program, which began in 1985, to rehabilitate its copper mining industry, including development of an electrolytic refinery. The refinery was projected to come on-stream by 1991 with an initial capacity of 40,000 tons of cathode per year and an ultimate design capacity of 100,000 tons per year. Gécamines was also proceeding with an exploration program in the southern region of the copper belt.

Zambia

Copper mine production by the state-owned Zambian Consolidated Copper Mines Ltd. (ZCCM) fell far short of the projected 508,000 tons envisioned when ZCCM began a 5-year plan in 1984 to streamline and rationalize its production. The decline in production was caused by several factors: low equipment availability owing to insufficient spare parts; insufficient skilled labor and an exodus of engineering staff; unreliable transportation; and a shortage of sulfuric acid for expanded leach operations. The sulfuric acid shortfall was aggravated by a fire at midyear at the Nkana smelter acid plant.

ZCCM set aside $9.1 million for worker training, a sixteenfold increase over that originally budgeted for that purpose. ZCCM's labor shortage was attributed to an exodus of expatriates and to a recruitment problem.

At the Nchanga Div., the largest of ZCCM's four operating divisions, refined production fell at the high-grade leach plant owing to the poor condition of a drum filter. At Mufulira, the Lufubu shaft extension project began processing ore in April, and development of the Mufulira West extension continued. Recovery of copper from the tailings leach plant was lower than projected owing to a lower than expected content of acid-soluble copper. At the Nkana Div., production was hindered by hoist breakdowns, an explosives shortage, and by closure of the Mindola north shaft area in February and March as a precaution against flooding.

TABLE 7

ESTIMATED PRODUCTION COSTS AT PRODUCING COPPER MINES

(January 1988 U.S. dollars per pound of refined copper)

	Number of mines	Mine operating cost	Mill operating cost[1]	Smelter refinery cost[2]	(Less) byproduct credit	Net operating cost	Taxes[3]	Cash costs	Recovery of capital[4]	Total production cost[3 5]
Average annual production costs:[6]										
Australia	4	$0.33	$0.14	$0.16	$0.23	$0.39	$0.00	$0.39	$0.07	$0.47
Canada[7]	18	.47	.30	.52	.92	.36	.00	.37	.18	.54
Chile	7	.15	.16	.09	.05	.34	.00	.34	.05	.39
Peru	5	.21	.30	.33	.07	.76	.02	.79	.14	.92
Philippines	7	.28	.37	.24	.49	.39	.04	.43	.10	.53
United States	18	.18	.28	.17	.10	.52	.01	.53	.07	.61
Zaire	4	.27	.14	.29	.25	.45	.01	.46	.03	.48
Zambia	9	.32	.26	.25	.08	.76	.08	.84	.06	.89
Other	40	.35	.36	.28	.42	.57	.01	.59	.15	.74
Total[5] or average	**112**	**.26**	**.25**	**.24**	**.27**	**.47**	**.01**	**.48**	**.09**	**.57**
Life-of-the-mine production costs:[8]										
Australia	4	$0.47	$0.22	$0.19	$0.44	$0.44	$0.00	$0.44	$0.07	$0.51
Canada[7]	18	.61	.31	.68	1.23	.37	.00	.37	.18	.55
Chile	7	.18	.21	.09	.05	.42	.00	.43	.05	.48
Peru	5	.19	.30	.36	.22	.63	.01	.64	.15	.80
Philippines	7	.24	.31	.24	.28	.52	.03	.55	.10	.65
United States	18	.16	.26	.17	.09	.50	.01	.50	.07	.57
Zaire	4	.29	.15	.25	.19	.51	.01	.52	.03	.54
Zambia	9	.35	.26	.25	.08	.77	.08	.85	.06	.91
Other	40	.28	.34	.28	.34	.56	.02	.58	.16	.74
Total[5] or average	**112**	**.25**	**.26**	**.21**	**.23**	**.50**	**.01**	**.51**	**.09**	**.60**

[1] Includes copper recovery by leaching.
[2] Includes cost of transportation and cost of byproduct and coproduct smelting.
[3] Taxes and production costs are at a zero percent rate of return and do not include State or Federal revenue based taxes.
[4] Average over life-of-the-mine capital cost.
[5] Data may not add to totals shown because of independent rounding.
[6] Based on annual production rates and ore grades for 1988.
[7] Includes Inco Ltd.'s and Falconbridge Ltd.'s Sudbury nickel-copper operations.
[8] Based on life-of-the-mine production rates and ore grades. Does not necessarily reflect 1988 operating grade and production.

Source: U.S. Bureau of Mines, Minerals Availability System (MAS) cost analysis. Prepared by Kenneth Porter.

TECHNOLOGY

The Office of Technology Assessment issued a comprehensive report on the technology and competitiveness of the U.S. copper industry. The report concluded that the revitalized U.S. copper industry could compete in all but the worst foreseeable markets. It concluded that the industry's turnaround came entirely from its own efforts with little Federal Government assistance. Although smaller, the industry was still a world leader in smelter and refinery production, ranking second in mine production. According to the report, the application of modern technology and productivity improvement measures had positioned the U.S. industry to weather all but the most adverse conditions. The report also analyzed options available to the Federal Government and industry to enhance the industry's competitive position.[14]

The Bureau of Mines issued several open file reports on in situ copper mining, including a generic in situ copper mine design manual. The procedures described provided the U.S. mining industry with technology for designing environmentally sound, low cost, in situ leach mining operations from small, deep, and/or low-grade copper oxide deposits. During the course of its research, the Bureau developed several procedures for designing in situ operations. One was a systematic method for assessing the commercial feasibility of the deposit.[15]

In September, the Bureau of Mines and the Santa Cruz Joint Venture signed an agreement to conduct an in situ copper leach mining research project at the Santa Cruz deposit, 7 miles west of Casa Grande, AZ. The objective was to determine operating costs, projected copper production, engineering parameters, and environmental impact. The agreement covered the first phase of a projected five-phase project. Phase 1 was to include a hydrologic evaluation of the ore and environmental permit application preparation. The project was expected to cost about $19.5 million.

Pilot test results of the three-in-one smelter under development in the United Kingdom were reported as encouraging. Designed to handle metallurgically complex ores that could not previously be smelted, the pilot unit was built by five major European companies, Billiton Research BV, BP Minerals, Metallurgie Hoboken-Overpelt S.A., RTZ Metals Ltd., and Simon Carves Ltd., in collaboration with the British Technology Group and the British Department of Trade and Industry. The EC was funding a second phase of the research for a further 2½ years.[16]

Engelhard Corp.'s new Silvabrite 100 lead-free solder gained listing by the International Association of Plumbers and Mechanical Officials (IAPMO), which published the Uniform Plumbing Code (UPC). IAPMO found the solder met all the ASTM standards and recommended it as an alternative to conventional lead-based solders. Silvabrite 100 was composed of tin, copper, and a small amount of silver. The solder was developed because of the concern about lead leaching into potable water carried by copper tubing.[17]

The National Aeronautics and Space Administration issued a preliminary report evaluating tungsten fiber-reinforced copper matrix composites as a liner material for combustion chamber walls in advanced rocket engines. The report indicated that the composite material exhibited a 90% increase in strength with only a loss of 5% in thermal conductivity compared with the liner in use.[18]

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[1] Physical scientists, Division of Nonferrous Metals.

[2] All quantities in this chapter are given in metric tons unless otherwise specified.

[3] Metals Week. Government. Dec. 26, 1988, p. 8.

[4] Arizona Geology. Revenues From State Trust Lands. V. 19, No. 1, spring 1989, pp. 6–7.

[5] Metals Week. Government. Mar. 20, 1989, p. 3.

[6] ASARCO Incorporated. 1988 Annual Report. 36 pp.

[7] Pages 29–30 of work cited in footnote 6.

[8] Skillings' Mining Review. Copper Range Co. To Again Exceed 50,000 Ton Copper Production Mark in 1989 at White Pine Mine in Michigan in the Fourth Year Since Reopening. Jan. 21, 1989, pp. 1–7.

[9] Cyprus Minerals Co. Press release. Englewood, CO, May 11, 1989, p. 1.

[10] Leaching Technology Inc. and Union Carbide Industrial Gas Products. Progress Report on In Situ Solution Mining of a New Mexico Chalcocite Deposit. May 1989, 15 pp.

[11] Phelps Dodge Corp. 1988 Annual Report. 33 pp.

[12] The Wallace (Idaho) Miner. Montana Abandoned Pit an Ecological Disaster. Dec. 15, 1988, p. 3.

[13] Wenatchee (Washington) World. Polluting Smokestack Finally Will Come Down. June 23, 1988, p. 4.

[14] Office of Technology Assessment. Copper, Technology & Competitiveness. U.S. Congress, Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, 1988, 272 pp.

[15] Davidson, D. H., R. E. Weeks, and J. F. Edwards. Generic In Situ Copper Mine Design Manuel. Vols. I, II, III, IV, and V, OFR 4(1)–89, OFR 4(2)89, OFR 4(3)–89, OFR 4(4)–89, and OFR 4(5)–89; available from National Technical Information Service, U.S. Dept. of Commerce, Springfield, VA 22161, 1988.

[16] The Miner Newspaper. Three-In-One Smelter. Mar. 1988, p. 26.

[17] American Metal Market. New Lead-Free Solder Gets OK for Listing by Plumbers. V. 95, No. 177, Sept. 11, 1987. p. 5.

[18] Westfall, L. J., and D. W. Petrasek. Fabrication and Preliminary Evaluation of Tungsten Fiber Reinforced Copper. Lewis Research Center, Cleveland, OH, NASA Tech. Memo. 100845, May 1988, 19 pp.

TABLE 8

PERCENTAGE OF COPPER ORE AND RECOVERABLE COPPER EXTRACTED FROM OPEN PIT AND UNDERGROUND MINES IN THE UNITED STATES

Year	Open pit		Underground	
	Ore	Copper[1]	Ore	Copper[2]
1984	92	87	8	13
1985	88	89	12	11
1986	87	86	13	14
1987	88	84	12	16
1988	93	88	7	12

[1] Includes copper from dump leaching.
[2] Includes copper from dump, waste, and tailings leached; also as a byproduct from other sources.

TABLE 9

MINE PRODUCTION OF RECOVERABLE COPPER IN THE UNITED STATES, BY MONTH AND BY STATE

(Metric tons)

	1984	1985[r]	1986[r]	1987[r]	1988
Month:					
January	92,971	92,696	98,725	101,357	113,288
February	87,863	87,087	86,953	91,928	102,605
March	96,124	100,168	96,343	105,707	121,081
April	91,250	93,639	93,840	97,753	111,958
May	95,045	96,832	97,117	104,130	120,580
June	98,000	90,223	95,879	101,722	115,936
July	88,235	90,711	94,777	104,221	116,242
August	89,032	87,444	94,418	107,272	128,286
September	88,074	81,896	97,201	105,403	120,145
October	94,382	94,218	99,969	104,807	123,761
November	92,507	91,384	92,253	108,674	121,082
December	89,130	98,525	96,738	110,664	124,681
Total	**1,102,613**	**1,104,823**	**1,144,213**	**1,243,638**	**1,419,645**
State:					
Arizona	746,453	795,622	786,111	751,073	845,445
California	W	W	W	—	W
Colorado	W	W	W	W	898
Idaho	3,701	3,551	W	W	2,269
Illinois	—	W	W	W	W
Michigan	—	W	W	W	W
Missouri	5,818	13,410	W	W	W
Montana	W	15,092	W	W	W
Nevada	W	W	W	—	W
New Mexico	W	W	W	246,532	258,660
Total[1]	**1,102,613**	**1,104,823**	**1,144,213**	**1,243,638**	**1,419,645**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes Tennessee, Utah, and data indicated by symbol W; 1987 also includes Washington.

TABLE 10

TWENTY-FIVE LEADING COPPER-PRODUCING MINES IN THE UNITED STATES IN 1988, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of copper
1	Morenci	Greenlee, AZ	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated and leached.
2	Bingham Canyon	Salt Lake, UT	BP Minerals America.	Do.
3	Tyrone	Grant, NM	Phelps Dodge Corp. and Burro Chief Copper Co.	Copper ore, concentrated and leached.
4	Chino	do.	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated and leached.
5	San Manuel	Pinal, AZ	Magma Copper Co.	Do.
6	Ray	do.	ASARCO Incorporated	Copper ore, concentrated and leached.
7	Bagdad	Yavapai, AZ	Cyprus Bagdad Copper Co.	Copper-molybdenum ore, concentrated and leached.
8	Sierrita	Pima, AZ	Cyprus Sierrita Corp.	Do.
9	Pinto Valley	Gila, AZ	Pinto Valley Copper Corp.	Do.
10	Mission Complex	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
11	Continental	Silver Bow, MT	Montana Resources Inc.	Copper-molybdenum ore, concentrated and leached.
12	Inspiration	Gila, AZ	Cyprus Miami Mining Corp.	Copper-molybdenum ore, leached.
13	White Pine	Ontonagon, MI	Copper Range Co.	Copper ore, concentrated.
14	Troy	Lincoln, MT	ASARCO Incorporated	Silver-copper ore, concentrated.
15	Casteel	Iron, MO	The Doe Run Co.	Lead-copper ore, concen trated.
16	Pinos Altos	Grant, NM	Cyprus Pinos Altos Corp.	Copper ore, concentrated.
17	Ox-Hide	Gila, AZ	Cyprus Miami Mining Corp.	Copper ore, leached.
18	San Xavier	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
19	Miami	Gila, AZ	Pinto Valley Copper Corp.	Copper ore, leached.
20	Silver Bell	Pima, AZ	ASARCO Incorporated	Do.
21	Magmont	Iron, MO	Cominco American Incorporated	Lead ore, concentrated.
22	Mineral Park	Mohave, AZ	Cyprus Minerals Co.	Copper ore, leached.
23	Buick	Iron, MO	The Doe Run Co.	Lead ore, concentrated.
24	Lakeshore	Pinal, AZ	Cyprus Casa Grande Corp.	Copper ore, leached.
25	Fletcher	Reynolds, MO	The Doe Run Co.	Lead ore, concentrated.

TABLE 11

MINE PRODUCTION OF COPPER-BEARING ORES AND RECOVERABLE COPPER CONTENT OF ORES PRODUCED IN THE UNITED STATES, BY SOURCE AND TREATMENT PROCESS

(Metric tons)

Source and treatment process	1984		1985		1986		1987		1988	
	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper
Mined copper ore:										
Concentrated[1]	168,226,000	883,338	[r]164,029,000	[r]905,537	[r]170,020,000	[r]906,072	201,434,000	[r]991,857	222,207,000	1,113,965
Leached[2]	3,588,000	106,597	[r]1,161,000	98,453	[r]2,456,000	135,448	1,198,000	[r]162,365	1,308,000	228,049
Total	**171,814,000**	**989,935**	**[r]165,190,000**	**[r]1,003,990**	**[r]172,476,000**	**[r]1,041,520**	**202,632,000**	**[r]1,154,222**	**223,515,000**	**1,342,014**
Copper precipitates shipped; leached from tailings, dump, and in-place material	120,437	80,845	118,096	82,948	111,050	79,031	[r]110,511	[r]70,136	70,720	50,284
Miscellaneous:										
Silver ore	4,487,000	22,334	[r]1,004,000	3,745	[r]552,000	2,599	275,000	[r]1,194	464,000	2,098
Lead ore	4,748,000	5,818	6,433,000	13,410	3,336,000	7,405	W	4,463	5,357,000	8,176
Other copper-bearing ores[3]	22,821,000	3,681	[r]4,867,000	[r]729	[r]2,513,000	[r]13,659	[r]5,766,000	[r]13,622	4,864,000	17,073
Grand total[4]	**XX**	**1,102,613**	**XX**	**[r]1,104,823**	**XX**	**[r]1,144,213**	**XX**	**[r]1,243,638**	**XX**	**1,419,645**

[r]Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1] Includes the following methods of concentration: dual process (concentration followed by leaching) and froth flotation.
[2] At least 85% of leached ore processed by electrowinning. Actual figures are as follows: 1984—100,180; 1985—90,438; 1986—125,359 (revised); 1987—161,131(revised); and 1988—227,992 tons of electrowon copper (see table 3).
[3] Includes copper-lead ore, gold ore, gold-silver ore, lead-zinc ore, molybdenum ore, tungsten ore, zinc ore, fluorspar, flux ores, cleanup, ore shipped directly to smelters, and tailings.
[4] Data may not add to totals shown because of independent rounding.

TABLE 12

RECOVERABLE COPPER, GOLD, AND SILVER CONTENT OF CONCENTRATED COPPER ORE IN 1988

State	Ore concentrated (thousand metric tons)	Recoverable metal content				Value of gold and silver per metric ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Metric tons	Percent			
Arizona	138,374	644,921	0.47	60,117	4,765,636	$0.42
Other[1]	83,833	469,044	.56	303,196	10,696,980	2.42
Total or average	**222,207**	**1,113,965**	**.50**	**363,313**	**15,462,616**	**1.17**

[1] Includes Michigan, Montana, Nevada, New Mexico, and Utah.

TABLE 13

BLISTER AND ANODE COPPER PRODUCED IN THE UNITED STATES, BY SOURCE OF MATERIAL

(Metric tons)

Source	1984	1985	1986	1987	1988
Ores and concentrates:					
Domestic	989,924	939,257	[1]908,087	[1]972,141	[1]1,042,954
Foreign	24,200	1,424	W	W	W
Secondary materials	169,296	250,138	287,841	276,640	320,201
Total	**1,183,420**	**1,190,819**	**1,195,928**	**1,248,781**	**1,363,155**

W Withheld to avoid disclosing company proprietary data; included with "Domestic."
[1] Includes production from foreign ores and concentrates.

TABLE 15

COPPER PRODUCTION BY REFINERY SHAPE AT REFINERIES IN THE UNITED STATES

(Thousand metric tons)

	1987	1988
Billets	W	W
Cathodes	[r]1,412	1,738
Ingots and ingot bars	W	W
Wirebars	W	W
Other forms	130	119
Total	**[r]1,542**	**1,857**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other forms."

TABLE 14

PRIMARY AND SECONDARY COPPER PRODUCED BY REFINERIES AND ELECTROWINNING PLANTS IN THE UNITED STATES

(Metric tons)

	1984[r]	1985[r]	1986	1987[r]	1988
PRIMARY					
Electrolytic	1,033,116	[1]966,778	[1]948,623	[1]965,621	[1]1,178,028
Electrowon	100,180	90,463	[r]125,359	161,287	227,992
Fire refined	40,782	W	W	W	W
Total	**1,174,078**	**1,057,241**	**[r]1,073,982**	**1,126,908**	**1,406,020**
SECONDARY					
Electrolytic	161,203	264,834	292,686	311,312	347,442
Fire refined	145,334	106,953	113,258	103,426	103,736
Total	**306,537**	**371,787**	**405,944**	**414,738**	**451,178**
Grand total	**1,480,615**	**1,429,028**	**[r]1,479,926**	**1,541,646**	**1,857,198**
Primary domestic materials[2]	1,079,062	1,003,713	[r 3]1,073,982	[3]1,126,908	[3]1,406,020
Primary foreign materials[2]	95,016	53,528	W	W	W
Secondary materials	306,537	371,787	405,944	414,738	451,178
Total	**1,480,615**	**1,429,028**	**[r]1,479,926**	**1,541,646**	**1,857,198**

[r] Revised. W Withheld to avoid disclosing company proprietary data.
[1] Includes fire-refined copper.
[2] The separation of refined copper into metal of domestic and foreign origins can only be approximated at this stage of processing.
[3] Includes primary foreign materials.

TABLE 16

APPARENT CONSUMPTION OF COPPER POWDER AND FLAKES IN THE UNITED STATES

Year	Production (kilograms)	Imports[1]		Exports		Apparent consumption[2] (kilograms)
		Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	
1978	16,991,985	1,152,734	$4,300	1,712,838	$4,597	16,431,881
1979	17,410,984	1,061,870	4,832	1,780,554	6,453	16,692,300
1980	13,202,988	895,675	4,675	1,765,621	6,397	12,333,042
1981	13,593,988	1,238,963	5,635	1,129,023	4,441	13,703,928
1982	9,685,991	1,063,677	4,521	959,288	3,834	9,790,380
1983	11,454,990	1,400,278	5,300	785,902	2,799	12,069,366
1984	12,782,989	1,490,086	5,341	893,326	3,419	13,379,749
1985	9,775,991	1,142,977	4,601	1,140,705	4,074	9,778,263
1986	7,897,993	1,276,570	5,198	1,367,283	5,353	7,807,280
1987	[r]8,439,868	1,154,438	5,843	2,240,438	11,239	7,353,868
1988	9,369,965	1,429,931	9,180	2,663,611	11,074	8,136,285

[r] Revised.
[1] Revised to include copper flakes.
[2] Production plus imports minus exports.

Sources: U.S. Bureau of Mines and U.S. Department of Commerce, Bureau of the Census.

TABLE 17

PRODUCTION, SHIPMENTS, STOCKS, AND IMPORTS OF COPPER SULFATE IN THE UNITED STATES

(Metric tons)

Year	Production		Shipments[1]	Stocks, Dec. 31	Imports
	Quantity	Copper content			
1984	34,859	8,862	37,006	3,564	1,884
1985	32,740	8,265	31,952	4,353	2,958
1986	34,154	8,616	33,540	4,967	2,683
1987	33,340	8,418	35,338	2,969	4,765
1988	34,184	8,630	32,943	4,210	10,992

[1] Includes consumption by producing companies.

TABLE 18

BYPRODUCT SULFURIC ACID (100% BASIS) PRODUCED IN THE UNITED STATES[1]

(Metric tons)

Plant type	1984	1985	1986	1987	1988
Copper[2]	2,251,312	2,230,257	2,308,804	2,542,602	2,892,655
Lead[3]	248,474	267,159	122,228	116,311	133,672
Zinc[4]	442,517	430,946	379,803	410,460	416,617
Total	**2,942,303**	**2,928,362**	**2,810,835**	**3,069,373**	**3,442,944**

[1] Includes acid from foreign materials.
[2] Excludes acid made from pyrite concentrates.
[3] Includes acid processed at molybdenum plants to avoid disclosing company proprietary data.
[4] Excludes acid made from native sulfur.

TABLE 19

COPPER RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Metric tons)

	1984	1985	1986	1987[r]	1988
KIND OF SCRAP					
New scrap:					
Copper-base	637,201	621,984	635,495	689,999	768,963
Aluminum-base	21,919	13,330	22,891	25,871	24,104
Nickel-base	68	328	221	240	118
Zinc-base	31	35	27	12	—
Total	**659,219**	**635,677**	**658,634**	**716,122**	**793,185**
Old scrap:					
Copper-base	443,585	487,199	461,490	481,460	499,848
Aluminum-base	16,929	15,459	15,859	16,401	19,271
Nickel-base	102	689	84	70	86
Zinc-base	79	60	36	6	25
Total	**460,695**	**503,407**	**477,469**	**497,937**	**519,230**
Grand total	**1,119,914**	**1,139,084**	**1,136,103**	**1,214,059**	**1,312,415**
FORM OF RECOVERY					
As unalloyed copper:					
At electrolytic plants	186,712	264,835	292,686	311,312	347,442
At other plants	151,477	122,834	121,760	112,445	113,787
Total	**338,189**	**387,669**	**414,446**	**423,757**	**461,229**
In brass and bronze	735,154	716,833	671,184	736,725	800,582
In alloy iron and steel	1,705	2,498	1,366	973	739
In aluminum alloys	43,511	29,423	45,781	47,932	46,048
In other alloys	307	1,803	359	506	347
In chemical compounds[1]	1,048	858	2,967	4,166	3,470
Total	**781,725**	**751,415**	**721,657**	**790,302**	**851,186**
Grand total	**1,119,914**	**1,139,084**	**1,136,103**	**1,214,059**	**1,312,415**

[r] Revised.
[1] Data do not include copper sulfate prior to 1986.

TABLE 20

COPPER RECOVERED AS REFINED COPPER AND IN ALLOYS AND OTHER FORMS FROM COPPER-BASE SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF OPERATION

(Metric tons)

Type of operation	From new scrap		From old scrap		Total	
	1987r	1988	1987r	1988	1987r	1988
Ingot makers and secondary smelters	24,013	24,970	122,313	127,102	146,326	152,072
Refineries[1]	131,869	148,216	282,869	302,962	414,738	451,178
Brass and wire-rod mills	514,835	573,331	34,866	35,590	549,701	608,921
Foundries and manufacturers	18,905	22,071	37,623	31,099	56,528	53,170
Chemical plants	377	375	3,789	3,095	4,166	3,470
Total	**689,999**	**768,963**	**481,460**	**499,848**	**1,171,459**	**1,268,811**

r Revised.
[1] Electrolytically refined and fire-refined scrap based on source of material at smelter level.

TABLE 21

PRODUCTION OF SECONDARY COPPER AND COPPER-ALLOY PRODUCTS IN THE UNITED STATES, BY ITEM PRODUCED FROM SCRAP

(Metric tons)

Item produced from scrap	1987r	1988
UNALLOYED COPPER PRODUCTS		
Electrolytically refined copper	311,312	347,442
Fire-refined copper	103,426	103,736
Copper powder	8,440	9,370
Copper castings	579	681
Total	**423,757**	**461,229**
ALLOYED COPPER PRODUCTS		
Brass and bronze ingots:		
Tin bronzes	24,340	24,952
Leaded red brass and semired brass	103,616	108,376
High-leaded tin bronze	7,425	8,022
Yellow brass	12,253	8,831
Manganese bronze	8,430	8,691
Aluminum bronze	7,171	8,804
Nickel silver	3,494	3,538
Silicon bronze and brass	4,953	5,437
Copper-base hardeners and master alloys	6,638	7,086
Miscellaneous	9,557	6,573
Total	**187,877**	**190,310**
Brass mill and wire-rod mill products	681,292	750,096
Brass and bronze castings	44,723	41,593
Brass powder	281	252
Copper in chemical products	4,166	3,470
Grand total	**1,342,096**	**1,446,950**

r Revised.

TABLE 22

COMPOSITION OF SECONDARY COPPER-ALLOY PRODUCTION IN THE UNITED STATES

(Metric tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze ingot production:[1]							
1987[r]	151,068	5,865	10,205	20,040	666	33	187,877
1988	152,159	6,156	10,971	20,638	351	35	190,310
Secondary metal content of brass mill products:							
1987[r]	[2]552,857	595	2,576	123,954	1,310	—	[2]681,292
1988	[2]611,763	780	1,721	133,663	2,168	1	[2]750,096
Secondary metal content of brass and bronze castings:							
1987[r]	38,647	1,136	1,958	2,884	42	56	44,723
1988	37,644	870	1,269	1,714	41	55	41,593

[r] Revised.

[1] About 96% from scrap and 4% from other than scrap in 1987 and in 1988.

[2] Includes copper recovered from scrap at wire mills to avoid disclosing company proprietary data.

TABLE 23

STOCKS AND CONSUMPTION OF PURCHASED COPPER SCRAP IN THE UNITED STATES IN 1988, BY CLASS OF CONSUMER AND TYPE OF SCRAP

(Metric tons, gross weight)

Class of consumer and type of scrap	Stocks, Jan. 1[1]	Net receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
SECONDARY SMELTERS/REFINERS						
No. 1 wire and heavy	3,333	111,039	77,411	35,362	112,773	1,599
No. 2 wire, mixed heavy and light	24,793	345,424	44,238	303,391	347,629	22,588
Composition or soft red brass	2,195	40,430	6,145	34,507	40,652	1,973
Railroad-car boxes	142	794	—	848	848	88
Yellow brass	3,911	68,635	41,038	27,960	68,998	3,548
Cartridge cases	—	137	—	124	124	13
Automobile radiators (unsweated)	4,906	102,594	3,020	99,409	102,429	5,071
Bronze	1,516	15,619	2,609	13,420	16,029	1,106
Nickel silver and cupronickel	281	2,903	898	1,708	2,606	578
Low brass	179	4,687	2,481	1,688	4,169	697
Aluminum bronze	79	204	25	224	249	34
Refinery brass	2,424	30,403	8,627	21,817	30,444	2,383
Low-grade scrap and residues	9,317	87,773	44,246	26,486	70,732	26,358
Total	**53,076**	**810,642**	**230,738**	**566,944**	**797,682**	**66,036**
BRASS AND WIRE-ROD MILLS[2]						
No. 1 wire and heavy	15,937	271,233	251,607	19,626	271,233	15,101
No. 2 wire, mixed heavy and light	2,529	57,667	46,577	11,090	57,667	2,718
Yellow brass	11,543	256,226	249,295	6,931	256,226	9,458
Cartridge cases and brass	13,509	139,349	138,807	542	139,349	15,960
Bronze	1,073	4,568	4,568	—	4,568	657
Nickel silver and cupronickel	1,759	12,274	12,029	245	12,274	2,416
Low brass	2,374	15,711	15,385	326	15,711	2,670
Aluminum bronze	—	13	13	—	13	—
Total	**48,724**	**757,041**	**718,281**	**38,760**	**757,041**	**48,980**
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy	2,318	32,410	11,247	21,402	32,649	2,079
No. 2 wire, mixed heavy and light	277	3,881	1,318	2,718	4,036	122
Composition or soft red brass	4,783	11,454	7,507	5,479	12,986	3,251
Railroad-car boxes	211	2,401	—	2,397	2,397	215
Yellow brass	483	6,814	3,978	3,010	6,988	309
Cartridge cases	—	138	—	138	138	—
Automobile radiators (unsweated)	340	1,765	—	1,935	1,935	170
Bronze	841	697	43	656	699	839
Nickel silver and cupronickel	5	85	25	63	88	2
Low brass	43	1,893	1,642	154	1,796	140
Aluminum bronze	53	741	90	658	748	46
Low-grade scrap and residues	—	47	47	—	47	—
Total[3]	**9,354**	**62,326**	**25,897**	**38,610**	**64,507**	**7,173**

See footnotes at end of table.

TABLE 23—Continued

STOCKS AND CONSUMPTION OF PURCHASED COPPER SCRAP IN THE UNITED STATES IN 1988, BY CLASS OF CONSUMER AND TYPE OF SCRAP

(Metric tons, gross weight)

Class of consumer and type of scrap	Stocks, Jan. 1[1]	Net receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
GRAND TOTAL						
No. 1 wire and heavy	21,588	414,682	340,265	76,390	416,655	18,779
No. 2 wire, mixed heavy and light	27,599	406,972	92,133	317,199	409,332	25,428
Composition or soft red brass	6,978	51,884	13,652	39,986	53,638	5,224
Railroad-car boxes	353	3,195	—	3,245	3,245	303
Yellow brass	15,937	331,675	294,311	37,901	332,212	13,315
Cartridge cases	13,509	139,624	138,807	804	139,611	15,973
Automobile radiators (unsweated)	5,246	104,359	3,020	101,344	104,364	5,241
Bronze	3,430	20,884	7,220	14,076	21,296	2,602
Nickel silver and cupronickel	2,045	15,262	12,952	2,016	14,968	2,996
Low brass	2,596	22,291	19,508	2,168	21,676	3,507
Aluminum bronze	132	958	128	882	1,010	80
Low-grade scrap and residues[4]	11,741	118,223	52,920	48,303	101,223	28,741
Total	**111,154**	**1,630,009**	**974,916**	**644,314**	**1,619,230**	**122,189**

[1] Revised from 1987 closing stocks.
[2] Brass and wire-rod mill stocks include home scrap; purchased scrap consumption is assumed equal to receipts, so lines in "BRASS AND WIRE-ROD MILLS" and "GRAND TOTAL" sections do not balance.
[3] Of the total shown, chemical plants reported the following: unalloyed copper scrap, 390 tons new and 3,224 tons old.
[4] Includes refinery brass.

TABLE 24

CONSUMPTION OF COPPER AND BRASS MATERIALS IN THE UNITED STATES, BY ITEM

(Metric tons)

Item	Brass mills	Wire-rod mills	Foundries, chemical plants, miscellaneous users	Secondary smelters-refiners	Total
1987:[r]					
Copper scrap	[1] 687,549	W	71,670	823,032	1,582,251
Refined copper[2]	488,629	1,593,886	41,748	1,436	2,125,699
Hardeners and master alloys	28,975	—	3,193	—	32,168
Brass ingots	—	—	132,854	—	132,854
Slab zinc	76,454	—	5,158	2,718	84,330
Miscellaneous	—	—	—	710	710
1988:					
Copper scrap	[1] 757,041	W	64,507	797,682	1,619,230
Refined copper[2]	486,843	1,673,562	47,486	2,607	2,210,498
Hardeners and master alloys	3,104	—	2,145	—	5,249
Brass ingots	—	—	143,485	—	143,485
Slab zinc	81,678	—	4,496	3,735	89,909
Miscellaneous	—	—	—	97	97

[r] Revised. W Withheld to avoid disclosing company proprietary data.
[1] Includes consumption of copper scrap at wire-rod mills to avoid disclosing company proprietary data.
[2] Detailed information on consumption of refined copper can be found in table 28.

TABLE 25

PRODUCTION, SHIPMENTS, AND STOCKS OF BRASS AND WIRE-ROD MILL SEMIFABRICATES

(Metric tons)

	Production	Shipments	Stocks, Dec. 31
BRASS MILLS			
1986	1,266,009	1,250,705	71,910
1987	1,301,804	1,316,632	54,759
1988	1,342,595	1,337,432	72,443
WIRE-ROD MILLS			
1986	1,281,908	1,282,523	95,816
1987	1,422,450	1,505,776	96,746
1988	1,516,461	1,531,055	82,153

TABLE 26

APPARENT CONSUMPTION OF COPPER IN THE UNITED STATES

(Metric tons)

Period	Refined copper production	Copper in old scrap	Net refined imports	Stock change during period	Apparent consumption
1984	r1,174,078	460,695	353,285	−128,000	r2,116,058
1985	r1,057,241	503,407	339,788	−244,000	r2,144,436
1986	r1,073,982	477,469	489,532	−95,000	r2,135,983
1987	r1,126,908	r497,937	459,962	−112,000	r2,196,807
1988:					
January	110,014	41,150	40,330	10,000	181,494
February	108,669	44,086	28,458	11,000	170,213
March	119,913	49,263	31,397	3,000	197,573
April	120,029	42,493	25,418	−2,000	189,940
May	116,962	43,083	17,793	−21,000	198,838
June	116,209	43,703	12,793	−24,000	196,705
July	115,674	34,398	17,023	12,000	155,095
August	118,808	44,355	20,948	−1,000	185,111
September	112,230	46,307	10,585	−11,000	180,122
October	120,302	43,093	29,087	−9,000	201,482
November	123,293	43,321	25,528	—	192,142
December	123,917	43,978	13,986	17,000	164,881
Total	**1,406,020**	**519,230**	**273,346**	**−15,000**	**2,213,596**

r Revised.

TABLE 27

FOUNDRIES AND MISCELLANEOUS MANUFACTURERS CONSUMPTION OF BRASS INGOT AND REFINED COPPER AND COPPER SCRAP IN THE UNITED STATES, BY GEOGRAPHIC DIVISION AND STATE

(Metric tons)

Geographic division and State	Tin bronzes	Leaded red brass and semi-red brass	Yellow, leaded and low brass[1]	Manganese bronze	Nickel silver[2]	Aluminum bronze	Total brass ingot	Hardeners and master alloys[3]	Refined copper consumed	Copper scrap consumed
1984[r]	28,056	84,528	7,551	4,907	1,457	6,425	132,924	2,430	34,427	68,387
1985[r]	27,328	87,053	8,014	6,216	1,788	7,052	137,451	3,133	54,390	66,557
1986[r]	33,651	81,288	9,702	5,735	2,336	5,506	138,218	3,146	43,416	63,323
1987[r]	31,198	79,074	7,365	7,433	2,239	5,545	132,854	3,193	40,649	67,316
1988:										
Atlantic:										
Middle: New Jersey, New York, Pennsylvania	7,680	7,932	1,072	945	175	861	18,665	56	8,284	9,445
South: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	7,505	14,376	383	444	303	733	23,744	29	5,949	4,067
Central:										
East North: Illinois, Indiana, Michigan, Ohio, Wisconsin	8,716	36,420	4,518	2,769	1,024	2,005	55,452	1,123	13,995	31,183
South: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	4,116	13,963	528	865	106	842	20,420	70	10,490	4,213
West North: Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota	1,043	4,761	468	428	14	902	7,616	149	4,105	3,722
Mountain and Pacific:										
Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington	1,862	8,941	973	762	99	1,548	14,185	338	2,119	7,082
New England:										
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	467	941	715	266	401	613	3,403	380	1,543	1,181
Total	**31,389**	**87,334**	**8,657**	**6,479**	**2,122**	**7,504**	**143,485**	**2,145**	**46,485**	**60,893**

[r] Revised.

[1] Includes silicon bronze and brass.

[2] Includes copper nickel and nickel bronze and brass.

[3] Includes special alloys.

TABLE 28

REFINED COPPER CONSUMED IN THE UNITED STATES, BY CLASS OF CONSUMER

(Metric tons)

Class of consumer	Cathodes	Wirebars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1987:[r]							
Wire-rod mills	1,584,052	W	W	W	—	9,834	1,593,886
Brass mills	253,469	13,845	56,558	71,921	92,704	132	488,629
Chemical plants	W	—	—	—	—	1,099	1,099
Ingot makers	W	—	W	—	W	1,436	1,436
Foundries	1,545	W	8,833	W	W	3,835	14,213
Miscellaneous[1]	13,874	W	8,626	W	W	3,936	26,436
Total	**1,852,940**	**13,845**	**74,017**	**71,921**	**92,704**	**20,272**	**2,125,699**
1988:							
Wire-rod mills	1,673,562	—	—	—	—	—	1,673,562
Brass mills	273,438	14,037	37,168	63,037	99,025	138	486,843
Chemical plants	W	—	—	—	—	1,001	1,001
Ingot makers	W	—	W	—	—	2,607	2,607
Foundries	1,532	W	8,509	—	W	4,542	14,583
Miscellaneous[1]	18,878	W	8,114	W	W	4,910	31,902
Total	**1,967,410**	**14,037**	**53,791**	**63,037**	**99,025**	**13,198**	**2,210,498**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and other manufacturers.

TABLE 29

STOCKS OF COPPER IN THE UNITED STATES, DECEMBER 31

(Thousand metric tons)

Period	Blister and materials in process of refining[1]	Refined copper					
		Electrolytic refiners	Wire-rod mills	Brass mills	Other[2]	New York Commodity Exchange	Total
1984	245	[r]121	134	27	[r]31	251	564
1985	146	66	100	20	25	109	320
1986	135	36	66	14	25	84	225
1987	150	29	28	15	24	17	113
1988:							
January	157	30	33	21	24	15	123
February	160	28	47	20	24	15	134
March	159	38	44	19	25	11	137
April	134	43	40	18	25	9	135
May	115	32	29	12	24	17	114
June	128	19	18	14	24	15	90
July	126	20	25	12	23	22	102
August	115	17	24	17	23	20	101
September	113	14	24	16	24	12	90
October	124	14	22	16	24	5	81
November	124	15	23	15	23	5	81
December	119	16	29	17	24	12	98

[r] Revised.
[1] Includes copper in transit from smelters in the United States to refineries therein.
[2] Includes secondary smelters, chemical plants, foundries, and miscellaneous plants; includes 20,000 tons in the National Defense Stockpile.

TABLE 30

DEALERS' MONTHLY AVERAGE BUYING PRICE FOR COPPER SCRAP AND CONSUMERS' ALLOY-INGOT PRICES AT NEW YORK, BY TYPE

(Cents per pound)

Year and month	Scrap: No. 2 heavy copper	Scrap: No. 1 composition (red brass)	Ingot: No. 115 brass (85-5-5-5)	Ingot: Yellow brass (405)
1987:[r]				
January	37.50	36.50	81.50	70.75
February	37.50	36.50	81.50	70.75
March	37.86	36.50	81.50	70.75
April	39.50	36.50	81.50	70.75
May	41.15	37.75	81.50	70.75
June	42.50	38.50	81.50	70.75
July	44.68	39.05	81.82	70.75
August	49.07	39.50	85.00	73.25
September	49.50	39.50	86.29	74.54
October	53.32	41.41	88.00	76.25
November	55.39	42.13	91.39	78.25
December	64.73	44.86	99.27	83.02
Average	**46.06**	**39.06**	**85.06**	**73.38**
1988:				
January	77.10	83.50	100.50	84.25
February	68.00	77.43	98.49	82.24
March	63.50	73.50	97.70	81.45
April	63.12	73.00	99.00	82.75
May	70.07	70.45	99.00	82.75
June	70.59	71.80	99.00	84.15
July	69.80	71.08	99.00	89.75
August	69.54	70.50	99.00	89.75
September	72.36	70.50	99.50	90.05
October	78.93	78.79	105.35	94.10
November	83.66	82.50	109.80	98.48
December	85.50	89.47	110.00	99.75
Average	**72.68**	**76.04**	**101.36**	**88.29**

[r] Revised.

Source: American Metal Market.

TABLE 31

AVERAGE MONTHLY PRICES FOR REFINED COPPER IN THE UNITED STATES AND ON THE LONDON METAL EXCHANGE

(Cents per pound)

Month	1987				1988			
	U.S. producers delivered price Cathode[2]	COMEX first position	LME cash price[1]		U.S. producers delivered price Cathode[2]	COMEX first position	LME cash price[1]	
			Cathode	High grade[3]			Standard	Grade A
January	64.99	60.76	59.27	61.04	132.50	123.22	115.93	120.66
February	65.53	61.73	60.46	62.57	107.52	99.73	102.30	105.62
March	68.07	63.57	62.36	66.45	109.72	103.92	103.51	106.96
April	67.13	62.37	63.86	68.29	103.64	97.50	100.00	103.64
May	70.99	66.47	66.27	68.94	104.37	99.27	100.77	110.84
June	74.35	69.89	69.85	71.27	114.28	108.97	104.95	115.15
July	80.42	76.19	76.68	76.83	104.85	98.78	96.77	100.35
August	82.18	77.63	79.51	79.63	101.45	96.21	96.18	99.78
September	85.61	80.99	81.86	82.11	116.12	111.24	105.13	110.38
October	88.85	83.04	87.63	89.16	138.05	133.48	127.65	133.24
November	108.53	103.92	109.67	114.35	152.32	147.08	143.82	149.81
December	133.32	127.49	123.41	129.96	161.27	155.81	153.94	158.62
Average	**82.50**	**77.84**	**78.40**	**80.88**	**120.51**	**114.60**	**112.58**	**117.92**

[1] Based on average monthly rates of exchange.
[2] Listed as "U.S. producer cathode."
[3] Includes both cathode and wirebar.

Source: Metals Week.

TABLE 32

U.S. EXPORTS OF COPPER, BY COUNTRY

Country	Ore and concentrate (copper content)		Ash and residues[1] (copper content)		Refined		Unalloyed copper scrap		Blister and precipitates	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1987	124,749	$157,010	5,999	$13,154	9,197	$18,928	108,535	$104,901	12,339	$12,463
1988:										
Australia	—	—	1	2	1	2	—	—	—	—
Belgium	—	—	2,163	4,974	213	537	2,813	4,057	3	4
Brazil	—	—	29	4	51	124	594	936	—	—
Canada	8,425	15,430	625	878	3,844	5,885	29,174	32,357	10,276	16,849
China	9,358	19,271	—	—	3,494	9,098	427	496	16	51
Dominican Republic	—	—	—	—	—	—	—	—	2	3
Finland	1,784	2,296	—	—	—	—	—	—	—	—
France	—	—	3	7	1,506	4,036	—	—	(2)	2
Germany, Federal Republic of	41,556	78,203	445	2,666	1,321	3,423	9,751	13,596	4,917	13,140
Hong Kong	—	—	—	—	537	1,509	1,433	1,149	671	1,919
India	—	—	396	487	85	132	2,015	2,358	(2)	3
Israel	—	—	—	—	1	3	—	—	5	7
Italy	2	2	2	14	4,522	10,406	834	1,065	2	4
Japan	131,220	256,287	267	674	13,496	34,459	16,130	25,810	—	—
Korea, Republic of	10,645	26,821	76	97	6,128	14,331	19,541	39,041	14,965	24,627
Kuwait	—	—	39	156	—	—	—	—	—	—
Mexico	1,951	1,242	—	—	8,536	20,041	11,496	20,353	529	828
Netherlands	—	—	11	7	8,694	20,882	924	2,037	3	4
Philippines	3,185	10,533	69	92	96	160	—	—	18	17
Singapore	—	—	18	26	1,279	3,203	2,098	3,066	197	634
Spain	35	65	9	17	—	—	3,379	2,228	1,056	5,825
Sweden	—	—	—	—	124	335	—	—	—	—
Switzerland	—	—	—	—	—	—	—	—	2	14
Taiwan	2,986	9,853	207	148	1,611	2,987	16,292	12,185	534	1,661
United Kingdom	—	—	11	17	2,270	5,662	2,311	3,103	—	—
Venezuela	—	—	—	—	—	—	305	607	59	115
Other	—	—	8	12	519	1,324	256	487	82	271
Total[3]	**211,147**	**420,003**	**4,380**	**10,276**	**58,325**	**138,539**	**119,773**	**164,933**	**33,337**	**65,978**

See footnotes at end of table.

TABLE 32—Continued

U.S. EXPORTS OF COPPER, BY COUNTRY

Country	Pipes and tubing		Plates and sheets		Wire and cable, bare		Wire and cable, insulated		Other copper manufactures[4]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1987	**6,551**	**$18,250**	**539**	**$2,827**	**10,194**	**$42,869**	**88,240**	**$490,556**	**3,723**	**$9,511**
1988:										
Australia	3	35	—	—	30	231	1,533	12,862	(2)	79
Bahamas	23	36	—	—	38	117	441	2,223	—	—
Belgium	30	98	(2)	3	28	83	159	3,951	—	—
Brazil	291	991	—	—	5	27	254	4,243	13	48
Canada	1,369	4,938	398	1,930	1,285	7,257	42,807	113,977	1,023	3,671
China	(2)	2	22	167	71	1,321	782	7,009	1	3
Dominican Republic	2	6	1	7	796	6,979	1,385	4,178	383	834
Ecuador	17	157	(2)	3	8	31	133	631	—	—
Egypt	40	133	—	—	21	132	1,480	6,971	136	61
France	22	128	(2)	9	10	150	1,617	39,759	—	—
Germany, Federal Republic of	2	9	31	192	113	690	2,620	29,514	11	86
Hong Kong	88	242	(2)	4	36	298	1,139	9,280	18	79
India	4	13	—	—	31	341	135	1,632	4	25
Israel	185	544	7	35	8	118	276	3,603	—	—
Italy	3	21	2	11	50	307	711	7,727	6	72
Jamaica	12	54	—	—	40	195	264	1,094	5	17
Japan	13	52	28	307	122	825	921	21,347	42	198
Korea, Republic of	140	619	19	64	30	389	860	9,369	16	69
Kuwait	324	1,198	—	—	3	50	166	598	—	—
Mexico	451	1,675	263	646	8,460	27,235	37,010	209,524	546	1,574
Netherlands	442	1,479	11	61	8	56	956	9,178	4	13
Philippines	109	364	5	89	45	154	717	3,378	—	—
Saudi Arabia	653	2,461	1	3	30	213	2,280	9,271	2	16
Singapore	129	541	6	42	84	442	1,321	12,321	6	49
Spain	384	1,385	—	—	13	90	1,580	9,594	1	18
Sweden	—	—	(2)	2	8	75	210	9,572	1	5
Switzerland	2	20	—	—	27	331	865	3,510	21	334
Taiwan	239	991	7	49	81	245	1,232	11,946	70	428
Trinidad and Tobago	—	—	—	—	17	72	428	1,027	1	5
United Arab Emirates	328	918	(2)	6	(2)	38	64	888	—	—
United Kingdom	348	1,160	24	134	296	1,784	6,702	60,925	6	26
Venezuela	626	3,115	24	325	80	384	486	3,060	3	15
Yugoslavia	—	—	—	—	—	—	22	257	—	—
Other	1,466	5,238	13	54	545	2,791	7,079	42,738	31	134
Total[3]	**7,749**	**28,623**	**863**	**4,141**	**12,422**	**53,449**	**118,636**	**667,158**	**2,350**	**7,861**

[1] Includes matte.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
[4] Excludes copper wire cloth.

Source: Bureau of the Census.

TABLE 33

U.S. EXPORTS OF COPPER SCRAP, BY COUNTRY

Country	Unalloyed copper scrap				Copper-alloy scrap			
	1987		1988		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium	1,955	$2,057	2,813	$4,057	7,276	$6,674	8,715	$8,870
Brazil	3,017	3,621	594	936	6,384	7,055	589	907
Canada	11,134	17,288	29,174	32,357	21,156	37,095	23,607	38,567
China	191	79	427	496	180	404	1,040	838
France	—	—	48	51	96	403	699	797
Germany, Federal Republic of	4,331	4,242	9,751	13,596	7,723	10,127	20,986	33,248
Hong Kong	3,317	1,919	1,433	1,149	521	363	206	212
India	494	375	2,015	2,358	11,866	9,364	13,184	14,371
Italy	6,141	5,727	834	1,065	6,510	5,287	1,948	2,450
Japan	15,550	20,396	16,130	25,810	24,040	34,346	17,225	31,365
Korea, Republic of	9,662	12,279	19,541	39,041	26,091	31,786	44,044	70,221
Mexico	12,277	17,961	11,496	20,353	5,723	8,179	10,094	23,637
Netherlands	369	348	924	2,037	803	896	1,115	2,214
Philippines	948	252	—	—	115	39	—	—
Singapore	1,145	1,059	2,098	3,066	232	174	1,138	1,260
Spain	8,053	3,473	3,379	2,228	6,269	2,780	10,099	3,936
Sweden	2	2	15	40	1,599	2,585	1,614	3,866
Switzerland	1	17	15	3	163	110	53	63
Taiwan	28,713	12,208	16,292	12,185	54,657	34,097	39,596	36,697
Trinidad and Tobago	44	5	—	—	704	702	956	1,037
United Kingdom	746	1,245	2,311	3,103	2,698	3,544	2,698	5,181
Venezuela	196	238	305	607	127	611	150	416
Other	249	110	178	395	346	317	193	407
Total [1]	**108,535**	**104,901**	**119,773**	**164,933**	**185,279**	**196,938**	**199,949**	**280,560**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 34

U.S. IMPORTS FOR CONSUMPTION OF UNMANUFACTURED COPPER (COPPER CONTENT), BY COUNTRY

Country	Ore and concentrate		Matte		Blister and anode		Refined		Unalloyed scrap		Total[1]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1987	**2,339**	**$2,013**	**6,869**	**$9,339**	**24,084**	**$41,976**	**469,159**	**$734,647**	**33,123**	**$45,121**	**535,574**	**$833,096**
1988:												
Belgium	—	—	—	—	—	—	1,266	3,727	—	—	1,266	3,727
Canada	—	—	144	149	18	36	177,804	440,755	26,181	69,505	204,149	510,445
Chile	—	—	30	52	48,268	87,626	82,745	203,969	72	137	131,115	291,784
Costa Rica	—	—	—	—	—	—	—	—	203	390	203	390
Dominican Republic	—	—	—	—	—	—	—	—	588	1,142	588	1,142
Finland	—	—	—	—	—	—	400	1,288	—	—	400	1,288
Germany, Federal Republic of	—	—	—	—	—	—	5,055	11,253	101	320	5,156	11,573
Ivory Coast	—	—	—	—	5,123	7,524	—	—	—	—	5,123	7,524
Jamaica	—	—	—	—	—	—	—	—	176	316	176	316
Japan	—	—	—	—	29,166	66,729	([2])	3	10	7	29,176	66,739
Mexico	953	1,937	5,236	9,944	1,038	1,960	42	92	7,290	10,554	14,559	24,487
Netherlands	—	—	—	—	—	—	5,050	12,342	—	—	5,050	12,342
Norway	—	—	—	—	—	—	354	852	—	—	354	852
Panama	—	—	—	—	—	—	—	—	887	1,455	887	1,455
Papua New Guinea	1,823	5,980	—	—	—	—	—	—	—	—	1,823	5,980
Peru	—	—	49	201	2,977	7,403	13,469	32,190	—	—	16,495	39,794
South Africa, Republic of	—	—	—	—	8,904	19,442	1,800	3,694	—	—	10,704	23,136
Sweden	—	—	—	—	—	—	3,771	11,158	—	—	3,771	11,158
Taiwan	—	—	—	—	—	—	—	—	24	180	24	180
Trinidad and Tobago	—	—	—	—	—	—	—	—	190	318	190	318
United Kingdom	—	—	—	—	—	—	18	53	38	161	56	214
Venezuela	—	—	—	—	—	—	—	—	570	993	570	993
Yugoslavia	—	—	—	—	—	—	1,995	5,357	—	—	1,995	5,357
Zaire	—	—	—	—	2,956	6,879	30,481	64,341	—	—	33,437	71,220
Other	—	—	2	54	3	24	7,421	19,421	821	1,646	8,247	21,145
Total[1]	**2,776**	**7,917**	**5,462**	**10,399**	**98,453**	**197,621**	**331,671**	**810,495**	**37,152**	**87,124**	**475,512**	**1,113,556**

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 35

U.S. IMPORTS FOR CONSUMPTION OF COPPER SCRAP, BY COUNTRY

Country	Unalloyed copper scrap		Copper-alloy scrap		
	Quantity (metric tons)	Value (thousands)	Gross weight (metric tons)	Copper content (metric tons)	Value (thousands)
1987	**33,123**	**$45,121**	**44,183**	**32,874**	**$51,696**
1988:					
Bahamas	34	50	61	40	32
Barbados	65	122	23	14	22
Belgium	—	—	1520	882	1469
Canada	26,181	69,505	28,145	21,506	46,314
Chile	72	137	1,753	1,739	5,027
Costa Rica	203	390	60	45	89
Dominican Republic	588	1,142	873	780	1,464
France	108	673	72	54	1,377
Germany, Federal Republic of	101	320	207	149	446
Guatemala	186	259	124	111	126
Haiti	6	7	129	111	210
Honduras	48	94	97	87	102
Hong Kong	—	—	131	94	195
Jamaica	176	316	185	143	169
Japan	10	7	191	151	216
Mexico	7,290	10,554	12,786	7,457	12,829
Netherlands	—	—	17	11	696
Netherlands Antilles	126	156	226	198	261
Panama	887	1,455	670	517	778
Peru	—	—	130	86	150
Singapore	—	—	37	25	384
Sweden	—	—	74	47	119
Switzerland	—	—	11	17	18
Taiwan	24	180	272	253	674
Trinidad and Tobago	190	318	278	215	321
United Kingdom	38	161	119	116	321
Venezuela	570	993	943	703	1,349
Other	249	285	392	297	610
Total	**37,152**	**87,124**	**49,526**	**35,848**	**75,768**

Source: Bureau of the Census.

TABLE 36

COPPER: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Albania[e]	16.1	16.2	17.6	17.8	15.0
Algeria	.1	—	—	—	—
Argentina	.2	.4	.3	.4	[2].5
Australia	235.7	259.8	248.4	232.7	246.0
Bolivia	1.6	1.7	.3	([3])	[2].2
Botswana[4]	21.5	21.7	19.0	19.0	[2]24.4
Brazil	35.2	41.0	40.2	[r e]40.0	[2]44.4
Bulgaria[e]	80.0	80.0	80.0	80.0	80.0
Burma	12.0	16.7	11.4	17.3	[2]13.8
Canada:[5]					
By concentration or leaching	721.8	738.6	697.8	790.2	752.5
Leaching (electrowon)	—	—	.7	3.9	4.0
Chile[6]	1,307.5	1,359.8	1,399.4	1,412.9	[2]1,472.0
China[e]	180.0	185.0	185.0	[r]250.0	300.0
Colombia	.2	—	—	—	—
Congo	—	.5	.7	1.3	1.0
Cuba	2.7	3.1	3.3	[e]3.0	3.0
Cyprus[7]	[r]1.3	[r]1.1	.6	.1	.1
Czechoslovakia[e]	[r]10.2	[r]10.1	[r]8.5	[r]9.4	10.0
Ecuador	.2	.1	.1	.1	.1
Finland	31.3	28.0	25.9	20.4	18.0
France	.1	.2	.3	.3	.3
German Democratic Republic[e]	12.0	12.0	10.0	9.0	9.0
Germany, Federal Republic of[8]	1.0	.9	.8	1.5	.7
Guatemala	—	([9])	([9])	([9])	—
Honduras	.8	5.1	[e]5.0	.6	[2].5
India	44.1	45.9	48.1	56.5	[2]58.5
Indonesia	82.5	88.7	95.8	102.0	[2]121.5
Iran[e 10]	[2]43.3	50.0	[r]60.0	[r]60.0	70.0
Israel	([9])	—	—	—	—
Italy	.9	.1	—	—	—
Japan	43.3	43.2	34.9	23.8	[2]16.7
Korea, North[e]	15.0	15.0	15.0	15.0	15.0
Korea, Republic of	.3	.3	.2	.2	([3])
Malaysia	28.9	30.5	28.3	30.1	22.5
Mexico:					
By concentration or leaching	[r]180.4	[r]169.1	181.1	244.0	268.8
Leaching (electrowon)	9.3	8.0	8.0	9.7	[2]11.4
Mongolia[e]	118.0	128.0	136.0	[r]140.0	160.0
Morocco	22.1	22.0	20.2	16.6	16.6
Mozambique	.3	.1	.3	[e].2	.2
Namibia	47.4	48.0	49.6	37.6	40.0

See footnotes at end of table.

TABLE 36—Continued

COPPER: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Nepal	(3)	(3)	(3)	(3)	(3)
Norway	25.0	19.0	21.9	22.0	16.0
Oman	16.2	[r]15.8	16.1	16.0	[2]17.1
Papua New Guinea	164.4	175.0	178.2	217.7	[2]218.6
Peru:[6]					
By concentration or leaching	322.4	363.9	369.9	381.9	278.4
Leaching (electrowon)	31.5	27.4	27.5	24.5	[2]19.9
Philippines	233.4	222.2	222.6	216.1	[2]218.1
Poland	431.0	431.3	434.0	438.0	440.0
Portugal[6]	.4	.3	.2	.1	[2]1.4
Romania[e 8]	25.0	26.0	27.0	26.0	26.0
South Africa, Republic of[8]	198.2	195.4	184.2	188.1	[2]170.1
Spain	63.1	[r]61.1	53.5	16.3	15.2
Sweden	87.0	91.8	87.4	85.0	82.0
Turkey[11]	[r]24.5	[r]26.6	21.1	24.0	26.4
U.S.S.R.[e 8]	590.0	600.0	620.0	630.0	640.0
United Kingdom	.7	.6	.6	.8	.8
United States:[8]					
By concentration or leaching	1,002.4	[r]1,012.2	1,018.8	1,082.5	[2]1.191.7
Leaching (electrowon)	100.2	90.4	125.4	161.1	[2]228.0
Yugoslavia[e 11]	[2]137.6	141.3	144.9	144.3	[2]120.1
Zaire:					
By concentration or leaching	252.9	244.0	212.5	[r e]217.5	250.0
Leaching (electrowon)	309.1	313.9	319.2	307.5	280.0
Zambia:[12]					
By concentration or leaching (smelted)	406.8	354.7	322.6	318.7	300.0
Leaching (electrowon)	125.9	103.9	139.3	144.4	100.0
Zimbabwe[e]	24.0	21.6	21.4	[r]19.8	16.9
Total	**[r]7,879.0**	**[r]7,969.3**	**8,001.1**	**8,327.9**	**8,453.4**

[e]Estimated. [p]Preliminary. [r]Revised.
[1] Data represent copper content by analysis of concentrates produced except where otherwise noted. Table includes data available through July 5, 1989.
[2] Reported figure.
[3] Less than 50 tons.
[4] Copper content of pelletized nickel-content matte produced in smelter.
[5] Blister copper plus recoverable copper in concentrates, matte, etc., exported.
[6] Recoverable copper content by analysis of concentrates for export plus nonduplicative total of copper content of all metal and metal products produced indigenously from domestic ores and concentrates; includes leach production for electrowinning in Chile and Portugal.
[7] Copper content of cement copper.
[8] Recoverable content.
[9] Revised to zero.
[10] Data are for years beginning Mar. 21 of that stated.
[11] Copper content by analysis of ore mined.
[12] Data are for fiscal years beginning Apr. 1 of year stated. Copper reported recovered during smelting and electrowinning.

TABLE 37

COPPER: WORLD SMELTER PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country[2] and metal origin	1984	1985	1986	1987[p]	1988[e]
Albania, primary[e]	[3]12.6	12.6	13.7	14.0	14.5
Australia:					
Primary	179.8	167.7	169.6	172.9	[3]177.7
Secondary	8.1	7.7	9.2	[e]8.5	9.0
Total	**187.9**	**175.4**	**178.8**	**[r e]181.4**	**186.7**
Austria, secondary	24.6	25.9	25.5	38.7	38.4
Belgium:[e]					
Primary	.5	.9	2.0	1.5	1.5
Secondary	75.5	114.2	106.0	60.7	65.0
Total	**76.0**	**115.1**	**108.0**	**62.2**	**66.5**
Brazil, primary	61.3	93.9	116.0	147.0	150.0
Bulgaria:[e]					
Primary	57.0	87.0	87.0	87.0	87.0
Secondary	3.0	3.0	3.0	4.0	5.0
Total	**60.0**	**90.0**	**90.0**	**91.0**	**92.0**
Canada:					
Primary	504.3	493.3	472.7	499.4	537.0
Secondary[e]	11.0	17.0	12.0	14.0	14.0
Total[e]	**515.3**	**510.3**	**484.7**	**[r]513.4**	**551.0**
Chile, primary[4]	1,098.3	1,088.4	1,123.9	[r e]1,107.0	1,130.0
China, primary[e]	210.0	225.0	225.0	300.0	300.0
Czechoslovakia:					
Primary	10.0	10.2	[e]10.0	[e]10.0	10.0
Secondary[e]	[3]2.4	2.4	2.4	2.4	2.4
Total[e]	**[3]12.4**	**12.6**	**12.4**	**12.4**	**12.4**
Finland:					
Primary	71.2	[e]71.0	84.5	77.4	78.0
Secondary[e]	[3]12.1	12.0	12.0	12.0	12.0
Total[e]	**[3]83.3**	**83.0**	**[r]96.5**	**[r]89.4**	**90.0**
France, secondary	6.8	7.0	6.1	7.0	7.0
German Democratic Republic, primary[e]	14.0	14.0	[r]15.0	[r]16.0	15.0
Germany, Federal Republic of:					
Primary	148.8	152.4	161.9	[e]161.0	160.0
Secondary	76.7	94.6	76.7	[e]76.5	78.0
Total	**225.5**	**247.0**	**238.6**	**[e]237.5**	**238.0**
Hungary, secondary[e]	.1	.1	.1	.1	.1
India, primary	40.5	32.5	39.1	32.9	[3]44.2
Iran, primary[e]	47.9	60.0	60.0	60.0	50.0
Japan:					
Primary	821.1	802.3	827.7	871.0	[3]854.6
Secondary	107.9	130.3	134.4	109.0	[3]139.4
Total	**929.0**	**932.6**	**962.1**	**980.2**	**[3]994.0**

See footnotes at end of table.

TABLE 37—Continued

COPPER: WORLD SMELTER PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country[2] and metal origin	1984	1985	1986	1987[p]	1988[e]
Korea, North:[e]					
Primary	15.0	15.0	15.0	15.0	15.0
Secondary	3.0	3.0	3.0	3.0	3.0
Total	**18.0**	**18.0**	**18.0**	**18.0**	**18.0**
Korea, Republic of, primary and secondary	100.2	106.9	165.0	157.9	[3]169.0
Mexico, primary	70.3	68.2	74.7	101.4	150.0
Namibia, primary	46.4	43.3	45.7	35.5	[3]33.2
Norway, primary	36.8	38.2	35.2	29.7	31.0
Oman, primary	[r]15.1	[r]14.2	14.7	15.7	[3]16.8
Peru, primary	298.8	326.6	286.2	311.8	[3]243.8
Philippines, primary	109.2	133.8	124.3	124.7	125.0
Poland:[e]					
Primary	360.0	370.0	375.0	[r]385.0	385.0
Secondary	15.0	20.0	25.0	25.0	25.0
Total	**375.0**	**390.0**	**400.0**	**[r]410.0**	**410.0**
Portugal:[e]					
Primary	2.5	2.6	3.0	2.0	2.5
Secondary	1.0	2.0	3.0	2.0	2.0
Total	**3.5**	**4.6**	**6.0**	**4.0**	**4.5**
Romania:[e]					
Primary	32.0	32.0	32.0	30.0	28.0
Secondary	6.0	6.0	7.0	8.0	8.0
Total	**38.0**	**38.0**	**39.0**	**38.0**	**36.0**
South Africa, Republic of, primary	178.7	191.7	[e]192.0	[e]192.0	180.0
Spain:					
Primary	97.0	88.0	[e]95.0	[e]96.7	96.0
Secondary	30.0	40.0	[e]40.0	[e]42.0	43.0
Total	**127.0**	**128.0**	**[e]135.0**	**[e]138.7**	**139.0**
Sweden:					
Primary	79.8	74.7	83.4	92.9	90.0
Secondary	22.9	26.0	19.1	12.7	14.0
Total	**102.7**	**100.7**	**102.5**	**105.6**	**104.0**
Taiwan, primary	48.4	46.7	50.4	47.0	[3]43.3
Turkey:					
Primary	31.8	33.5	35.2	[r e]19.3	12.8
Secondary	.2	.4	.3	[r e].1	.1
Total	**32.0**	**33.9**	**35.5**	**[r e]19.4**	**[3]12.9**
U.S.S.R.:[e]					
Primary	735.0	750.0	770.0	780.0	800.0
Secondary	141.0	143.0	145.0	147.0	150.0
Total	**876.0**	**893.0**	**915.0**	**927.0**	**950.0**

See footnotes at end of table.

TABLE 37—Continued

COPPER: WORLD SMELTER PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country[2] and metal origin	1984	1985	1986	1987[p]	1988[e]
United States:					
Primary[5]	1,014.1	940.7	908.1	972.1	[3]1,043.0
Secondary	169.3	250.1	287.8	276.6	[3]320.2
Total	**1,183.4**	**1,190.8**	**1,195.9**	**1,248.7**	**[3]1,363.2**
Yugoslavia:					
Primary	84.7	137.0	196.4	103.4	105.0
Secondary	91.7	52.2	31.5	62.4	65.0
Total	**176.4**	**189.2**	**227.9**	**165.8**	**170.0**
Zaire, primary:					
Electrowon	309.1	313.9	319.2	307.5	280.0
Other	171.5	172.9	178.9	179.9	160.0
Total	**480.6**	**486.8**	**498.1**	**487.4**	**440.0**
Zambia, primary:[6]					
Electrowon	93.8	79.8	94.4	79.3	60.0
Other	416.7	387.0	345.5	347.8	327.0
Total	**[r]510.5**	**[r]466.8**	**439.9**	**427.1**	**387.0**
Zimbabwe, primary[7]	22.7	20.4	20.4	18.8	[3]16.1
Grand total	**[r]8,455.2**	**[r]8,655.2**	**8,816.9**	**8,914.2**	**9,022.7**
Of which:					
Primary:					
Electrowon	[r]402.9	[r]393.7	413.6	386.8	340.0
Other	[r]7,143.8	[r]7,197.7	7,289.2	7,457.8	7,513.1
Secondary	[r]808.3	[r]956.9	949.1	911.7	1,000.6
Undifferentiated	[r]100.2	106.9	165.0	157.9	169.0

[e]Estimated. [p]Preliminary. [r]Revised.
[1] This table includes total production of copper metal at the unrefined stage, including low-grade cathode produced by electrowinning methods. The smelter feed may be derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through July 5, 1989.
[2] Argentina presumably produces some smelter copper utilizing its own small mine output together with domestically produced cement copper and possibly using other raw materials including scrap, but the levels of such output cannot be reliably estimated.
[3] Reported figure.
[4] Data include electrowon production; estimated to be 35,000 to 45,000 metric tons per year that is fire refined and cast into wirebars; detailed data are not available.
[5] Figures for U.S. primary smelter production may include a small amount of copper derived from precipitates shipped directly to the smelter for further processing; production derived from electrowinning and fire refining is not included. Copper content of precipitates shipped directly to smelter are as follows, in metric tons: 1984—87,262 (revised); 1985—90,963 (revised); 1986—89,120 (revised); 1987—71,370; and 1988—50,341.
[6] For fiscal years beginning Apr. 1 of year stated. Includes smelter production plus the portion of electrowon production presumed to be low-grade (reported as "Refined shapes," assumed fire refined, in "Finished Production"); other electrowon production presumed to be high-grade (reported as "leach cathode" in "Finished Production") is listed in refinery table.
[7] Refined figure; unrefined data not available. Includes production from low-grade electrowon cathodes produced in nickel processing.

TABLE 38

COPPER: WORLD REFINERY PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Albania, primary[e]	11.5	11.5	11.7	12.0	13.0
Australia:					
Primary	171.2	163.8	164.0	178.9	[2]191.2
Secondary	26.0	30.5	21.1	28.8	[2]26.7
Total[3]	**197.2**	**194.3**	**185.1**	**207.8**	**[2]217.9**
Austria:					
Primary	9.6	8.2	7.1	3.9	5.0
Secondary	34.3	35.0	32.6	32.9	38.0
Total[3]	**43.9**	**43.2**	**39.6**	**36.8**	**43.0**
Belgium:					
Primary	351.7	340.5	337.8	345.9	310.0
Secondary	76.0	115.0	120.0	130.0	125.0
Total	**427.7**	**455.5**	**457.8**	**475.9**	**435.0**
Brazil:					
Primary	61.3	93.9	116.0	147.0	[2]148.0
Secondary	36.0	49.0	50.0	52.2	[2]38.0
Total	**97.3**	**142.9**	**166.0**	**199.2**	**[2]186.0**
Bulgaria, primary and secondary[e]	62.0	93.0	95.0	95.0	97.0
Canada:					
Primary	504.3	499.6	493.4	491.2	[2]528.7
Secondary[e]	35.0	34.0	33.0	34.0	37.0
Total[e]	**539.3**	**533.6**	**526.4**	**525.2**	**565.7**
Chile, primary	879.7	884.3	942.3	970.3	980.0
China, primary and secondary[e]	310.0	400.0	400.0	400.0	400.0
Czechoslovakia, primary and secondary[e]	[2]26.1	26.5	26.5	26.5	27.0
Egypt, secondary[e]	[2]2.6	2.6	2.7	[r]2.5	2.5
Finland:[e]					
Primary	[2]47.3	46.5	52.2	47.5	42.0
Secondary	10.0	12.0	12.0	12.0	12.0
Total	**[2]57.3**	**58.5**	**64.2**	**59.5**	**54.0**
France:					
Primary[e]	15.0	13.7	15.1	13.3	14.3
Secondary	25.9	30.0	27.4	[e]26.0	30.2
Total[e]	**40.9**	**43.7**	**[r]42.5**	**39.3**	**44.5**
German Democratic Republic, primary and secondary[e]	[r]69.0	[r]75.0	[r]73.0	[r]72.0	72.0
Germany, Federal Republic of:					
Primary	[r]207.3	[r]209.9	238.1	195.2	192.2
Secondary	171.7	204.3	183.9	204.7	234.2
Total	**[r]379.0**	**[r]414.2**	**422.0**	**399.9**	**426.4**
Hungary, primary and secondary[e]	12.8	12.8	12.8	12.5	12.5
India, primary:					
Electrolytic	32.6	28.0	37.9	29.8	[2]38.9
Fire refined[e]	1.0	1.0	1.0	[2]0.8	1.0
Total[e]	**33.6**	**29.0**	**38.9**	**[r]30.6**	**39.9**

See footnotes at end of table.

TABLE 38—Continued

COPPER: WORLD REFINERY PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Iran, primary[e 4]	5.0	12.0	12.0	12.0	12.0
Italy, secondary	50.3	64.3	65.4	[e]65.1	65.0
Japan:					
Primary	821.1	802.3	827.7	871.0	[2]854.6
Secondary	114.1	133.6	115.4	109.4	[2]100.5
Total[3]	**935.2**	**936.0**	**943.0**	**980.3**	**[2]955.1**
Korea, North, primary and secondary[e]	22.0	22.0	22.0	22.0	22.0
Korea, Republic of:					
Primary	129.1	140.1	157.8	154.6	[2]168.3
Secondary[e]	7.9	11.5	7.2	[2]3.3	[2]0.7
Total[e]	**137.0**	**151.6**	**165.0**	**[2]157.9**	**[2]169.0**
Mexico:					
Primary:					
Electrowon	9.3	8.0	8.0	9.7	[2]11.4
Other[e]	69.0	[r]96.1	[r]67.8	[r]100.2	98.9
Secondary[e]	[2]13.9	[r]19.4	[r]13.7	[r]20.2	20.0
Total[3]	**92.2**	**123.6**	**89.5**	**130.0**	**[2]130.3**
Norway, primary[5]	30.3	31.1	30.5	29.4	[2]31.7
Oman, primary	[r]14.9	[r]14.0	14.5	15.5	[2]16.5
Peru, primary:					
Electrowon	31.5	27.4	27.5	24.5	[2]19.9
Other	188.6	[r]226.8	225.6	200.3	[2]159.5
Total[3]	**220.0**	**[r]254.2**	**253.1**	**224.8**	**[2]179.4**
Philippines, primary	99.2	130.2	134.5	132.1	[2]132.2
Poland, primary[6]	372.3	387.0	388.0	390.0	[2]401.0
Portugal, primary	5.3	4.5	5.3	[r e]5.3	6.0
Romania:[e]					
Primary	33.0	33.0	32.0	30.0	30.0
Secondary	12.0	12.0	11.0	12.0	12.0
Total	**45.0**	**45.0**	**43.0**	**42.0**	**42.0**
South Africa, Republic of, primary[6]	155.7	164.3	158.6	152.7	148.0
Spain:					
Primary	117.4	101.7	130.6	100.4	[2]108.8
Secondary	39.0	50.0	24.5	51.0	[2]50.0
Total	**156.4**	**151.7**	**155.1**	**151.4**	**[2]158.8**
Sweden:					
Primary	53.5	[e]52.0	68.7	80.9	70.0
Secondary	10.4	12.7	15.8	11.0	12.0
Total	**63.9**	**[e]64.7**	**84.5**	**91.9**	**82.0**
Taiwan:					
Primary	40.4	46.7	50.4	47.0	[2]43.3
Secondary[e]	8.0	8.0	8.0	10.0	10.0
Total[e]	**48.4**	**54.7**	**58.4**	**57.0**	**53.3**

See footnotes at end of table.

TABLE 38—Continued

COPPER: WORLD REFINERY PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Turkey, primary	[r]51.4	60.6	75.1	75.6	75.6
U.S.S.R.:[e]					
Primary	790.0	810.0	830.0	840.0	850.0
Secondary	141.0	143.0	145.0	147.0	149.0
Total	**931.0**	**953.0**	**975.0**	**987.0**	**999.0**
United Kingdom:					
Primary	69.5	63.9	62.4	54.0	50.9
Secondary	67.4	61.6	63.2	68.3	72.3
Total[3]	**136.8**	**125.4**	**125.6**	**122.3**	**123.2**
United States:					
Primary:					
Electrowon	100.2	[r]90.5	125.4	161.3	[2]228.0
Other	[r]1,073.9	[r]966.8	948.6	965.6	[2]1,178.0
Secondary	[r]306.5	[r]371.8	405.9	414.7	[2]453.3
Total	**[r]1,480.6**	**[r]1,429.0**	**1,479.9**	**1,541.6**	**[2]1,859.3**
Yugoslavia:					
Primary	80.3	[e]80.0	[e]81.0	98.8	100.0
Secondary	47.4	[e]55.4	[e]59.4	40.1	45.4
Total[3]	**127.6**	**135.4**	**140.4**	**138.9**	**[2]145.4**
Zaire, primary	224.8	221.4	218.0	210.0	[2]202.6
Zambia, primary:[7 8]					
Electrowon	[r]38.7	[r]33.2	50.6	69.5	50.0
Other	[r]491.6	[r]463.3	447.0	426.7	380.0
Total[3]	**[r]530.3**	**[r]496.5**	**497.6**	**496.3**	**430.0**
Zimbabwe, primary	22.7	20.4	20.4	18.8	[2]16.1
Grand total[3]	**[r]9,148.3**	**[r]9,473.3**	**9,661.4**	**9,814.9**	**10,071.8**
Of which:					
Primary[3]	[r]7,411.0	[r]7,388.4	7,614.5	7,711.6	7,907.7
Secondary[3]	[r]1,235.3	[r]1,455.6	1,417.6	1,475.3	1,533.6
Primary and secondary, undifferentiated	[r]501.9	[r]629.3	629.3	628.0	630.5

[e]Estimated. [p]Preliminary. [r]Revised.

[1] This table includes total production of refined copper, whether produced by pyrometallurgical or electrolytic refining methods and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. To the extent possible, primary and secondary output of each country is shown separately. In most cases, total refinery production is officially reported, and in some, the distribution between primary and secondary has been estimated. Table includes data available through July 5, 1989.

[2] Reported figure.

[3] Data may not add to totals shown because of independent rounding.

[4] Data are for fiscal year beginning Mar. 21 of that stated.

[5] May include small quantities of secondary.

[6] Although only primary production is reported, an unknown but small additional output of secondary refined copper may have been produced.

[7] Data are for fiscal year beginning Apr. 1 of that stated.

[8] Electrowon covers only presumably high-grade cathodes, reported as "leach cathodes." Other includes presumably low-grade electrowon cathodes that were fire refined and cast into shapes, reported as "refined shapes."

DIATOMITE

By Arthur C. Meisinger[1]

U.S. sales of processed diatomite increased to 693,000 short tons valued at nearly $144 million compared with that in 1987. Apparent domestic consumption increased for the second straight year with filter-grade and filler-grade diatomite sales accounting for 81% of the domestic market. Domestic exports increased 17% to the highest level since 1981 and accounted for 23% of domestic production. California continued to be the leading producing State. The United States accounted for about 34% of estimated world production in 1988.

DOMESTIC DATA COVERAGE

Domestic production data for diatomite are developed by the Bureau of Mines from one voluntary survey of U.S. plant operations. Of the 12 operations to which a survey request was sent, 9 responded and represented 87% of the total production shown in table 1. Production for the remaining nonrespondents was estimated using reported prior year data adjusted by trends in employment and other guidelines.

DOMESTIC PRODUCTION

Domestic production (sales) of diatomite, compared with that of 1987, increased 5% in quantity and 7% in value. Diatomite was processed by 7 companies in 11 plants in 5 States. California continued to be the leading producing State followed by Nevada, Washington, Oregon, and Arizona.

As in previous years, the major domestic producers were Manville Products Corp., with operations at Lompoc, CA; Grefco Inc., Dicalite Div., at Lompoc and Burney, CA, and Mina, NV; Eagle-Picher Minerals Inc. at Sparks and Lovelock, NV, and Vale, OR; and Witco Corp., Inorganic Specialties Div., at Quincy, WA. Other producers were Whitecliff Industries, Mammoth, AZ; CR Minerals Corp., Fernley, NV; and Oil-Dri Production Co., Christmas Valley, OR.

CONSUMPTION AND USES

Apparent domestic consumption of processed diatomite increased slightly to 534,000 tons compared with that of 1987. Domestic and export sales of filter-grade diatomite increased 5% from 454,000 tons in 1987 to 476,000 tons. Sales of filler-grade diatomite increased 11% from 105,000 tons to 117,000 tons. Sales of diatomite for insulation increased slightly, and that used for absorbents and additives decreased slightly, compared with those of 1987.

PRICES

The average unit value of sales for processed diatomite was $207 per ton, a small increase over that of 1987.

TABLE 1

DIATOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
Domestic production (sales)	627	635	628	658	693
Total value of sales	120,926	127,030	128,362	134,239	143,774

TABLE 2

DIATOMITE SOLD OR USED,[1] BY MAJOR USE

(Percent of U.S. production)

Use	1984	1985	1986	1987	1988
Fillers	22	21	17	16	17
Filtration	67	66	67	69	69
Insulation	1	1	3	2	2
Other[2]	10	12	13	13	12

[1] Includes exports.
[2] Includes absorbents, additives, and silicate admixtures.

TABLE 3

AVERAGE ANNUAL VALUE PER TON[1] OF DIATOMITE, BY MAJOR USE

Use	1986	1987	1988
Fillers	$220.53	$226.54	$220.88
Filtration	219.69	217.60	221.67
Insulation	129.96	109.72	109.88
Other[2]	116.72	120.54	127.15
Weighted average	**204.28**	**204.17**	**207.35**

[1] Based on unrounded data.
[2] Includes absorbents, additives, and silicate admixtures.

FOREIGN TRADE

U.S. exports of processed diatomite increased 17% to 162,000 tons from that of 1987. Average unit value was $243 per ton compared with $238 per ton in 1987. Diatomite was exported to 73 countries, and the quantity represented 23% of domestic production. The following five countries received 53% of the total: Canada, 24,800 tons; Japan, 22,800 tons; Australia, 15,500 tons; the Federal Republic of Germany, 12,300 tons; and the United Kingdom, 10,000 tons.

Imports of diatomite were 3,000 tons, of which 68% was supplied by the Federal Republic of Germany.

TABLE 4

U.S. EXPORTS OF DIATOMITE

(Thousand short tons and thousand dollars)

Year	Quantity	Value[1]
1985	120	28,519
1986	131	32,180
1987	139	33,075
1988	162	39,374

[1] U.S. Customs.

WORLD CAPACITY

The data in table 5 are rated annual capacity for diatomite processing plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgement of the author, can be brought into production within a short period of time with minimum capital expenditure. Plant capacity for diatomite is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines.

WORLD REVIEW

World production was estimated to be 2 million tons for the fourth consecutive year. France, Romania, the United States, and the U.S.S.R. accounted for 77% of total production.

[1] Industry economist, Branch of Industrial Minerals.

TABLE 5

WORLD DIATOMITE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

	Rated capacity[1]
North America:	
Mexico	50
United States	935
Other	5
Total	**990**
Europe:	
Denmark[2]	100
France	290
Other	860
Total	**1,250**
Africa	10
Asia	80
Oceania	20
South America	50
World total	**2,400**

[1] Includes capacity at operating plants as well as at plants on standby basis.
[2] Includes estimated diatomite content of moler earth.

TABLE 6

DIATOMITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Algeria	2	3	4	[e]4	4
Argentina	6	[r]11	16	[r][e]11	11
Australia	7	8	10	15	12
Brazil (marketable)	18	14	13	[r][e]13	13
Canada[e]	4	4	5	5	5
Chile	2	3	3	4	3
Colombia[e]	([2])	([2])	([2])	([2])	—
Costa Rica	[e]1	—	—	—	—
Denmark:[3]					
Diatomite[e]	11	7	7	7	7
Moler	70	79	80	[e]73	73
France	273	298	[e]287	[e]276	276
Germany, Federal Republic of	54	53	54	52	52
Iceland	30	32	25	[e]28	28
Italy[e]	31	33	30	31	31
Kenya	2	[r]3	2	1	1
Korea, Republic of	53	59	60	71	66
Mexico	49	50	40	38	39
Peru	8	16	11	[r][e]11	11
Portugal	2	2	2	[e]2	2
Romania[e]	331	331	331	309	309
South Africa, Republic of	([4])	1	2	([4])	([4])
Spain	80	106	141	[e]110	110
Thailand	1	([4])	([4])	([4])	([4])
Turkey[e]	[5]3	3	3	3	3
U.S.S.R.[e]	265	270	276	281	287
United Kingdom[e]	([4])	([4])	([4])	([4])	([4])
United States	627	635	628	658	[5]693
Total	**[r]1,930**	**[r]2,021**	**2,030**	**2,003**	**2,036**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 19, 1989.
[2]Revised to zero.
[3]Data represent sales.
[4]Less than 1/2 unit.
[5]Reported figure.

FELDSPAR, NEPHELINE SYENITE, AND APLITE

By Michael J. Potter[1]

FELDSPAR

Total U.S. feldspar production in 1988, including soda, potash, mixed feldspar, and feldspar-silica mixtures, was 715,000 short tons with a value of $26.4 million. Although housing starts were down compared with those of the previous year, feldspar usage in construction-related end uses was comparable to that of 1987 due to activity in the remodeling market. Imports of crude and ground nepheline syenite were about 310,000 tons with a total value of $11.2 million.

Domestic Data Coverage

Domestic production data for feldspar are developed by the Bureau of Mines by means of a voluntary survey. Of the 13 active operations, 10, or 77%, responded, representing an estimated 79% of the total production data for feldspar shown in table 1. The remaining 21% was estimated from prior years' data adjusted to current industry levels.

Legislation and Government Programs

According to provisions of the Tax Reform Act of 1969, which continued in force throughout 1988, the depletion rate allowed on domestic and foreign feldspar production was 14%.

Domestic Production

Soda feldspar is defined commercially as containing 7% soda (Na_2O) or higher; potash feldspar contains 10% potash (K_2O) or higher. However, in order to publish information on potash feldspar without revealing company proprietary data in this report, feldspars containing 8% K_2O or more are defined as potash feldspars. Hand-cobbed or hand-sorted feldspar is usually obtained from pegmatites and is relatively high in K_2O compared with Na_2O. Hand cobbing continued to be a minor fraction of total production in 1988. Feldspar flotation concentrates, most of the U.S. output, are classified as either soda, potash, or mixed feldspar, depending on the relative amounts of Na_2O and K_2O present. Feldspar-silica mixtures, feldspathic sand, can either be naturally occurring or a flotation product. Total feldspar content of this mixture was 29% of total feldspar output during 1988.

Feldspar was mined in six States, led by North Carolina and followed in descending order by Connecticut, California (estimated), Georgia, Oklahoma, and South Dakota. North Carolina accounted for 71% of the total. Twelve U.S. companies operating 13 beneficiating plants and 1 grinding plant produced feldspar or feldspar-silica mixtures for shipment to more than 31 States and foreign countries, including Canada and Mexico. Of the 12 companies, 3 produced potash feldspar, and the remainder produced soda or mixed feldspar or feldspathic sand mixtures. North Carolina had six plants, California had three, and Connecticut, Georgia, Oklahoma and South Dakota each had one. The grinding plant was in South Carolina.

The data for potash feldspar were

TABLE 1

SALIENT FELDSPAR AND NEPHELINE SYENITE STATISTICS

		1984	1985	1986	1987	1988
United States:						
Feldspar:						
Produced[1]	short tons	710,000	700,000	735,000	720,000	715,000
Value	thousands	$23,500	$22,800	$26,100	$26,100	$26,400
Exports	short tons	10,080	9,280	12,000	9,634	13,712
Value	thousands	$920	$680	$1,024	$691	$769
Imports for consumption	short tons	25	952	1,251	4,833	6,827
Value	thousands	$15	$1,150	$542	$477	$659
Nepheline syenite:						
Imports for consumption	short tons	377,945	332,604	298,806	308,685	309,844
Value	thousands	$14,218	$11,435	$11,280	$11,401	$11,233
Consumption, apparent[2] (feldspar plus nepheline syenite)	thousand short tons	1,078	1,024	1,023	1,024	1,018
World: Production (feldspar)	do.	[r]4,182	[r]4,449	4,537	[p]4,705	[e]4,728

[e]Estimated. [p]Preliminary. [r]Revised.
[1] Includes hand-cobbed feldspar, flotation-concentrate feldspar, and feldspar in feldspar-silica mixtures; includes potash feldspar (8% K_2O or higher).
[2] Production plus imports minus exports.

TABLE 2

FELDSPAR[1] PRODUCED IN THE UNITED STATES

(Thousand short tons and thousand dollars)

Year	Hand-cobbed		Flotation concentrate		Feldspar-silica mixtures[2]		Total[3]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1984	7	124	502	17,874	201	5,503	710	23,500
1985	14	W	487	16,781	197	W	700	22,800
1986	13	W	522	19,855	200	W	735	26,100
1987	10	W	492	17,800	219	W	720	26,100
1988	14	W	498	18,657	204	W	715	26,400

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes potash feldspar (8% K_2O or higher).
[2] Feldspar content.
[3] Data may not add to totals shown because of independent rounding.

collected from the three U.S. producers of this material; some of this feldspar contained less than 10% K_2O (8% to 10% K_2O).

In February 1988, Foote Mineral Co. was acquired by Cyprus Minerals Co. and was renamed Cyprus Foote Mineral Co.

TABLE 3

PRODUCERS OF FELDSPAR AND FELDSPATHIC MATERIALS IN 1988

Company	Plant location	Product
APAC Arkansas Inc.	Muskogee, OK	Feldspar-silica mixture.
California Silica Products Co.	San Juan Capistrano, CA	Do.
Calspar Div. of Steelhead Resources Inc.	Santa Fe Springs, CA	Soda feldspar.
Cyprus Foote Mineral Co.	Kings Mountain, NC	Feldspar-silica mixture.
The Feldspar Corp.	Middletown, CT	Soda feldspar.
Do.	Monticello, GA	Potash feldspar.
Do.	Spruce Pine, NC	Soda feldspar.
Do.	Montpelier, VA	Aplite.
Indusmin Inc.	Spruce Pine, NC	Soda feldspar.
KMG Minerals Inc.	Kings Mountain, NC	Potash feldspar.
Lithium Corp. of America	Bessemer City, NC	Feldspar-silica mixture.
Pacer Corp.	Custer, SD	Potash feldspar.
Spartan Minerals Corp.	Pacolet, SC	Feldspar-silica mixture.
Unimin Corp.	Spruce Pine, NC	Soda feldspar.
U.S. Silica Co.	Oceanside, CA	Feldspar-silica mixture.

Consumption and Uses

Of the total feldspar sold or used in the United States, 54% went into glassmaking, including container glass and glass fiber, and 44% was used in pottery.

According to the U.S. Department of Commerce, glass containers composed 23% of the rigid container market in 1987. Metal cans made up 59%, and plastic containers composed the remaining 18%. End-use markets for the rigid container industry were approximately evenly distributed among soft drinks, other beverages, and food. Glass containers should continue to be a strong competitor because of recycling, aggressive marketing strategies, and commitment to research.[2]

Housing starts in 1988 decreased to 1.45 million compared with 1.6 million in 1987. However, feldspar usage in 1988 in plumbing fixtures, tile, and glass fiber for insulation was comparable to that of 1987 due to strong activity in the remodeling market.

The quantity of potash feldspar sold or used in 1988 was 94,500 tons with a value of $6.24 million.

Prices

Published feldspar prices were the same as those of 1987. Industrial Minerals (London), December 1988, listed the following prices for feldspar, per short ton, f.o.b. plant, bulk:

Producing States	1987	1988
Ceramic grade:		
Middleton, CT., minus 200 mesh	$53.25	$53.25
Monticello, GA., 200 mesh, high potash	73.50	73.50
Spruce Pine, NC., 170–250 mesh	44.00	44.00
Glass grade:		
Middleton, CT., 96% plus 200 mesh	39.00	39.00
Monticello, GA., 92% plus 200 mesh, high potash	54.00	54.00
Spruce Pine, NC., 97.8% plus 200 mesh	30.75	30.75

Source: Industrial Minerals (London), No. 255, Dec. 1988, p. 82.

TABLE 4

FELDSPAR[1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Thousand short tons and thousand dollars)

Use	1987		1988	
	Quantity	Value	Quantity	Value
Hand-cobbed:				
Pottery	4	W	5	W
Other	3	W	7	W
Total	**7**	**W**	**12**	**W**
Flotation concentrate:				
Glass	218	7,845	217	7,937
Pottery	277	14,460	287	15,591
Total[2]	**495**	**22,305**	**503**	**23,528**
Feldspar-silica mixtures:[3]				
Glass	179	8,417	181	7,569
Pottery	34	W	32	W
Total[2]	**213**	**W**	**212**	**W**
Total:[2]				
Glass[4]	398	16,262	397	15,506
Pottery	316	W	324	W
Other[5]	3	W	7	W
Total	**720**	**32,900**	**730**	**33,300**

W Withheld to avoid disclosing company proprietary data; included in "Total".
[1] Includes potash feldspar (8% K_2O or higher).
[2] Data may not add to totals shown because of independent rounding.
[3] Feldspar content.
[4] Includes container glass and glass fiber.
[5] Includes enamel, filler, etc., and unknown.

Foreign Trade

U.S. exports classified as feldspar, leucite, and nepheline syenite increased 42%. Feldspar imports for consumption increased 59%.

In addition to feldspar and nepheline syenite, the United States imported 46,100 tons of "Other crude, natural mineral fluxes" with a value of $2.9 million. This represented a 4% increase in tonnage compared with that of 1987. Also, 21,200 tons of "Other mineral fluxes, crushed" were imported with a value of $2.4 million. This was a 149% increase in tonnage compared with that of 1987.

The tariff schedule in force throughout 1988 for most favored nations provided for a 2.9% ad valorem duty on ground feldspar; imports of unground feldspar were admitted duty free.

World Capacity

The data in table 9 are rated capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Because actual capacity data were not available, recent peak production during the past 5 years for the United States and foreign countries was considered to be equal to rated capacity.

World Review

Australia.—Consolidated Feldspar Ltd. began operation of a new plant to produce glass- and ceramic-grade feldspar, largely for export to Asia. The facility was located at Broken Hill, New South Wales, at the Triple Chance mining complex. The company planned to mine and process material from the same ore body to obtain crushed beryl and mica concentrates.[3]

Canada.—A technical evaluation and a market feasibility study for production of rubidium feldspar from a deposit in Manitoba, Canada, has been published.[4] The feldspar, which is high in potash and contains 1.3% rubidium oxide, is a byproduct of a lithium recovery operation. The paper discussed general feldspar production in North America; projected demand for all feldspatnic materials; and estimated initial sales volume of the rubidium feldspar in glass, electrical insulators,

TABLE 5

DESTINATION OF SHIPMENTS OF FELDSPAR[1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

(Short tons)

State	1984	1985	1986	1987	[2]1988
Alabama	15,100	W	20,100	W	W
California [e][3]	45,000	50,000	50,000	50,000	50,000
Florida	20,300	16,900	20,000	14,200	W
Georgia	96,000	95,300	91,600	86,500	93,100
Illinois	38,000	37,000	27,900	28,700	29,700
Indiana	35,700	W	W	W	30,100
Kentucky	13,300	16,200	16,900	W	17,000
Louisiana	21,300	12,200	14,100	14,900	13,900
Maryland	7,400	7,400	7,000	6,400	7,200
Massachusetts	10,800	W	W	W	W
Mississippi	12,000	W	W	W	13,200
Missouri	4,400	4,700	6,100	5,200	4,900
New Jersey	53,200	W	W	W	W
New York	10,800	W	W	W	W
North Carolina	16,400	17,000	20,700	40,500	23,700
Ohio	64,900	65,800	68,200	64,400	64,700
Pennsylvania	37,200	31,100	33,600	36,400	29,200
South Carolina	17,400	W	W	W	W
Texas	41,400	42,000	45,000	44,000	W
West Virginia	28,500	27,000	24,400	19,800	18,700
Wisconsin	11,100	W	W	W	W
Other [4]	99,800	277,400	289,400	306,000	332,400
Total[5]	**700,000**	**700,000**	**735,000**	**720,000**	**730,000**

[e] Estimated. W Witheld to avoid disclosing company proprietary data; included with "Other destinations."
[1] Includes potash feldspar (8% K_2O or higher).
[2] An estimated 68% of these data were obtained by survey forms; the remaining 32% were estimated.
[3] Data are incomplete and estimates are very rough.
[4] Includes Arkansas, Colorado, Connecticut, Kansas, Michigan, Minnesota, Oklahoma, Rhode Island, Tennessee, Virginia, States indicated by symbol W, and other unspecified States. Also includes exports to Canada, Mexico, and other foreign countries.
[5] Data may not add to totals shown because of independent rounding.

sanitary ware, porcelain enamel, tile, and other end uses. The estimated initial market volume obtainable for a Manitoba producer was around 30,000 tons per year. A prime market for the high-potash feldspar is electrical porcelain insulators. The higher molten viscosity of high-potash feldspar results in less sagging or warping on firing, an important factor when ceramic bodies are large, as in the case with electrical insulators. High-potash feldspar has higher electrical resistivity than ordinary feldspar, and a rubidium feldspar would theoretically have an even higher electrical resistivity. Electrical insulators are composed of 15% to 50% of potash feldspar by weight.

Canspar Minerals Inc. began to mine and market handcobbed, high-potash, low-iron feldspar for dental use in 1988 from an operation near Buckingham, Quebec. The company was examining the possibility of employing mining techniques which would enable them to mine larger volumes of material for the chinaware and electrical insulator industries.

France.—Annual production of feldspar in recent years ranged from 190,000 tons to 238,000 tons per year. Ets Baux S.A., with three mines, has been a dominant producer, with output over 100,000 tons annually. In 1987, 64% of the company's soda and mixed feldspar production was used in the manufacture of glass and the remainder in ceramics. About 78% of the output was used domestically. Other feldspar producers included Ste. des Feldspaths du Midi and Ste. des Feldspaths du Morvan. The mainly soda-rich feldspar was used in sanitary ware, tile, and paving. Phonolite, similar to microcline feldspar, was produced by Société d'Exploitation de Sables et Minéraux S.A. (SAMIN) for use in local green glass, because its iron oxide content of 2% was too high for white glass.[5]

Greece.—Most raw materials for glass and ceramics were imported until the early 1980's. Mevior S.A. began operation of a plant in Assiros near Thessaloniki to produce soda feldspar mainly for domestic consumption in ceramic tile, sanitary ware, and glass. High-quality quartz was also produced. Porcel S.A. built a plant in Paranesti, Drama Prefecture, designed for an annual output of 18,000 tons of potash feldspar containing 10% K_2O, 2,000 tons of potash feldspar with 13% K_2O, 7,000 tons of mixed feldspar for the domestic glass industry, and 1,000 tons of mica as a byproduct. The potash feldspar was mainly for export as the domestic market was small.

In order to reduce imports of glass sand of 100,000 tons per year, some local deposits were evaluated. Beneficiation tests on Nestos River bed sands in eastern Macedonia yield fairly good quality soda and potash feldspar and silica sand. Test work on the Mesologos

TABLE 6

DESTINATION OF SHIPMENTS OF POTASH FELDSPAR[1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES

(Short tons)

Destination	1984	1985	1986	1987	1988
Illinois, Indiana, Wisconsin	5,800	5,800	5,500	W	W
Maryland, New York, West Virginia	21,800	28,000	25,600	W	W
Ohio	9,000	8,200	W	W	W
Pennsylvania	13,500	8,200	W	W	W
Texas	200	200	300	W	W
Canada	4,600	5,200	3,500	W	W
Other[2]	16,400	21,400	39,200	W	W
Total	**71,300**	**77,000**	**74,100**	**W**	**94,500**

W Witheld to avoid disclosing company proprietary data; included with "Other."
[1] K_2O content of 8% or higher.
[2] Includes Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Kansas, Kentucky, Louisiana, Michigan, Massachusetts, Minnesota, Missouri, New Jersey, North Carolina, Oklahoma, South Carolina, Tennessee, Virginia, States indicated by symbol W, and other unspecified States. May also include countries.

TABLE 7

U.S. EXPORTS OF FELDSPAR, BY COUNTRY

Country	1987		1988	
	Short tons	Value	Short tons	Value
Canada	1,864	$100,403	1,454	$76,986
Dominican Republic	1,661	91,147	294	17,754
Italy	623	32,960	1,274	66,216
Mexico	1,309	122,760	2,954	199,653
Panama	—	—	970	50,439
Taiwan	1,002	101,291	5,182	269,692
Venezuela	2,272	143,717	734	38,160
Other	903	99,010	850	50,197
Total	**9,634**	**691,288**	**13,712**	**769,097**

Source: Bureau of the Census.

sand deposit in west Macedonia produced mixed feldspar for glass and ceramics and quartz sand for glass, foundry sand, and other uses. Further exploratory drilling and pilot plant work is required.[6]

Mexico.—Feldspar consumption in glass making was expected to increase slightly due to the introduction of nonreturnable bottles and growth of beer exports. However, a trend to reduce alumina content in glass batches from 1.5% to 1.0% and the emergence of plastic polyethylene terephthalate (PET) containers as competition for glass were factors hindering feldspar growth. Ceramics, the other major end use for feldspar, was showing strong growth, especially in sanitary ware and tile.

Two major feldspar operations supplied much of the Mexican output. Materias Primas Minerales de Ahuazotepec S.A., in Puebla, produced soda feldspar in glass and ceramic grades, with 60% of the output used in glass production. The company planned to increase its fine grinding capacity from 15,000 tons per year to around 40,000 tons per year by late 1988.

A second major producer, Materias Primas Minerales de San Jose S.A., in Guanajuato, produced potash feldspar. The company's annual capacity was around 176,000 tons but production was only at one-half that level. Most of the glass and ceramic grades of feldspar were being used domestically, but some fine-ground material was being exported to California.[7]

Sweden.—Svenska Forshammar AB announced an internal change in the running of its quartz and feldspar business, effective January 1, 1988. Production and marketing from the company's plant in Riddarhyttan were to be taken over by Ernström Mineral AB, in Orebo.[8]

Technology

Proper handling and beneficiation of recycled glass cullet are important in obtaining a furnace-ready raw material. Large quantities of cullet are being used by the glass container industry, with even more recycling being anticipated as glass-recycling efforts are established in more communities. Some of the contaminants found in recycled cullet include magnetic metal, such as steel bottle caps and jar lids; nonmagnetic metals, such as aluminum from bottle caps, pull tabs, etc.; ceramic materials, including pottery, porcelain, brick, clay, etc.; ground contamination, such as stones and dirt; and organics, including paper, plastic labels, wood, etc.[9]

Lightweighting, or making a container with less glass while maintaining its capacity, and glass recycling in Europe have not caused a major reduction so far in raw material consumption. An average bottle weight reduction of 2% has occurred since 1980 in most countries, and a reduction of 5% was pro-

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF FELDSPAR, BY TYPE AND COUNTRY

Type and country	1987 Short tons	1987 Value[1]	1988 Short tons	1988 Value[1]
Crude:				
Canada	194	$1,982	—	—
Germany, Federal Republic of	—	—	12	$3,507
Mexico	150	2,341	56	2,487
Netherlands	—	—	7	1,975
Ground, crushed, or pulverized:				
Canada	—	—	19	6,278
Germany, Federal Republic of	—	—	25	5,076
Korea, Republic of	35	6,577	—	—
Mexico	4,377	418,170	6,708	639,643
United Kingdom	43	16,916	—	—
Total	**[r]4,799**	**[r]445,986**	**6,827**	**658,966**

[r] Revised.
[1] Customs value.

Source: Bureau of the Census.

TABLE 9

WORLD ANNUAL FELDSPAR PRODUCTION CAPACITY, DECEMBER 31, 1988

Rated Capacity[1]

Country	Capacity
North America:	
Mexico	117
United States	735
Total	**852**
South America:	
Brazil	138
Venezuela	50
Other	107
Total	**295**
Europe:	
Finland	62
France	238
Germany, Federal Republic of	355
Italy	1,364
Norway	88
Poland	66
Romania[e]	95
Spain	154
Sweden	55
U.S.S.R.[e]	370
Yugoslavia	54
Other	68
Total	**2,969**
Africa:	
South Africa, Republic of	93
Other	30
Total	**123**
Asia and Oceania:	
India	55
Korea, Republic of	199
Thailand	198
Other	235
Total	**687**
World total	**[2]4,930**

[e] Estimated.
[1] Includes capacities of operating plants as well as plants on standby basis.
[2] Data do not add to total shown because of independent rounding.

jected over the next 5 to 10 years. Recycling has grown dramatically in Europe in recent years; however, its measurable effect on raw materials consumption has only been a reduction of 10%. Recycling may reach an upper limit of around 50% until certain constraints can be dealt with, such as the separation of white, amber, and green cullet.[10]

Feldspar typically comprises 25% to 35% of sanitary ware, such as wash basins, bidets, and toilets. A new energy-efficient sanitary ware dryer reportedly cuts drying time from 24 to 96 hours to a maximum of 6 hours. The Rapide dryer from Thermic Designs Ltd. of Stoke-on-Trent, England, can be fired by gas, diesel oil, or electricity. Indirect heating by hot water or steam is also possible, and waste heat from a kiln can be utilized.[11]

NEPHELINE SYENITE

Nepheline Syenite was produced by Indusmin Ltd., a division of Falconbridge Ltd., from two operations at Blue Mountain, Ontario, Canada. In Norway, nepheline syenite was produced at the Elkem Nefelin A/S, underground mining operation on the arctic island of Stjernøya. Sales were mostly to markets in Western Europe. On January 1, 1988, the company, which was previously known as Norsk Nefelin, a unit under the Mineral Division of Elkem A/S, became a separate limited company under the name Elkem Nefelin.[12]

Nepheline syenite and feldspar, as filler-extender specialty products, are used in paints and coatings, in interior and exterior formulations, and in both solvent and water-based coatings. The paints can be highly pigmented, translucent, and clear and range from rela-

TABLE 10

FELDSPAR: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina	20	[r]30	18	25	22
Australia	4	7	11	13	12
Austria	3	15	3	5	5
Brazil[3]	[r]105	121	133	[e]138	138
Burma	7	3	3	2	2
Chile	3	3	3	1	1
Colombia	36	38	39	37	39
Ecuador	2	4	3	2	2
Egypt	8	21	21	18	18
Finland	62	58	52	57	55
France	230	190	238	[e]231	231
Germany, Federal Republic of	328	355	273	342	330
Guatemala	5	6	6	8	8
Hong Kong	127	120	39	25	28
India	44	51	51	55	55
Iran	36	35	[e]35	[e]35	35
Italy	1,086	1,230	1,364	[e]1,320	1,320
Japan[4]	39	34	35	37	31
Kenya	1	1	—	[e]1	1
Korea, Republic of	140	160	144	199	198
Mexico	93	[e]110	94	117	110
Morocco[e]	1	1	1	1	1
Mozambique[e]	1	([5])	([5])	([5])	([5])
Nigeria	—	[e]2	3	1	1
Norway[6]	75	88	[e]88	[e]88	88
Pakistan	6	6	13	7	9
Peru	4	—	21	[e]11	11
Philippines	13	6	[e]7	[e]7	7
Poland	51	66	63	61	55
Portugal	32	32	37	45	41
Romania[e]	94	95	95	90	90
South Africa, Republic of	43	36	58	73	[7]93
Spain[8]	151	150	149	[e]151	154
Sri Lanka	6	11	8	8	8
Sweden	55	46	[e]44	[e]44	44
Taiwan	17	12	29	31	28
Thailand	82	115	127	186	198
Turkey	[e]11	[e]22	[e]22	33	[7]62
U.S.S.R.[e]	360	370	370	370	370
United Kingdom (china stone)	7	7	8	[e]8	8
United States	710	700	735	720	[7]715
Uruguay	2	1	[e]1	[e]1	1
Venezuela	43	34	38	48	50

See footnotes at end of table.

tively crude and inexpensive traffic paints to fine furniture finishes. Paint and coatings account for 90% of the demand for specialty feldspathic products. The feldspathic share of the market for fillers and extenders in paint is about 6%. Syenite and feldspar are also used in rubber, adhesives, and plastics, such as high traffic vinyl flooring, polyacrylate corrugated roofing, and polyester signs and building facades. Nepheline syenite in microwave ovenware helps prevent the ware from heating up when exposed to microwave radiation.[13]

Prices for Canadian nepheline syenite listed in Industrial Minerals (London), December 1988, were $21.50 to $30.50 per ton for glass grade, 30 mesh, bulk, carlots-trucklots, depending on iron content; $64 to $66 per ton for ceramic grade, 200 mesh, bagged, 10-ton lots; and $85 to $99 per ton for filler-extender grade, bagged.

APLITE

Aplite is a feldspar mineral that has more than one geological definition. However, aplite from the one active U.S. operation contains primarily lime-soda feldspar. Aplite, usually unsuitable for use in ceramics, has been used in the manufacture of glass when it is sufficiently low in iron. With an annual production of approximately 490,000 tons, Japan has been the world's largest producer of aplite.

Aplite of glassmaking quality was produced in the United States by The Feldspar Corp. near Montpelier, Hanover County, VA.

Domestic output decreased compared with that of 1987. The data are company proprietary and cannot be released for publication. Aplite traditionally has a somewhat lower price than feldspar. Industrial Minerals (London), December 1988, gave a value of $25.75 per ton for glass grade, bulk, 100% plus 200 mesh, f.o.b. Montpelier, VA.

[1] Physical scientist, Branch of Industrial Minerals.

[2] Sheppard, L. M. Glass Containers Marketed For Growth. Am. Ceram. Soc. Bull., v. 67, No. 11, Nov. 1988, p. 1788.

[3] Mining Magazine. Feldspar Makes the Grade. V. 158, No. 6, June 1988, p. 457.

[4] Andrews, P. R. A., G. H. K. Pearse, and R. O. Burt. Product and Market Evaluation of a Rubidium Feldspar from Bernic Lake, Manitoba, Canada. Paper from 8th "Ind. Miner." International Congress., Boston, Mass., Apr. 24-27, 1988, pp. 255-269.

[5] Russell, A. Industrial Minerals of France. Ind. Miner. (London), No. 249, June 1988, pp. 28-29.

[6] Georgiades, G. Greek Raw Materials for the Glass and Ceramics Industry. Ind. Miner. (London), No. 247, Apr. 1988, pp. 135-139.

[7] Griffiths, J. Mexico's Industrial Minerals. Ind. Miner. (London), No. 250, July 1988, pp. 35, 37.

[8] Industrial Minerals (London). Company News. No. 249, June 1988, p. 74.

[9] DeNapoli, F. J. and W. M. Kilpatrick. Effective Beneficiation of Recycled Cullet for Use in Glass Container Furnaces. Am. Ceram. Soc. Bull., v. 67, No. 11, Nov. 1988, pp. 1798-1801.

[10] Reynolds, A. Lightweighting and Recycling. Ind. Miner. (London), No. 246, Mar. 1988, pp. 50, 57.

[11] Ceramic Industry. Drying Sanitaryware: Job Gets Slashed to Six Hours. V. 131, No. 5, Oct. 1988, pp. 35-36.

[12] Industrial Minerals (London). Mineral Notes. No. 244, Jan. 1988, p. 63.

[13] Mommsen, R. W. Nepheline Syenite and Feldspar As Functional Filler/Extender Pigments. Paper from 8th "Ind. Miner." Internat. Cong., Boston, Mass., Apr. 24-27, 1988, pp. 273, 275, 276.

TABLE 10—Continued

FELDSPAR: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Yugoslavia	37	54	53	50	50
Zambia	([5])	([5])	([5])	([5])	([5])
Zimbabwe	2	3	2	3	3
Total	**[r]4,182**	**[r]4,449**	**4,537**	**4,705**	**4,728**

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through May 3, 1989.

[2] In addition to the countries listed, Czechoslovakia, Madagascar and Namibia produce feldspar, but output is not officially reported and available general information is inadequate for the formulation of reliable estimates of output levels.

[3] Series excludes production of leucite and sodalite; data consist only of that material reported by Brazil under the heading of "Feldspar." Data represent the sum of (1) run-of-mine production for direct sale and (2) salable beneficiated product; total run-of-mine feldspar production was as follows in thousand short tons: 1984—93; 1985—109 (revised); 1986—116; 1987—109; and l988—110 (estimated).

[4] In addition, the following quantities of aplite concentrate were produced, in thousand short tons: 1984—486; 1985—517; 1986—493; 1987—484; and 1988—520 (estimated).

[5] Less than 1/2 unit.

[6] Excludes nepheline syenite.

[7] Reported figure.

[8] Includes pegmatite.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF NEPHELINE SYENITE

Year	Crude		Ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1986	2,970	$205	295,836	$11,075
1987	3,720	142	304,965	11,259
1988	2,882	111	306,962	11,122

Source: Bureau of the Census.

FERROALLOYS

By Clark R. Neuharth[1]

Overall domestic demand for ferroalloys and related metals and materials increased significantly compared with that of 1987. Both domestic production and imports rose to meet demand. Prices generally rose as supplies were sometimes short.

DOMESTIC DATA COVERAGE

Domestic production data for ferroalloys are developed by the Bureau of Mines by means of monthly and annual voluntary domestic surveys. Typical of these surveys are the three separate monthly surveys for chromium alloys and metal, manganese alloys and metal, and silicon alloys and metal, and the annual survey for ferroalloys. Of the 35 operations to which a survey was sent, 31 responded; 2 of the facilities listed in table 2 were known to be nonoperational during the year.

LEGISLATION AND GOVERNMENT PROGRAMS

The South Carolina Research Authority, a public corporation created by the State's government to support high-technology industries, was awarded a $3.5 million Federal grant for the purpose of increasing U.S. competitiveness in the world ferrochromium market. Financing for the program was to be provided under defense appropriations for fiscal year 1989. Macalloy Corp., Arthur D. Little Co., Clemson University, and technology experts from the Massachusetts Institute of Technology were named as key participants in the program. The first stage of the program was to consist of the design and development of a 2,000-kilowatt plasma-arc furnace, which would be located at Macalloy's facility in Charleston, SC.

The Secretary of the U.S. Department of the Interior and the Governor of the State of Oregon formed a task force to study chromium-containing black sand deposits in the coastal terraces off the Oregon shore. The task force was directed to define the extent of the black sand deposits and to evaluate their economic and strategic importance.

The U.S. Department of Defense assumed authority for the management and operations of the National Defense Stockpile, which was previously held by the Federal Emergency Management Agency and the General Services Administration (GSA). Stockpile policy matters were placed under the direction of the Assistant Secretary for Production and Logistics, while control of operations was given to the Defense Logistics Agency (DLA). DLA decided to exercise a third year option under terms of a 1987 agreement signed by GSA and two ferroalloy producers, Macalloy and Elkem Metals Co., to extend its ferrochromium and ferromanganese upgrading program into 1989. Under the extension, Macalloy was expected to upgrade 124,627 short tons of chromium ore to ferrochromium, while Elkem's contract calls for the upgrading of 102,947 short tons of manganese ore into 58,571 short tons of ferromanganese. The combined contracts were valued at approximately $62 million. DLA also announced its plans to spend $30 million on the upgrading of chromium, columbium, tantalum, vanadium, and titanium materials. The new upgrading plan called for the conversion of 1,500 short tons of low-carbon ferrochromium to electrolytic chromium metal, 48,500 pounds of columbium metal powder to high-purity columbium, 40,000 pounds of tantalum metal powder to high-purity tantalum, 5,000 short tons of titanium sponge to a high-purity form of the metal, and 540 short tons of vanadium pentoxide to a high-purity form.

The Office of the United States Trade Representative considered the domestic silicon industry's request for an end to duty-free imports of certain silicon products. The request, filed by the Ferroalloys Association, was to end exemption of the 5.5% duty on imports of silicon metal in the 99.0%- to 99.7%-pure category from two countries, Argentina and Yugoslavia. Both of these countries were considered by the industry to be long-time producers of silicon metal. Imports of the 99.0%- to 99.7%-pure silicon metal from the two countries combined accounted for about 30% of all silicon metal imports into the United States in 1987 and 1988. A final decision in the case was pending at yearend.

The U.S. Court of Appeals of the District of Columbia Circuit Court ordered the Environmental Protection Agency (EPA) to relist six hazardous wastes from the smelting and refining of aluminum, copper, ferrochromium, ferrochromium-silicon, lead, and zinc. EPA was also ordered to complete its statutory responsibilities under subtitle C of the Resource Conservation and Recovery Act (RCRA). These wastes had previously been excluded from regulation by the Bevill Amendment to the

TABLE 1

GOVERNMENT INVENTORY OF FERROALLOYS, DECEMBER 31, 1988

(Thousand short tons)

Alloy	Stock-pile grade	Non-stock-pile grade	Total
Ferrochromium:			
High-carbon	595	1	596
Low-carbon	300	19	319
Ferrochromium-silicon	57	1	58
Ferrocolumbium (contained columbium)	.3	.2	.5
Ferromanganese:			
High-carbon	757	—	757
Medium-carbon	29	—	29
Ferrotungsten (contained tungsten)	.4	.6	1
Silicomanganese	24	—	24

RCRA, which also required EPA to study their toxicity. The court decision required EPA to complete a listing of hazardous wastes from these industries by yearend. EPA was also directed to complete the studies of these wastes and to submit a report to Congress in early 1989.

In September 1988, President Reagan signed a United States-Canada free trade agreement which will eliminate all tariffs and most nontariff trade barriers between the two countries by 1999. The pact contained some provisions concerning United States-Canadian trade of ferroalloys and related materials, including the elimination of duties on ferrosilicon products. Canadian approval of the agreement was pending at yearend.

DOMESTIC PRODUCTION

Domestic production and shipments of ferroalloys and related metals overall increased 28% and 13%, respectively, in 1988 compared with those of 1987. The increase was the result of continued strong demand by major ferroalloy-consuming industries. Capacity utilization by bulk ferroalloy producers, especially producers of silicon alloys and silicon metal, was at its highest level of the past several years.

Estimated ferrous scrap consumption by the domestic ferroalloys industry was 300,000 tons in 1988, up from 250,000 tons in 1987. The Ferroalloys Association reported that its member companies consumed 5.3 billion kilowatt hours of electricity in 1988, up from 4.1 billion kilowatt hours in 1987.

A number of companies increased production to meet the higher demand by rekindling idle furnaces, and in one case a complete plant was reactivated. Domestic production of silicon-containing ferroalloys and metal increased nearly 20% compared with that of 1987.

Globe Metallurgical Inc. brought four furnaces back on line at its Beverly, OH, plant to increase production of ferrosilicon, ferrosilicon-based alloys, and silicon metal and continued production of silicon metal at its facility in Selma, AL. The increases at Beverly placed the company's capacity utilization at 100% for the first time since 1981.

Elkem rekindled furnaces at two of its production facilities. As the year began, Elkem completed the reactivation of a 75,000 ton-per-year furnace at its plant in Ashtabula, OH, doubling the ferrosilicon production level there. However, in February, Elkem was forced to temporarily suspend production of 50% ferrosilicon and specialty foundry alloys at Ashtabula, owing to a power failure at a local powerplant. A significant amount of production was lost, but full production was resumed the following month. Owing to growing demand from the stainless steel industry, Elkem brought back production of charge chrome in the second quarter of the year at its facility in Marietta, OH. The move reversed a 15-year trend of declining U.S. output of ferrochromium. Elkem also sold a 70% interest in its coal-fired generating plant in Marietta to American Municipal Power-Ohio, since the Marietta ferroalloy operation was only partially utilizing the generator's supply.

American Alloys Inc., new owners of Foote Mineral Co.'s ferroalloy plant in Graham, WV, reactivated all three of the facility's furnaces for ferrosilicon production. The plant had not been in operation since 1985. The first two furnaces were started early in the year, while the company was planning to use the third for silicon metal production. The company later postponed indefinitely the silicon metal plans, owing to a favorable ferrosilicon market and lack of materials needed to convert the furnace to silicon metal production.

Northwest Alloys Inc., a subsidiary of Aluminum Co. of America (Alcoa), restarted a 27-megawatt electric furnace in Addy, WA, in April to produce 75% ferrosilicon. The furnace had been idle for over 2 years, and Northwest Alloys had been buying 75% ferrosilicon on the open market. However, with the price of that material steadily rising over the past year, the company saw the reactivation as a good opportunity to supply their own needs. Production of 75% ferrosilicon at Addy was considered totally captive, since the company used it to produce magnesium, which was used by the parent, Alcoa.

Dow Corning Corp. reactivated its silicon metal furnace at Springfield, OR, in September. The furnace was completely relined after a lining failure had stopped production late in 1987.

Silicon Metaltech Inc. completed its purchase of the M.A. Hanna Co.'s silicon plant at Rock Island, WA, spending $16 million on the plant and quartz mining operations in Canada.

Affiliated Metals and Minerals Inc., a ferromolybdenum and ferrovanadium producer based in Pittsburgh, PA, filed for protection under Chapter 11 of the Federal Bankruptcy Code. Affiliated's New Castle Vanadium Corp., a joint venture with Shieldalloy Corp., will not be affected by the move.

Ohio Ferro-Alloys Corp. (OFA), Canton, OH, approved a financial reorganization plan submitted by the U.S. Bankruptcy Court that permitted the company to emerge from its Chapter 11 protection of over 2 years. OFA announced that unsecured creditors collectively would receive 15% ownership in the company and that their repayment would come from future cash flow. The company also changed its name to SiMetco, reflecting that its only remaining business was silicon metal production. All of the company's three furnaces at its Montgomery, AL, facility were refurbished during the year and all were operating at yearend.

Strategic Minerals Corp. announced plans to reopen its Hot Springs, AR, vanadium mine in 1989. The only U.S. primary vanadium operation had been closed for 3 years, but company officials stated that significantly higher prices resulting from very tight supplies would make operation of the mine economically feasible.

SKW Alloys Inc. purchased ESM Inc., Valencia, PA. ESM, a producer of desulfurization agents for the iron and steel industry, will continue its operations as before, but under a new name, ESM II Inc.

Boulder Gold NS (Australia), through its wholly-owned subsidiary Chrome Corp. International, Denver, CO, announced the planned construction of a ferrochromium smelter near Columbus, MT, pending the results of a feasibility study and confirmation of a local ore deposit. The smelter would utilize the Coal Ore Direct Iron Reduction process for chromite, developed by Krupp Industrietechnik (Federal Republic of Germany). Krupp completed pilot plant testing and was preparing a range of performance guarantees. Smelter feed for the operation initially would come from an existing 600,000-ton chromite stockpile at Columbus; however, continued operation would require reopening of the Mouat chromite mine. The smelter also would consume Montana coal.

CONSUMPTION AND USES

Overall demand for ferroalloys and related metals increased significantly in 1988 owing to increased production of iron and steel, aluminum, and chemicals. Approximate increases in demand (i.e., apparent consumption) for ferroalloy materials containing chromium, manganese, and silicon were 30%, 20%, and 15%, respectively.

PRICES

Published prices for most ferroalloys and related materials rose steadily throughout 1988 owing to tight supplies resulting from increased demand by consuming industries. For example, the price for imported charge chrome (50% to 55% chromium) on January 1 was 58 cents per pound of contained chromium and rose to over $1 in Sep-

TABLE 2

FERROALLOYS[1] PRODUCED AND SHIPPED FROM FURNACES IN THE UNITED STATES

	1987				1988			
	Net production		Net shipments		Net production		Net shipments	
	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)
Chromium alloys[2]	117,634	61	126,423	$107,078	W	62	W	W
Chromium metal	(3)	100	(3)	(3)	W	100	W	W
Manganese alloys[4]	112,945	78	128,638	101,768	W	74	W	W
Manganese metal	(5)	100	(5)	(5)	W	100	W	W
Silicon alloys[6]	357,255	52	374,865	193,227	495,299	55	475,453	$298,822
Silicon metal	149,428	99	149,713	186,578	164,348	99	162,283	218,934
Total[7]	**737,262**	**XX**	**779,639**	**588,651**	**659,647**	**XX**	**637,736**	**517,756**
Ferrocolumbium	(8)	65	(8)	(8)	NA	NA	NA	NA
Ferrophosphorus	40,188	23	40,642	6,171	66,381	24	50,963	9,583
Other[9]	r35,676	XX	51,686	123,669	316,857	XX	296,355	408,322
Total[7]	**75,864**	**XX**	**92,328**	**129,840**	**383,238**	**XX**	**347,318**	**417,905**
Grand total[7]	**813,126**	**XX**	**871,967**	**718,491**	**1,042,885**	**XX**	**985,054**	**935,661**

r Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1] Does not include alloys consumed in the making of other ferroalloys.
[2] Includes ferrochromium, ferrochromium-silicon, chromium briquets, exothermic chromium additives, and other miscellaneous chromium alloys.
[3] Included with chromium alloys.
[4] Includes ferromanganese, fused-salt electrolytic low- and medium-carbon ferromanganese (massive manganese), and silicomanganese.
[5] Included with manganese alloys.
[6] Includes ferrosilicon and miscellaneous silicon alloys.
[7] Data may not add to totals shown because of independent rounding.
[8] Included with "Other."
[9] Includes ferroaluminum, ferroboron and other complex boron additive alloys, ferromolybdenum, ferrotitanium, ferrovanadium, ferrozirconium, silvery pig iron, other miscellaneous alloys, and items indicated by symbol W.

TABLE 3

PRODUCERS OF FERROALLOYS IN THE UNITED STATES IN 1988

Producer	Plant location	Products[1]	Type of furnace
FERROALLOYS (EXCEPT FERROPHOSPHORUS)			
Affiliated Metals and Minerals Inc.	New Castle, PA	FeMo, FeV	Metallothermic.
Aluminum Co. of America, Northwest Alloys Inc.	Addy, WA	FeSi, Si	Electric.
AMAX Inc., Climax Molybdenum Co. Div.	Langeloth, PA	FeMo	Metallothermic.
American Alloys Inc.	New Haven, WV	FeSi, Si	Electric.
Applied Industrial Minerals Corp. (AIMCOR)	Bridgeport, AL	FeSi, other[2]	do.
	Kimball, Tn	do.	do.
Cabot Corp.	Revere, PA	FeCb	Metallothermic.
Cyprus Minerals Co., Duval Corp.	Sahuarita, AZ	FeMo	do.
Dow Corning Corp.	Springfield, OR	Si	Electric.
Elkem A/S, Elkem Metals Co.	Alloy, WV	Cr. FeB, FeCr, FeMn, Fesl, Mn, Si, SiMn, other.[2]	Electric and electrolytic.
	Ashtabula, OH		
	Marietta, OH		
	Niagara Falls, NY		
Globe Metallurgical Inc.	Beverly, OH	FeCr, FeSi, Si	Electric.
	Selma, AL		
Keokuk Ferro-Sil Inc.	Keokuk, IA	FeSi, silvery pig iron.	do.
Kerr-McGee Chemical Corp.	Hamilton (Aberdeen), MS	Mn	Electrolytic.
Macalloy Corp.	Charleston, SC	FeCr	Electric.
Metallurg Inc., Shieldalloy Metallurgical Corp.	Cambridge, OH	Cr, FeAl, FeB, FeCb, FeTi, FeV, other.[2]	Electric and metallothermic.
	Newfield, NJ		
Reactive Metals and Alloys Corp.	West Pittsburgh, PA	FeAl, FeB, FeTi, other.[2]	do.
Reading Alloys Inc.	Robesonia, PA	FeCb, FeV	Metallothermic.
Reynolds Metals Co.	Sheffield, AL	Si	Electric.
Satra Concentratres	Steubenville, OH	FeCr	Slag conversion.
Silicon Metaltech Inc.	Wenatchee, WA	FeSi, Si	Electric.
Simetco	Montgomery, AL	Si	do.
SKW Alloys Inc.	Calvert City, KY	FeCr, FeCrSi	do.
	Niagara Falls, NY	FeSi, Si	do.
Strategic Minerals Corp. (STRATCOR), U.S. Vanadium Corp.	do.	FeV, FeW	do.
Teledyne Inc., Teledyne Wah Chang, Albany Div.	Albany, OR	FeCb	Metallothermic.
Union Oil Co. of California, Molycorp Inc.	Washington, PA	FeB, FeMo	Electric and metallothermic.
Universal Consolidated Co., Nickel Mountain Resources	Riddle, OR	FeNi, FeSi	Electric.
FERROPHOSPHORUS			
FMC Corp., Industrial Chemical Div.	Pocatello, ID	FeP	do.
Monsanto Co., Monsanto Industrial Chemicals Co.	Soda Springs, ID	do.	do.
Occidental Petroleum Corp., Hooker Chemical Co., Industrial Chemicals Group	Columbia, TN	do.	do.
Stauffer Chemical Co., Industrial Chemical Div.	Mount Pleasant, TN	do.	do.
	Silver Bow, MT	do.	do.

[1] Cr, chromium metal; FeAl, ferroaluminum; FeB, ferroboron; FeCb, ferrocolumbium; FeCr, ferrochromium; FeCrSi, ferrochromium-silicon; FeMn, ferromanganese; FeMo, ferromolybdenum; FeNi, ferronickel; FeP, ferrophosphorus; FeSi, ferrosilicon; FeTi, ferrotitanium; FeV, ferrovanadium; FeW, ferrotungsten; FeZr, ferrozirconium; Mn, manganese metal; Si, silicon metal; SiMn, silicomanganese.
[2] Includes specialty silicon alloys, zirconium alloys, and miscellaneous ferroalloys.

TABLE 4

REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ADDITIVES IN 1988, BY END USE[1]

(Short tons of alloys unless otherwise specified)

End use	FeMn	SiMn	FeSi	FeTi	FeP	FeB
Steel:						
Carbon	354,264	85,585	65,006	967	8,483	503
Stainless and heat-resisting	[2]18,874	5,306	81,371	3,023	10	26
Other alloy	[2]80,260	[2]24,026	72,062	274	1,335	313
Tool	[2]402	(3)	2,483	(3)	—	W
Unspecified	977	429	135	6	—	—
Total steel	**454,777**	**115,346**	**221,057**	**4,270**	**9,828**	**842**
Cast irons	12,142	1,642	232,819	W	2,141	W
Superalloys	[4]158	W	376	708	—	W
Alloys (excluding alloy steels and superalloys)	19,478	W	56,449	958	123	111
Miscellaneous and unspecified	5,128	1,917	116,210	54	—	81
Total	**491,683**	**118,905**	**626,911**	**5,990**	**12,092**	**1,034**
Percent of 1987	113	104	120	129	103	124

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] FeMn, ferromanganese including spiegeleisen and manganese metal; SiMn, silicomanganese; FeSi, ferrosilicon including silicon metal, silvery pig iron, and inoculant alloys; FeTi, ferrotitanium; FeP, ferrophosphorous; FeB ferroboron including other boron materials.
[2] Part included with "Steel: Unspecified."
[3] Included with "Steel: Unspecified."
[4] Part included with "Miscellaneous and unspecified."

TABLE 5

REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ALLOYING ELEMENTS IN 1988, BY END USE[1]

(Short tons of contained elements unless otherwise specified)

End use	FeCr	FeMo	FeW	FeV	FeCb	FeNi
Steel:						
Carbon	[2]4,724	109	—	1,388	1,000	—
Stainless and heat-resisting	212,229	221	81	45	455	11,988
Other alloy	[2]27,203	1,559	85	2,454	998	253
Tool	[2]2,299	W	349	530	(3)	—
Unspecified	(4)	(4)	(4)	(4)	14	—
Total steel	**246,455**	**1,889**	**515**	**[5]4,418**	**2,467**	**12,241**
Cast irons	[2]4,217	686	W	22	—	290
Superalloys	[2]9,254	51	W	10	459	55
Alloys (excluding alloy steels and superalloys)	[2]2,760	116	W	654	W	331
Miscellaneous and unspecified	5,044	376	11	225	544	19
Total	**267,730**	**3,118**	**526**	**5,329**	**3,470**	**12,936**
Percent of 1987	105	123	189	115	134	74

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] FeCr, ferrochromium including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum including calcium molybdate; FeW; ferrotungsten; FeV, ferrovanadium including other vanadium-carbon-iron ferroalloys; FeCb, ferrocolumbium including nickel columbium; FeNi, ferronickel.
[2] Part included with "Miscellaneous and unspecified."
[3] Included with "Steel: Unspecified."
[4] Included with "Miscellaneous and unspecified."
[5] Data do not add to total shown because of independent rounding.

tember, before falling to 88 cents by yearend. The yearly average was 82.9 cents compared with 43.5 cents in 1987. The price for imported ferromanganese containing 78% manganese rose from $380 per long ton of alloy to $600. The yearly average, approximately $500, was nearly 50% higher than that of 1987. List prices for imported ferrosilicon, containing 50% and 75% silicon, rose from 47 cents per pound of contained silicon to 55 cents and 66 cents, respectively, and their respective yearly averages of 51 cents and 55.6 cents were 35% and 54% higher than those of 1987. Comparable price increases were seen for domestically produced ferroalloy materials.

FOREIGN TRADE

The overall trade deficit for ferroalloys nearly doubled from $490 million in 1987 to $910 million. A trade surplus of $52 million was recorded for ferroalloy metals compared with a surplus of $13 million in 1987.

Exports of ferroalloys and related metals overall and the associated values increased 12% and 70%, respectively, compared with those of 1987. The United States exported ferrosilicon to 25 countries in 1988. Over three-quarters of that material was shipped to Canada and Japan. Nearly 60% of U.S. silicon metal exports went to Japan, with the remainder distributed among 40 other countries. Exports of manganese metal increased 71% compared with those of 1987, with Canada and the Netherlands receiving the largest shares.

Imports for consumption of ferroalloys and related metals were supplied by 42 countries and increased 31% compared with those of 1987. Geographic sources and their respective share of total U.S. imports of ferroalloys and related metals were Africa, 37%; Europe, 28%; the Western Hemisphere, 25%; Asia, 4%; Oceania, 4%; and the Mideast, 2%. The Republic of South Africa continued to be the main source

TABLE 6

REPORTED STOCKS OF FERROALLOYS HELD BY PRODUCERS AND CONSUMERS IN THE UNITED STATES AT YEAREND

(Short tons)

	Producer		Consumer		Total	
	1987 (gross weight)	1988 (gross weight)	1987 (gross weight)	1988 (gross weight)	1987 (gross weight)	1988 (gross weight)
Chromium alloys[1]	5,687	9,736	24,900	33,537	30,587	43,273
Manganese alloys[2]	W	W	W	W	64,803	112,375
Silicon alloys[3]	81,400	84,747	20,375	24,398	101,775	109,145
Ferroboron[4]	127	81	252	238	379	319
Ferrophosphorous	25,326	22,461	1,307	1,635	26,663	24,096
Ferrotitanium	W	W	773	842	773	842
Total	**112,540**	**117,025**	**47,607**	**60,650**	**224,980**	**290,050**
	1987 (contained element)	1988 (contained element)	1987 (contained element)	1988 (contained element)	1987 (contained element)	1988 (contained element)
Ferrocolumbium[5]	W	NA	W	W	W	W
Ferromolybdenum[6]	742	2,334	277	286	1,019	2,620
Ferronickel	—	—	NA	—	NA	—
Ferrotungsten	W	—	68	62	68	62
Ferrovanadium[7]	W	W	372	704	372	704
Total	**742**	**2,334**	**717**	**1,052**	**1,459**	**3,386**

NA Not available. W Withheld to avoid disclosing company proprietary data.
[1] Includes ferrochromium, ferrochromium-silicon, other chromium alloys and chromium metal.
[2] Includes ferromanganese, silicomanganese, and manganese metal.
[3] Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal.
[4] Consumer totals include other boron materials.
[5] Consumer totals include nickel columbium.
[6] Consumer totals include calcium molybdate.
[7] Includes other vanadium-carbon-iron ferroalloys.

of U.S. imports of ferroalloy materials overall, accounting for 32% of total imported ferroalloys and related metals. Of the total imported chromium and manganese alloys, the Republic of South Africa supplied 40% and 39%, respectively. The second leading suppliers of these materials were Zimbabwe (18%) for chromium and France (19%) for manganese. Imports of ferrosilicon overall remained unchanged compared with those of 1987. The principal sources of ferrosilicon were Brazil, 34%; Venezuela, 17%; the U.S.S.R., 12%; Canada, 10%; and Norway, 8%. Imports of silicon metal overall increased 68%, owing mostly to increased shipments from Argentina, Brazil, and China. The principal sources of silicon metals were Brazil, 21%; Canada, 20%; Argentina, 16%; and China, 15%.

WORLD CAPACITY

The data in Table 9 are rated capacity for smelters as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure. Bulk ferroalloy smelter, or in some cases blast furnace, capacity is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines.

WORLD REVIEW

Albania

A water shortage caused a slowdown in chrome ore production and exports.[2]

Australia

A 40-million-ton chromium deposit was discovered by Dragon Resources Ltd. Company representatives stated that the deposit had potential as a source for chromium chemicals or high-chromium pig iron for stainless steel production.[3] The Barrack Silicon Pty. Ltd. silicon project was scheduled to come on line in the third quarter of

TABLE 7

U.S. EXPORTS OF FERROALLOYS AND FERROALLOY METALS

Alloy	1986		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ferroalloys:						
Ferrocerium and alloys	37	$319	90	$653	39	$341
Ferrochromiun and ferrochromium-silicon	6,035	5,693	4,568	5,730	8,863	12,503
Ferromanganese	4,323	2,650	2,851	2,144	3,442	2,950
Silicomanganese	2,004	687	697	493	7,467	4,975
Ferromolybdenum	166	928	81	605	56	382
Ferrophosphorous	38,377	4,393	34,699	4,334	21,363	3,434
Ferrosilicon	11,331	8,306	15,049	11,647	28,912	25,379
Ferrovanadium	513	4,647	436	4,081	629	6,732
Ferroalloys, n.e.c.	10,029	11,561	19,073	14,938	12,871	18,981
Total ferroalloys [1]	**72,814**	**39,184**	**77,543**	**44,626**	**83,643**	**75,678**
Metals:						
Chromium	321	2,972	415	4,670	350	4,847
Manganese	5,146	7,892	5,775	9,748	9,859	16,242
Silicon	5,378	65,157	9,247	106,213	10,304	184,205
Total ferroalloy metals [1]	**10,845**	**76,020**	**15,437**	**120,631**	**20,514**	**205,294**
Grand total [1]	**83,660**	**115,204**	**92,980**	**165,257**	**104,156**	**280,972**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF FERROALLOYS AND FERROALLOY METALS

Alloy	1987 Gross weight (short tons)	1987 Content (short tons)	1987 Value (thousands)	1988 Gross weight (short tons)	1988 Content (short tons)	1988 Value (thousands)
Chromium alloys:						
Ferrochromium containing 3% or more carbon	283,613	158,505	$112,546	412,219	241,842	$288,596
Ferrochromium containing less than 3% carbon	42,246	26,940	37,723	53,341	35,572	64,133
Ferrochromium-silicon	8,356	3,117	4,920	10,349	3,732	4,471
Total chromium alloys [1]	**334,215**	**188,562**	**155,189**	**475,909**	**281,146**	**357,200**
Manganese alloys:						
Ferromanganese containing 1% or less carbon	20,132	17,852	17,203	20,935	18,729	22,704
Ferromanganese containing more than 1% to 4% carbon	50,442	41,359	22,951	86,913	70,123	52,670
Ferromanganese containing more than 4% carbon	297,104	230,166	73,476	423,433	327,006	136,846
Silicomanganese	191,418	[2] 124,315	58,461	232,214	152,884	91,928
Spiegeleisen	209	([3])	168	147	([3])	131
Total manganese alloys [1]	**559,305**	**413,692**	**172,260**	**763,642**	**568,742**	**304,280**
Silicon alloys:						
8% to 30% silicon	3,675	607	1,132	6,111	1,437	1,356
30% to 60% silicon, over 2% magnesium	6,965	3,252	5,286	12,239	5,940	8,330
30% to 60% silicon, n.e.c.	58,747	29,076	22,456	56,549	28,285	28,474
60% to 80% silicon, over 3% calcium	15,191	10,019	11,267	17,870	11,583	17,386
60% to 80% silicon, n.e.c.	145,855	109,531	68,410	137,291	102,916	102,164
80% to 90% silicon	—	—	—	—	—	—
Over 90% silicon	226	214	200	838	796	353
Total silicon alloys [1]	**230,658**	**152,698**	**108,749**	**230,897**	**150,957**	**158,063**
Other ferroalloys:						
Ferrocerium and other cerium alloys	105	([3])	1,294	111	([3])	1,348
Ferromolybdenum	1,908	1,142	8,042	1,852	1,184	8,504
Ferronickel	45,391	21,136	57,481	44,577	16,067	116,990
Ferrophosphorous	—	—	—	12	([3])	16
Ferrotitanium and ferrosilicon titanium	1,425	([3])	2,521	1,711	([3])	6,180
Ferrotungsten and ferrosilicon tungsten	429	331	1,776	861	660	3,260
Ferrovanadium	422	342	3,777	148	119	2,271
Ferrozirconium	617	([3])	765	745	([3])	1,165
Ferroalloys, n.e.c. [4]	3,940	([3])	22,722	4,859	([3])	26,792
Total other ferroalloys [1]	**54,236**	**XX**	**98,379**	**54,876**	**XX**	**166,525**
Total ferroalloys [1]	**1,178,414**	**XX**	**534,577**	**1,525,367**	**XX**	**986,182**
Metals:						
Chromium	4,356	([3])	24,096	4,523	([3])	29,877
Manganese	8,991	([3])	9,614	11,730	([3])	14,946
Silicon (96% to 99% silicon)	2,662	([3])	2,584	15,087	([3])	17,197
Silicon (99% to 99.7% silicon)	33,448	33,144	32,960	45,941	45,516	50,353
Silicon (over 99.7% silicon)	820	([3])	38,754	1,022	([3])	41,168
Total ferroalloy metals [1]	**50,277**	**XX**	**108,008**	**78,303**	**XX**	**153,541**
Grand total [1]	**1,228,690**	**XX**	**642,585**	**1,603,670**	**XX**	**1,139,722**

XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Manganese content only.
[3] Not recorded.
[4] Principally ferrocolumbium.

Source: Bureau of the Census.

TABLE 9

WORLD PRODUCTION CAPACITY FOR BULK FERROALLOYS, DECEMBER 31, 1988[1]

(Thousand short tons, gross weight)

Country	Capacity
Albania	50
Argentina	121
Australia	243
Belgium	105
Brazil	1,064
Bulgaria	[2]35
Canada	288
Chile	([3])
China	1,093
Colombia	[2]10
Czechoslovakia	[2]138
Egypt	75
Finland	176
France	718
Germany, Democratic Republic	[2]102
Germany, Federal Republic	369
Greece	33
Hungary	([3])
Iceland	72
India	489
Italy	332
Japan	1,551
Korea, North	[2]85
Korea, Republic of	96
Mexico	319
Norway	1,370
Peru	([3])
Philippines	124
Poland	[2]235
Portugal	120
Romania	[2]195
South Africa, Republic of	2,129
Spain	429
Sweden	364
Switzerland	([3])
Taiwan	108
Turkey	66
United Kingdom	97
United States	1,414
U.S.S.R.	3,713
Uruguay	([3])
Venezuela	107
Yugoslavia	407
Zimbabwe	233
Other[4]	375
Total	**19,000**

[1] Consists of ferroalloys of chromium, manganese, and silicon and silicon metal.
[2] Excludes silicon materials, which are included with "Other."
[3] Included with "Other."
[4] Includes silicon-containing ferroalloys and silicon metal.

1989. The project would consist of two 18-megawatt electric furnaces with a combined output of 24,300 metric tons per year. The company had signed sales agreements for over one-half of the planned output.[4]

Belgium-Luxembourg

Applied Industrial Minerals Corp. of the United States planned to invest more than $20 million in a new carbon-silica composite project in Antwerp, Belgium. The composite, named Silgro, could be used for furnace feed in the production of silicon metal. The new plant would be capable of producing about 100,000 tons per year of Silgro.[5] Continental Alloys SA of Luxembourg, a producer of specialty ferroalloys, planned a financial restructuring under the legal status of Gestion Controlee, a concept similar to that of Chapter 11 filing in the United States. However, the company continued production, and shipments were not expected to be interrupted.[6]

Brazil

According to Anuario da industria brasileira de ferroligas, production of ferroalloy materials neared 1 million metric tons (mt) overall, an 8% increase over that of 1987, as Brazil continued to expand its ferroalloys industry domestically and abroad. The largest increase was for the production of silicon-containing ferroalloys and metal, while those for chromium- and manganese-containing alloys were only one-half that of the overall increase. Electric power rationing, which had affected production in 1987, was ended, and a number of producers, including Cia. Paulista de Ferro-Ligas, Inonibras Inoculantes e Ferroligas Nipo-Brasileros S/A, Sibra—Eletrometalugea S/A, Cia. de Ferro Ligas da Bahia, and Electrovale S/A Industria e Comercio, continued ferrosilicon expansion plans. Italmagnesio S/A Indusreia e Comercio instituted a plan for buying idled electric furnaces located in Europe and Japan as part of a multinational project in Venezuela (see **Venezuela**). Both consumption and exports of ferroalloy materials overall increased nearly 20%.

Camargo Correa Metais S/A started production of silicon metal with two of the four 18,000-kilovolt-ampere (k•VA) electric furnaces at its newly constructed plant in the Para State. The remaining two furnaces are scheduled for startup in 1990.[7]

Provale, a 140,000-metric-ton-per-year ferromanganese joint venture among Prometal Produtos Metalurgicos S.A., the state-owned Cia. Vale do Rio Doce, and the U.S.S.R., was abandoned.

Canada

Timminco Ltd. restarted its 19.2-megawatt furnace at Beauharnois, Quebec, to produce ferrosilicon for sale. The company produced ferrosilicon for internal use in another furnace throughout the year. Its third furnace, which had been used to produce manganese ferroalloys, remained idle. The 19.2-megawatt furnace and another of the company's three furnaces had been shut down in July 1987.[8] Production of manganese ferroalloys at the Elkem Metals Canada Inc.'s Beauharnois, Quebec, plant was interrupted twice during the year. The first incident involved an explosion in the plant's condenser batteries, in which the company was reported to have lost about 10,000 metric tons of silicomanganese production. Later in the year, a refractory burn-through halted production of high-carbon ferromanganese.[9]

China

The Government announced a ban on exports of ferrosilicon from three of its northern Provinces, Jilin, Liaoning, and Heilongjian, which formed the heart of the country's steel industry. The three Provinces accounted for some 140,000 tons of ferrosilicon production, of which a significant portion had previously been exported. In the past few years, China significantly increased its ferrosilicon exports to the world market, primarily to Japan, but in 1988 the country's growing steel industry demanded much more ferrosilicon than in years past. Export taxes on manganese ferroalloys were also imposed late in the year, and further restrictions on a number of other materials including chrome ore, and chromium-containing ferroalloys, and molybdenum ore, were announced for 1989.[10]

Dominican Republic

In May, an agreement was signed by Falconbridge Dominicana C. por A. and the Dominican Republic ending a 6-month dispute over export duties. The dispute caused several months of delayed nickel shipments to other countries and at one point halted production for more than 1 month at the company's Bonao ferronickel plant.[11]

Finland

Outokumpu Oy planned to increase its production capacity for charge chrome by 30% to 200,000 metric tons per year at its Tornio plant. Completion of the expansion was scheduled for early 1990 and was expected to cost about $20 million.[12]

France

Pechiney Electrométallurgie completed its conversion of ferrosilicon production capacity to that of silicomanganese at its Dunkirk facility and continued production of ferrosilicon at Laudon.[13] Chromeurope S.A., a subsidiary of Ferroaleaciones Españolas S.A. of Spain, began production of high-carbon ferrochromium at its new Dunkirk facility. The first of two furnaces, a 12,000 kV•A unit, was tapped in March. The second, a 16,000 kV•A unit, was under construction and scheduled to come on-line in 1989.[14]

India

Indian Charge Chrome Ltd. completed construction of its new 200,000-metric-ton-per-year ferrochromium production facility near Bhubaneswar in Orissa State, which had been scheduled to commence production at yearend.[15]

Japan

Owing to high energy costs, Toyo Denka Koga closed its 17,400-metric-ton-per-year ferrosilicon production facility in Kochi, leaving the county with only three ferrosilicon producers, Japan Metals & Chemicals Co. Ltd., Yahagi Iron, and Yakushima Denko.[16] Two ferrochromium producers; Pacific Metals Co. and NKK Corp., rekindled capacity to increase production, while a third, Nippon Denko, planned to reactivate an old furnace in the Philippines. Significant increases in demand from the country's stainless steel industry prompted the moves.[17]

Demand for ferroalloy materials increased significantly, owing to a 7.3% increase in raw steel production. The Japanese Ferroalloys Association reported that production of ferroalloys and related materials totaled 1.02 million metric tons in 1988, a 13.5% increase over that of 1987. Annual production increases of 12% and 16% were recorded for chromium- and manganese-containing alloys, while ferrosilicon production was unchanged compared with that of 1987. Imports of ferroalloy materials overall increased 23.4% compared with those of the previous year, according to the Ministry of Finance. The largest annual increases in imports of ferroalloy materials were for ferronickel (62.6%), ferrosilicon (39.3%), and ferrochromium (10.8%), while imports of manganese-containing alloys overall increased about 5% compared with those of 1987.

Norway

Norsk Jern Holding AS and the FESIL group signed a letter of intent in which FESIL agreed to take over Norsk Jern Holding's electric pig iron plant in Mo I Rana and convert two electric furnaces to produce 70,000 metric tons of ferrosilicon annually.[18]

Philippines

Ferro Chemicals Inc. reactivated a 10,000-kV•A furnace for ferrochromium production at its plant on Mindamao Island. The company had already been producing ferrochromium in a 6,000-kV•A unit and with the addition, was expected to produce at a rate of 27,000 metric tons per year.[19] Integrated Chrome, a joint venture among Nippon Denko of Japan and Philippine principals, planned a ferrochromium project that was expected to start up in 1989 and have an annual capacity of 15,000 metric tons per year.[20]

South Africa, Republic of

Owing to increased world demand for ferrochromium, a number of the country's ferroalloy producers were involved in expansions or plans for future expansions, and one new company joined the ranks as a ferrochromium producer. Middleburg Steel and Alloys (Pty) Ltd. (MSA) planned a major expansion of its current ferrochromium and stainless steel operations in which new technology was to be used. The expansion was expected to raise MSA's current ferrochromium production capacity from 230,000 to 430,000 metric tons per year and its stainless steel production capacity from 100,000 to 150,000 metric tons per year by 1990.[21] Chromecorp Technology (Pty.) Ltd. completed construction of two 30,000-kV•A electric furnaces at its new 120,000-metric-ton-per-year ferrochromium production facility at Randburg, Transvaal, becoming the country's fifth ferrochromium producer. Output from the new facility was scheduled primarily for export.[22] Consolidated Metallurgical Industries, the country's third largest producer of ferrochromium, planned the expansion of its 160,000-metric-ton-per-year facility to 200,000 metric tons per year.[23] Tubatse Ferrochrome (Pty) Ltd., a subsidiary of South African Manganese Amcor Ltd., began construction of two new 60,000-metric-ton-per-year ferrochromium furnaces to be complete in 1989.[24]

Spain

Ferroastur—Ferroaleaciones Especiales Asturianas S.A., a specialty ferroalloy producer, suspended production owing to financial difficulties.[25]

Swaziland

An international consortium led by Australian Overseas Mining Ltd. (AOM) and the Swazi Government conducted a feasibility study on the possibility of building a 120,000-metric-ton-per-year ferrochromium production facility near a 50-million-ton chromite reserve. AOM considered the project economically viable and approval for startup was granted by the Swazi Government.[26]

Sweden

Owing to rising power costs, KemaNord Industrikemi AB cut silicon metal production 40% at its 24,000-metric-ton-per-year facility in Ljungaverk.[27]

Turkey

Etibank completed one of two 24,000-kV•A electric furnaces under construction at its Elazig ferrochromium production facility. Completion of the second furnace was scheduled for mid-1990. The combined production capacity of the two furnaces was expected to be 100,000 metric tons per year, mostly for export to the United States and European countries.[28]

Venezuela

Strategic Minerals and Materials Corp. of the United States signed an agreement with Procesadora Paraguana CA (Propaca) to obtain 25% of the needed feed material for its vanadium processing plant in the United States. Propaca's new facility, which would process the vanadium-bearing feed material from petroleum coke, was under construction in the State of Punto Fijo.[29] Elkem Technology of Norway entered into agreements with two Venezuelan companies, the state-owned Corporacion Venezulana de Guyana (CVG) and Fesilven, a CVG holding and the country's largest ferroalloy producer. The agreements included a feasibility study of plants to produce silicon metal and carbon products and cooperation on silicon marketing and technology development in South America. Approval of the agreements by the Venezuelan Government was pending.[30] CVG, along with Italmagnesio of Brazil and other investors, planned for a large multiplant aluminum and ferroalloys complex at Puerto Ordaz near the Guri hydroelectric plant. As part of the project, Italmagnesio instituted a plan for buying idled electric furnaces in Europe and Japan.[31]

Zimbabwe

Zimbabwe Mining and Smelting Co. (ZIMASCO) reactivated a 12.5-kV•A furnace to increase its output of high-carbon ferrochromium. The company also continued construction of a 3-kV•A furnace for remelting ferrochromium fines. The two projects combined were expected to raise ZIMASCO's ferrochromium production by about 30,000 metric tons per year to 190,000 metric tons per year by 1990.[32]

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[1] Physical scientist, Branch of Ferrous Metals.

[2] The TEX Report. V. 20, No. 4759, Sept. 7, 1988, p. 4.

[3] American Metal Market. V. 96, No. 222, Nov. 14, 1988, p. 1.

[4] Metals Week. V. 59, No. 35, Aug. 29, 1988, p. 1.

[5] American Metal Market. V. 96, No. 47, Mar. 9, 1988, p. 1.

[6] Metal Bulletin (London). No. 7252, Jan. 18, 1988, p. 15.

[7] The TEX Report. V. 20, No. 4767, Sept. 20, 1988, p. 7.

[8] Metals Week. V. 59, No. 25, June 20, 1988, p. 2.

[9] Metal Bulletin (London). No. 7324, Oct. 6, 1988, p. 19.

[10] The TEX Report. V. 20, No. 4832, Dec. 26, 1988, p. 2.

[11] ———. V. 20, No. 7289, June 2, 1988, p. 7.

[12] Metals Week. V. 59, No. 40, Oct. 10, 1988, p. 2.

[13] Metal Bulletin (London). No. 7283, May 9, 1988, p. 21.

[14] The TEX Report. V. 20, No. 4735, Aug. 3, 1988, p. 5.

[15] Metal Bulletin (London). No. 7323, Oct. 3, 1988, p. 19.

[16] Metals Week. V. 59, No. 7, Feb. 15, 1988, p. 1.

[17] Metal Bulletin (London). No. 7324, Oct. 6, 1988, p. 19.

[18] The TEX Report. V. 20, No. 4799, Nov. 8, 1988, p. 10.

[19] ———. V. 20, No. 4615, Feb. 9, 1988, p. 7.

[20] ———. V. 20, No. 4783, Oct. 14, 1988, p. 7.

[21] American Metal Market. V. 96, No. 113, June 10, 1988, p. 2.

[22] The TEX Report. V. 20, No. 4825, Dec. 15, 1988, p. 10.

[23] Metals Week. V. 59, No. 39, Oct. 3, 1988, p. 1.

[24] The TEX Report. V. 20, No. 4768, Sept. 21, 1988, p. 2.

[25] Metal Bulletin (London). No. 7254, Jan. 25, 1988, p. 11.

[26] ———. No. 7303, July 21, 1988, p. 17.

[27] ———. No. 7302, July 18, 1988, p. 16.

[28] The TEX Report. V. 20, No. 4760, Sept. 8, 1988, p. 6.

[29] American Metal Market. V. 96, No. 97, May 18, 1988, p. 8.

[30] The TEX Report. V. 20, No. 4779, Oct. 7, 1988, p. 3.

[31] ———. V. 20, No. 4788, Oct. 21, 1988, p. 2.

[32] ———. V. 20, No. 4602, Jan. 21, 1988, p. 17.

TABLE 10

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
Albania: Electric furnace, ferrochromium[e]	44	47	51	51	51
Argentina: Electric furnace:					
Ferromanganese	26	26	22	24	[4]21
Silicomanganese	15	8	14	13	[4]14
Ferrosilicon	22	21	25	26	[4]29
Other	4	5	6	7	[4]9
Total	**67**	**60**	**67**	**70**	**[4]73**
Australia: Electric furnace:[5]					
Ferromanganese	78	78	67	56	[4]64
Silicomanganese	35	28	25	47	[4]49
Ferrosilicon	20	21	21	20	20
Total[6]	**133**	**127**	**113**	**123**	**133**
Austria: Electric furnace, undistributed	14	13	13	13	13
Belgium: Electric furnace, ferromanganese[e]	105	99	96	[r]99	105
Brazil: Electric furnace:					
Ferromanganese	117	149	181	171	[4]199
Silicomanganese	205	199	196	207	[4]213
Ferrosilicon	167	200	240	255	[4]295
Silicon metal	30	32	41	44	[4]87
Ferrochromium	138	140	121	116	[4]143
Ferrochromium-silicon	8	10	10	9	[4]10
Ferronickel	37	37	38	39	[4]37
Other	60	68	68	67	[4]87
Total[6]	**762**	**835**	**894**	**908**	**[4]1,071**
Bulgaria: Electric furnace:					
Ferromanganese[e 7]	24	33	35	34	34
Ferrosilicon[e]	17	15	17	17	18
Other[e]	1	1	1	1	1
Total[6]	**42**	**50**	**53**	**52**	**53**
Canada: Electric furnace:[e]					
Ferromanganese[7]	128	130	139	141	143
Ferrosilicon	88	93	97	99	99
Silicon metal	28	28	29	33	33
Total[6]	**244**	**250**	**265**	**273**	**275**
Chile: Electric furnace:					
Ferromanganese	5	7	7	7	[4]7
Silicomanganese	([8])	1	2	1	[4]1
Ferrosilicon	7	5	4	5	[4]6
Other	2	1	2	2	[4]4
Total[6]	**15**	**14**	**14**	**15**	**[4]18**

TABLE 10—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
China: Furnace type unspecified:[e 9]					
Ferromanganese[e 7]	540	540	660	720	720
Ferrosilicon	215	215	220	250	280
Silicon metal	24	[r]30	[r]45	[r]70	75
Ferrochromium[10]	130	130	130	140	170
Other[11]	80	80	80	110	110
Total[6]	**990**	**[r]996**	**[r]1,135**	**[r]1,290**	**1,355**
Colombia: Electric furnace:[e 12]					
Ferrosilicon	1	1	1	1	1
Ferronickel	47	33	51	57	[4]46
Total	**48**	**34**	**52**	**58**	**47**
Czechoslovakia: Electric furnace:					
Ferromanganese[e 7]	96	103	101	101	101
Ferrosilicon[e]	31	33	33	33	33
Silicon metal[e]	4	5	6	6	6
Ferrochromium[e]	26	28	28	28	28
Other[e 11]	9	10	9	9	9
Total[6]	**166**	**177**	**[e]176**	**[e]176**	**176**
Dominican Republic: Electric furnace, ferronickel	[r]69	[r]71	62	89	81
Egypt: Electric furnace, ferrosilicon	8	[e]8	8	8	8
Finland: Electric furnace, ferrochromium	65	147	147	158	149
France:					
Blast furnace:					
Spiegeleisen[e]	1	1	1	1	1
Ferromanganese	362	367	302	[r e]302	309
Electric furnace:					
Silicomanganese[13]	38	26	24	[e]24	24
Ferrosilicon	226	217	216	[e]216	216
Silicon metal	78	[e]77	[e]77	[e]77	77
Ferrochromium[10]	21	1	[e]1	[e]1	20
Other[14]	134	107	85	[e]85	85
Total[6]	**860**	**797**	**707**	**[r e]706**	**732**
German Democratic Republic: Electric furnace:					
Ferromanganese[e 7]	69	69	75	75	76
Ferrosilicon[e]	25	25	29	29	29
Silicon metal[e]	4	4	4	4	4
Ferrochromium[e]	21	21	24	24	25
Other[e 11]	17	17	17	17	18
Total[6]	**137**	**137**	**149**	**149**	**152**

TABLE 10—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
Germany, Federal Republic of:					
Blast furnace:					
Ferromanganese[e]	263	179	206	[r]209	215
Ferrosilicon[e]	77	47	76	77	72
Electric furnace:					
Ferromanganese[e 7]	24	28	39	33	33
Ferrosilicon[e]	39	44	55	44	50
Ferrochromium[e]	50	55	66	61	61
Other[e 11]	60	62	67	66	68
Total[6]	**513**	**414**	**509**	**[r]490**	**499**
Greece: Electric furnace:					
Ferrochromium	36	39	42	46	44
Ferronickel[e]	58	66	[4]11	6	[4]10
Total[6]	**[e]94**	**[e]105**	**54**	**[e]52**	**54**
Hungary: Electric furnace:[e]					
Ferrosilicon	10	10	10	10	11
Silicon metal	2	2	2	2	2
Other	2	2	2	2	1
Total	**14**	**14**	**14**	**14**	**14**
Iceland: Electric furnace, ferrosilicon	67	67	74	77	[4]77
India: Electric furnace:					
Ferromanganese	134	180	197	191	193
Silicomanganese	35	[e]1	[e]1	1	1
Ferrosilicon	56	44	55	56	55
Silicon metal[e]	[7]3	3	3	4	3
Ferrochromium	61	73	93	104	110
Ferrochromium-silicon	4	14	[e]11	14	13
Other	([8])	[e]1	[e]1	1	1
Total[6]	**295**	**316**	**362**	**371**	**376**
Indonesia: Electric furnace, ferronickel	25	26	25	9	29
Italy: Electric furnace:					
Ferromanganese	56	19	[e]28	[e]28	28
Silicomanganese	80	71	[e]66	[e]66	66
Ferrosilicon	78	83	[e]55	[e]55	55
Silicon metal[e]	15	15	13	13	13
Ferrochromium	14	64	[e]22	[e]22	22
Other[15]	56	17	[e]33	[e]33	33
Total[6 15]	**299**	**270**	**[e]217**	**[e]217**	**217**

TABLE 10—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
Japan: Electric furnace:					
Ferromanganese	535	487	396	366	[4]417
Silicomanganese	257	239	164	101	[4]118
Ferrosilicon	169	166	118	81	[4]81
Ferrochromium[10]	350	375	309	291	[4]326
Ferronickel	239	250	221	224	[4]267
Other[16]	14	14	11	9	[4]11
Total[6]	**1,564**	**1,531**	**1,218**	**1,073**	**[4]1,220**
Korea, North: Furnace type unspecified:[e 9]					
Ferromanganese[7]	77	77	77	77	77
Ferrosilicon	33	33	33	33	33
Other[11]	22	22	22	22	22
Total	**132**	**132**	**132**	**132**	**132**
Korea, Republic of: Electric furnace:					
Ferromanganese	65	68	59	64	[4]84
Ferrosilicon	39	38	34	14	[4]10
Other	55	60	73	100	[4]99
Total[6]	**159**	**167**	**167**	**178**	**[4]193**
Mexico: Electric furnace:					
Ferromanganese	177	169	172	178	[4]182
Silicomanganese	46	43	67	88	[4]88
Ferrosilicon	25	30	19	20	[4]18
Ferrochromium	8	7	3	7	[4]10
Other	2	3	2	1	[4]1
Total[6]	**258**	**253**	**263**	**294**	**[4]299**
New Caledonia: Electric furnace, ferronickel[e]	125	155	144	127	[4]161
Norway: Electric furnace:					
Ferromanganese	314	237	226	212	220
Silicomanganese	310	267	271	262	260
Ferrosilicon	482	425	389	371	370
Silicon metal[e]	100	112	110	110	110
Ferrochromium[e]	4	—	—	—	—
Ferrochromium-silicon[e]	([8])	—	—	—	—
Other[e 14]	4	3	3	3	3
Total[6]	**1,215**	**1,045**	**998**	**958**	**963**
Peru: Electric furnace:					
Ferromanganese	[r]([8])	[r]([8])	([8])	2	2
Ferrosilicon	[r]([8])	[r]([8])	([8])	([8])	([8])
Total[7]	**[r]([8])**	**[r]([8])**	**1**	**2**	**2**

TABLE 10—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
Philippines: Electric furnace:					
Ferrosilicon[e]	20	22	22	—	10
Ferrochromium	53	56	[e]61	[e]63	84
Total	**73**	**78**	**[e]83**	**[e]63**	**94**
Poland:					
Blast furnace:					
Spiegeleisen	4	3	[e]3	[e]4	4
Ferromanganese	99	88	94	[e]94	94
Electric furnace:					
Ferromanganese[e 7]	53	54	54	54	53
Ferrosilicon[e]	56	57	56	55	55
Silicon metal[e]	11	12	12	11	11
Ferrochromium[e]	53	54	54	53	50
Other[e 11]	19	18	18	18	18
Total[6]	**295**	**287**	**[e]291**	**[e]289**	**285**
Portugal: Electric furnace:					
Ferromanganese[e 17]	51	46	22	28	11
Silicomanganese[e 17]	26	28	11	17	6
Ferrosilicon[e]	10	10	6	5	3
Silicon metal[e]	12	12	8	6	3
Other	([8])	([8])	([8])	([8])	([8])
Total[6]	**99**	**96**	**46**	**[e]55**	**23**
Romania: Electric furnace:[e]					
Ferromanganese	96	88	90	89	88
Silicomanganese	45	43	44	43	44
Ferrosilicon	57	55	56	55	55
Silicon metal	5	5	5	5	5
Ferrochromium	50	49	49	46	46
Total[6]	**253**	**240**	**244**	**239**	**238**
South Africa, Republic of: Furnace type unspecified:[9]					
Ferromanganese	261	365	372	347	331
Silicomanganese	199	287	334	346	353
Ferrosilicon	99	83	92	91	93
Silicon metal	38	39	39	37	37
Ferrochromium	956	939	959	1,048	1,100
Ferrochromium-silicon	30	6	6	30	23
Other[e 18]	([8])	([8])	1	1	1
Total[e 6]	**1,583**	**1,720**	**1,802**	**[r]1,900**	**1,938**

TABLE 10—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
Spain: Electric furnace:					
Ferromanganese[e]	94	95	95	99	99
Silicomanganese[e]	77	77	77	77	77
Ferrosilicon[e]	66	67	67	66	66
Silicon metal[e]	66	68	68	77	77
Ferrochromium[e]	15	19	19	22	22
Other[e]	1	4	4	6	6
Total[6] [11]	**321**	**331**	**[e]331**	**[e]347**	**347**
Sweden: Electric furnace:					
Ferrosilicon	26	31	[e]28	33	33
Silicon metal	22	[e]22	[e]22	22	22
Ferrochromium	148	149	139	121	125
Ferrochromium-silicon	34	29	[e]28	28	28
Other	1	([8])	([8])	([8])	([8])
Total[11]	**230**	**232**	**[r e]217**	**204**	**208**
Switzerland: Electric furnace:[e]					
Ferrosilicon	3	3	3	3	3
Silicon metal	2	2	2	2	2
Total	**5**	**5**	**5**	**5**	**5**
Taiwan: Electric furnace:					
Ferromanganese	22	20	22	19	[4]28
Silicomanganese	25	25	23	21	[4]23
Ferrosilicon	26	19	15	8	[4]12
Total[6]	**73**	**64**	**61**	**47**	**[4]63**
Turkey: Electric furnace:					
Ferrosilicon[e]	[4]8	8	8	[4]5	[4]6
Ferrochromium	53	[r e]55	[e]55	58	66
Total	**61**	**[r e]63**	**[e]63**	**63**	**72**
U.S.S.R.:					
Blast furnace:					
Spiegeleisen	[r e]22	21	22	21	21
Ferromanganese	[e]606	633	662	654	660
Ferrophosphorus	[e]29	29	29	28	28
Electric furnace:[19]					
Ferromanganese[e]	661	744	772	772	772
Silicomanganese[e]	198	209	220	220	220
Ferrosilicon[e]	827	827	882	937	937
Silicon metal[e]	70	66	72	72	72
Ferrochromium[e]	463	463	468	474	496
Ferrochromium-silicon[e]	13	13	14	15	15
Other[14]	250	254	265	265	276
Total[6]	**[r]3,139**	**[r]3,259**	**3,406**	**3,458**	**3,497**

TABLE 10—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
United Kingdom:					
Blast furnace, ferromanganese	83	85	[e]83	101	99
Electric furnace, undistributed[e]	14	11	11	11	11
Total[6]	**97**	**96**	**[e]94**	**[r e]112**	**110**
United States: Electric furnace:[20]					
Ferromanganese[21]	171	154	117	113	W
Ferrosilicon	490	442	339	356	[4]495
Silicon metal	141	121	124	147	[4]164
Ferrochromium[22]	95	110	105	118	W
Other[23]	190	151	130	84	[4]383
Total[6]	**1,088**	**977**	**816**	**818**	**[4]1,043**
Uruguay: Electric furnace, ferrosilicon	([8])	([8])	([8])	([8])	([8])
Venezuela: Electric furnace:					
Ferromanganese	2	[e]2	([8])	([8])	([8])
Silicomanganese	10	24	32	31	33
Ferrosilicon	49	67	56	55	61
Total[6]	**61**	**94**	**88**	**86**	**94**
Yugoslavia: Electric furnace:					
Ferromanganese	49	39	44	42	44
Silicomanganese	41	48	46	47	58
Ferrosilicon	104	101	110	109	119
Silicon metal	31	36	35	35	55
Ferrochromium	69	81	76	62	84
Ferrochromium-silicon	12	8	8	7	9
Other	12	16	19	19	30
Total[6]	**318**	**329**	**338**	**321**	**399**
Zimbabwe: Electric furnace:					
Ferromanganese	2	2	[e]2	([24])	2
Ferrochromium	196	172	[e]171	234	200
Ferrochromium-silicon[25]	47	59	[e]55	23	44
Total[6]	**245**	**233**	**[e]228**	**257**	**246**
Grand total[6]	**[r]16,470**	**[r]16,461**	**16,293**	**16,496**	**17,390**
Of which:					
Blast furnace:					
Speigeleisen[26]	[r]27	[r]25	26	26	26
Ferromanganese[26]	1,413	[r]1,352	1,347	1,360	1,377
Ferrosilicon	77	47	76	77	72
Ferrophosphorus	29	29	29	28	28
Total blast furnace	**[r]1,546**	**[r]1,453**	**1,478**	**1,491**	**1,503**

TABLE 10—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1984	1985	1986	1987[p]	1988[e]
Electric furnace:[9]					
Ferromanganese[27]	3,154	r3,126	3,058	2,998	[28]3,006
Silicomanganese[27 29]	r1,642	r1,624	1,617	1,612	1,648
Ferrosilicon	r3,666	r3,586	3,493	3,498	3,742
Silicon metal	686	r691	717	777	858
Ferrochromium[30]	3,119	r3,274	3,193	3,348	[28]3,432
Ferrochromium-silicon[25 29]	r148	r139	132	126	[28]142
Ferronickel	r600	r638	552	551	631
Other[31]	995	r916	919	928	1,276
Undistributed	28	24	24	24	24
Total electric furnace	**r14,038**	**r14,018**	**13,705**	**13,862**	**14,759**
Furnace type unspecified:					
Ferromanganese[9]	878	982	1,109	1,144	1,128

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Table includes data available through July 12, 1989.

[2] To the extent possible, ferroalloy production of each country has been separated according to the furnace type from which production is obtained; production derived from metallothermic operations is included with electric-furnace production.

[3] To the extent possible, ferroalloy production of each country has been separated so as to show individually the following major types of ferroalloys: spiegeleisen, ferromanganese, silicomanganese, ferrosilicon, silicon metal, ferrochromium, ferrochromium-silicon, and ferronickel. Ferroalloys other than those listed that have been identified specifically in sources, as well as those ferroalloys not identified specifically but which definitely exclude those listed previously in this footnote have been reported as "Other." For countries for which one or more of the individual ferroalloys listed separately in this footnote have been inseparable from some other ferroalloys owing to the nation's reporting system, such deviations are indicted by individual footnotes. In instances where ferroalloy production has not been subdivided in sources, and where no basis is available for estimation of individual component ferroalloys, the entry has been reported as "Undistributed."

[4] Reported figure.

[5] Data for year ending Nov. 30 of that stated.

[6] Data may not add to totals shown because of independent rounding.

[7] Includes silicomanganese.

[8] Less than 1/2 unit.

[9] Although furnace type has not been specified for any ferroalloy production for China, North Korea, and the Republic of South Africa, all output of these countries has been included under "Electric furnace" (and metallothermic) output except for their production of ferromanganese, which is reported separately.

[10] Includes ferrochromium-silicon, if any was produced.

[11] Includes ferrochromium-silicon and ferronickel, if any was produced.

[12] Colombia is reported to produce ferromanganese also, but output is not reported quantitatively and no basis is available for estimation.

[13] Includes silicospiegeleisen.

[14] Includes ferronickel, if any was produced.

[15] Series excludes calcium silicide.

[16] Includes calcium-silicon, ferrotungsten, ferromolybdenum, ferrovanadium, ferrocolumbium, and other ferroalloys.

[17] Estimated figures based on reported exports and an allowance for domestic use.

[18] Ferrovanadium only; other minor ferroalloys may be produced, but no basis is available for estimation.

[19] Soviet production of electric furnace ferroalloys is not reported; estimates provided are based on crude source material production and availability for consumption (including estimates) and upon reported ferroalloy trade, including data from trading partner countries.

[20] U.S. production of ferronickel cannot be reported separately in order to conceal corporate proprietary information.

[21] U.S. output of ferromanganese includes silicomanganese and manganese metal.

[22] U.S. output of ferrochromium includes ferrochromium-silicon, chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[23] Includes ferronickel.

[24] Revised to zero.

[25] In previous years, these data appeared as "Ferrosilicon."

[26] Spiegeleisen for the Federal Republic of Germany is included with "Blast furnace ferromanganese."

[27] Ferromanganese includes silicomanganese and manganese metal for U.S. and silicomanganese (if any was produced) for countries carrying footnote 7 on "Ferromanganese" data line.

[28] U.S. production under "Other."

[29] Includes silicospiegeleisen for France.

[30] Ferrochromium includes material listed in footnote 22 for the United States and ferrochromium-silicon (if any was produced) for countries carrying footnote 10 on "Ferrochromium" data line.

[31] Includes ferronickel production for France, Norway, the U.S.S.R., and the United States.

FLUORSPAR

By David E. Morse[1]

In the United States, fluorspar was shipped by one major producer and two smaller producers that supplied less than 10% of the Nation's requirements. Supplementing fluorspar as a domestic source of fluorine was byproduct fluosilicic acid production from some phosphoric acid and hydrofluoric acid (HF) producers. Imports of fluorspar, which continued to supply most of the United States requirements, increased nearly 30% over those of 1987, and HF imports were 15% higher than reported in the previous year.

DOMESTIC DATA COVERAGE

Domestic production and consumption data for fluorspar are developed by the Bureau of Mines from four separate, voluntary surveys of U.S. operations. Surveys are conducted to obtain fluorspar mine production and shipments, fluosilicic acid production, and fluorspar briquet consumption. Of the five fluorspar mining operations to which a survey request was sent, 60% responded. Production statistics in table 1 are withheld to protect company proprietary data. Of the 13 fluosilicic acid producers, all responded, representing 100% of the quantity reported. Of the five briquet producers, 80% responded, representing 92% of the quantity reported. The consumption survey was sent to approximately 90 operations quarterly and to 40 additional operations annually. Of the operations surveyed quarterly, 64% responded. Of the operations surveyed on an annual basis, 68% responded. Together, quarterly and annual responses represented 76% of the apparent consumption data shown in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

At yearend, the National Defense Stockpile fluorspar inventory was unchanged from yearend 1987 and remained well below the stockpile goals of 1.4 million short tons for acid grade and 1.7 million tons for metallurgical grade. Depletion allowances against Federal taxes of 22% and 14%, respectively, remained in effect for domestic and foreign production by U.S. companies.

In September 1987, the United States and 22 other nations signed the Montreal Protocol on Substances that Deplete the Ozone Layer. The protocol, under the auspices of the United Nations Environmental Program, mandated a freeze in chlorofluorocarbon (CFC) consumption at the 1986 level by July 1989, followed by a 20% reduction

TABLE 1

SALIENT FLUORSPAR STATISTICS[1]

		1984	1985	1986	1987	1988
United States:						
Production:						
Finished (shipments)[e]	short tons	72,000	66,000	78,000	70,000	70,000
Value f.o.b. mine	thousands	W	W	W	W	W
Exports	short tons	12,266	9,671	16,215	2,860	3,457
Value	thousands	$1,292	$1,063	$1,801	$340	$381
Imports for consumption[1]	short tons	703,711	552,959	552,785	585,911	759,646
Value[2]	thousands	$65,241	$49,639	$45,675	$48,430	$69,168
Consumption (reported)	short tons	752,581	567,623	578,837	598,368	607,434
Consumption (apparent)[3]	do.	742,431	682,965	571,288	[r]709,512	797,857
Stocks, Dec. 31:						
Domestic mines:						
Finished	do.	W	W	W	W	W
Consumer	do.	120,267	46,590	89,872	33,411	61,743
World: Production	do.	[r]5,322,502	[r]5,618,409	5,521,399	[p]5,460,518	[e]5,708,761

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Excludes fluosilicic acid (H_2SiF_6) or imports of hydrofluoric acid (HF) and cryolite.
[2]C.i.f. U.S. port.
[3]U.S. primary and secondary production plus imports, minus exports, plus adjustments for Government and industry stock changes.

by mid-1993 and an additional 30% reduction by mid-1998. The U.S. Senate approved the terms of the treaty in March 1988, and the President signed the agreement in early April.

DOMESTIC PRODUCTION

Illinois remained the leading producing State, accounting for over 90% of all U.S. shipments. Data on shipments of fluorspar by State and grade are withheld to avoid disclosing company proprietary data.

Ozark-Mahoning Co., the Nation's largest fluorspar producer and a subsidiary of Pennwalt Corp., operated two mines and a flotation plant in Pope and Hardin Counties, IL. Ozark-Mahoning also dried imported fluorspar to supplement its production. Hastie Trucking and Mining Co. operated near Cave-In-Rock, IL. Inverness Mining Co., a former producer, dried imported fluorspar at its facilities at Cave-In-Rock, IL, and East Liverpool, OH, for sale primarily to consumers in the ceramic industry. J. Irving Crowell, Jr. & Son produced and shipped metallurgical-grade fluorspar from its Crowell-Daisy Mine in Nye County, NV.

The Kentucky-Illinois Fluorspar Co. operated a flotation plant reprocessing tailings for most of the year near Salem, KY. The company had in 1987 acquired from USX Corp. the fluorspar reserves, mines, and processing facilities that had formerly been owned by Cerro Corp., Marathon Oil Co., and United States Steel Corp.

Ozark acquired the southern Illinois assets of Inverness in December. Inverness allowed the two mines on the property to flood in 1984; Ozark planned to dewater the mines and resume operations by mid-1989. Ozark also continued to explore for additional fluorspar reserves in southern Illinois.

Reported shipments of fluorspar briquets for use in steel furnaces decreased to approximately 54,000 tons valued at $5.5 million. Fluorspar briquets were produced by two plants owned by Cameto Inc., one plant owned by Mercier Corp., one plant owned by National Briquetting Co., and one plant owned by Oglebay Norton Co. Oglebay Norton also dried, packaged, and shipped imported ceramic- and acid-grade fluorspar.

Nine plants processing phosphate rock for the production of phosphoric acid and one plant producing HF sold or used 57,700 tons of byproduct fluosilicic acid, which was equivalent to 102,000 tons of fluorspar. Three fluosilicic acid producer plants were idle in 1988.

CONSUMPTION AND USES

Acid-grade fluorspar, containing greater than 97% calcium fluoride (CaF_2), was used primarily as a feedstock in the manufacture of HF. Ceramic-grade fluorspar, containing 85% to 95% CaF_2, was used for the production of glass and enamel, to make welding rod coatings, and as a flux in the steel industry. Metallurgical-grade fluorspar, containing 60% to 85% or more CaF_2, was used primarily as a fluxing agent by the steel industry.

Reported domestic consumption of both acid- and subacid-grades increased for the third consecutive year. The HF and steel industries accounted for 74% and 24%, respectively, of reported consumption. According to the American Iron and Steel Institute (AISI), domestic production of raw steel increased from 89.2 million tons in 1987 to 99.3 million tons in 1988. A comparison of the AISI data with fluorspar consumption data collected by the Bureau of Mines from the U.S. steel industry shows, on the average, a decreasing rate of fluorspar consumption per ton of raw steel produced during 1986-88. In 1987, AISI combined raw steel output from open-hearth and basic oxygen furnaces. A calculation of unit consumption for those types of furnaces was not possible.

Type of furnace	Fluorspar consumption (pounds per short ton)		
	1986	1987	1988
Open hearth	13.51	NA	8.86
Basic oxygen	2.95	NA	3.07
Electric	2.03	1.91	1.91
Industry average	**3.03**	**2.96**	**2.95**

NA Not available.

In the ceramic industry, fluorspar was used as a flux and as an opacifier in the production of flint glass, white or opal glass, and enamels. Fluorspar was used in the manufacture of glass fibers, aluminum, cement, and brick, and was also used in the melt shop by the foundry industry.

Five companies reported fluorspar consumption for the production of HF. The U.S. Department of Commerce, Bureau of the Census, reported that anhydrous, technical, and aqueous HF, 100% basis, "produced and withdrawn from the system," was over 216,700 tons, compared with the 1987 quantity of 212,276 tons.

HF was used to produce synthetic cryolite and aluminum fluoride in the aluminum industry, in petroleum alkylation, in uranium and rare metals processing, in glass etching, and in manufacture of herbicides and fluoride salts. The largest use of HF was for the production of a wide range of fluorocarbon chemicals including fluoropolymers and CFC's. CFC's were produced by five companies. According to data from the U.S. International Trade Commission, production of trichlorofluoromethane (F-11) was unchanged at nearly 112,000 tons; dichlorodifluoromethane (F-12) increased 4% to 192,200 tons, and chlorodifluoromethane (F-22) increased 14% to 162,000 tons, compared with revised 1987 figures. As a consequence of the adoption of the terms of the Montreal

Protocol, F-11 and F-12 production will probably decrease continuously for the next 10 years and may be phased out completely when adequate substitutes are developed and tested. Because F-22 is not a fully halogenated CFC and is broken down in the lower atmosphere, it was not included in the list of ozone-depleting substances covered by the Montreal Protocol.

The manufacture of synthetic cryolite and aluminum fluoride for use in aluminum reduction cells was a major use of HF. An estimated 40 to 60 pounds of fluorine was consumed for each ton of aluminum produced. Aluminum fluoride was used by the ceramic industry for some body and glaze mixtures and in the production of specialty refractory products. It was used in the manufacture of aluminum silicates and in the glass industry as a filler.

HF was consumed in the manufacture of uranium tetrafluoride that was used in the process of concentrating uranium isotope 235 for use as nuclear fuel and in fission explosives. It was also used in stainless steel pickling, petroleum alkylation, glass etching, oil and gas well treatment, as a cleaner and etcher in the electronics industry, and in the manufacture of a host of fluorine chemicals used in dielectrics, metallurgy, wood preservatives, pesticides, mouthwashes, decay-preventing dentifrices, plastics, and water fluoridation.

Fluosilicic acid was used primarily in water fluoridation, either directly or after processing to sodium silicofluoride, and to make aluminum fluoride for the aluminum industry.

STOCKS

Fluorspar consumer stocks increased 85% from the low level reported in 1987. Although there are no supporting data, dealer stocks of acid-grade are believed to have increased significantly because reported imports were over

TABLE 2

U.S. CONSUMPTION (REPORTED) OF FLUORSPAR, BY END USE

(Short tons)

End use or product	Containing more than 97% calcium fluoride (CaF_2)		Containing not more than 97% calcium fluoride (CaF_2)		Total	
	1987	1988	1987	1988	1987	1988
Hydrofluoric acid (HF)	438,803	449,469	—	—	438,803	449,469
Glass and fiberglass	2,219	2,042	9,597	1,019	11,816	3,061
Enamel and pottery	W	W	1,168	281	1,168	281
Welding rod coatings	6,883	35	918	281	7,801	316
Primary aluminum and magnesium	W	W	W	W	W	W
Iron and steel castings	W	W	4,548	5,217	4,548	5,217
Open-hearth furnaces	391	—	21,966	22,683	22,357	22,683
Basic oxygen furnaces	W	—	77,203	88,972	77,203	88,972
Electric furnaces	1,468	1,700	30,937	32,969	32,405	34,669
Other	1,516	177	751	2,581	2,267	2,766
Total	**451,280**	**453,423**	**147,088**	**154,003**	**598,368**	**607,434**
Stocks, Dec.31: Consumer	23,976	26,861	9,435	34,882	33,411	61,743

W Withheld to avoid disclosing company proprietary data; included with "Other."

TABLE 3

U.S. CONSUMPTION (REPORTED) OF SUBACID GRADES OF FLUORSPAR IN 1988, BY END USE

(Short tons)

End use or product	Containing not more than 97% calcium fluoride (CaF_2)		
	Flotation concentrates	Lump or gravel	Briquets or pellets
Chemicals and allied products: Welding fluxes	126	155	—
Glass, ceramic, brick:			
Glass	985	34	—
Other glass, clay products	254	27	—
Primary metals:			
Iron and steel (foundries)	—	5,217	—
Steel mills:			
Basic oxygen furnaces	8,416	47,543	33,013
Electric furnaces	8,582	19,146	5,241
Open-hearth furnaces	2,000	15,483	5,200
Other identified end uses	—	2,589	—
Total	**20,363**	**90,194**	**43,454**

200,000 tons in the fourth quarter of 1988, and reported consumption was about 110,000 tons for the same period. Reported acid-grade consumer stocks also decreased 6,000 tons in the fourth quarter. Producer stock data are withheld to avoid disclosing company proprietary information.

PRICES

Domestic producer prices for all grades of fluorspar and fluorspar briquets were published in the Engineering and Mining Journal through April 1988. The published prices for domestic material had not changed in 4 years. Yearend 1988 prices were not available. The average c.i.f. value for imported metallurgical-grade fluorspar from Mexico was $77.35 per ton in the fourth quarter of 1988; the average c.i.f. value of imported acid-grade from Europe, the Republic of South Africa, and Mexico was $100.10 per ton, $111.50 per ton, and $88.95 per ton, respectively, during the fourth quarter. Additional costs to consumers included import duties, vessel unloading, and transportation to the consumption site.

Yearend price quotations from the Chemical Marketing Reporter (CMR) were $0.6875 per pound for anhydrous HF and $49.00 per 100 pounds for aqueous HF, 70%, in tanks. The CMR yearend price quotation for cryolite was $550 per ton and for fluosilicic acid, 100% basis, in tanks, was $325 per ton.

FOREIGN TRADE

According to the Bureau of the Census, U.S. exports of fluorspar increased by 21% and had an average value of $110 per ton. Synthetic cryolite exports increased to 13,300 tons representing 16,000 tons of equivalent fluorspar, valued at $4.8 million. In descending order of the quantity exported, the

TABLE 4

PRICES OF DOMESTIC AND IMPORTED FLUORSPAR

(Dollars per short ton)

	1987	1988
Domestic, f.o.b. Illinois-Kentucky:		
Metallurgical: 70% effective CaF_2 briquets	125	NA
Ceramic, variable calcite and silica:		
88% to 90% CaF_2	100	NA
95% to 96% CaF_2	170	NA
97% CaF_2	165–175	NA
Acid, dry basis, 97% CaF_2:		
Carloads	173	NA
88% effective CaF_2 briquets	180	NA
European and South African:[1] Acid, term contracts	92.45–95.25	NA
Mexican:[2]		
Metallurgical:		
70% effective CaF_2, f.o.b. vessel, Tampico	80.06	NA
70% effective CaF_2, f.o.b. cars, Mexican border	75.63	NA
Acid, bulk: 97+%, Mexican border	108.33	NA

NA Not available.
[1] C.i.f. duty paid, east coast, Great Lakes, and gulf ports.
[2] U.S. import duty, insurance, and freight not included.
Source: Engineering and Mining Journal, Dec. 1987.

TABLE 5

U.S. EXPORTS OF FLUORSPAR, BY COUNTRY

Country	1987 Quantity (short tons)	1987 Value	1988 Quantity (short tons)	1988 Value
Australia	—	—	61	$6,073
Canada	2,036	$216,373	2,349	240,690
Dominican Republic	458	65,412	808	95,771
Ghana	211	31,636	65	13,559
Gibraltar	—	—	24	9,612
Indonesia	—	—	20	2,032
Mexico	—	—	100	10,835
Taiwan	—	—	30	3,000
Venezuela	155	26,894	—	—
Total	**2,860**	**340,315**	**3,457**	**381,572**

Source: Bureau of the Census.

most important importers of U.S. produced synthetic cryolite were Venezuela, Australia, Ghana, and Argentina. According to the reported data, the average export value for synthetic cryolite was $359 per ton.

Imports for consumption of fluorspar increased substantially with Mexico remaining the most important supplier, followed by, in descending order of the quantity imported, the Republic of South Africa, China, Spain, Kenya, and Italy. The average unit value, in dollars per ton, of acid- and subacid-grade fluorspar, was $97.98 and $64.75, respectively. U.S. import duties remained in effect for all grades of fluorspar. The duty was $1.875 per ton for acid-grade and 13.5% ad valorem for ceramic- and metallurgical-grade material.

Imports for consumption of HF increased 15% to a quantity equivalent to approximately 196,000 tons of fluorspar with an average value of $815 per ton. Imports of synthetic and natural cryolite had an average c.i.f. value of $749 per ton and represented 12,000 tons of equivalent fluorspar.

The United States also imported many fluorochemicals, including ammonium bifluoride, chlorodifluoromethane, dichlorodifluoromethane, fluorocarbon polymers, hexafluoropropylene, polytetrafluoroethylene, and trichlorofluoromethane.

WORLD CAPACITY

The data in table 9 are rated capacity for mines and beneficiation plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT

Country and customs district	1987		1988	
	Quantity (short tons)	Value [1] (thousands)	Quantity (short tons)	Value [1] (thousands)
CONTAINING MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Austria: San Francisco	1	$1	—	—
Canada:				
Houston	3,821	298	13,908	$1,645
Laredo	—	—	1,128	147
New Orleans	2,312	295	15,896	1,860
Total	**6,134**	**594**	**30,932**	**3,652**
China:				
Houston	29,686	2,436	45,008	3,672
New Orleans	5,716	459	42,125	3,787
Total	**35,402**	**2,895**	**87,133**	**7,459**
France: Houston	157	57	—	—
Germany, Federal Republic of:				
Milwaukee	10	5	—	—
Wilmington	—	—	6	4
Kenya:				
Houston	827	714	16,647	1,410
Laredo	1,764	106	10,789	3,365
Total	**2,591**	**820**	**27,436**	**4,775**
Mexico:				
Baltimore				
El Paso	92,229	7,195	80,893	6,352
Houston	14,446	1,143	30,958	2,593
Laredo	49,360	4,701	41,975	4,090
New Orleans	21,290	1,759	46,380	4,789
Nogales	56	1	—	—
Philadelphia	709	55	998	78
Total	**178,090**	**14,854**	**201,204**	**17,902**
Morocco: New Orleans	29,838	2,684	—	—
South Africa, Republic of:				
Baltimore	—	—	1,333	167
Houston	16,625	1,330	36,477	3,436
Laredo	—	—	2,204	265
New Orleans	163,037	14,960	153,505	16,659
Total	**179,662**	**16,290**	**193,519**	**20,527**
Italy: New Orleans	—	—	17,384	1,774
Spain: New Orleans	19,912	2,243	43,706	5,338
Grand total	**451,796**	**40,442**	**601,320**	**61,427**

See footnote at end of table.

TABLE 6—Continued

U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT

Country and customs district	1987 Quantity (short tons)	1987 Value[1] (thousands)	1988 Quantity (short tons)	1988 Value[1] (thousands)
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Canada:				
Buffalo	—	—	75	$11
Seattle	34	$6	34	2
Total	**34**	**6**	**109**	**13**
China: New Orleans	6,901	413	18,863	1,172
Italy:				
Miami	23	16	—	—
New York	71	36	—	—
San Francisco	—	—	38	18
Total	**94**	**52**	**38**	**18**
Mexico:				
Baltimore	6,644	479	13,060	1,146
Buffalo	—	—	171	16
El Paso	4,631	224	4,878	517
Laredo	15,395	638	20,177	908
New Orleans	92,124	5,620	93,923	5,812
Philadelphia	8,255	543	7,006	635
Seattle	34	5	101	14
Total	**127,083**	**7,509**	**139,316**	**9,048**
United Kingdom: Houston	3	7	—	—
Grand total	**134,115**	**7,987**	**158,326**	**10,251**

[1] C.i.f. value at U.S. port.

Source: Bureau of the Census.

temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Normal production practices for many underground fluorspar operations are 2-shift-per-day mining operations with 1 shift for blasting and ventilation; associated milling operations are continuous with 2 or 3 shifts per week dedicated to maintenance and cleaning.

WORLD REVIEW

World fluorspar consumption and production increased compared with 1987 because of greater demands in the HF and steel sectors. China, Mexico, Mongolia, and the U.S.S.R. were the major producers. International prices trended upward after being stagnant for 5 years. Fluorspar exports from China continued to increase to an estimated 875,000 tons; China's fluorspar exports were 700,000 tons, 770,000 tons, and 855,000 tons in 1985, 1986, and 1987, respectively, and have been offered to consumers at attractive prices. U.S. imports from China nearly tripled to 104,000 tons in 1988 from the 35,000 tons received in 1987.

Thirty-six nations producing over 90% of world CFC output agreed to the terms of the Montreal Protocol on substances that deplete atmospheric ozone. Major producers of CFC's in the United States, Western Europe, and Japan agreed to a combined effort to begin the lengthy toxicity testing of replacements for F-11 and F-12 for food industry uses. The United States, the United Kingdom, and the Federal Republic of Germany called for a faster reduction in CFC production and use than mandated in the Protocol, which would reduce CFC production and consumption to 50% of 1986 levels by 1998. The argument for an accelerated reduction timetable was evidence of an ozone hole in the atmosphere surrounding Antarctica in the austral winter and significant ozone reductions over the Arctic Ocean during the northern winter.

In Mexico, the Instituto Mexicano de la Fluorita A.C. was dissolved. Data on Mexican sales by grade, which the Institute had published, were, in the future to be distributed by the Mexican Chamber of Mines. The Government of Mexico was to continue to publish data on total fluorspar production and exports by grade; production data by grade were not available for 1988.

[1] Physical scientist, Branch of Industrial Minerals.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF HYDROFLUORIC ACID (HF), BY COUNTRY

Country	1987		1988	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Canada	37,833	$34,989	41,496	$36,660
Colombia	20	22	—	—
France	22	14	—	—
Germany, Federal Republic of	124	141	58	165
Israel	17	16	—	—
Japan	3,061	2,458	2,637	2,215
Mexico	72,340	57,262	86,617	67,313
United Kingdom	281	309	428	547
Total	**113,698**	**95,211**	**131,236**	**[2]106,901**

[1] C.i.f. value at U.S. port.
[2] Data do not add to total shown because of independent rounding.
Source: Bureau of the Census.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF CRYOLITE, BY COUNTRY

Country	1987		1988	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Brazil	—	—	60	$27
Canada	2,372	$1,215	2,090	1,127
China	1,163	550	240	134
Denmark	4,666	2,176	3,321	2,636
Germany, Federal Republic of	163	110	508	425
Greenland	—	—	21	24
Italy	1,406	857	858	628
Japan	3,029	2,324	1,816	1,695
Netherlands	210	129	469	416
Other	596	332	352	198
Total	**13,605**	**7,693**	**9,735**	**7,310**

[1] C.i.f. value at U.S. port.
Source: Bureau of the Census.

TABLE 9

WORLD FLUORSPAR ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

	Rated capacity[1] [2]
North America:	
Canada	85
Mexico	1,350
United States	80
Total	**1,515**
South America:	
Argentina	40
Brazil	80
Total	**120**
Europe:	
Czechoslovakia	110
France	320
German Democratic Republic	110
Germany, Federal Republic of	110
Italy	220
Romania	35
Spain	350
U.S.S.R.	650
United Kingdon	350
Total	**2,250**
Africa:	
Kenya	100
Morocco	100
South Africa, Republic of	750
Tunisia	50
Total	**1,000**
Asia:	
China	1,500
India	30
Korea, North	50
Korea, Republic of	10
Mongolia	900
Thailand	200
Total	**2,540**
World total	**7,580**

[1] Includes capacity at operating plants as well as plants on standby basis.

[2] In addition to the countries listed, Egypt, Greece, Iran, Pakistan, Sweden, and Turkey produce fluorspar, but available information is inadequate for the formulation of a reliable capacity determination.

TABLE 10

SALES OF MEXICAN FLUORSPAR, BY GRADE

(Short tons)

Grade	1984	1985	1986	1987	1988
Acid	508,235	409,800	427,181	430,478	NA
Ceramic	54,562	51,982	51,541	52,509	NA
Metallurgical	230,375	309,490	246,226	245,332	NA
Submetallurgical	117,113	57,779	73,242	105,158	NA
Total	**910,285**	**829,051**	**798,190**	**833,477**	**NA**

NA Not available.

Source: Instituto Mexicano de la Fluorita A.C.

TABLE 11

FLUORSPAR: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2] and grade[3]	1984	1985	1986	1987[p]	1988[e]
Argentina	25,526	[r]33,744	43,074	48,544	44,000
Brazil (marketable):					
Acid grade	48,878	47,048	59,034	64,745	66,000
Metallurgical grade	34,578	32,754	34,237	34,405	35,000
Total	**83,456**	**79,802**	**93,271**	**99,150**	**101,000**
Canada: Acid grade[e]	—	—	—	11,000	40,000
China:[e]					
Acid grade	[r]385,800	[r]496,000	[r]496,000	[r]606,300	716,500
Metallurgical grade	[r]440,900	[r]441,000	[r]496,000	[r]496,000	496,000
Total	**[r]826,700**	**[r]937,000**	**[r]992,000**	**[r]1,102,300**	**1,212,500**
Czechoslovakia[e]	106,000	105,000	105,000	105,000	105,000
Egypt	893	94	88	855	860
France:					
Acid and ceramic grades	175,378	176,370	163,142	[e]165,000	165,000
Metallurgical grade	80,469	70,548	55,000	[e]55,000	55,000
Total	**255,847**	**246,918**	**218,142**	**[e]220,000**	**220,000**
German Democratic Republic[e]	110,000	110,000	110,000	99,000	99,000
Germany, Federal Republic of (marketable)	91,787	91,644	97,923	93,918	95,000
Greece[e]	[4]330	300	300	300	300
India:[e]					
Acid grade	13,000	[4]12,243	[r]8,400	[r]9,100	9,000
Metallurgical grade	6,000	[4]5,511	[r]4,533	[r]4,909	5,000
Total	**19,000**	**[4]17,754**	**[4]12,933**	**[4]14,009**	**14,000**
Iran:[e 5]	3,600	3,600	3,600	3,600	3,600
Italy:					
Acid grade	121,618	105,215	100,200	[e]101,000	100,000
Metallurgical grade	85,904	62,569	60,116	[e]60,600	59,000
Total	**207,522**	**167,784**	**160,316**	**[e]161,600**	**159,000**
Kenya: Acid grade	51,343	64,126	56,054	66,348	66,000
Korea, North: Metallurgical grade[e]	44,000	44,000	44,000	44,000	44,000
Korea, Republic of: Metallurgical grade	5,150	777	268	69	110
Mexico:[6]					
Acid grade	379,725	417,469	466,954	451,777	NA
Ceramic grade	40,307	30,011	14,984	13,244	NA
Metallurgical grade	235,079	297,897	290,076	338,005	NA
Submetallurgical grade[7]	115,878	57,779	73,263	105,158	NA
Total	**770,989**	**803,156**	**845,277**	**908,184**	**[4]853,638**
Mongolia: Metallurgical grade[e]	823,400	867,500	870,800	[r]860,000	871,000
Morocco: Acid grade	72,642	81,956	91,500	85,980	86,000
Pakistan	3,002	3,499	4,798	4,049	4,400
Romania: Metallurgical grade[e]	22,000	22,000	22,000	20,000	20,000

See footnotes at end of table.

TABLE 11-Continued

FLUORSPAR: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2] and grade[3]	1984	1985	1986	1987[p]	1988[e]
South Africa, Republic of:					
Acid grade	318,892	341,949	323,382	[e]307,500	319,900
Ceramic grade	4,963	6,310	8,491	[e]7,700	8,803
Metallurgical grade	28,010	36,676	36,171	[e]33,800	41,050
Total	**351,865**	**384,935**	**368,044**	**349,000**	**[4]369,753**
Spain:					
Acid grade	279,128	294,068	283,413	[e]253,500	264,600
Metallurgical grade	46,788	42,808	27,946	[e]27,600	28,700
Total	**325,916**	**336,876**	**311,359**	**[e]281,100**	**293,300**
Sweden	3,807	3,493	3,307	[e]3,300	3,300
Thailand:					
Acid grade	62,998	39,506	12,677	([4])	([8])
Metallurgical grade	253,783	289,972	172,411	112,874	110,000
Total	**316,781**	**329,478**	**185,088**	**112,874**	**110,000**
Tunisia: Acid grade	49,064	44,767	40,596	35,994	35,000
Turkey: Metallurgical grade[e]	[r]2,489	[r]5,500	[r]11,000	[r]11,000	11,000
U.S.S.R.[e]	606,000	617,000	617,000	617,000	617,000
United Kingdom	150,686	184,086	146,607	[e]154,000	160,000
United States (shipments)[e]	72,000	66,000	78,000	70,000	70,000
Grand total	**[r]5,322,502**	**[r]5,618,409**	**5,521,399**	**5,460,518**	**5,708,761**

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Table includes data available through May 10, 1989.

[2]In addition to the countries listed, Bulgaria is believed to have produced fluorspar in the past, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.

[3]An effort has been made to subdivide production of all countries by grade (acid, ceramic, and/or metallurgical). Where this information is not available in official reports of the subject country, the data have been entered without qualifying notes.

[4]Reported figure.

[5]Data are for fiscal year beginning Mar. 21 of that stated.

[6]Data for 1984-87 were provided by the Instituto Mexicano de la Fluorita A.C.; figure for total production for 1988 was provided by Mexican Government sources. Comparable Mexican Government figures for total production for previous years covered in this table are, as follows, in short tons: 1984-691,626; 1985-768,762; 1986-834,190; 1987-797,625.

[7]Same grade range as metallurgical but primarily contains greater quantities of silica impurities.

[8]Revised to zero.

GALLIUM

By Deborah A. Kramer[1]

Although total U.S. demand for gallium in 1988 did not change appreciably from that in 1987, significant advances were made in gallium arsenide (GaAs) processing technology, and new GaAs components were introduced that could increase U.S. demand. Improvements in GaAs processing techniques ultimately led to increased material yields and consequently less GaAs scrap generation. GaAs integrated-circuit manufacturers developed new digital components for use in large-scale commercial applications. In many cases, these components would be direct replacements for silicon components in supercomputers and in less powerful computer systems. In the optoelectronics market, GaAs visible-diode lasers offered potential as a replacement for helium-neon lasers in applications such as stationary bar-code scanners, high-end laser printers, and other equipment.

World production and capacity in 1988 were about the same as in 1987, but significant capacity additions planned in Australia and the Federal Republic of Germany are expected to increase world capacity significantly in 1989.

DOMESTIC DATA COVERAGE

Domestic consumption data for gallium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 39 operations to which a survey request was sent, 97% responded, representing 68% of the consumption shown in tables 1, 2, and 3. Consumption data were adjusted to reflect full industry coverage.

DOMESTIC PRODUCTION

The only domestic producer, St. George Mining Corp., a subsidiary of Musto Explorations Ltd. of Canada, filed for bankruptcy under chapter 11 of the Federal Bankruptcy Code in July. St. George had operated a mine and processing plant in St. George, UT, until September 1987 when the facilities were closed because of technical and financial difficulties. Until that time, St. George recovered low-grade gallium and a germanium concentrate at the plant. At the end of July 1988, Hecla Mining Co. announced that it entered an option agreement to acquire the assets of St. George, subject to approval by the U.S. Bankruptcy Court for the District of Utah.[2]

Eagle-Picher Industries Inc. recovered and refined gallium from primary and secondary source materials at its plant in Quapaw, OK. Recapture Metals Inc. recovered gallium from GaAs scrap at its plant in Blanding, UT.

Rhône-Poulenc S.A. of France delayed construction of a 50,000-kilogram-per-year gallium purification plant in Freeport, TX, until gallium demand increases sufficiently to warrant the new plant. Construction originally was scheduled for completion by the end of 1988.

Sulzer Brothers Inc. reportedly dismantled its 15,000-kilogram-per-year gallium extraction plant in Gramercy, LA, which had been scheduled to begin operating in 1988. Possible infringement upon patented technology was cited as the reason for dismantling the plant. Sulzer's plant was originally scheduled to provide a gallium chloride solution for use in a solar neutrino capture experiment in Italy.

Degerstrom Inc., an open pit mining contractor, planned to begin a project to recover gallium from phosphate flue dust in Soda Springs, ID. Dust from the nearby phosphate mine and plant owned by Monsanto Co. was to be the company's feedstock. Degerstrom's proprietary process involves treating the dust with sulfuric acid to produce phosphoric acid and then extracting the gallium through an organic separation process. The company also expected to recover silver. The new plant, with a planned annual capacity of 4,000 kilograms of gallium, was scheduled for completion by the summer of 1989.

Mountain States Resources Corp., Salt Lake City, UT, announced that it acquired 7,600 acres of mining claims with occurrences of gallium and germanium. The company was testing large samples of ore to determine the concentrations of these metals. Early testing results indicated that their concentrations were approximately 0.05%.

CONSUMPTION

Domestic gallium consumption remained stable in 1988; however, improvements in recent years in processing techniques have increased material yields and reduced the scrap generated during device fabrication.

In November, Cominco Ltd. sold its

TABLE 1

SALIENT U.S. GALLIUM STATISTICS

(Kilograms unless otherwise specified)

	1984	1985	1986	1987	1988
Production[e]	—	—	[1]750	W	—
Imports for consumption	9,669	7,961	17,202	12,490	12,160
Consumption	7,060	7,396	16,043	10,729	10,741
Price per kilogram	$525	$525	$525	$525	$525

[e] Estimated. W Withheld to avoid disclosing company proprietary data.
[1] Reported figure.

electronic materials operations to Johnson Matthey Ltd. The sale included the Cominco Electronic Materials Div., which distributed gallium in the United States, and a plant in Trail, British Columbia, Canada, which recovered gallium from imported sources. Johnson Matthey planned to continue operating the existing plants.

Because of financial difficulties resulting from the slow commercial market development for GaAs integrated circuits, GAIN Electronics Inc. ceased operation in October. The company, established in 1984, was largely backed financially by Mitsui & Co. in Japan and had planned to produce integrated circuits for defense and commercial markets.[3]

TriQuint Semiconductor Inc. announced the availability of 4-inch-diameter wafers for GaAs integrated circuit production. Most GaAs devices have been made on 2- and 3-inch-diameter GaAs wafers. The 4-inch-diameter wafers allow production of more devices per wafer than with the smaller wafers. This reduces the generation of scrap. As device production using 4-inch-diameter wafers increases in volume, the production cost is expected to decrease.

Gazelle Microcircuits Inc. announced the development of a GaAs integrated circuit that is an exact replacement for a silicon integrated circuit but is two to three times faster. This represented the first high-volume commercial application for a GaAs digital component.[4] Gazelle also announced a 2-year, $16.9 million GaAs manufacturing contract with TriQuint, which was believed to be the largest contract ever signed for commercial production of GaAs integrated circuits. TriQuint will use its manufacturing capabilities for 4-inch-diameter wafers to supply Gazelle with wafers and assembled, packaged integrated circuits.

GigaBit Logic Corp. announced the introduction of a new GaAs static random-access memory component that has both high processing speeds suitable for use in supercomputers and has features for cache storage suitable for less powerful systems. The new component also was designed to be a "drop in" replacement for a silicon integrated circuit. According to analysts, the new GaAs memory component had a good chance of reaching shipments of 100,000 units per year when it attains full production levels.[5] Other new digital components and new processing techniques were discussed in a review of the GaAs industry.[6]

TABLE 2

U.S. CONSUMPTION OF GALLIUM,[1] BY END USE

(Kilograms)

End use	1988
Optoelectronic devices:	
Laser diodes and light-emitting diodes	3,891
Photodetectors and solar cells	2,178
Integrated circuits:	
Analog	2,320
Digital	829
Research and development	1,235
Specialty alloys	83
Other	205
Total	**10,741**

[1] Includes gallium metal and gallium compounds.

Sanders Associates, a subsidiary of Lockheed Corp., increased processing yields at its GaAs monolithic microwave integrated circuits (MMIC) production facility in Nashua, NH. The company achieved yields as high as 80% on production of one type of chip, an amplifier, which means that 80% of the MMIC produced from wafers passed post-production testing. Typical yields for other devices made at the facility were 40% to 50%. The amplifier was used in a radar jamming system, present in a wide variety of U.S. Navy aircraft.[7]

Manufacturers discovered a method to produce gallium aluminum arsenide (GaA1As) diode lasers that emit red light and have improved the production process so that long-lived commercial products are feasible. The recently introduced visible-diode laser was to be aimed at markets that use conventional helium-neon lasers, but the visible-diode laser was expected to offer advantages in power consumption, size, reliability, and

TABLE 3

STOCKS, RECEIPTS, AND CONSUMPTION OF GALLIUM,[1] BY GRADE

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
1987:				
97.0% to 99.9%	105	68	64	109
99.99% to 99.999%	2	58	58	2
99.9999%	706	10,522	10,607	211
99.99999%				410
Total	**813**	**10,648**	**10,729**	**732**
1988:				
97.0% to 99.9%	109	—	93	16
99.99% to 99.999%	2	239	205	36
99.9999%	211	6,516	6,368	359
99.99999%	410	4,042	4,075	377
Total	**732**	**10,797**	**10,741**	**788**

[1] Consumers only.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF GALLIUM (UNWROUGHT WASTE AND SCRAP), BY COUNTRY

Country	1987		1988	
	Kilograms	Value	Kilograms	Value
Canada	107	$51,807	177	$50,046
France	6,364	2,497,584	4,923	1,923,249
Germany, Federal Republic of	1,215	517,809	1,129	378,165
Italy	13	5,680	294	65,834
Japan	451	202,409	51	29,185
Mexico	—	—	17	7,299
Singapore	21	11,576	91	23,960
Spain	—	—	11	4,795
Suriname	96	48,960	—	—
Switzerland	4,081	1,496,466	5,423	1,844,675
United Kingdom	142	41,757	44	13,707
Total	**12,490**	**4,874,048**	**12,160**	**4,340,915**

Source: Bureau of the Census.

performance. The primary application for visible-diode lasers is in bar-code scanners. Other applications include high-end laser printers, microfilm equipment, and surveying and construction equipment.[8]

PRICES

Quoted gallium prices at yearend 1988 were the same as those at yearend 1987. Yearend prices for gallium materials quoted in the American Metal Market were as follows, in dollars per kilogram: gallium metal, 99.99999% pure, in 100-kilogram lots, $525; gallium metal, 99.99% pure, in 100-kilogram lots, $435; gallium metal, 99.9999% pure, imported, $460 to $490; gallium oxide, 99.99% pure, imported, $400 to $420; and gallium oxide, 99.999% pure, $435.

FOREIGN TRADE

Gallium export data were combined with data for other metals and compounds by the Bureau of the Census and could not be separately identified. Some information on gallium exports is available through The Journal of Commerce Port Import/Export Reporting Service (PIERS). According to PIERS, 2,789 kilograms (gross weight) of gallium metal and gallium arsenide scrap was exported in 1988, principally to France and the Federal Republic of Germany. Smaller quantities were exported to Hong Kong, the Republic of Korea, and Venezuela. Data from PIERS may not be complete because this source provides information only on materials that are transported by ship.

WORLD CAPACITY

Data in table 5 are estimates of rated annual capacity for primary gallium recovery plants as of December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Capacity data include only those plants that recover virgin gallium. They do not include purification capacity or secondary recovery capacity, although some of the plants that recover gallium also have facilities for purification and/or secondary recovery. A significant increase in capacity was scheduled for 1989 when Rhône-Poulenc's 50,000-kilogram-per-year gallium extraction facility comes on-stream.

WORLD REVIEW

Although individual countries do not publish gallium production data, total world production was estimated to

TABLE 5

WORLD ANNUAL PRIMARY GALLIUM PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Kilograms)

North America: United States[2]	12,000
Europe:	
Czechoslovakia	3,000
France	20,000
Germany, Federal Republic of	12,000
Hungary	4,000
Norway	5,000
Total	**44,000**
Asia:	
China	8,000
Japan	17,000
Total	**25,000**
World total	**81,000**

[1] Includes capacity at operating plants as well as at plants on standby basis.
[2] All U.S. capacity is standby capacity as of Dec. 31, 1988.

be about 45,000 kilograms. A review of world supply, technology, and uses was published by the Bureau of Mines.[9]

Australia

Construction of a 2,000-kilogram-per-day pilot plant for treating ore from the Brockman Deposit in Western Australia began in January. This deposit contained significant quantities of gallium in addition to columbium, tantalum, yttrium, and rare-earth oxides, and it is jointly operated by West Coast Holdings Ltd. and Greater Pacific Investments Ltd. The pilot plant was constructed at Warren Springs Laboratory in the United Kingdom, which had developed processing techniques to recover the contained metals as oxides. Depending upon the success of the pilot plant, eventual plans are to construct a 600,000-kilogram-per-day full-scale plant near the deposit in Western Australia.

Rhône-Poulenc announced that its 50,000-kilogram-per-year gallium extraction plant under construction near Pinjarra, Western Australia, was expected to be operational by the summer of 1989. Rhône-Poulenc's feedstock for the new plant was to come from Alcoa of Australia Ltd.'s alumina refinery nearby.

Germany, Federal Republic of

Ingal International Gallium GmbH planned to construct a 20,000-kilogram-per-year virgin gallium extraction plant at Stade to replace its facility in Lunen, which was closed in 1988. The Stade facility was expected to be fully operational by 1989. Ingal also operated a gallium purification plant in Schwandorf, where annual capacity was increased to 20,000 kilograms in 1987.

Wacker-Chemitronic GmbH developed a proprietary polishing process to yield ultrasmooth GaAs wafer surfaces, reducing the roughness by 10 times compared with typically available wafers. The surface quality of GaAs wafers is particularly important when very thin epitaxial films are deposited. The West German company was offering pretreated wafers that can be used immediately for epitaxial growth without prior cleaning or preetching needed. This development could decrease GaAs device production costs by eliminating some processing steps.[10]

Japan

Total gallium supply, including that from recycled material, was estimated to be 36,400 kilograms in 1988. Primary high-purity metal production was estimated to be 12,000 kilograms, and imports of low- and high-purity gallium were expected to be 12,400 kilograms. France and the Federal Republic of Germany were the principal import sources for high-purity metal, and China, Czechoslovakia, and Hungary were the sources for low-purity gallium imports.[11]

U.S.S.R.

A solar neutrino capture experiment was planned as a joint project between the United States and the Soviet Union, to begin in 1989. This experiment would require 70,000 kilograms of metallic gallium to be buried in a tunnel 2.5 miles into the Andyrchi Mountain in the Caucasus range, but the project was expected to begin when 30,000 kilograms of gallium were in place. The Soviet Union will provide the gallium for the project, and U.S. participants are from Los Alamos National Laboratory, Princeton University, and the University of Pennsylvania. Solar neutrinos are theorized to be produced when hydrogen fuses into helium, the process that is the source of the sun's power. Because of their small mass and lack of electrical charge, neutrinos have not been detected. Gallium is a useful material for detecting these low-energy particles, because, when a neutrino collides with an atom of gallium, the gallium changes into an atom of a detectable radioactive isotope of germanium. Detecting solar neutrinos may be important in providing information about the sun.

TECHNOLOGY

The U.S. Government continued to contract with private firms for research and development on GaAs components for defense and space applications. International Telegraph & Telephone Corp. received a $1 million contract from the U.S. Air Force to develop variable-power GaAs transmit-receive modules for phased-array radar systems. The company planned to use a new technology it developed to increase the module's power output.[12] Epitaxx Inc. was awarded a $50,000 contract by the National Aeronautics and Space Administration (NASA) to develop a linear array of indium gallium arsenide (InGaAs) detectors to be used in remote sensing and imaging. NASA also awarded a $485,000 contract to Spire Corp. to develop low-cost GaA1As laser arrays for solid-state laser pumps. Spire planned to develop high-power, quantum-well lasers suitable for NASA's needs under the contract. Varian Associates Inc. received contracts worth more than $1 million from Aerojet Electro Systems to develop low-cost methods for manufacturing GaAs devices for use in the U.S. Army's sense-and-destroy-armor program.

Scientists at American Telephone & Telegraph Co.'s (AT&T) Bell Laboratories developed GaAs infrared detectors that have the same wavelength of detection as those made of mercury cadmium telluride (HgCdTe). HgCdTe detectors are used in aerospace and defense applications, but the material is more expensive, less stable, and harder to fabricate than GaAs. One advantage of using GaAs in the infrared detectors is that high-speed integrated circuits also made from GaAs can be fabricated on the same substrate as the detector; HgCdTe detectors require separate integrated circuits made from silicon. It also may be possible to build focal-plane arrays of GaAs detectors with as many as 100 by 100 detectors instead of the smaller arrays now possible with HgCdTe.[13]

Texas Instruments Inc. created a prototype for a new integrated circuit using a combination of GaAs, GaAlAs, and InGaAs that could potentially fit 100 times the functions of today's typical integrated circuit in the same space and consume less power. The device, a quantum-effect transistor, will require the development of new techniques to manufacture and interconnect the devices before it can become commercially feasible. The active regions in the prototype range between 10 and 20 nanometers in size; within these small dimensions, electrons in the devices act like waves rather than particles. Electrons occupy discrete energy levels and resonate when they are confined to regions the size of their wavelengths. Thus, quantum-effect transistors can switch at speeds thousands of times faster than conventional devices.[14]

Researchers at IBM Corp. announced that they have achieved ballistic transport of positive electrical changes through GaAs. In ballistic transport, the electrical charge goes directly through a solid without being slowed by collisions with the atoms in the solid. The same research team demonstrated ballistic transport with electrons about 3 years ago, but it was thought that the positive electrical charges were too heavy to achieve ballistic transport. If ballistic transport could be demonstrated in transistors and other devices, faster, more powerful computers could be developed.

A transistor capable of switching at a speed of 113 gigahertz was developed jointly by engineers from Cornell University and Siemens Corp. Research and Technology Laboratories. The new transistor, created by molecular beam epitaxy, consists of multiple layers of silicon-doped GaAs and GaAlAs. In developing the device, silicon-doping was precisely controlled so that the active regions could be grown with few defects, which would inhibit electron flow. The technology behind this transistor was expected to find applications in high-speed satellite communications, spacecraft communications, and radar systems.

Ford Microelectronics and Ford Aerospace, divisions of Ford Motor Co., have demonstrated large-scale digital integrated circuits and HgCdTe photovoltaic detectors fabricated on GaAs-on-silicon substrates. GaAs-on-silicon substrates have potential uses in military communications, supercomputers, and high-speed data processing.

A GaAs solar cell with a sunlight-to-electricity conversion efficiency of 28.1% was developed by Varian Associates Inc. This efficiency was the highest measured for a GaAs solar cell. Scientists at Arco Solar, a division of Atlantic Richfield Corp., and the Solar Energy Research Institute increased the efficiency of a solar cell array from 8% to 11.2% by doping copper indium diselenide with atoms of gallium. Solar panels made from copper indium diselenide produce high amounts of electric current, but the material's maximum voltage was low, thus limiting its efficiency. Gallium atoms were introduced into the material, allowing the voltage to be raised without decreasing the current. Arco planned to market the new solar panels for limited commercial use by 1990.

Chemists at Cornell University were developing a compound to produce GaAs low-temperature vapor-deposition techniques. In conventional high-temperature vapor deposition, the gallium and arsenic are present in separate compounds, with the arsenic normally in the form of arsine, a toxic gas. The chemists developed a complex organic compound containing one gallium atom and one arsenic atom linked to each other; normally molecules with both gallium and arsenic atoms react to form pairs or chains. The new organic molecule was designed so that its reaction with butanol at room temperature would remove the accessory molecules, leaving only GaAs. Although not volatile enough to be used for vapor deposition, the organic gallium molecule will serve as a springboard to produce similar compounds to be used in GaAs vapor deposition.

Researchers at IBM and the Airtron Div. of Litton Industries Inc. manufactured lanthanum gallate for use as a substrate for superconductors. Crystals of lanthanum gallate are easier and less expensive to produce than strontium titanate and other superconductor substrates. It also has the potential to overcome problems with overheating in circuits that operate at high frequencies, a difficulty occurring with other superconductor substrates.

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GEM STONES

By Gordon T. Austin[1]

Production value of natural gem materials in the United States during 1988 increased about 103% to $43.5 million. The materials produced included faceting rough, lapidary rough, carving material, specimen material, natural and cultured freshwater pearls, mother of pearl, and coral.

The combined production value of synthetic and simulant gem materials was reported to be $16.3 million, about a 7% increase over that of 1987. Synthetic gems are manmade and have the same optical, physical, and chemical properties and the same appearance as the natural gem that they represent. Synthetic gem materials produced in the United States include alexandrite, coral, diamond, emerald, garnet, lapis lazuli, quartz, ruby, sapphire, spinel, and turquoise. Simulants are manmade gem materials that have an appearance similar to that of a natural gem material but have different optical, physical, and chemical properties. The gem simulants produced in the United States include coral, cubic zirconia, lapis lazuli, malachite, and turquoise. Additionally, certain colors of synthetic sapphire and spinel, used to represent other gem stones, would be classed as simulants. Cubic zirconia is the major simulant and is produced in both colored and colorless varieties.

The gem materials were sold to wholesale and retail outlets, in gem and mineral shops, at gem and mineral shows, to cutting factories, and to jewelry manufacturers.

DOMESTIC DATA COVERAGE

Estimates of U.S. production were developed by the Bureau of Mines from the "Gems and Gem Stones Survey," a voluntary survey of U.S. operations, and from Bureau estimates of unreported production. Of the approximately 300 operations to which a survey request was sent, 82% responded, accounting for about 95% of the total production, 92% of the natural production, and 100% of the synthetic and simulant production.

The 300 operations surveyed in 1988 were an increase of about 14% compared with the number of operations surveyed in 1987. The response rate was essentially unchanged. Production by nonresponding operations, by professional collectors, and by amateur or hobbyist collectors was estimated by the Bureau. These estimates were based on information from published data, conversations with gem and mineral dealers, analyses of gem and mineral shows and sales statistics, and from information informally supplied by collectors. In the formal voluntary survey and the informal surveys, the Bureau is totally dependent upon the cooperation of the producers, brokers, dealers, and collectors. Individuals and companies have been very cooperative and forthcoming with information. The Bureau is very appreciative of this cooperation.

DOMESTIC PRODUCTION

Each of the 50 States produced at least $1,000 worth of gem materials. Ten States accounted for 95% of the total value of natural gem material produced. The States, in order of declining value of production, with their 1987 standing shown in parenthesis, were Tennessee (1), California (2), Arizona (3), Arkansas (4), Montana (5), Oregon (10), North Carolina (7), Idaho (8), Missouri (9), and Utah (19). Certain States were known for the production of a single gem material, i.e., Tennessee for freshwater pearls and Arkansas for quartz, whereas other States produced a wide variety of gem materials. Arizona is best known for the widest variety of gem materials. Production included agate, amethyst, antlerite, azurite, chrysocolla, fire agate, garnets, jade, malachite, onyx, peridot, petrified wood, precious opal, shattuchite, smithsonite, and turquoise. California, Idaho, Montana, and North Carolina also produced a wide variety of gem materials. North Carolina was the only State to have produced all four of the major gems: diamond, emerald, ruby, and sapphire.

The average production value of natural gem materials for the past 10 years was $12.5 million per year, with a high of $43.5 million in 1988 and a low of $6.9 million in 1980. The value of production for the past 10 years must be separated into two trends. The first trend was the period between 1979 and 1985, during which time approximately 24 producers were surveyed. Production averaged $7.5 million per year and was generally level. The second trend, 1986 to the present, production averaged $24.2 million and was the result of an increase of 1,150% in the number of producers surveyed.

The reported production value of synthetic and simulant gem materials was $16.3 million in 1988. The reported value of production increased 7%, however, the quantity of materials produced was significantly greater. A shift in the types of materials produced, primarily a change from colored cubic zirconia to colorless cubic zirconia, resulted in the production of lower value material. Thirteen firms, five in California, four in Arizona, and one each in Massachusetts, Michigan, New Jersey, and Ohio, produced synthetic and simulant gem material. The six States, in order of declining value of production, were Massachusetts, California, New Jersey, Michigan, Ohio, and Arizona.

Dia Em Resources Ltd. and LKA International Inc. completed the evaluation of their Rist and Ellis Emerald Mines at Hiddenite, NC. Using the beryllometer designed and built by LKA to assist in sorting emeralds from waste materials, approximately 3,000 carats of emerald was recovered. Analysis of all of the data collected indicated that the property did not have the degree of commercial viability required by LKA to continue to the next phase of the project. LKA plans to dispose of the property in 1989. It announced plans to also sell the two largest emerald crystals ever found in the United States, the 1,438-carat Stephenson and the 1,686.3-carat LKA crystal.

A 0.25-carat diamond was recovered during testing of a bulk ore sample from a North Carolina placer gold mine. The stone, positively identified by a mineralogist, was of industrial grade. The diamond was the seventh largest found in North Carolina, the largest being 4.33 carats. A company geologist stated that the find was interesting, but would not change the company's approach to the project.

The Dow Chemical Co. sold its 6-year-old diamond exploration project in the Upper Peninsula of Michigan to Crystal Exploration Inc. of Denver, CO, a subsidiary of Restech International Ltd. of Sydney, Australia. Dow discovered seven kimberlite pipes, and core drilling yielded a scattering of sand-grain-size diamonds. The diamonds were too few and too small for commercial production. A Dow spokesperson stated that more exploration and mining expertise was needed and that Dow was not a hard-rock mining company. Dow retained an option to take part in the exploration and development and to share in any profits.

Amselco Exploration Inc., a subsidiary of British Petroleum Co. of Canada, and Exmin Corp., a subsidiary of the Belgian company Sibeka (Société d'Entreprises et d'Investissements S.A.), continued exploration for diamonds on leased lands in Michigan and Wisconsin. Exmin continued diamond exploration efforts in Minnesota.

Three firms continued their diamond exploration project in the State Line District on the Colorado-Wyoming border.

The Diamond Mining Task Force, appointed in 1986 by the Arkansas Governor to assist the State Parks, Recreation, and Travel Commission in determining if commercial diamond mining would be allowed at the Crater of Diamonds State Park, recommended preliminary tests of the Park to determine the size of the reserve. Whether the area will be tested is up to the State Parks, Recreation, and Travel Commission. The recommended tests included drilling 10 angled core holes, about 2.5 inches in diameter and 850 feet long. The recommendations set a $350,000 price tag on the testing and stated that funding should come from private sources. Sunshine Mining Co., which started a joint venture called Arkansas Diamond Development Co., proposed to conduct an estimated $3 million in geological testing without any written guarantee that they will receive a commercial contract to mine diamonds. At yearend, studies were under way and no decisions had been made concerning the mining project.

Recent mining on private land at Opal Butte in Morrow County, OR, approximately 35 miles south of Heppner, produced a wide variety of very fine-quality opals. The varieties produced included hyalite, rainbow, contra luz, hydrophane, crystal opal, fire opal, blue opal, and dendritic opal. The opal occurs in rhyolite geodes in a decomposed perlite.[2]

A number of mines in southern Oregon started producing gem labordorite feldspar in 1988. The material comes in a wide range of colors, including yellow (the most common), pink, peach, salmon, red-orange, red-green, blue-green, and bicolored red and green. The best red faceting-grade material cuts some of the finest gem feldspar available. The mines also produce sunstone, a feldspar with schiller that is caused by millions of microscopic copper platelets on the cleavage planes of the feldspar. Sunstone is the State gem stone of Oregon.

American Pearl Farms of Tennessee completed its second significant harvest of cultured freshwater pearls. American currently has five pearl farms under operation and acquired additional water acreage for a sixth farm to be established during 1989. The new farm is planned to be nine times larger than the existing farms.

During December 1988, the largest and heaviest faceted gem stone ever cut was completed by a U.S. cutter. The 36,853-carat champagne colored topaz was cut from a 46-pound crystal mined in Brazil. The stone was cut in a diamond shape that was 13.75 inches long, 6.13 inches thick, and 4.75 inches wide. This was the third consecutive year in which record-size gem stones were cut in the United States. The unnamed stone was displayed for the first time at the Tucson Gem and Mineral Show in Tucson, AZ. The stone was offered for sale at $3 a carat, a total asking price of $110,600.

CONSUMPTION

Domestic gem materials production was consumed in commercial and amateur manufacture of jewelry, in gem and mineral collections, and in the production of objects of art. The value of U.S. apparent consumption was estimated to be a record high $3,703 million, an increase of about 7%. The average annual estimated consumption for the past 10 years was $2,506 million, with a high of $3,703 million in 1988 and a low of $1,238 million in 1979. The trend of estimated consumption for the past 10 years was one of continued growth with about 199% increase or an annual compounded growth rate of about 13%.

The U.S. estimated apparent consumption of diamonds increased about 25% in quantity and value to 8.3 million carats and $3.1 billion, respectively. The average annual apparent consumption of diamonds for the past 10 years was 4.6 million carats, with a high of 8.3 million carats in 1988 and a low of 1.2 million carats in 1981. The trend for apparent consumption, quantity and value, for the past 10 years was one of significant increase. Apparent consumption of diamonds increased about 153% in quantity and 216% in value over that period.

The estimated apparent consumption of colored stones, led by emerald, ruby, and sapphire, was valued at $353.8 million, an increase of 18%. The annual average consumption of colored stones for the past 7 years was valued at $316.3 million, with a high of $361.0 million in 1984 and a low of $252.4 million in 1982. The trend for apparent consumption of colored stones for the past 7 years was one of fluctuating increases and decreases, but the general tread was one of increased consumption.

The estimated apparent consumption of pearls—natural, cultured, and imitations—was $168.9 million, an increase of about 5%. This was the first increase after 3 years of decreases from the 7-year high in 1984. The value was about 82% greater than the 7-year low in 1982, but was about 7% less than the 7-year average of $181.8 million per year.

Estimated apparent consumption of synthetic and imitation gem materials decreased about 5% to $105.9 million. Average apparent consumption of synthetic and imitation gem materials for the past 7 years was $65.2 million, with a high of $109.1 million in 1987 and a low of $29.9 million in 1979. The trend for apparent consumption for the past 7 years was one of generally strong growth. Apparent consumption increased about 251% over the 7 years or averaged an annual compounded rate of growth of about 23% a year during the period.

It was estimated by the American Diamond Industry Association that U.S. jewelers sold 19.8 million pieces of diamond jewelry worth a total of $11.3 billion during 1988.

PRICES

The average U.S. wholesale asking price of the top 25 grades (D–H color and IF through VS_2 clarity) of a 1-carat diamond fluctuated between $6,200 and $7,000 and was $7,000 at yearend. The average value per carat of all grades, sizes, and types of gem-quality diamonds consumed in the United States, based on 1988 estimated apparent consumption, was $373, unchanged from that of 1987. The average value of diamonds consumed in the United States for the past 10 years, based on the estimated annual apparent consumption, was $490 per carat, with a high of $1,128 per carat in 1981 and a low of $298 per carat in 1979. The trend for the average annual value of diamonds consumed for the past 10 years was one of rapid increase from the 10-year low in 1979 to the 10-year high in 1981 followed by a general decline until an apparent stabilization in 1987.

The average yearend wholesale purchase price of a fine-quality 1-carat ruby, paid by retail jewelers on a per stone or memo basis, was $3,500, an increase of 17%. The average value of all rubies imported into the United States increased 19% to $30.06 per carat. The average annual value of all rubies imported into the United States for the past 7 years was $24.31 per carat, with a high of $34.04 per carat in 1982 and a low of $16.42 per carat in 1984. The trend for the value of ruby imports for the past 7 years was one of rapid decline, 52% for the period from 1982 to 1984. This was followed by a steady, moderate increase of 16% annual recovery.

The average yearend wholesale purchase price of a fine-quality 1-carat sapphire, paid by retail jewelers on a per stone or memo basis, was $1,400, an increase of 33%. The average value of all sapphires imported into the United States decreased 17% to $23.22 per carat. The average annual value of all sapphires imported into the United States for the past 7 years was $20.66 per carat, with a high of $27.97 per carat in 1987 and a low of $18.50 per carat in 1984. The trend for the value of sapphires imports for the past 7 years was one of fluctuating increases and decreases with the 1988 value ending the 7-year period about 5% below the beginning value in 1982.

The average yearend wholesale purchase price of a fine-quality 1-carat emerald, paid by retail jewelers on a per stone or memo basis, was $2,600, an increase of 8%. The average value of all emeralds imported into the United States increased 15% to $78.79 per carat. The average annual value of all emeralds imported into the United States for the past 10 years was $54.99 per carat, with a high of $78.79 per carat in 1988 and a low of $35.06 per carat in 1984. The trend for the value of emerald imports for the past 10 years was one of fluctuating increases and decreases from 1979 through 1984 followed by a steady moderate growth resulting in the 1988 average value being about 71% greater than 1979.

FOREIGN TRADE

Export value of all gem materials increased 36% to $1,010 million, the first time ever that exports have exceeded a billion dollars. The quantity of diamonds exported was essentially unchanged at 590,412 carats, however, the value of exports increased about 38% to $908.9 million. The average annual quantity of diamonds exported for the past 10 years was 369,264 carats, with a high of 590,412 in 1988 and a low of 184,871 in 1982. The trend for the quantity of diamonds exported for the past 10 years was one of moderate decline, 13%, during the first 4 years, followed by significant growth, 219%, from the low in the period from 1982 to 1988. The average annual value of diamond exports for the past 10 years was $521.6 million, with a high of $908.9 million in 1988 and a low of $292.8 million in 1982. The trend for the value of diamond exports for the past 10 years was one of significant decline, 113%, over 4 years, followed by 3 years of moderate growth, 32%, leading to 3

TABLE 1

PRICES OF U.S. CUT DIAMONDS, BY SIZE AND QUALITY

Carat weight	Description, color[1]	Clarity[2] (GIA terms)	Price range per carat[3] Jan. 1988–Jan. 1989	Average[4] July 1988
0.25	G	VS1	$1,100–$1,300	$1,300
.25	G	VS2	950– 1,100	1,100
.25	G	SI1	800– 880	880
.25	H	VS1	950– 1,100	1,100
.25	H	VS2	900– 1,000	1,000
.25	H	SI1	780– 860	860
.50	G	VS1	2,300– 2,500	2,500
.50	G	VS2	2,100– 2,300	2,300
.50	G	SI1	1,800– 1,900	1,900
.50	H	VS1	2,200– 2,300	2,300
.50	H	VS2	2,000– 2,100	2,100
.50	H	SI1	1,700– 1,800	1,800
.75	G	VS1	2,600– 3,000	2,900
.75	G	VS2	2,500– 2,700	2,700
.75	G	SI1	2,200– 2,300	2,300
.75	H	VS1	2,400– 2,600	2,600
.75	H	VS2	2,200– 2,300	2,300
.75	H	SI1	2,000– 2,100	2,100
1.00	G	VS1	4,200– 4,600	4,600
1.00	G	VS2	3,700– 4,100	4,100
1.00	G	SI1	3,200– 3,500	3,500
1.00	H	VS1	3,700– 4,100	4,100
1.00	H	VS2	3,300– 3,600	3,600
1.00	H	SI1	3,900– 3,200	3,200

[1] Gemological Institute of America (GIA) color grades: D—colorless; E—rare white; H-I—traces of color.
[2] Clarity: IF—no blemishes; VVS1—very, very slightly included; VS—very slightly included; VS2—very slightly included, but more visible; SI1—slightly included.
[3] Jeweler's Circular-Keystone. V. 159, No. 2, Feb. 1989.
[4] Jeweler's Circular-Keystone. V. 154, No. 2, Aug. 1988.

TABLE 2

PRICES OF U.S. CUT COLORED GEM STONES, BY SIZE[1]

Gem stone	Carat weight	Price range per carat in 1988[2]	Average price per carat[2]	
			Jan. 1988	Jan. 1989
Amethyst	1	$6– $10	$8	$8
Aquamarine	1	100– 250	175	175
Emerald	1	1,800–3,000	2,400	2,600
Garnet, tsavorite	1	700–1,200	950	650
Ruby	1	2,500–3,500	3,000	3,500
Sapphire	1	600–1,500	1,050	1,400
Tanzanite	1	275– 450	354	300
Topaz	1	6– 9	7.50	9
Tourmaline, red	1	60– 125	92.50	92.50

[1] Fine quality.
[2] Jewelers' Circular-Keystone. V. 159, No. 2, Feb. 1989, p. 399. These figures represent a sampling of net prices that wholesale colored stone dealers in various U.S. cities charged their cash customers during.

years of significant growth, 136%, which resulted in a record-high year in 1988.

Exports of other precious and semiprecious stones, cut but unset, increased about 51% to $68.5 million. The average annual export value for the past 7 years for cut but unset natural gem stones, other than diamonds and pearls, was $38.8 million, with a high of $68.5 million in 1988 and a low of $27.7 million in 1984. The 7-year trend for the export value of these gem materials was one of fluctuating increases and decreases, but resulted in a significant overall increase of 131% for the period. Exports of the same types of gem materials, except as uncut and unset, increased 15% to $24.2 million. The average annual value of exports for the past 7 years was $16.9 million, with a high of $24.2 million in 1988 and a low of $12.2 million in 1985. The 7-year trend for the value of exports was one of 4 years of moderate, 29% decline, followed by 3 years of significant, 98% growth, which resulted in an overall growth of 58% for the period.

Exports of synthetic gem material, cut and uncut but not set, increased slightly to $6.0 million. The average annual value of exports for the past 7 years was $5.2 million, with a high of $7.7 million in 1982 followed by a low of $3.7 million in 1983. The 7-year trend for the value of exports was one of extreme decline, 52%, from 1982 to 1983; followed by a steady, moderate growth, 62%, over the next 5 years.

Exports of natural, cultured, and imitation pearls, not set or strung, increased about 22% to $2.2 million.

Reexports of gem material increased 10% to $407.9 million. The quantity of diamonds reexported decreased about 21% to 1.5 million carats, the third lowest amount in the past 10 years. However, the value of diamonds exported increased about 4% to $319.0 million. The average annual quantity of diamonds reexported for the past 10 years was 1.9 million carats, with a high of 3.0 million carats in 1981 and a low of 1.0 million in 1979. The 10-year trend for the quantity of diamonds reexported was highly mixed. The period started with an extreme increase, 207%, through 1981, followed by a moderate decline, 37%, through 1984, followed by 3 years of essentially level reexports, leading to the most recent decline in 1988. The average annual value of reexported diamonds for the past 10 years was $295.4 million, with a high of $412.8 million in 1981 and a low of $186.0 million in 1985. The 10-year trend for the value of reexports was one of extreme increase, 58%, for 1979–82, moderate decline, 55%, for the next 4 years, followed by 3 years of significant increase, 72%, which resulted in the average annual value ending the period 22% greater than it started.

The reexports of natural gem materials, cut but not set, other than diamonds and pearls, increased about 37% to $55.1 million, a record high for the 7-year period for which data were available. The average annual value of reexports for the past 7 years was $37.1 million, with a high of $55.1 million in 1988 and a low of $22.9 million in 1985. The 7-year trend for the value of reexports was one of alternating decreases and increases with the increases prevailing and resulting in a 70% rise in value during the period. The reexports of natural gem materials, not cut or set, other than diamonds and pearls, increased about 1,600% to $22.2 million. The extremely large increase was most likely the result of reexporting uncut colored stones to worldwide cutting centers for cutting and reexport to the United States as finished gems. The average annual value of reexports for the past 7 years was $12.2 million, with a high of $22.2 million in 1988 and a low of $1.3 million in 1987. The 7-year trend for the value of reexports was one of extreme increases and decreases, with the value at the end of the period increasing by 192%. Reexports of natural, cultured, and imitation pearls and synthetic gem materials was $11.3 million and $0.3 million, respectively.

The value of all gem materials imported increased about 24% to $5,063 million. The value of imported gem diamonds accounted for about 85% of the total. The value of imported gem diamonds increased 26% to a record high $4,306 million. The increase in the value of cut diamonds imported accounted for 81% of the total dollar increase. The average annual value of imports for the past 10 years was $2,330 million, with a high of $4,306 million in 1988 and a low of $1,859 million in 1979. The 10-year trend for the value of diamond imports was one of generally steady continuous growth with an increase of 132% for the period. During the period, the value of imported uncut diamonds increased 72%, while the value of imported cut stones increased 869%.

TABLE 3

U.S. EXPORTS AND REEXPORTS OF DIAMOND (EXCLUSIVE OF INDUSTRIAL DIAMOND), BY COUNTRY

Country	1987		1988	
	Quantity (carats)	Value[1] (millions)	Quantity (carats)	Value[1] (millions)
Exports:				
Belgium	162,009	$122.9	163,246	$142.4
Canada	24,943	17.8	24,104	18.4
France	1,943	4.3	7,946	11.4
Germany, Federal Republic of	3,842	4.0	3,736	4.7
Hong Kong	100,365	148.2	92,067	208.1
Israel	172,634	110.8	169,433	137.9
Japan	62,404	144.1	74,566	196.2
Singapore	5,686	7.0	5,135	9.2
Switzerland	30,161	76.3	23,929	141.9
Thailand	14,028	9.3	16,082	12.2
United Kingdom	4,151	8.2	3,641	20.6
Other	5,221	7.5	6,527	5.9
Total	**587,387**	**660.4**	**590,412**	**908.9**
Reexports:				
Belgium	1,184,952	101.1	833,081	104.4
Canada	5,424	.8	5,855	1.2
China	2,062	.1	14,009	.3
Germany, Federal Republic of	24,840	2.6	31,236	2.6
Hong Kong	82,491	27.2	34,682	19.6
India	84,893	2.9	139,684	5.0
Israel	199,579	70.3	137,820	65.9
Japan	95,919	7.2	114,904	10.2
Netherlands	47,313	3.2	89,000	9.4
Switzerland	39,765	57.7	34,234	77.5
United Kingdom	101,300	18.4	26,929	12.6
Other	74,333	16.2	83,026	10.3
Total	**1,942,871**	**307.7**	**1,544,460**	**319.0**

[1] Customs value.

Source: Bureau of the Census.

The value of imports for all other gem materials, led by emerald, ruby, and sapphire, increased 14% to $757.6 million. Emerald imports increased about 23% to $174.6 million. The average annual value of emerald imports for the past 10 years was $139.5 million, with a high of $174.6 million in 1988 and a low of $105.1 million in 1979. The 10-year trend for the value of emerald imports was one of fluctuating increases and decreases resulting in a 66% increase for the period.

The value of ruby imports increased 21% to $72.0 million, the fifth highest value in the past 10 years. The 10-year average annual value of imports was $70.6 million, with a high of $93.8 million in 1981 and a low of $30.0 million in 1979. The 10-year trend of import values was one of extreme fluctuations. The period ended with values having increased 140%, but were still 23% below the high for the period. The value of sapphire imports increased 10% to $81.5 million, the fifth highest value in the past 10 years. The 10-year average annual value of sapphire imports was $71.1 million, with a high of $95.1 million in 1986 and a low of $24.2 million in 1979. The 10-year trend for the value of imports was one of extremely fluctuating increases and decreases. The period ended with the value 237% greater than at the beginning, but still 14% below the high for the period.

The value of imported gem materials, other than diamond, emerald, ruby, and sapphire, increased 10% to $429.5 million. The average annual value of imports was $315.8 million, with a high of $429.5 million in 1988 and a low of $153.3 million in 1979. The 10-year trend for the value of imports was one of fluctuating increases and decreases resulting in an overall increase of 180% for the period.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY

Kind, range, and country of origin	1987		1988	
	Quantity (carats)	Value[1] (millions)	Quantity (carats)	Value[1] (millions)
Rough or uncut, natural:[2]				
Belgium	323,742	$82.0	305,142	$111.8
Brazil	44,287	5.4	349,461	10.7
Israel	28,029	7.3	38,734	8.2
Netherlands	2,930	2.9	57,791	7.9
South Africa, Republic of	37,870	28.7	48,515	44.9
Switzerland	5,185	12.6	14,307	8.2
United Kingdom	797,759	208.3	619,461	317.5
Venezuela	7,901	.7	684	.1
Other	121,657	72.1	210,203	79.3
Total	**1,369,360**	**420.0**	**1,644,298**	**588.6**
Cut but unset, not over 0.5 carat:				
Belgium	1,307,990	468.2	1,035,452	406.7
Brazil	33,352	8.7	34,554	13.7
Canada	21,750	8.8	9,156	4.1
Hong Kong	241,251	41.8	285,268	63.1
India	3,198,504	670.8	3,758,747	886.1
Israel	1,511,724	629.8	1,109,474	532.8
Netherlands	51,959	13.6	27,588	26.8
South Africa, Republic of	14,461	11.8	5,532	5.1
Switzerland	73,268	40.3	76,169	36.8
United Kingdom	18,321	15.8	23,406	22.9
Other	144,708	33.3	160,707	37.9
Total	**6,617,288**	**1,942.9**	**6,526,053**	**2,036.0**
Cut but unset, over 0.5 carat:				
Belgium	384,789	380.1	709,527	578.9
Hong Kong	12,361	21.3	59,949	40.1
India	110,019	28.0	386,422	111.3
Israel	468,132	406.1	906,752	675.2
Netherlands	8,403	11.6	7,859	12.9
South Africa, Republic of	27,654	41.3	22,762	40.6
Switzerland	37,583	81.7	24,281	95.1
United Kingdom	29,155	42.6	17,546	45.3
Other	56,345	47.5	92,028	81.8
Total	**1,134,441**	**1,060.2**	**2,227,126**	**1,681.2**

[1] Customs value.
[2] Includes some natural advanced diamond.

WORLD REVIEW

De Beers Consolidated Mines Ltd.'s

sales of uncut diamonds through the Central Selling Organization in 1988 were reported to be a record $4.17 billion compared with $3.07 billion in 1987, an increase of approximately 36%. Sales of colored gem stones also remained very strong.

Emerald was mined in Australia, Brazil, Colombia, India, Mozambique, Pakistan, the Republic of South Africa, the U.S.S.R., Zambia, and Zimbabwe. Sapphire was produced in Australia, Colombia, Kenya, Malawi, Nigeria, Sri Lanka, Tanzania, Thailand, and the United States. Aquamarine was produced in Afghanistan, Brazil, China, India, Nigeria, Pakistan, the Republic of South Africa, Tanzania, the United States, and Zambia. Ruby was produced in Afghanistan, Burma, India, Kenya, Sri Lanka, Tanzania, Thailand, and the United States.

Angola

Endiama, the Government-owned and operated diamond mining company, signed an agreement with Lazare-Kaplan International (LKI) of New York that allows LKI to export to the United States $20 million per year of Angolan rough diamonds. Endiama is marketing diamonds through a total of five rough dealers: LKI, Industrial Diamond Corp. of London, and three Antwerp firms, George Evens, Arslanian Freres, and IDH Diamonds.

The leaders of the Angolan UNITA movement announced the discovery of huge deposits of diamonds in the areas of Cuado and Cubango. The spokesperson stated that the deposits were in the firm control of UNITA and that they plan to develop the deposits as soon as possible.

Australia

Freeport Bow River Properties Inc., the operating company of the Freeport-McMoRan Australia Ltd. and Gem Exploration and Minerals Ltd. joint venture, started production from the Bow River alluvial diamond project. Diamond output was about 480,000

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF NATURAL PRECIOUS AND SEMIPRECIOUS GEM STONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY

Kind and country	1987 Quantity (carats)	1987 Value[1] (millions)	1988 Quantity (carats)	1988 Value[1] (millions)
Emerald:				
Belgium	30,190	$3.9	11,963	$5.6
Brazil	112,194	7.0	80,199	6.4
Colombia	195,403	44.6	243,521	63.8
France	8,401	1.9	13,817	3.2
Germany, Federal Republic of	38,034	3.9	34,376	2.4
Hong Kong	170,853	15.2	135,384	14.7
India	1,231,033	17.0	1,205,636	20.4
Israel	60,942	19.4	89,399	24.7
Japan	5,637	.6	20,102	1.0
South Africa, Republic of	5	(2)	4	(2)
Switzerland	58,789	18.3	65,021	20.6
Taiwan	3,697	(2)	256	(2)
Thailand	104,058	3.0	216,501	3.8
United Kingdom	7,652	2.2	8,026	2.9
Other	48,032	4.6	91,701	5.1
Total	**2,074,920**	**141.6**	**2,215,906**	**174.6**
Ruby:				
Belgium	12,078	.7	8,926	1.3
Brazil	3,102	(2)	4,945	.2
Colombia	3,198	(2)	258	(2)
France	6,219	1.6	5,885	3.4
Germany, Federal Republic of	18,267	.8	26,530	1.0
Hong Kong	42,687	3.6	47,152	4.6
India	302,323	.9	318,575	1.1
Israel	7,043	.6	38,593	1.6
Japan	335,381	.5	11,572	.8
Switzerland	41,492	14.1	40,183	11.6
Thailand	1,536,723	31.4	1,822,557	40.5
United Kingdom	11,523	2.9	8,443	3.6
Other	37,781	2.3	61,703	2.3
Total	**2,357,817**	**58.7**	**2,395,322**	**72.0**
Sapphire:				
Australia	—	—	2,883	.2
Austria	1,000	(2)	603	(2)
Belgium	21,356	1.2	20,024	.9
Brazil	2,580	(2)	9,528	.2
Canada	6,905	.7	16,177	.9
Colombia	2,234	(2)	1,398	(2)
France	7,048	1.1	46,296	2.3
Germany, Federal Republic of	12,067	1.6	26,750	1.0

See footnotes at end of table.

TABLE 5—Continued

U.S. IMPORTS FOR CONSUMPTION OF NATURAL PRECIOUS AND SEMIPRECIOUS GEM STONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY

Kind and country	1987 Quantity (carats)	1987 Value[1] (millions)	1988 Quantity (carats)	1988 Value[1] (millions)
Hong Kong	63,684	$5.4	123,689	$5.8
India	84,973	.5	149,488	1.2
Israel	14,254	1.1	8,931	1.1
Japan	48,460	.4	22,662	.6
Korea, Republic of	9,793	([2])	6,438	([2])
Singapore	7	([2])	4,705	.2
Sri Lanka	55,241	3.1	39,259	2.4
Switzerland	46,786	11.3	32,446	10.2
Thailand	2,121,376	42.7	2,878,129	50.2
United Kingdom	110,112	3.9	10,102	2.9
Other	37,847	1.0	110,301	1.4
Total	**2,645,723**	**74.0**	**3,509,809**	**81.5**
Other:				
Rough, uncut:				
Australia	NA	.8	NA	.9
Brazil		20.7		29.7
Colombia		5.5		2.4
Hong Kong		1.4		.5
Nigeria		.2		.2
Pakistan		1.2		1.0
South Africa, Republic of		.3		4.8
Switzerland		.1		1.7
United Kingdom		([2])		.6
Zambia		.1		.9
Other		3.8		5.5
Total	**NA**	**34.1**	**NA**	**48.2**
Cut, set and unset:				
Australia	NA	6.1	NA	12.6
Brazil		17.2		18.6
Canada		.6		.4
China		2.7		2.3
Germany, Federal Republic of		13.7		15.8
Hong Kong		28.7		27.4
India		5.7		5.1
Japan		128.8		144.5
Switzerland		3.0		3.1
Taiwan		11.1		11.3
Thailand		11.7		14.2
United Kingdom		1.0		1.7
Other		21.2		17.7
Total	**NA**	**251.5**	**NA**	**274.7**

NA Not available.
[1] Customs value.
[2] Less than 1/10 unit.

Source: Bureau of the Census.

TABLE 6

VALUE OF U.S. IMPORTS OF SYNTHETIC AND IMITATION GEM STONES, INCLUDING PEARLS, BY COUNTRY

(Million dollars)[1]

Country	1987	1988
Synthetic, cut but unset:		
Austria	1.3	2.0
France	.8	.6
Germany, Federal Republic of	9.2	9.1
Japan	1.8	2.1
Korea, Republic of	11.6	8.1
Switzerland	4.6	6.0
Other	5.0	5.6
Total	**34.3**	**33.5**
Imitation:		
Austria	50.7	49.4
Czechoslovakia	2.1	2.7
Germany, Federal Republic of	7.1	6.7
Japan	3.7	4.6
Other	8.0	6.2
Total	**71.6**	**69.6**

[1] Customs value.

Source: Bureau of the Census.

carats. The diamond production was about 20% gem quality, 70% near-gem quality, and 10% bort.

Argyle Diamond Mines Pty. Ltd.'s annual diamond production from the AK-1 pipe increased by nearly 14% to a record 34,553,724 carats. Argyle's annual production accounted for about 37% of the world's production of natural diamonds. Additional deposits of alluvial diamonds in the lower reaches of the Smoke and Limestone Creeks that drain the AK-1 pipe add about 60 million carats to Argyle's resources. Mining of these alluvial diamonds is scheduled to begin in 1989, annual production is projected to be about 2 million carats. Argyle Diamond Sales Ltd. announced the sale of a brilliant-cut 1.51-carat purple-red diamond for an Australian record price of $1 million per carat. The diamond was cut in Perth.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF PRECIOUS AND SEMIPRECIOUS GEM STONES

(Thousand carats and thousand dollars)

Stones	1987		1988	
	Quantity	Value[1]	Quantity	Value[1]
Diamonds:				
Rough or uncut	1,369	$420,004	1,644	$588,611
Cut but unset	7,752	3,003,090	8,753	3,717,151
Emeralds: Cut but unset	2,075	141,575	2,216	174,623
Coral: Cut but unset, and cameos suitable for use in jewelry	NA	3,060	NA	2,967
Rubies and sapphires: Cut but unset	5,004	133,396	5,905	153,552
Marcasites		766		1,229
Pearls:				
Natural	NA	3,879	NA	3,389
Cultured	NA	151,854	NA	171,693
Imitation	NA	6,259	NA	7,198
Other precious and semiprecious stones:				
Rough, uncut	NA	34,079	NA	48,186
Cut, set and unset	NA	78,215	NA	79,056
Other	NA	13,716	NA	19,795
Synthetic:				
Cut but unset	82,697	30,958	81,096	28,995
Other	NA	3,358	NA	4,485
Imitation gem stone	NA	65,311	NA	62,404
Total	**XX**	**4,089,520**	**XX**	**5,063,334**

NA Not available. XX Not applicable.
[1] Customs value.

Source: Bureau of the Census.

Gem Exploration Ltd. reported success in a sampling program for the Kununurra project in Western Australia. Four alluvial diamonds weighing 1.42 carats were recovered from ancient alluvial deposits of the Ord River. The stones discovered included both gem and industrial quality.

Capricorn Resources Australia NL launched Australia's first underwater diamond exploration project. Using crocodile- and shark-proof cages to protect the divers, underwater work was started in the Joseph Bonaparte Gulf off the north coast of Western Australia. The company believes that diamonds from the Argyle and Bow River areas have washed into the gulf. To date the divers have recovered four diamonds averaging 0.27 carat from samples taken from the seabed.

Max Resources NL was preparing to develop a diamond prospect at Nullagine, about 200 kilometers southwest of Port Hedland. Nullagine would become Australia's third diamond mine. Annual production is projected to be 138,000 carats, of which 60% will be gem quality.

The value of sapphires exported from Australia increased by about 23% to $24.6 million. Sapphires were mined in the Anakie District and Lava Plains in Queensland, and in the New England District of New South Wales. The production value of opals increased about 17% to $97 million. Most of the increase was due to increased production from the Sheepyard Field, which started production in 1987. Australia also produced agate, amethyst, aquamarine, chrysoprase, garnet, peridot, rhodonite, and zircon; the export value of these materials increased 28% to $8.7 million.[3] Australia also produces the Pool Emerald, a laboratory grown hydrothermal emerald that was recrystallized from emerald from the Emerald Pool Mine in Western Australia.

Belgium

The total value of diamond imports and exports was about $12.4 billion, a record for any diamond center. Antwerp was the largest trading center.

Botswana

Debswana, the operator of the diamond mining joint venture between De Beers and the Botswana Government, announced plans to build a new diamond processing plant at the Jwaneng Mine. The plant would recover diamonds too small to be recovered by old methods. Annual production should increase about 10% from the present production of about 7.6 million carats.

Brazil

Brasaust Mineracal, the Brazilian subsidiary of the Australian companies Gem Exploration and Minerals and Titan Resources, completed the first phase of a bulk sampling program of the Estrela do Sul diamond project in Minas Gerais State. Of 20 samples totaling 574 cubic meters, 2 samples with a combined volume of 35.4 cubic meters yielded 8 diamonds weighing 3.75 carats. The best sample returned an equivalent grade of 11.8 carats per 100 cubic meters. A total of 1,290 cubic meters of material was collected from the palaeo-conglomerate.

Canada

Monopros Ltd., a subsidiary of De Beers, announced the discovery of a kimberlite near Prince Albert, Saskatchewan. Monopros conducted a bulk sampling program, but has not revealed the results. Rumors circulated that Monopros had exposed a diamond pipe on its property and that overburden removal could reveal additional potential. Other major companies have established large land positions in the area.

China

It was reported the Mount Yimeng area in Shandong Province has an estimated 11.2 million carats of diamond reserves, the largest of any Province in China. Two Government-owned mines currently operate in the area producing a total of 30,000 carats per year. Five of the largest diamonds discovered in China have come from this area.

Construction was started in northeast China on the country's largest diamond mine. Located in Wafangdian, Liaoning Province, the mine will cost an estimated $19 million. It was forecasted that the mine will produce about 118,000 carats per year once production begins in 1989.

A Hong Kong-based jewelry firm established a new diamond-polishing factory in the city of Shunde, Guangdong Province. The cutting facility, which began with 10 cutters trained in Thailand, was expected to eventually increase its work force to a total of 300 workers.

Argyle Diamond Sales and the Australian Government set up a diamond cutting and polishing factory at Shunyi, near Beijing. When in full operation, the factory will employ approximately 1,000 Chinese workers processing near-gem material.

Colombia

The Colombian Ministry of Mines and Ecominas, the state mining company, is attempting to improve the image of the emerald industry. The industry has been racked by violence, smuggling, and ecologically damaging mining practices. In an effort to correct the damaging mining practices and to better determine production, Ecominas began to periodically monitor the operations of the 4 large concessionaires and the 14 smaller subcontractors. Marketing improvements, through the establishment of a national federation of emerald producers and traders (supported by the state) and the creation of an emerald exchange in Bogota, were implemented.

Guinea

A 181.77-carat diamond, recovered in November from the Aredor Mine, was purchased by a syndicate of buyers for $8.6 million. At $47,400 per carat, it was the highest per carat price ever paid for a rough diamond. A spokesperson for Bridge Oil Ltd., Australia, a partner in the mine, said the stone should polish out to a D-color, between 85 and 100 carats. There are only 16 white diamonds over 100 carats in the world. If the stone is D-color, flawless, and 100 carats it could sell for more than $18 million.

India

A 50-carat rare blue diamond crystal was found in the gravel of the Mahanadi River between Boudh and Sonepur. The area produced alluvial diamonds, most were yellow to brown in color, in sizes up to 10 carats.

Israel

Exports of diamonds were about $2.6 billion, an increase of 23% compared with that of 1987. Approximately 43% was exported to the United States and about 35% to the Far East.

Namibia

CDM Ltd. experienced a decrease in total diamond production because of a decrease in the grade of the materials processed. Technical problems with the No. 1 plant and No. 4 plant pretreatment facility did not allow for an offset of the lower grades with higher throughput. The No. 4 pretreatment facility was put into production only to find that modifications were needed because of the extreme variations of the materials being treated. The modifications were completed by yearend. CDM announced that construction of a new mine at Auchas on the Orange River would begin in early 1989.

A new diamond-sorting operation was opened in Windhoek. Namibia Ltd. operates the plant with about 80 Namibians that were trained by the Central Selling Organization personnel. Previously, the sorting was done in Kimberly, the Republic of South Africa.

An extremely rich alluvial diamond deposit was discovered near Luderitz by the Namibian West Coast Diamond Co. The deposit was about 120 meters off the coast in about 6 meters of water. In 7 hours, two divers recovered 931 diamonds weighing a total of 1,550 carats, indicating a extremely rich deposit.

Sierra Leone

The Diamond Corp. West Africa Ltd., a subsidiary of De Beers, reportedly closed its operations in Sierra Leone where it had been involved in buying and exporting diamonds for over 30 years. Meanwhile, the Government of Sierra Leone announced it had licensed 15 exporters to legally export diamonds. Each exporter was required to deposit $0.5 million monthly in the Central Bank of which $0.3 million can be used. The remaining $0.2 million must be used to help local imports with hard currency. Currently, it is believed that a majority of Sierra Leone diamonds enter the world markets through Liberia.

South Africa, Republic of

The reopening of the Koffiefontein Mine was delayed when heavy rains flooded the No. 2 shaft and damaged underground installations. Underground production finally began in

July with full production planned for the second quarter of 1989.

At the Buffels inland complex, Langhoogte Mine reserves were exhausted early in the year, and thereafter, new reserves at Nuttabooi were mined. Extensions to the security area to include Nuttabooi, and the new haul road were completed during the first quarter of the year.

Sri Lanka

Reports indicated a diamond rush was underway in Koslanda township in the highland tea growing area. The diamond finds were concentrated along the course of the Menik Ganga River near the Diyaluma Waterfall, a famous tourist attraction. In the past, the local villagers, in their search for sapphires, had dismissed the diamonds as barren stones, but experts report they are high-quality diamonds.

TECHNOLOGY

Cutters Choice, a division of Dyna-Systems of Boise, ID, began marketing a new lap for cutting and polishing gem stones. The new laps were made of glass instead of the traditional metal. Glass gives the laps a flatter surface, which is less scratch-prone and not as harsh in cutting although it cuts faster. In commercial-cutting factory tests, the laps stayed sharp longer than metal laps. The company markets 12 different glass laps.

The U.S.S.R. announced the development of automatic crystal growth equipment that can produce large, 30-centimeter by 8-centimeter, synthetic crystals of all precious stones except diamond and tourmaline. The growth of the large tubelike crystals require about 38 hours. The "Diacont" automatic crystal growth equipment was developed by the Institute for Crystallography, Moscow, in collaboration with the Central Research Institute for Physics, Budapest.

The Laboratory for Hydrothermal Growth at the Institute of Geology and Geophysics, Siberian Branch of the U.S.S.R. Academy of Sciences in Novosibirsk, produced a selection of unusual hydrothermally grown synthetic beryl crystals. Deposited over colorless beryl seeds, ionic dopants resulted in a number of different colors. Purple resulted from doping with a combination of chromium and manganese. Intense pink was caused by manganese alone. Blue was the product of copper, and rich slightly orangy red color was from traces of cobalt. It is known that at least one other color, a dark sapphire blue, was produced. It is not known how much of the material has been grown or if it will be commercially produced.[4]

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Gems and Gemology. V. 24, No. 4, Winter 1988, pp. 229-236.

[3] Australian Bureau of Mineral Resources. Australian Mineral Industry Annual Review. Preliminary Summary 1988. Gemstones, Feb. 1989.

[4] Page 252 of work cited in footnote 2.

TABLE 8

DIAMOND: WORLD PRODUCTION, BY TYPE AND COUNTRY[1]

(Thousand carats)

Country	Natural															Synthetic[3]
	1984			1985			1986			1987[p]			1988[e]			
	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total	
Angola	652	250	902	464	250	714	240	10	[e]250	180	10	[e]190	950	50	1,000	—
Australia	3,415	2,277	5,692	4,242	2,828	7,070	13,145	16,066	29,211	13,650	16,683	30,333	17,517	17,517	[4]35,034	—
Botswana	5,810	7,104	12,914	6,318	6,317	12,635	9,610	3,500	13,110	9,367	3,840	13,207	10,801	4,428	[4]15,229	—
Brazil	200	550	750	233	217	450	310	315	625	309	213	522	310	300	610	—
Central African Republic	236	101	337	190	87	277	259	99	358	304	108	412	[4]284	[4]59	[4]343	—
China[e]	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	15,000
Czechoslovakia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5,000
France	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4,000
Ghana	35	311	346	60	[r]576	[r]636	[r]83	[r]438	521	[r]65	[r]400	465	49	303	352	—
Greece	—	—	—	—	—	—	—	—	—	—	—	—	([5])	—	([5])	1,000
Guinea	44	3	47	123	9	132	190	14	204	163	12	175	136	10	146	—
Guyana[e]	6	8	14	[r]4	7	11	3	6	[3]9	4	7	11	1	3	[4]4	—
India	13	2	15	14	2	16	13	[r]3	16	[r]16	[r]3	19	16	3	19	—
Indonesia[e]	5	22	27	5	22	27	5	22	27	5	25	30	5	25	30	—
Ireland	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	90,000
Ivory Coast[e] [6]	20	5	25	15	5	20	10	4	14	15	[r]6	[r]21	15	5	20	—
Japan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25,000
Liberia	108	132	240	66	72	138	63	189	252	60	190	[e]250	67	100	[4]167	—
Namibia	884	46	930	865	45	910	970	40	1,010	[r]987	[r]50	1,037	901	37	[4]938	—
Romania	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5,000
Sierra Leone[6]	240	105	345	243	106	349	215	100	315	[r]150	[r]75	225	100	75	175	—
South Africa, Republic of:																
Finsch Mine	1,714	3,184	4,898	1,770	3,184	4,954	1,821	3,208	5,029	1,455	2,701	4,156	1,372	2,548	3,920	—
Premier Mine	765	1,785	2,550	820	1,864	2,684	882	1,977	2,859	772	1,713	2,485	696	1,543	2,239	—
Other De Beers properties[7]	1,452	593	2,045	1,500	569	2,069	1,428	529	1,957	1,427	546	1,973	1,388	531	1,919	—
Other	585	65	650	460	35	495	342	41	383	409	30	439	283	21	304	—
Total	**4,516**	**5,627**	**10,143**	**4,550**	**5,652**	**10,202**	**4,473**	**5,755**	**10,228**	**4,063**	**4,990**	**9,053**	**3,739**	**4,643**	**8,382**	**25,000**
Swaziland	7	10	17	9	12	21	17	23	[e]40	17	23	[e]40	60	90	150	—
Sweden	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25,000
Tanzania	193	84	277	165	71	236	133	57	190	[r]105	[r]45	[r e]150	105	45	150	—
U.S.S.R.[e]	4,300	6,400	10,700	4,400	6,400	10,800	4,400	6,400	10,800	[r]4,400	[r]6,400	[r]10,800	4,500	6,500	11,000	41,500
United States	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	W
Venezuela	40	232	272	35	180	215	45	189	234	50	200	[e]250	50	200	250	—
Yugoslavia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5,000
Zaire	5,169	13,290	18,459	4,032	16,127	20,159	4,661	18,643	23,304	[r]3,885	[r]15,540	19,425	3,800	15,200	19,000	—
Total	**26,093**	**37,359**	**63,452**	**[r]26,233**	**[r]39,785**	**[r]66,018**	**39,045**	**52,672**	**91,717**	**37,995**	**49,620**	**87,615**	**43,606**	**50,393**	**93,999**	**241,500**

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company propriety data.

[1] Table includes data available through May 31, 1989. Total diamond output (gem plus industrial) for each country actually is reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1984–87), Botswana (1987), Brazil (1987), Central African Republic (1984–88), Guinea (1984–87), and Liberia (1984–86), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural, and for most countries, is based on the best available data at time of publication.

[2] Includes near-gem and cheap-gem qualities.

[3] Includes all synthetic diamond production.

[4] Reported figure.

[5] Less then 1/2 unit.

[6] Figures are estimates based on reported exports and do not include smuggled diamonds.

[7] Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

GOLD

By John M. Lucas[1]

The domestic and international gold mining industry continued to produce at record levels, improving again upon the previous year's performance. While registering its ninth successive year of phenomenal growth during which domestic production has risen by nearly 600%, the U.S. gold mining industry increased production during 1988 by 30%, to nearly 6.5 million ounces.[2] Nevada continued as the country's principal gold producing State, producing a 57% share of newly mined gold. The demand for gold in fabricated products, especially jewelry, in the market economy countries rose strongly during the year while the hoarding of gold bars outside of Europe and North America increased to record levels.

DOMESTIC DATA COVERAGE

Domestic mine production data for gold are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the lode-mine production survey of gold, silver, copper, lead, and zinc mines. Of the 179 lode-producing gold operations to which a survey form was sent, 177 responded, representing a 99% response rate. Production for the nonrespondents was estimated, using reported prior-year production levels, adjusted by trends in employment, and other guidelines such as company annual reports, the news media, and State agency reports.

LEGISLATION AND GOVERNMENT PROGRAMS

Public Law 100–673, the Bicentennial of the United States Congress Commemorative Coin Act, enacted on November 17, authorized the minting of up to 1 million $5 gold coins, weighing 8.359 grams each; 3 million $1 silver coins; weighing 26.73 grams each; and 4 million half-dollar clad coins. Part of the proceeds from the sale of the coins was to be applied toward reducing the National debt. Public Law 100–647, approved by the President on November 11, 1988, as the Technical and Miscellaneous Revenue Act of 1988, contained legislation allowing the inclusion in individual retirement accounts (IRA), of any coin issued under the laws of any State. The intent of the legislation was reportedly to allow recently issued State bullion pieces, such as the gold South Dakota Centennial Medallion, to be included in IRA's, thereby providing equal treatment for IRA investments, as accorded the American Eagle coins.

The Environmental Protection Agency (EPA) promulgated effluent limitations, guidelines, and standards for gold placer mining on May 24, 1988.[3] The new regulations, which became effective July 7, 1988, required, with some exemptions, 100% recycling of placer mine process waters.

In late 1988, in response to the growth in telemarketing fraud and investment swindles involving sales of gold bullion and investment in questionable mining ventures, the North American Securities Administrators Association Inc. (NASAA) and the Council of Better Business Bureaus Inc., issued an Investor Alert entitled "Dirt Pile Gold Swindles." The alert was prepared to educate the public regarding the organization, characteristics, and pitfalls of the classic "dirt pile" or "gold-in-the-ground" swindle. The NASAA is composed of representatives from the securities regulatory agencies of all 50 States plus Puerto Rico.

DOMESTIC PRODUCTION

Of the nearly 6.5 million ounces of gold produced in the Nation, 71% was attributable to the 25 leading producers. The average recoverable gold content of precious metals ores processed from lode mines was 0.04 ounce per short ton, while placer gravels yielded an average of 0.03 ounce per cubic yard washed.

Alaska

According to a preliminary State summary report on Alaska's mineral industry, the value of exploration expenditures in Alaska nearly tripled from about $16 million spent during 1987 to more than $44 million in 1988.[4] A major portion of these expenditures was directed toward precious metals exploration.

The large increase in exploration activity was focused primarily in southern Alaska and included work by Echo Bay Mines Ltd. at its old Alaska-Juneau or A–J Mine at Juneau and its Kensington Mine project near Berner's Bay, 50 miles north of Juneau. Other companies with lode gold prospects in southeastern Alaska included Newmont Gold Corp. (NGC), FMC Gold Corp., Curator American Inc., and Lac Minerals Ltd.

Increased gold exploration activity was also reported from other Alaskan regions. Some of the companies conducting major exploration drilling programs on lode gold deposits included Placer Dome Inc., Solomon Gold Corp., and BHP-Utah International Inc. near Nome in the western region; Tricon Mining Inc., Nerco Minerals Co., American Copper & Nickel Co. Inc., and BP Minerals America Inc., in the eastern interior region; Battle Mountain Gold Co. (BMG) and Cominco Alaska Inc., in the Southwestern region; Golden Zone Resources Inc., Cominco, AMAX Exploration Inc., and Hunt, Ware & Proffett in the South-Central region; and BMG and Ashton Mining Inc. in the Alaska Peninsula region.

Alaskan gold production again led all other mineral commodities and accounted for nearly one-half of the value of mineral production in the State.-

TABLE 1

SALIENT GOLD STATISTICS

		1984	1985	1986	1987	1988
United States:						
Mine production	thousand troy ounces	2,085	2,427	3,739	[r]4,947	6,460
Value	thousands	$751,833	$771,032	$1,376,855	[r]$2,216,027	$2,831,281
Percentage derived from:						
Precious metal ores		87	92	96	91	W
Base-metal ores		11	5	2	6	W
Placers		2	3	2	3	2
Refinery production:						
Domestic and foreign ores	thousand troy ounces	2,101	2,076	[r]2,431	3,613	4,431
Secondary (old scrap)	do.	1,769	1,602	[r]1,520	[r]2,053	1,698
Exports:						
Refined	do.	3,482	2,888	3,554	2,288	8,724
Other	do.	1,499	1,078	1,441	1,558	1,829
Imports for consumption:						
Refined	do.	6,032	6,361	13,800	2,423	1,852
Other	do.	1,837	1,865	1,949	1,420	1,124
Gold contained in imported coins[1]	do.	2,769	2,064	1,101	1,084	[2]414
Net deliveries from foreign stocks in Federal Reserve Bank	do.	381	484	4,692	3,059	6,697
Stocks, Dec. 31:						
Industry[3]	do.	752	596	925	[r]752	1,196
Futures exchange	do.	2,359	[4]2,110	[4]2,809	[4]2,625	[4]1,435
Department of the Treasury:						
American Eagle gold coin sales	do.	—	—	([5])	[r] [6]2,659	[6]805
Bicentennial of the U.S. Constitution coin sales		—	—	—	([7])	[8]866
Gold medallion sales[9]	do.	419	48	([10])	—	—
Olympic gold coin sales	do.	[11]156	24	([12])	—	—
Statue of Liberty gold coin sales	do.	—	[12]121	([13])	—	—
1988 Olympic coin sales		—	—	—	—	([14])
Consumption in industry and the arts	do.	3,140	3,097	3,126	[r]3,233	3,161
Price:[15] Average per troy ounce		$360.66	$317.66	$368.24	$447.95	$438.31
Employment[16]		6,900	6,900	8,300	11,100	13,100
World:						
Production, mine	thousand troy ounces	[r]46,929	[r]49,284	51,534	[p]53,034	[e]58,454
Official reserves[17]	million troy ounces	1,142.5	1,145.2	1,145.5	[r]1,143.5	1,149.2

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Calculated by the Gold Institute from reports by the U.S. Bureau of the Census.
[2]Beginning 1988 net imports (exports).
[3]Unfabricated refined gold held by refiners, fabricators, dealers, and U.S. Department of Defense.
[4]Commodity Exchange Inc. only. Stocks held by other exchanges estimated to be less than 2% of totals shown.
[5]Sales program began on Oct. 20, 1986; sales adjusted and included in 1987 total.
[6]Fiscal year begins Oct. 1 of previous year indicated.
[7]1987 sales included in 1988 based on fiscal year beginning Oct. 1.
[8]Total sales, program began July 1, 1987, and ended June 30, 1988.
[9]Sales program began July 15, 1980.
[10]No sales. No action was taken on the reauthorization bill by the 99th Congress.
[11]Includes coins sold in 1982 and 1983 for delivery in 1984.
[12]Authorization sales program fulfilled in 1985.
[13]Sales completed by yearend 1985 for delivery in early 1986.
[14]Sales program began Feb. 15, 1988; to be completed June 3, 1989. Sales data were not available at time of publication.
[15]Engelhard Industries quotation.
[16]Mine Safety and Health Administration.
[17]Held by market economy country central banks and governments and international monetary organizations.

Source: International Monetary Fund.

TABLE 2

VOLUME OF U.S. GOLD FUTURES TRADING

(Million troy ounces)

Exchange	Location	1984	1985	1986	1987	1988
Chicago Board of Trade	Chicago	9.73	5.42	4.00	[r]8.07	11.82
Commodity Exchange Inc.	New York	911.55	788.40	842.96	1,029.31	949.64
International Monetary Market[1]	Chicago	.88	(2)	(2)	[2]26.16	.01
MidAmerica Commodity Exchange	do.	2.02	1.04	.70	.65	.49
Total		**924.18**	**794.86**	**847.66**	**1,064.19**	**961.96**

[r] Revised.
[1] A division of the Chicago Mercantile Exchange.
[2] Less than 1,000 ounces traded. Trading ceased July 10, 1985, and resumed June 16, 1987.

Gold production reported to the Bureau of Mines was about 135,000 ounces; however, an informal annual survey of Alaska's gold producers by the Alaska State Division of Geological and Geophysical Surveys (DGGS) suggested that more than 265,000 ounces, had actually been produced. This figure compares with similarly derived figures for 1982–87. According to the DGGS report, the increase in 1988 gold production reflected increased production from several of the State's largest placer operations and from two interior lode mines.

The Valdez Creek Mining Co.'s placer operation east of Cantwell, which produced 52,961 ounces of gold doré, was the State's largest producer in 1988. Approximately 200 small gold placer operations produced at levels similar to those of 1987. A combined production of 21,500 ounces of lode gold was produced at the State's only two lode gold mines, Citigold Alaska Inc.'s La Teko Mine and Tricon Mining Inc.'s Grant Mine. The LaTeko or Ryan Lode property and the Grant Mine are open pit mines that use heap leaching and conventional milling recovery methods, respectively; both are located on the highly mineralized Ester Dome area near Fairbanks.

Mines under development in Alaska during 1988 included the new Greens Creek Mine located on Admiralty Island near Juneau. Greens Creek, under development by a joint venture composed of BP Minerals, Hecla Mining Co., CSX Oil and Gas Corp., and Exalas Resources Corp., was to begin production in early 1989. In addition to values in lead, zinc, and silver, Greens Creek was expected to produce about 36,000 ounces of gold per year.

Western Gold Exploration and Mining Co. Ltd. Partnership (WestGold), 50% held by Inspiration Gold Inc., recovered over 35,000 ounces of gold in its second full season of offshore operation with its mining vessel, the *BIMA*. In November, the U.S. Department of the Interior's Mineral Management Service completed the draft Environmental Impact Statement on its

TABLE 3

MINE PRODUCTION OF GOLD IN THE UNITED STATES, BY STATE

(Troy ounces)

State	1984	1985	1986	1987	1988
Alaska[1]	19,433	44,733	48,271	[r]122,548	135,340
Arizona	54,897	52,053	W	[r]57,592	146,259
California	85,858	187,813	425,617	[r]587,605	721,512
Colorado	60,010	43,301	120,347	178,795	164,809
Idaho	W	44,306	70,440	97,773	103,463
Michigan	—	W	W	W	W
Montana	181,190	160,262	W	[r]229,653	294,976
Nevada	1,020,546	1,276,114	2,098,980	[r]2,679,520	3,675,526
New Mexico	W	45,045	39,856	W	W
North Carolina	—	—	12	—	—
Oregon	W	W	W	W	W
South Carolina	—	W	W	W	W
South Dakota	310,527	356,103	W	W	449,514
Utah	W	135,489	W	W	W
Washington	W	W	W	W	W
Total	**2,084,615**	**2,427,232**	**3,739,015**	**[r]4,947,040**	**6,459,539**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] These figures reported to the Bureau of Mines, probably understate production. Data collected by the State indicate production to have been as follows, in troy ounces: 1984—175,000; 1985—190,000; 1986—160,000; 1987—230,000; and 1988—265,000.

planned late 1989 sale of leases for the mining of gold and other minerals on submerged Federal lands in Norton Sound, adjacent to State offshore leases presently being worked by the *BIMA*.

To help placer miners and other industrial water users comply with the State's water turbidity standards, the Alaska Department of Environmental Conservation adopted new mixing-zone water quality regulations; testing of the new regulations was scheduled for 1989 with implementation to follow in the 1990 season.

Arizona

Increased gold production in 1988 reflected in large part the contribution of several new gold mines, especially the Copperstone Mine in La Paz County and the McCabe Mine and the Congress flux-ore mine in Yavapai County. Flux-ore is unprocessed high-silica gold ore that is shipped directly as a flux to copper smelters where the gold values are ultimately recovered as a byproduct of copper smelting.

The open pit Copperstone Mine, which completed its first full year of production in 1988, was the State's largest primary gold producer. During the year, the mine owners, Cyprus Copperstone Gold Corp., began driving a decline ramp to gain access to the deep underground reserves beneath and to the east of the surface operation. This new $10 million project was expected to begin production in mid-1989 and add 40,000 ounces of gold per year to the existing 60,000 ounces of annual capacity.

Limited underground mining began in midyear at Stan West Corp.'s McCabe Mine near Prescott. The company expects McCabe, when fully operational, to produce at an annual rate of 50,000 ounces of gold and 140,000 ounces of silver. In March, Echo Bay Mines brought its small underground Congress Mine into production for an expected annual yield of about 25,000 ounces of gold. The Congress is located adjacent to an abandonded mine that had been worked from 1894 to 1911. Unprocessed flux-ore from the Congress was being trucked to a smelter; however, near yearend, the company was considering building an on-site mill. Other gold producers in the State included the Portland heap-leaching operation and the underground Tyro Mine, both in Mojave County, and the underground Gold Prince flux-ore mine of Queenstake Resources Ltd. in Cochise County. Intermittent production of placer gold occurred at several locations, and exploration for gold was conducted on properties located in Cochise, Maricopa, Pinal, Yavapai, and Yuma Counties.

California

Although the rate of new mine openings slowed from the pace set in earlier years, exploration and mine development continued in many of the State's historic gold-producing districts, while plant capacity expansions at several established mines were completed or nearing completion by yearend. Special elections held during the year in various areas of the California Mother Lode included initiatives to ban or restrict surface mining operations. Mariposa County voters defeated "Measure B," which proposed to eliminate "strip and open pit mining" by establishing a 10,000-foot buffer zone adjacent to homes, hospitals, and schools. Voters in Amador City, in Amador County, voted to ban surface mining operations and to require permits for all exploration. Legal and regulatory challenges were reportedly expected to be filed under provisions of the State Mining and Reclamation Act before the measure qualifies as a certified ordinance.

The largest gold producer, the McLaughlin Mine of Homestake Mining Co., located near Clearlake, 70 miles northeast of San Francisco, produced a record 203,827 ounces of gold. This production, representing an 8% increase over that of 1987, reflected the addition of new equipment as well as a record recovery rate of 95%. Installation of a new parallel oxide ore-processing circuit at the McLaughlin mill was nearing completion at yearend.

At Gold Fields Mining Corp.'s Mesquite Mine in Imperial County, a $20 million expansion to add three new open pits was completed during the year. The expansion project, comprising the opening of the Vista, Cherokee, and Rainbow pits (collectively called the VCR Project), was expected to increase ore throughput by about 50%. A new heap-leaching area, completed near yearend, was also constructed as part of the expansion project.

At least one new full-scale gold mine began production during the year and several others either began deposit development or were in various final permitting stages. In Inyo County, Sunshine Mining Co. and First Sierra Assets Inc. began production in April at an annual rate of about 20,000 ounces of gold and 50,000 ounces of silver. The new open pit heap-leaching operation, located near the town of Lone Pine, is reportedly at the site of earlier gold and silver mining operations conducted by Eagle-Picher Industries Inc.

Colorado

Denver continued to be the Nation's unofficial gold capital. To maintain closer contact with developments in the field and with mining support facilities, numerous local, national, and international gold mining firms were relocating their headquarters or principal offices to the Denver metropolitan area. This trend became especially apparent in October when Newmont Mining Corp. announced that, beginning in 1989, it was moving its headquarters and those of its subsidiary, Newmont Gold Co., in New York as well as its offices in Tucson, AZ, Danbury, CT, and Toronto, Ontario, Canada, to Denver, CO, thereby joining numerous other Denver-hosted gold mining firms reportedly responsible for more than 50% of the Nation's annual gold production.

The decline in gold production during 1988 reflected to some extent the decline in production at the State's two largest gold mines, Galactic Resources' Summitville Mine in Rio Grande County and the Sunnyside Mine at Silverton. Production at Summitville, a seasonal open pit heap-leaching mine, amounted to more than 66,000 ounces, or about 22,000 ounces less than in the previous year. Galactic foresaw a slight increase in production at the mine in 1989, then a decline to about 30,000 ounces per year by the end of 1991.

At the underground Sunnyside Mine, production declined to 31,205 ounces from the 47,000-ounce level produced during 1987. Effective June 1, the mine's owner, Echo Bay Mines Ltd., formed the Alta Bay joint venture with Silver King Mines Inc. and Pacific Silver Corp., both of Salt Lake City, UT. Echo Bay retained a 40% interest while Silver King and Pacific Silver held 60% though an affiliate, Alta Gold Co.

In May, Cobb Resources Corp. began production at its London Mine and mill near Fairplay in Park County. The mine, a substantial gold producer between the 1880's and 1940's, was acquired by Cobb in 1978. Cobb's partner in the underground mine was Boulder Gold Inc.

Western Mining Corp. Holdings Ltd. (WMCH) of Australia continued underground rehabilitation, exploration, development, and limited gold and silver production at its 76%-held Camp Bird Joint Venture at the Camp Bird Mine in Ouray County. In Lake County, Leadville Mining and Milling Corp. announced at midyear that limited trial milling had begun in conjunction with development work at its Hopemore underground gold and silver mine near Leadville. The Cripple Creek and Victor Gold Mining Co., operating at various sites in Teller County, reported recovering nearly 37,000 ounces of gold and over 30,000 ounces of silver from its Mine Dump Rock leaching project, the Portland Pit, and other material.

Exploration continued to be focused in historic gold-producing areas of the State. Battle Mountain Gold Co. continued work to bring its San Luis project on-stream in late 1989 or 1990 with production at the new Costilla County project targeted at 50,000 ounces per year.

Idaho

A gold pour on July 29 at the Yellow Pine Unit of Hecla Mining Co., marked the opening of Hecla's first venture into heap-leach gold mining. The first season of operation at the new open pit Valley County facility yielded nearly 21,000 ounces. This was lower than expected owing to the failure and subsequent cancellation of a processing contract with Pioneer Metals Corp. Under the contract, Pioneer was to toll-leach Hecla's Yellow Pine ore at Pioneer's nearby Stibnite—West End Mine facilities. At yearend, Hecla was studying other processing options. Pioneer and its partner at the Stibnite Mine, MinVen Gold Corp., announced that exploration during 1988 had nearly quadrupled reserves and identified promising areas to be targeted for study during 1989.

Seasonal open pit mining and heap-leaching operations were conducted at the Thunder Mountain gold mine, also in Valley County, by Coeur d'Alene Mines Corp., and the company began permitting procedures for a new open pit mine at nearby Lightning Peak. About 24,000 ounces of gold and 5 million ounces of silver were produced at Thunder Mountain during the 1988 season. In December, the Idaho Gold Corp. reportedly poured its first bar of doré from ore mined at its new Champagne Mine at Buffalo Gulch near Elk City in Idaho County. Full-scale seasonal operations at a rate of about 15,000 ounces per year were expected to begin at the new open pit facility in mid-1989. U.S. Antimony Corp. continued development at its Yellow Jacket Mine southwest of Salmon, processing some ore at its plant at Preacher's Cove in Lemhi County. In Custer County, Sunbeam Mining Co. pursued final permitting requirements for its new Sunbeam open pit vat leaching property on Jordan Creek.

The Idaho Land Board approved an application by A&T Mining to mine for placer gold on claims along the Salmon River near Lucille, Idaho County.

Meridian Minerals Co., a subsidiary of Burlington Resources Inc., and Canyon Resources Corp. with Minex Partners announced the discovery of a large gold deposit on their Beartrack property 10 miles west of Salmon in Lemhi County. The Beartrack deposit, estimated to contain more than 2 million ounces of gold, was reportedly the largest gold discovery in the State's history. In Owyhee County, War Eagle Mining Co. Inc. reported the discovery of gold-silver mineralization at War Eagle Mountain east of Silver City. Nerco Minerals Co. announced that exploration and drilling, ongoing since 1985, at its Florida Mountain property in Owyhee County had reached the prefeasibility stage. Florida Mountain is just east of Nerco's existing DeLamar Mine where a new heap-leaching plant was added in 1988 to complement the existing vat-leaching recovery system. Noranda Mining Co. submitted operating and reclamation plans for its proposed Black Pine heap-leaching operation near Bridge in Cassia County.

Other properties being explored during the year included the Golden Chest lode and placer deposits near Murray in Shoshone County, the Lava Creek deposit in Butte County, and the Erickson Reef property at Buffalo Gulch and the Robinson Dike property in Idaho County.

Montana

Gold continued to be the primary exploration target of Montana mineral activity during 1988. According to an annual review prepared by the Montana Bureau of Mines and Geology, the total number of new and renewed State exploration licenses issued during 1988 increased 73% over the 1987 total.[5] The production of gold, Montana's highest valued mineral commodity, rose by nearly 30% over that of the previous year.

The new open pit Montana Tunnels property of Pegasus Gold Corp. in Jefferson County and the underground Spotted Horse Mine of Chelsea Resources Ltd. in Fergus County completed their first full year of production during 1988. New gold mines beginning production by heap leaching during the year included Pangea Resources Ltd.'s Pauper's Dream Mine in Lewis and Clark County and Canyon Resources Corp.'s Kendall Mine in Fergus County. Equal partners, Gulf Titanium Ltd. and Cusac Industries Ltd., began limited underground production at their Cruse-Belmont gold mine in Lewis and Clark County. A new 200-ton-per-day mill under construction at the minesite was expected to be on-stream in 1989. In Madison County near Pony, 2900 Development Corp. brought its Atlantic and Pacific Mine into production. The first doré bar, recovered through heap leaching, was poured in October. Pegasus reported that construction work at its Beal Mountain project was essentially completed before yearend. Loading of ore on the leach pad was begun in October, and test leaching was conducted prior to winter shutdown. The mine was expected to produce 33,000 ounces when full-scale operations begin in 1989.

In the Little Rocky Mountains area of Phillips County, Pegasus reported producing nearly 112,000 ounces of gold by heap leaching at its open pit Zortman-Landusky Mine, Montana's largest gold mine. The company reported that new ore reserves containing about 470,000 ounces of gold were added during the year. At Pegasus' wholly owned Montana Tunnels Mine, in addition to values in silver, zinc, and lead, over 70,000 ounces of gold was produced. At Montana's second largest gold mine, Placer Dome's Golden Sunlight Mine near Whitehall, production during the year amounted to over 93,000 ounces, slightly higher than production during 1987.

The Jardine Joint Venture of Homestake and American Copper and Nickel Co. Inc. was expected to begin operation at its $32.4 million Mineral Hill Mine in Park County near Gardiner. The partners expected Mineral Hill to produce about 42,000 ounces of gold per year. CoCa Mines Corp. continued drilling and exploration at its Hog Heaven project southwest of Kalispell in Flathead County. Plans called for construction to begin in 1989 with production, at about 12,500 ounces per year, to begin in 1990.

Some larger Montana placer operations were reportedly active on Grasshopper Creek near Bannock, on Sauerkraut Creek near Lincoln, at Washington Gulch near Avon, on Gold Creek, and on Indian Creek west of Townsend.

Gold exploration was generally concentrated in the mountainous southwestern region of the State. Some of the companies actively exploring for gold included the following: Noranda Exploration Inc. and its partner Crown Butte Resources Ltd., Homestake Mining Co. and Mountain West Resources Inc., AMAX Exploration, ASARCO Incorporated, Battle Mountain Exploration, FMC, Freeport-McMoRan Co., Silver King Mines Inc., Sunshine Mining, and Valentine Gold Corp.

Nevada

The maintenance of the U.S. position as the world's third largest gold producer depended to a great extent upon developments in Nevada, which accounted for over 57% of domestic gold production.

Gold mines that reportedly began mining during the year included the following: the Adelaide Crown property in Humboldt County, developed by Icarus Exploration Co. and Grand Teton Industrious Inc.; Echo Bay Mines, Lander County Cove deposit; the Crofoot Mine of Granges Exploration Ltd. in Humboldt County, and the Battle Mountain Gold Co. (BMG) Canyon Placer operation in Lander County. In addition, the Green Hill or Olinghouse Placer Mine of Canaustra Gold Exploration Ltd. and Cliff Resources Corp. began operation and reportedly poured its first test gold in November. A ceremony was held in late October to mark the official opening of Corona Gold Inc.'s new wholly owned Santa Fe Gold Mine near Hawthorne in Mineral County. Following the 4 months of total construction time, U.S. Gold Corp. began open pit mining at its new White Pine Mine in White Pine County, and Homestake Mining Co. began seasonal mining operations at its first domestic heap leaching facility, the Wood Mine in Elko County.

The principal operations of Newmont Gold Co. (NGC), the largest producer of gold in North America, were located northwest of Carlin in Eureka and Elko Counties. NGC also controlled the largest block of gold ore reserves in the United States. During the year, NGC sold nearly 900,000 ounces of gold compared with sales of nearly 600,000 ounces in the previous year. NGC's total cash cost of production in 1988 was $230 per ounce, including royalties, selling, general and administrative expenses. NGC operated four mines during the year, producing 30.3 million tons of ore from 100.4 million tons of material mined, including waste. The mines operated were Gold Quarry (the largest in terms of ore mined), Genesis, Rain, and Blue Star. In addition, some stockpiled ores from the Carlin, North Star, and Post Mines were processed. The Post Mine was mined by American Barrick Resources Corp. (ABR) pursuant to a layback agreement with NGC that enables ABR to mine its contiguous Goldstrike deposit in Eureka County. The Goldstrike, Post, Gold Quarry, and numerous other deposits lie within a highly mineralized, northwest-trending zone known as the Carlin trend. NGC increased ore throughput by nearly 30%, and its heap-leaching operations were nearly doubled by the placement of nearly 22 million tons of ore on company leach pads. Two new mills, Mill No. 3 and Mill No. 5, were commissioned during the year; Mill No. 4, under construction near the Post Mine, was to be ready to operate by mid-1989. More or less contiguous with NGC properties along the Carlin trend, ABR's Goldstrike Mine contains two ore bodies within a continuous zone of sulfide mineralization, the Betze Deposit and the Deep Post Deposit. In 1988, Goldstrike yielded nearly 120,000 ounces of gold at an average operating cost of $167 per ounce. A new $25 million, 4,500-ton-per-day, carbon-in-leach mill was commissioned at the property in August. Near yearend, ABR announced a $365 million development plan aimed at recovering 10.4 million ounces of gold from the Post surface and Betze reserves during a period from 1989 to 2006. The plan was fully financed with a 1.05-million-ounce gold loan.

At the Round Mountain Mine in Nye County, the world's largest open pit, heap-leach gold mine, work proceeded on a $131 million expansion plan due for completion in 1989. Round Mountain, owned by Echo Bay, Homestake, and Case Pomeroy & Co., produced nearly 235,000 ounces of gold during the year.

Construction of additional capacity designed to better utilize the refractory portion of the ore at various other mines was under way at several locations. For example, at the Tonkin Springs Mine in White Pine County, operations were suspended during the year while the company began installation of one of the Nation's first commercial bioleaching plants designed to prepare refractory sulfide ores for conventional cyanide leaching. WestGold began biological leaching tests at a new pilot plant installed at its 72.5%-held Austin Gold Venture in Lander County. At the Jerritt Canyon Mine in Elko County, the owners, Freeport-McMoRan and FMC, were constructing a company-developed proprietary roasting circuit utilizing two fluid-bed roasters. The new circuit was expected to begin processing refractory ore in late 1989. Cortez Gold Mines Ltd. was also reportedly adding a fluid-bed roasting facility at its Cortez Mine in Lander County to increase gold recovery from refractory and carbonaceous ores from its Horse Canyon and Gold Acres deposits. A number of established Nevada mines such as FMC's Paradise Peak Mine near Gabbs, and AMAX Inc.'s Sleeper Mine in Humboldt County, expanded or were constructing heap-leaching facilities to process low-grade ores not previously handled during routine milling operations.

Numerous other properties were under development during 1988. Some of the mines expected to begin production during 1989 or 1990 included Bond International Gold Corp.'s Bullfrog Mine near Beatty; Rayrock Yellowknife Resources Inc.'s Marigold property near Valmy; and Humboldt Co. and BP Gold Co.'s Rawhide Mine in Mineral County.

Oregon

According to a State review of the year's activities, exploration continued to expand, with about 40 companies actively seeking gold at yearend.[6] The increase was due largely to Atlas Corp.'s announcement in August that exploration at its Grassy Mountain Prospect near Vale in Malheur County had uncovered an epithermal-type gold deposit bearing preliminary geologic reserves of over 1 million ounces. At yearend, a dozen or more prospects, including Grassy Mountain and Vale Buttes, were under examination in Malheur County by various companies including Asarco, American Copper, Malheur Mining Co., the Manville Corp., and Chevron Resources Co. In southwestern Oregon, 30 miles west of Lakeview in Lake County, Galactic Resources Ltd., through its subsidiary Quartz Mountain Gold Corp., conducted feasibility, metallurgical, and engineering studies on its Quartz Mountain property. Galactic outlined two large deposits, the Crone Hill and the Quartz Butte; a production decision was expected later.

South Carolina

With three active gold mines and several gold deposits under investigation, South Carolina became the focal point of gold interest in the Southeastern United States. Responding to this increased activity, several bills aimed at regulating the mining industry were introduced in the State General Assembly. One bill called for a tax on gold production equal to 10% of the average value per troy ounce of the metal on the London market for the prior year. Other bills contained several provisions aimed at regulating the environmental aspects of mining. None of the bills were acted on during 1988.

South Carolina's third and newest gold mine, the Ridgeway Mine in Fairfield County, north of Columbia, poured its first bar of production gold on December 6. The new open pit vat-leaching facility, owned by BP Minerals and Galactic Resources, was operated by the Ridgeway Mining Co. Production was expected to be about 135,000 ounces per year for an anticipated minelife of 11 to 12 years.

The Haile open pit gold mine in Lancaster County produced nearly 12,000 ounces in 1988, about 50% above production achieved during 1987. During the year, the mine owner, Piedmont Mining Co. Inc., installed new processing and stacking equipment and brought a new heap-leaching pad into operation. At the Brewer Mine in Jefferson County, Brewer Gold Co. announced the discovery of economic deposits of gold at five locations in adjoining Lancaster County. Any gold ore mined in Lancaster County would be transported to the heap-leaching facility at the Brewer Mine where open pit mining and heap leaching began in 1987.

Hawk Resources (USA) Ltd., a subsidiary of Hawk Investment Ltd., of Australia, entered into an agreement with Amselco Minerals Inc. to explore and develop Amselco's Barite Hill gold project located in McCormick County. Near yearend, Hawk acquired Amselco's interest in the property.

South Dakota

Gold production contributed the greatest share of value to South Dakota's nonfuel mineral revenues during 1988. Voters in South Dakota rejected a ballot initiative that sought to require surface mines started after January 1, 1988, to be reclaimed to approximate original contours. A second initiative that also was rejected would have more than doubled the present 2% gross sales tax on gold and silver produced from surface mines. Proceeds from the tax was to have been used to cleanup and restore old minesites. In March, legislation was enacted by the State exempting the new Bison gold and silver bullion coins from State retail sales taxes. The coins, together with a new gold South Dakota Centennial Medallion, were introduced to the market in early 1987. Both gold and silver coins were designed and minted in South Dakota, and each possessed a purity of 999 fine. Gold Bisons were available in eight sizes ranging from 1/20th of an ounce up to 10 ounces; silver Bisons came in four sizes from 1/2 ounce to 10 ounces. The gold used in both the Bison and the medallion came from the Homestake Mine at Lead, in Lawrence County. Homestake was the Nation's largest underground gold mine.

Operations at the 8,000-foot-deep Homestake Mine and Homestake Open Cut Mine during 1988 resulted in the production of 390,162 ounces of gold, up 20% from the previous year. Homestake's average production cost dropped to $298 per ounce from $329 a year earlier. Improved mine scheduling, higher grade ore blocks, and strict grade control led to a 17% increase in the grade of underground ore to 0.187 ounce per ton. The total tonnage milled rose 5% to over 2.45 million tons. Homestake's stepped-up exploration program in the mine was concentrated on new deep-level targets and on expansion of open cut reserves. Exploration in 1988 essentially replaced gold produced, leaving 1988 yearend reserves at 4.8 million ounces.

Brohm Mining Corp., a wholly owned subsidiary of MinVen Gold Corp., poured its first doré bar in October from the new Gilt Edge Mine. The Gilt Edge is an open pit heap-leaching operation located near Galena in Lawrence County. During 1988, Brohm began a 2-year expansion program aimed a raising the mine's annual gold output capacity from 43,000 ounces to 160,000 ounces or more; about 320,000 ounces of silver also would be recovered annually. MinVen's second Lawrence County gold mine, the Golden Reward property, was under construction at yearend with startup targeted for mid-1989. MinVen's partners at the Golden Reward were Ventures Trident L.P., Moruya Gold Mines of North America Inc., and Coin Lake Gold Mines Ltd. The operating company was Golden Reward Mining Co.

Wharf Resources (USA) Inc. continued production at its Annie Creek open pit, heap-leaching operation near Terry Peak in Lawrence County. Production during 1988 reportedly was 59,500 ounces, an increase of 13,500 ounces over 1987 production. In November Wharf completed construction on a new recovery plant at Annie Creek. The new plant was expected to boost recovery to about 70,000 ounces per year.

In other Lawrence County developments, Bond Gold Richmond Hill Inc., formerly St. Joe Gold Corp., received a State mining permit for its Richmond Hill and Turnaround gold deposits in late January. Mine construction began in late summer, and production was expected to begin in early 1989. Minerva Explorations Inc. announced plans to construct an open pit heap-leaching mine near Spearfish. Permits for the new mine at Johnson Gulch were being sought near yearend.

Utah

The Bingham Canyon Mine and the Mercur Mine, produced 291,000 ounces of gold and 115,390 ounces of gold, respectively, or sufficient production to place both operations within the top 15 gold producers in the Nation.

Near Salt Lake City, the $400 million modernization program at the Bingham Canyon Mine owned by BP Minerals was completed in 1988. Bingham Canyon, the world's deepest open pit copper mine, produced gold and silver as a byproduct of its copper mining operations. Four miles north of Bingham Canyon, BP Minerals continued development at its open pit Barney's Canyon gold mine. Barney's Canyon was scheduled to begin production in mid-1989, producing from two open pits and utilizing heap-leaching recovery methods; gold production was expected to average about 80,000 ounces a year during the projected minelife of 8 years.

At the Mercur Mine, in Toole County and west of Bingham Canyon, ABR reported that improvements made to the mill and dump-leaching facilities in the last 3 years continued to yield increased rates of gold production. The new $10 million pressure oxidation autoclave facility was commissioned in February. With the addition of the autoclave, ABR was able to increase gold recoveries from the mine's gold-bearing sulfide ores to 81%, compared with 35% for the same ore type without the autoclave unit.

Washington

In its annual review of Washington's Mineral Industry, the State reported that a record-high amount of more than 225,000 ounces of gold was produced from mines in Chelan and Ferry Counties during 1988, and that more than 62 companies were reported to be exploring, mostly for precious metals, in the State during the year.[7]

The largest gold mine, the Cannon Mine at Wenatchee in Chelan County, produced over 145,000 ounces of gold and about 250,000 ounces of silver. The owners of the mine, Asamera Minerals (U.S.) Inc. and Breakwater Resources Ltd., attributed the increase in production over that of the previous year to increased grades and higher productivity. Exploration on property held by Cannon, the Nation's second largest underground gold mine, continued to expand the mine's ore reserves and led to the discovery of a new area containing ore-grade mineralization south of the main ore body. In May, Asamera announced a $10 million, 3-year exploration and development program involving driving a 20,000-foot-long tunnel to reach and drill the discoveries.

The State's second largest gold mine is the underground Republic Unit, or Knob Hill Mine, of Hecla in Republic, Ferry County. Production at the mine increased about 15% to 80,301 ounces of gold and 354,077 ounces of silver. Gold production costs at the mine during 1988 reportedly amounted to about $135 per ounce. Seven veins of gold- and silver-bearing ore had been discovered in the Golden Promise area of the mine since the new high-grade area was discovered in 1985. The discovery was just prior to the planned closure of the mine owing to exhaustion of its known ore reserves. Also in Ferry County, Vulcan Mountain Inc., continued leaching operations at its Gold Dike Mine during part of the year. Echo Bay applied for permits to develop its proposed Kettle River and Overlook Mines, and a new cyanidation mill near Republic. Echo Bay expected to bring the Kettle River project on-stream in early 1990 with combined production from the two new mines amounting to about 110,000 ounces per year.

Gold exploration activities were generally concentrated in old gold producing districts of Chelan, Ferry, Okanogan, Stevens, and Whatcom Counties and, to a lesser extent, in King, Pend Oreille, and Snohomish Counties. Several well-known gold mining firms explored for

TABLE 4

TWENTY-FIVE LEADING GOLD-PRODUCING MINES IN THE UNITED STATES IN 1988, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of gold
1	Carlin Mines Complex	Eureka, NV	Newmont Gold Co.	Gold ore.
2	Homestake	Lawrence, SD	Homestake Mining Co.	Do.
3	Jerritt Canyon (Enfield Bell)	Elko, NV	Freeport-McMoran Gold Co.	Do.
4	Bingham Canyon	Salt Lake, UT	Kennecott-Utah Copper Division	Copper ore.
5	Round Mountain	Nye, NV	Round Mountain Gold Corp.	Gold ore.
6	Paradise Peak	do.	FMC Gold Co.	Do.
7	Sleeper	Humboldt, NV	Amax Gold Inc.	Do.
8	Fortitude and Surprise	Lander, NV	Battle Mountain Gold Co.	Do.
9	Chimney Creek	Humboldt, NV	Goldfields Mining Co.	Do.
10	McLaughlin	Napa, CA	Homestake Mining Co.	Do.
11	Mesquite	Imperial, CA	Goldfields Mining Co.	Do.
12	Cannon	Chelan, WA	Asamera Minerals (U.S.) Inc.	Do.
13	Goldstrike	Eureka, NV	Barrick Goldstrike Mines Inc.	Do.
14	Mercur	Tooele, UT	Barrick Mercur Gold Mines Inc.	Do.
15	Zortman-Landusky	Phillips, MT	Pegasus Gold Inc.	Do.
16	McCoy and Cove	Lander, NV	Echo Bay Mining Co.	Do.
17	Jamestown	Tuolumne, CA	Sonora Mining Corp.	Do.
18	Golden Sunlight	Jefferson, MT	Golden Sunlight Mines Inc.	Do.
19	Pinson and Prebble	Humboldt, NV	Pinson Mining Co.	Do.
20	Borealis	Mineral, NV	Echo Bay Mining Co.	Do.
21	Republic Unit	Ferry, WA	Hecla Mining Co.	Do.
22	Colosseum	San Bernardino, CA	Bond Gold Corp.	Do.
23	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Do.
24	New Summitville	Rio Grande, CO	Summitville Consolidated Mining Co Inc.	Do.
25	Copperstone	La Paz, AZ	Cyprus Copperstone Gold Corp.	Do.

TABLE 5

GOLD PRODUCED IN THE UNITED STATES, BY STATE, TYPE OF MINE, AND CLASS OF ORE

Year and State	Placer (troy ounces of gold)	Lode					
		Gold ore		Gold-silver ore		Silver ore	
		Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
1984	37,597	30,497,262	1,736,998	1,587,850	55,382	4,380,945	25,785
1985	73,299	35,908,918	2,170,920	1,043,854	41,801	3,836,130	31,288
1986	73,331	60,682,634	3,543,557	869,099	28,399	5,532,818	22,207
1987[r]	163,385	92,810,122	4,431,394	W	W	8,757,526	39,703
1988:							
Alaska	121,634	187,231	13,706	—	—	—	—
Arizona	1	W	W	—	—	—	—
California	W	14,912,993	697,953	—	—	—	—
Colorado	W	W	W	W	W	—	—
Idaho	—	2,013,143	69,913	W	W	W	W
Michigan	—	W	W	—	—	—	—
Montana	W	17,749,349	293,581	—	—	W	W
Nevada	W	90,374,962	3,604,825	W	W	9,732,733	64,750
New Mexico	—	W	W	—	—	W	W
Oregon	W.	—	—	—	—	—	—
South Carolina	—	W	W	—	—	—	—
South Dakota	—	W	W	—	—	—	—
Utah	—	W	W	22,611	6,489	W	W
Washington	—	W	W	—	—	—	—
Total	**152,831**	**140,967,865**	**5,815,971**	**W**	**W**	**10,552,980**	**66,723**
Percent of total gold	**2**	**XX**	**90**	**XX**	**([1])**	**XX**	**1**

Year and State	Lode				Total	
	Copper ore		Other[2]			
	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold[3]
1984	132,899,873	198,729	472,359	30,124	169,838,289	2,084,615
1985	149,464,862	74,633	4,476,684	35,291	194,730,448	2,427,232
1986	116,775,362	52,811	334,932	18,710	184,194,845	3,739,015
1987[r]	182,329,975	259,580	W	W	285,133,672	4,947,040
1988:						
Alaska	—	—	—	—	187,231	135,340
Arizona	151,280,957	60,117	W	W	152,561,282	146,259
California	—	—	W	W	14,930,631	721,512
Colorado	—	—	W	W	3,815,674	164,809
Idaho	—	—	W	W	3,500,049	103,463
Michigan	—	—	—	—	W	W
Montana	2,823,127	281	W	W	20,582,873	294,976
Nevada	W	W	W	W	100,133,812	3,675,526
New Mexico	W	W	W	W	W	W
Oregon	—	—	—	—	—	W
South Carolina	—	—	—	—	W	W
South Dakota	—	—	W	W	4,453,672	449,514
Utah	W	W	—	—	W	W
Washington	—	—	W	W	W	W
Total	**222,482,836**	**363,745**	**W**	**W**	**375,397,192**	**6,459,539**
Percent of total gold	**XX**	**6**	**XX**	**([1])**	**XX**	**100**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1] Less than 1/2 unit.
[2] Includes lead, zinc, copper-lead, lead-zinc, copper-zinc, copper-lead-zinc ores, and old tailings, etc.
[3] Includes lode and placer production.

TABLE 6

LODE GOLD PRODUCED IN THE UNITED STATES, BY STATE

Year and State	Amalgamation		Cyanidation		Smelting of concentrates			Smelting of ore		Total ore processed[1] (short tons)	Total gold recovered (troy ounces)
	Ore treated (short tons)	Gold recovered (troy ounces)	Ore treated (short tons)	Gold recovered (troy ounces)	Ore concentrated (short tons)	Concentrates smelted (short tons)	Gold recovered (troy ounces)	Ore smelted (short tons)	Gold recovered (troy ounces)		
1984	124,983	23,274	34,902,191	1,752,492	134,735,157	3,605,791	257,238	75,958	[2]14,214	169,838,289	[2]2,047,218
1985	20,812	3,741	39,602,183	2,088,815	154,886,138	3,220,471	231,706	221,315	[2]34,179	194,730,448	[2]2,358,441
1986	850,236	33,710	64,666,550	3,357,244	118,529,487	2,838,702	[2]262,703	148,572	[2]6,455	184,194,845	[2]3,660,112
1987[r]	W	W	97,969,796	4,173,564	173,338,538	3,781,727	564,185	W	W	285,133,673	[2]4,783,655
1988:											
Alaska	—	—	187,231	13,706	—	—	—	—	—	187,231	13,706
Arizona	—	—	W	W	151,340,217	2,542,711	60,981	W	W	152,561,282	146,258
California	W	W	14,912,649	691,219	W	W	W	W	W	14,930,631	W
Colorado	109,886	15,509	W	W	W	W	W	W	W	3,815,674	W
Idaho	—	—	2,842,997	101,317	657,052	35,413	2,146	—	—	3,500,049	103,463
Michigan	—	—	W	W	—	—	—	—	—	W	W
Montana	—	—	13,744,156	215,194	W	W	W	W	W	20,582,873	[2]294,976
Nevada	—	—	99,814,281	3,631,023	W	W	W	W	W	100,133,812	[2]3,675,526
New Mexico	—	—	38,000	850	W	W	W	W	W	W	W
South Carolina	—	—	W	W	—	—	—	—	—	W	W
South Dakota	—	—	W	W	—	—	—	W	W	4,453,672	449,514
Utah	—	—	W	W	W	W	W	22,611	6,489	W	W
Washington	—	—	W	W	W	W	W	W	W	W	W
Total	**W**	**W**	**146,668,855**	**5,577,917**	**228,354,780**	**4,375,355**	**677,000**	**W**	**W**	**375,397,192**	**6,306,708**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes old tailings and some non-gold-bearing ores not separable, in amounts ranging from 0.15% to 0.25% of the totals for the year listed.

[2] Includes some placer production to avoid disclosing company proprietary data.

gold and other precious metals on a Statewide basis.

CONSUMPTION

The data on consumption of gold shown in table 10 account for only part of the overall domestic market for commercial gold products. An important segment of market demand is also satisfied by imported gold-bearing products in various forms ranging from unfinished jewelry products, such as gold chain, to electronic equipment containing gold components.

TABLE 7

GOLD PRODUCED IN THE UNITED STATES BY CYANIDATION[1]

Year	Extraction in vats, tanks, and closed containers[2]		Leaching in open heaps or dumps[3]	
	Ore treated (short tons)	Gold recovered[4] (troy ounces)	Ore treated (short tons)	Gold recovered (troy ounces)
1984	13,503,143	1,165,983	21,399,048	586,509
1985	20,542,717	1,555,835	19,059,466	532,980
1986	27,106,861	2,358,641	37,559,689	998,603
1987[r]	32,417,462	2,405,103	65,552,334	1,768,461
1988	33,943,332	3,241,344	112,725,523	2,336,573

[r] Revised.

[1] May include small quantities recovered by leaching with thiourea, by bioextraction, and by proprietary processes.

[2] Including autoclaves.

[3] May include tailings and waste ore dumps.

[4] May include small quantities recovered by gravity methods.

TABLE 8

GOLD PRODUCED AT PLACER MINES IN THE UNITED STATES, BY METHOD OF RECOVERY[1]

Method of recovery	Mines producing	Washing plants	Material washed (thousand cubic yards)	Gold recoverable		
				Quantity (thousand troy ounces)	Value (thousands)	Average value per cubic yard
Bucketline dredging:						
1984	2	3	4,840	29	$10,387	$2.147
1985	3	4	3,958	32	10,185	2.573
1986	3	4	4,081	30	11,227	2.751
1987	4	5	9,333	112	49,989	[r]5.357
1988	3	4	7,553	83	36,497	4.833
Dragline dredging:						
1984	4	13	[2]126	[3]4	1,593	[4]2.908
1985	3	14	[2]156	[3]4	1,348	[4]2.224
1986	3	14	[2]14	[3]4	1,342	[4]12.862
1987	3	3	[2]93	[3]2	971	[4]6.262
1988	—	—	—	—	—	—
Hydraulicking:						
1984	1	1	28	([5])	90	3.220
1985	—	—	—	—	—	—
1986	1	1	100	([5])	17	.166
1987	—	—	—	—	—	—
1988	—	—	—	—	—	—
Nonfloating washing plants:						
1984	8	8	310	3	1,036	3.343
1985	6	6	959	31	9,690	10.102
1986	4	4	276	25	9,244	33.528
1987	6	6	832	15	6,698	8.048
1988	6	6	618	10	4,255	6.885
Underground placer, small-scale mechanical and hand methods, suction dredge:						
1984	10	11	197	1	454	2.304
1985	19	19	621	6	2,061	3.320
1986	24	24	887	14	5,175	5.833
1987	15	15	480	35	15,530	[r]32.366
1988	13	13	[2]1,096	[3]60	26,235	[4]23.935
Total placers:[6]						
1984	25	36	[2]5,501	[3]38	13,560	[4]2.242
1985	31	43	[2]5,694	[3]73	23,284	[4]3.913
1986	35	47	[2]5,358	[3]73	27,003	[4]4.823
1987	28	29	[2]10,738	[3]163	73,188	[4]6.816
1988	22	23	[2]9,267	[3]153	66,987	[4]7.228

[r] Revised.
[1] Data are only for those mines that report annually on the Bureau of Mines voluntary survey; there are many more, usually smaller and less well-established operations, mainly in Alaska, that do not report.
[2] Excludes tonnage of material treated at commercial sand and gravel operations recovering byproduct gold.
[3] Includes gold recovered at commercial sand and gravel operations.
[4] Gold recovered as a byproduct at sand and gravel operations not used in calculating average value per cubic yard.
[5] Less than 1/2 unit.
[6] Data may not add to totals shown because of independent rounding.

Gold futures contracts traded during 1988 on the Nation's futures exchanges represented about 962 million ounces of metal. Trading activity during the year was, however, less than in 1987 when nearly 1.1 billion ounces were traded. As in years past, the New York-based Commodity Exchange Inc. (COMEX), with nearly 99% of the trading volume, was by far the Nation's dominant gold futures exchange.

Despite a brief surge in sales in late 1987 and early 1988 following the sharp stock market declines in late 1987, sales by the U.S. Mint of the American Eagle gold coins failed to match the nearly 2.7 million ounces sold during fiscal year 1988. From the beginning of the Eagle program in October 1986 through the end of December 1988, nearly 3.8 million ounces of U.S. newly mined gold had been consumed in the minting process. Legislation mandating the use of U.S. newly mined gold in general-circulation gold coin programs was enacted in 1985.

Gold loans by commercial depository banks became a prominent method of financing new mine development during the year; the loans also served to infuse substantial amounts of gold into the supply of refined metal available to the market. Typically, a mining company derived development funds by selling borrowed gold after agreeing to repay the lending bank with post-development gold produced at its mines. Several million ounces of gold was estimated to have gone into the domestic and international markets from this source over the past several years, especially during 1988.

STOCKS

Reported Industrial stocks of refined gold increased substantially from levels reported at the close of the previous year. The rate of inventory build up was greatest during the June–September quarter, corresponding roughly with

TABLE 9

U.S. REFINERY PRODUCTION OF GOLD[1]

(Thousand troy ounces)

Raw material	1984	1985	1986[r]	1987[r]	1988
Concentrates and ores:					
Domestic and foreign	2,101	2,076	2,431	3,613	4,431
Old scrap	1,769	1,602	1,520	2,053	1,698
New scrap	1,543	1,510	1,633	1,277	2,416
Total	**5,413**	**5,188**	**5,584**	**[2]6,942**	**8,545**

[r] Revised.
[1] Data may include estimates.
[2] Data do not add to total shown because of independent rounding.

TABLE 10

U.S. CONSUMPTION OF GOLD,[1] BY END USE SECTOR[2]

(Thousand troy ounces)

End use	1984	1985	1986	1987[r]	1988
Jewelry and the arts:					
Karat gold	1,420	1,398	1,412	1,585	1,560
Fine gold for electroplating	23	24	86	101	47
Gold-filled and other	216	216	218	216	147
Total[3]	**1,658**	**1,638**	**1,716**	**1,901**	**1,754**
Dental	305	299	255	223	244
Industrial:					
Karat gold	39	39	39	38	7
Fine gold for electroplating	453	381	369	394	482
Gold-filled and other	675	731	741	673	674
Total[3]	**[r]1,168**	**[r]1,152**	**1,149**	**1,105**	**1,163**
Small items for investment[4]	8	7	6	3	([5])
Grand total[3]	**3,140**	**3,097**	**3,126**	**3,233**	**3,161**

[r] Revised.
[1] Gold consumed in fabricated products only; does not include monetary bullion.
[2] Data may include estimates.
[3] Data may not add to totals shown because of independent rounding.
[4] Fabricated bars, medallions, coins, etc.
[5] Less than 1/2 unit.

TABLE 11

YEAREND STOCKS OF REFINED GOLD IN THE UNITED STATES

(Thousand troy ounces)

	1984	1985	1986	1987	1988
Industry	752	596	925	[r]752	1,196
Futures exchange	2,359	[1]2,110	[1]2,809	[1]2,625	[1]1,435
Department of the Treasury[2]	262,814	262,672	262,032	262,388	261,890
Earmarked gold[3]	337,328	337,399	332,733	329,678	322,975

[r] Revised.
[1] Commodity Exchange Inc. only. Stocks held by other exchanges estimated to be less than 2% of totals shown.
[2] Includes gold in Exchange Stabilization Fund.
[3] Gold held for foreign and international official accounts at New York Federal Reserve Bank.

generally declining metal prices during the same period. Yearend stocks were up nearly 68% over stocks reported at the end of 1987. Conversely, the strong international demand for physical gold was reflected by a sharp decline in stocks certified for delivery by COMEX.

PRICES

The Engelhard Industries-London daily final price of gold ranged from $396 per ounce to $485 during the year. The average for the year was $438, nearly $10 per ounce lower than in 1987.

FOREIGN TRADE

U.S. gold exports were at the highest level in nearly a decade, reflecting the high international demand for gold and gold products, especially in Taiwan. Exports to Taiwan, essentially all refined bullion, accounted for nearly 52% of total gold exports. Following removal of gold from stringent foreign exchange controls in 1987, the Central Bank of Taiwan began large purchases of gold bullion to diversify that country's holdings of foreign exchange reserves. During the January–June 1988 period especially, Taiwan's receipts of gold amounted to nearly 8 million ounces, nearly 5.5 million ounces of which was imported from the United States. In April, the Office of the U.S. Special Trade Representative criticized the purchases as a strategy to artificially reduce Taiwan's large trade surplus with the United States. In response, the Central Bank announced that it would cease gold purchases from the United States but continue to purchase from other countries.

Uruguay continued to be an important source of U.S. gold imports, ranking second only to Canada. Though

TABLE 12

U.S. GOLD PRICES[1]

(Dollars per troy ounce)

Period	Low		High		Average
	Price	Date	Price	Date	
1984	307.90	Dec. 20	408.85	Mar. 5	360.66
1985	284.64	Feb. 25	341.30	Aug. 19 and 28	317.66
1986	326.70	Jan. 2	438.50	Oct. 8	368.24
1987	391.51	Feb. 18	501.25	Dec. 14	447.95
1988:					
January	459.43	Jan. 29	485.37	Jan. 8 and 11	478.04
February	427.52	Feb. 29	457.33	Feb. 2	443.30
March	430.28	Mar. 2	458.38	Mar. 31	445.01
April	448.41	Apr. 26	459.43	Apr. 18	453.26
May	444.20	May 6	459.33	May 19	452.18
June	434.94	June 29	466.14	June 3	452.75
July	432.58	July 26	446.21	July 20	439.03
August	427.17	Aug. 9	435.99	Aug. 1	432.66
September	396.62	Sept. 26	431.78	Sept. 1	414.14
October	396.77	Oct. 5	414.35	Oct. 17	408.12
November	412.25	Nov. 1	425.62	Nov. 28	421.35
December	411.60	Dec. 29	430.38	Dec. 5	419.84
Average and year	**396.62**	**Sept. 26**	**485.37**	**Jan. 8 and 11**	**438.31**

[1] Engelhard Industries daily quotation.

little or no gold is currently mined in Uruguay, that country continued to be an important shipping point for newly mined gold from numerous small mining operations throughout latin America, especially Brazil.

According to data calculated by The Gold Institute, Washington, DC. from reports received from the U.S. Bureau of the Census, gold coin net imports during 1988 amounted to 414,000 ounces.

WORLD CAPACITY

The data in table 15 are rated annual production capacities for gold mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time at a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Owing to the size, diversity, and explosive growth of primary gold production over the past decade, comprehensive world capacity data that would include all operating units that contribute to national totals are generally not available. Therefore, in the absence of appropriate data, certain broad assumptions must be employed to derive international capacity numbers that are compatible with production data shown in table 16.

Optimum engineering capabilities may be more or less restrained by a combination of factors relating to Government and business attitudes, climate, location, ore grade, and mineralogy. With these and other considerations in mind, the author derived and applied to annual production data, different conversion factors to approximate rated annual capacity for each producing nation.

Production data for individual nations, depending upon their perceived circumstances, was estimated to reflect from 75% of maximum capacity utilization for some essentially non-industrialized nations to 92% utilization for most industrialized nations.

Comprehensive data on gold refinery production and refinery capacity are essentially nonexistent. Consequently, the data shown in table 15 are necessarily incomplete and include only known or estimated capacity. Many areas marked on the table with NA (not available) may in fact host considerable capacity to refine material of primary and secondary origin. The relative ease by which gold can be refined to acceptable local standards complicates matters and precludes making any meaningful comparison with more reliable data such as mine production or estimates of industrial consumption.

WORLD REVIEW

The demand for gold for investment purposes and for jewelry fabrication was exceptionally strong throughout the Far East, rising to unprecedented levels during 1988. One contributing factor, aside from traditional attitudes regarding gold's intrinsic value, was that gold prices denominated in local currencies declined to historically low or "bargain-basement" levels in many Asian nations.

Consolidated Gold Fields, in its 23d annual review and summary of world gold supply and demand, Gold 1989,[8] estimated that the total supply of gold to the private sector of the market

TABLE 13

U.S. EXPORTS OF GOLD, BY COUNTRY[1]

Year and country	Ores and concentrates[2] Quantity (troy ounces)	Ores and concentrates[2] Value (thousands)	Wastes and scrap Quantity (troy ounces)	Wastes and scrap Value (thousands)	Doré and precipitates Quantity (troy ounces)	Doré and precipitates Value (thousands)	Refined bullion Quantity (troy ounces)	Refined bullion Value (thousands)	Total[3] Quantity (troy ounces)	Total[3] Value (thousands)
1984	3,298	$545	1,422,849	$503,237	72,470	$24,502	3,482,473	$1,284,718	4,981,090	$1,813,002
1985	2,448	771	980,147	303,413	95,774	30,147	2,888,309	919,433	3,966,678	1,253,764
1986	5,344	1,589	979,069	352,471	456,267	158,005	3,554,411	1,306,958	4,995,091	1,819,023
1987	44,525	19,818	903,182	390,832	610,087	264,008	2,288,404	1,034,186	3,846,198	1,708,844
1988:										
Argentina	—	—	—	—	—	—	411	120	411	120
Belgium			40,276	18,589	100	49	200	100	40,576	18,738
Canada	14,795	5,211	443,434	184,059	524,783	217,681	491,556	208,196	1,474,568	615,147
Chile	—	—	—	—	—	—	708	314	708	314
China	—	—	—	—	—	—	166,758	73,874	166,758	73,874
Dominican Republic	—	—	142	35	—	—	1,000	430	1,142	465
France	—	—	343,024	150,511	54	18	61,162	26,872	404,240	177,401
Germany, Federal Republic of	133	40	10,608	4,667	53,106	23,166	1,983	920	65,830	28,793
Hong Kong	25	7	6	2	207	67	1,207,802	515,247	1,208,040	515,323
India	40	11	—	—	—	—	892	400	932	411
Israel	—	—	—	—	407	126	129	42	536	168
Italy	327	98	4,831	1,812	864	255	1,003	459	7,025	2,624
Japan	—	—	1,417	461	4,227	1,179	84,752	38,001	90,396	39,641
Korea, Republic of	—	—	—	—	—	—	706	293	706	293
Lebanon	—	—	—	—	37	14	2,413	1,073	2,450	1,087
Luxembourg	—	—	—	—	—	—	2,564	1,192	2,564	1,192
Mexico	56	17	336	104	289	105	3,185	1,359	3,866	1,585
Netherlands	84	12	—	—	—	—	269,848	120,420	269,932	120,432
Peru	—	—	1,944	705	270	88	60,314	26,259	62,528	27,052
Singapore	—	—	—	—	—	—	10,052	4,093	10,052	4,093
Sweden	—	—	33,945	14,278	3,843	1,583			37,788	15,861
Switzerland	—	—	—	—	34,564	15,151	917,522	407,583	952,086	422,734
Taiwan	—	—	37	12	34	11	5,436,768	2,454,689	5,436,839	2,454,712
Thailand	—	—	250	107	750	330			1,000	437
Turkey	—	—	91	42	300	120	224	102	615	264
United Kingdom	29,013	13,038	267,719	117,456	12,673	4,982	243	88	309,648	135,564
Yugoslavia	—	—	—	—	—	—	1,210	529	1,210	529
Other	32	14	—	—	359	126	218	104	609	244
Total[3]	**44,505**	**18,449**	**1,148,060**	**492,840**	**636,867**	**265,051**	**8,723,623**	**3,882,757**	**10,553,055**	**4,659,098**

[1] Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.

[2] Includes gold content of base metal ores, concentrates, and matte destined for refining.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF GOLD, BY COUNTRY[1]

Year and country	Ores and concentrates[2] Quantity (troy ounces)	Ores and concentrates[2] Value (thousands)	Wastes and scrap Quantity (troy ounces)	Wastes and scrap Value (thousands)	Doré and precipitates Quantity (troy ounces)	Doré and precipitates Value (thousands)	Refined bullion Quantity (troy ounces)	Refined bullion Value (thousands)	Total[3] Quantity (troy ounces)	Total[3] Value (thousands)
1984	202,787	$69,061	357,119	$122,483	1,277,146	$461,763	6,031,550	$2,293,606	7,868,602	$2,946,914
1985	37,067	11,628	366,887	107,147	1,461,068	468,227	6,360,977	2,109,475	8,225,999	2,696,478
1986	37,618	13,094	520,317	159,786	1,391,061	504,457	13,800,451	5,016,558	15,749,447	5,693,896
1987	45,931	17,926	448,657	160,073	925,612	402,026	2,423,053	1,052,941	3,843,253	1,632,966
1988:										
Argentina	—	—	320	77	10,828	4,444	5,288	2,222	16,436	6,744
Australia	—	—	23	10	1,550	638	300	133	1,873	781
Barbados	—	—	2,002	741	—	—	—	—	2,002	741
Belgium	67	20	—	—	643	265	28,275	12,538	28,985	12,822
Bolivia	42	15	57,446	25,004	20,129	7,998	36,004	15,157	113,621	48,174
Brazil	35	14	129	46	160	73	22,493	10,181	22,817	10,314
Canada	2,464	967	48,271	17,702	547,619	230,217	1,023,788	444,205	1,622,142	693,091
Chile	306	117	4,169	1,892	15,098	6,708	222,356	100,372	241,929	109,090
China	—	—	—	—	2,562	1,114	194	83	2,756	1,197
Colombia	—	—	2,336	1,019	219	98	—	—	2,555	1,117
Costa Rica	1,085	398	—	—	1,189	487	—	—	2,274	884
Dominican Republic	—	—	37,463	9,595	185,745	85,020	1,760	572	224,968	95,186
Ecuador	535	183	1,456	518	2,137	715	8,256	2,801	12,384	4,216
Finland	—	—	—	—	2,642	1,260	7,194	2,893	9,836	4,152
Germany, Federal Republic of	—	—	117	7	5,126	2,630	4,962	2,219	10,205	4,856
Guyana	10,774	4,122	3,806	1,091	—	—	4,302	1,537	18,882	6,751
Honduras	4,501	1,399	2,684	1,160	—	—	158	60	7,343	2,619
Italy	—	—	310	75	—	—	2,017	771	2,327	846
Japan	37,975	15,501	235	61	—	—	164	74	38,374	15,636
Malaysia	—	—	1,365	212	—	—	403	158	1,768	370
Mexico	8,808	4,100	5,036	1,724	90	38	57,752	24,177	71,686	30,039
Panama	—	—	7,126	3,006	2,085	948	6,022	2,181	15,233	6,135
Papua New Guinea	14,450	6,036	—	—	—	—	—	—	14,450	6,036
Peru	—	—	4,777	1,796	1,623	661	7,959	3,437	14,359	5,893
Singapore	—	—	3,057	1,022	—	—	545	246	3,602	1,268
South Africa, Republic of	1,777	733	—	—	—	—	—	—	1,777	733
Switzerland	79	23	7,562	3,441	7,228	3,141	152,768	66,344	167,637	72,949
Togo	775	279	—	—	4,856	1,880	—	—	5,631	2,159
Trinidad	—	—	1,241	511	—	—	576	234	1,817	745
United Kingdom	—	—	381	134	4,285	1,943	3,711	1,621	8,377	3,698
Uruguay	—	—	15,642	7,410	12,710	5,337	220,043	90,479	248,395	103,226
Yugoslavia	—	—	1,200	407	—	—	27,818	12,590	29,018	12,997
Other	599	235	3,126	853	252	148	6,640	2,616	10,617	3,855
Total[3]	**84,272**	**34,141**	**211,280**	**79,513**	**828,776**	**355,763**	**1,851,748**	**799,901**	**2,976,076**	**1,269,318**

[1] Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.
[2] Includes gold content of base metal ores, concentrates, and matte destined for refining.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

economy countries fell 10% in 1988. Conversely, central bank purchases, particularly by Taiwan, increased significantly, but total world demand for gold fabrication rose 16% to a record 59.3 million ounces, thus absorbing nearly all of the conventional supply. Supply shortfalls were met by large increases in gold loan activity, forward selling by producers, and some disinvestment in Europe and North America. The demand for gold (including scrap gold) for fabrication into jewelry products grew almost 30%, to 47.7 million ounces. The consumption of 39.6 million ounces of newly mined gold in jewelry was 40% above that of the previous year. Gold used in industrial, decorative, and dental applications plus the minting of unofficial coins and medals increased somewhat over similar figures for 1987. Gold absorbed in the minting of official coins fell to 4.5 million ounces, a 32% decline from the 1987 level of 6.6 million ounces. On the other hand, hoarding of gold bars for investment or asset fixing, outside of Europe and North America, registered spectacular growth to a record 15.2 million ounces compared with 8.6 million ounces during the previous year. Bar hoarding in the Middle East and Far East rose 41% and 208%, respectively.

TABLE 15

WORLD GOLD ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand troy ounces)

Continent and country	Rated capacity[e] Mine	Rated capacity[e] Refinery[1]
North America:		
Canada	4,450	18,200
United States	7,000	11,000
Other	650	NA
Total	**12,100**	**29,200**
South America:		
Brazil	4,000	2,400
Other	3,000	100
Total	**7,000**	**2,500**
Europe:		
U.S.S.R.	10,250	10,500
Other	750	41,000
Total	**11,000**	**51,500**
Africa:		
South Africa, Republic of	21,600	26,000
Other	1,700	1,600
Total	**23,300**	**27,600**
Asia	5,200	5,000
Oceania:		
Australia	5,300	4,900
Other	1,600	NA
Total	**6,900**	**4,900**
World total	**65,500**	**120,700**

[e] Estimated. NA Not available.
[1] May include inseparable secondary capacity.

Investment buying in Japan was heaviest in the early months of 1988, in response to changes in the tax treatment of small savings accounts. Japan was the biggest single buyer of gold bars for investment, with a total of almost 5.7 million ounces; Taiwan registered a close second with an 86% increase to 5.0 million ounces. Net purchases of gold from the centrally planned economy countries was estimated at 8.3 million ounces or 36% less than estimated net purchases in 1987.

In February, Fidelity Printers and Refiners opened its new gold refinery in Harare, Zimbabwe. The new 1.6-million-ounce-per-year facility was built with technical assistance from the Perth Mint in Western Australia. Products from the new facility will be marketed stamped with the Zimbabwean bird, Zimbabwe's national emblem.

Australia

Australian gold production in 1988 easily surpassed the previous production record of 3.8 million ounces set in 1903. Twenty new gold mines were commissioned, ranging in capacity from several hundred ounces to over 100,000 ounces per year. According to a preliminary review by Australia's Bureau of Mineral Resources (BMR)[9] expenditures on private exploration for gold in Australia during the 1987–88 period increased 63% over the 1986–87 period and accounted for 73% of the total private-sector exploration for minerals other than petroleum and oil shale. At least 13 new discoveries of gold mineralization were made during the period, and additional reserves were added at a number of known deposits. BMR's estimate of minable gold resources increased 11% over similar data from 1987. BMR forecast that Australian production would peak in 1990 at 7.1 million ounces then decline to about 5.6 million ounces by 1993.

In May, the Government of Australia announced that for the first time since 1924, the Australian gold mining industry, after January 1, 1991, would be required to pay taxes on its gold mining revenues. After the target date, a company's gold mining income will be taxed at the new corporate tax rate of 39%. Despite the inclusion of several transitional arrangements designed to ease the impact of the tax decision, some industry observers suggested that many mines would hasten to mine higher grade ores before the tax begins and thereby stunt the exploration and development necessary to sustain long-term orderly growth. In addition, exploration for new deposits would be discouraged, small-scale or marginal producers would be forced out of business, and there would be a restructuring of the industry into fewer and larger operations. A paper addressing tax issues and the effects of gold taxation policies in Australia and other regions of the Pacific Rim was presented at the Perth International Gold Conference that convened in Perth, Western Australia, in October.[10]

Australia's largest gold producers during 1988 were the Boddington Mine in Western Australia, the Kidston Mine in Queensland, Temora in new South Wales, Stawell in Victoria, and the Granites Mine in the Northern Territory.

In northern Queensland, Australian Consolidated Minerals Ltd. started production at its Wirralie gold mine in

May. Output was expected to be about 50,000 ounces per year. In mid-1988 Carpentaria Gold Pty Ltd. resumed full-scale production at its Ravenswood property with a planned heap-leaching production of about 15,000 ounces per year. In 1891, the famous cyanide process developed by Scotsmen McArthur and Forrest was used for the first time in Australia at mines near Ravenswood. In April, Central Coast Exploration NL officially opened its Croyden Mine. Early in the year, Elders Resources Ltd. and Cyprus Gold Co. began full production at their 100,000-ounce-per-year Selwyn (Starra) Mine. Other mines opened in Queensland during 1988 included the Cement Hill Mine and the Horn Island Mine. Placer Pacific Ltd. and its partners neared production at their Mount Rawdon property where an economic evaluation of the deposit indicated a resource of nearly 1 million ounces of gold.

At Parkes, New South Wales, BHP Gold Mines Ltd. commissioned the London-Victoria Mine in November. In July, Mount Carrington Mines Ltd. poured its first gold at the Drake Mine near Cobar and CRA Ltd. sunk an exploration shaft on its most advanced gold project, The Peak.

In the State of Victoria, Broken Hill Holdings Ltd. started treatment of ore from its property at Gaffneys Creek, and KTM Gold Ltd. started production in the same area at its New Dempsey Mine. In February, Triad Minerals NL commissioned the new 165,000-ton-per-year carbon in pulp mill at its Maldon gold project near Bendigo. The Victoria Chamber of Mines reported that about two dozen gold and other mining projects were under development in the State.

In South Australia, Roxby Mining Corp., owned by WMCH and BP Austrialia Ltd., began mining at its copper-uranium-gold Olympic Dam project. Planned annual output at the huge underground mine includes 90,000 ounces of gold.

In May, WMCH with its partner began mining at their Goodall Mine near Adelaide River in the Northern Territory. Production at the new open pit facility was expected to peak at 55,000 ounces per year. In October, Carpentaria Gold opened its Tom's Gully surface mine east of Pine Creek. Carpentaria expected to recover 30,000 ounces of gold and 20,000 ounces of silver annually from Tom's Gully. Several mines, including Arimco NL's Carlton Mine and Cyprus' 25%-held Moline Mine, were due to begin production in 1989.

Western Australia continued to be the dominant gold producing State, accounting for about 70% of the Nation's production. Alcoa of Australia Ltd.'s Hedges Mine began in October with a planned annual gold output of 112,000 ounces. Austwhim Resources NL and its partner started production at their new open pit Mount Morgans Mine in March. Broken Hill Holdings and partner poured their first gold from the Corinthian and Hope Hill Mines in February. In October, the Laverton Joint Venture was opened by Hill Minerals NL and partners, mining gold ore from several sites around Laverton. Other mines in Western Australia beginning production during the year were the Bottle Creek Mine, the Peak Hill Mine, and the Mount Pleasant Mine.

New mines under construction in Western Australia and scheduled to come on-stream within the next 2 years include the following properties: the Big Bell Mine near Cue; the Tuckabianna Mine, also near Cue; the Forrestania Mine; the Lady Bountiful gold mine; the Golden Valley Mine; the Three Mile Hill property; Homestake Gold of Australia Ltd.'s Fortrum Mine; Metana Minerals NL's Rothsay project; Pancontinental Mining Ltd.'s Panglo property; Placer Pacific's Granny Smith Mine, near Laverton; the Higginsville project of Samantha Exploration NL and partners; and the Sons of Gwalia NL's Johnson Range property. Bond International Gold Inc. (BIG) moved ahead with plans to construct its Big Pit project at Kalgoorlie. BIG's plans call for consolidating a number of existing surface and underground mines along Kalgoorlie's famous Golden Mile into one huge open pit capable of ultimately producing 800,000 ounces of gold per year. Also at Kalgoorlie, Anglo American Pacific Ltd.'s Kaltails joint-venture project to reprocess the massive tailings dumps along the Golden Mile continued under development.

New gold refining capacity was under construction by the Western Australian Mint in Perth; its new gold refinery at Kalgoorlie poured its first bar of refined gold in August. The combined annual capacity of the new facilities when completed in early 1989 was expected to be about 3.4 million ounces.

Brazil

According to Consolidated Gold Field's review,[11] Brazilian gold production was about evenly divided between unregulated independent gold miners, known as garimpeiros, and established formal gold mining companies. There were reportedly upward of 800,000 garimpeiros working the numerous gold deposits scattered throughout the Amazon Basin.[12] Gold Fields reported that a new gold-producing province has drawn an estimated 40,000 garimpeiros to the Roraima area on the western frontier between Brazil and Venezuela. Production from this new area more than offset declining garimpeiro production at other remote surface and placer producing operations in the Amazon region where a classic gold rush has been in progress for nearly a decade. Of the major long-established garimpeiro-operated sites, only the Tapajós River area of Pará State registered any increased production. Other prominent gold-producing areas such as Alta Floresta, Cumaru, and Amapá maintained production at the previous year's level. Increased production from the Serra Pelada region of Pará reportedly reflected greater effort aimed at reworking existing tailings and mines in the nearby Morro da Cotia area.

Gold Fields noted that the new areas of interest in Roraima are at the headwaters of the Uraricoera, Mucajai, and Catimani rivers, that drain the Serra de Parima. The Serra de Parima is a ridge over 3,000 feet high that forms the border with Venezuela. Gold mineralization has reportedly been traced for more than 300 miles along the ridge.

The Constituent Assembly approved legislation during 1988 requiring majority local ownership of corporate mining ventures and moved toward expanding the direct participation of the Government in the gold mining industry.

Canada

At the close of 1988, there were 61 primary gold mines in Canada, accounting for about 80% of the total production shown in table 16, according to a report prepared by the Canadian Department of Energy, Mines, and Resources.[13] Canadian companies reportedly continued to invest more than 80% of their mineral exploration dollars in gold exploration, with some of the investment activity credited to the Canadian Government's Flow-Through Share Program, which allowed investors to purchase flow-through shares issued by mining companies, and then to write off more than 100% of their investment. Tax reforms begun in 1988 began to phase out flow-through financing and replace it with another Government program known as the Canadian Exploration Incentive Program or CEIP, due to come into effect at the beginning of 1989.

Several new gold mines began production during the year in Ontario, Canada's most important gold-producing Province, where 1988 production reached nearly 1.9 million ounces. In October, Canamax Resources Inc. poured the first gold at its new Kremzar Mine, north of Wawa, in northern Ontario. Also near Wawa, Muscocho Explorations Ltd. and McNellen Resources Inc. opened the Magino Mine. On August 8, the Holt-McDermott Mine of ABR was opened; the new $62 million facility was expected to produce in excess of 80,000 ounces per year. At Pickle Lake, Ontario, Bond International Gold Inc. opened its new 45,000-ounce-per-year Golden Patricia Mine in September. At Timmins, ERG Resources Inc. began recovering gold from the more than 200 million tons of tailings in the Timmins Porcupine area for an expected annual recovery of about 110,000 ounces. Lac Minerals announced plans to expand the milling capacity at its Macassa Mine at Kirkland lake to handle new Macassa ore as well as local gold-bearing tailings. Eastmaque Gold Mines Ltd. also reported that it was recovering gold in the tailings at a retreatment project opened in May at Kirkland Lake. The Golden Rose Mine of Noramco Mining Corp. was closed in 1988 until higher grade reserves could be located. The gold boom that started with the 1981 discovery and subsequent development and opening of three large mines at Hemlo, Ontario, continued in 1988; three Hemlo mines, the Golden Giant, Page-Williams, and David Bell, are among the largest gold mines in Canada.

In Quebec, Canada's second largest gold-producing Province, Rouyn Mining Resources Inc. and Lac Minerals opened the Francoeur gold mine; annual production was expected to be about 44,000 ounces. Lac Minerals was also a 50% owner of the Doyon Mine near Cadillac, Quebec's largest gold mine, which has an annual production of about 260,000 ounces. Two mines, Lac Minerals' Bousquet No. 2 Mine at Cadillac and Augmitto Explorations Ltd.'s Beauchastel gold project near Rouyn, were under development and were expected to open during 1989.

Other Canadian gold mines opened during 1988 included Skyline Exploration Ltd.'s Johnny Mountain Mine near Iskut River, British Columbia; Treminco Resources Ltd.'s Ptarmigan Mine near Yellow Knife in the Northwest Territories; and the Jolu Mine in Saskatchewan Province, jointly owned by Mahogany Mineral Resources Inc. and the Corona Corp. The Murray Brook Mine near New Castle, New Brunswick, was nearing production at yearend. Murray Brook's owners, Northumberland Mines Ltd. and Novagold Corp., expected the new mine to produce about 110,000 ounces of gold and 225,000 ounces of silver per year over a period of 5 years.

Europe

With less than a dozen European nations producing limited quantities of gold, there has been, nevertheless, considerable recent interest in exploring for and developing new sources of production. In mid-1988 Terra Mining AB commissioned its Bjorkdal Mine at Hebberfors near Skelleftea in northern Sweden; high-grade gold concentrates were produced at the mine's 1,100-ton-per-day gravity mill for an estimated annual yield of about 32,000 ounces. Several other Swedish gold-bearing deposits, including the Akerberg and the Pohtohavaare copper-gold properties, were reportedly under development during the year. In March, Glamis Gold Ltd. and BioMet Technology Inc. executed an agreement with Charter Exploraciones S.A., to develop the Salave gold property in Spain's Oviedo Province, 500 miles northwest of Madrid.

Exploration for gold has been under way in several other European nations for a number of years. During 1988, there were reports of exploration activity in Italy, Turkey, Yugoslavia, and elsewhere, including Ireland and Scotland. In Scotland, Ennex International PLC reportedly moved toward a late 1989 startup at its Cononish gold mine under development at Cononish, near Tyndrun.

During the year, the U.S.S.R., estimated to be the world's second largest gold producer, began minting precious metals commemorative coins. In December, the first of a series of annual sets consisting of six precious metal coins, including two gold coins, were introduced to the market at a ceremony in New York, NY. However, due to U.S. trade restrictions on the importation of Soviet gold, the coins will be available only to citizens of countries outside of the United States. The Soviets were also reportedly considering plans to increase the use of various financial instruments linked to gold; reportedly under consideration are bullion-backed loans, futures contracts, and bonds with gold warrants attached.

Oceania

Considerable exploration effort and funding continued to be directed toward the search for and development of gold deposits in the southwestern Pacific nations of Indonesia, Papua New Guinea, the Solomon Islands, Fiji, and New Zealand. The principal targets, as in recent years past, were high-tonnage, low-grade epithermal gold deposits.

In Papua New Guinea, drilling and evaluation proceeded at Lihir Island, east of the island of New Ireland, one of the largest and most exciting discoveries made anywhere in recent years. Data released at yearend indicated gold reserves in excess of 18 million ounces contained in two ore bodies, together known as the Lihir Deposit. The deposit, discovered in August 1982, was owned by Kennecott Niugini, a joint venture between Kennecott Explorations (Aust) Ltd. and Niugini Mining Ltd. In October, the Government of Papua New Guinea announced that before exploration is completed in late 1989, a special lease will be awarded to Kennecott Niugini to develop the mine. Niugini Mining also continued exploration of gold prospects in the nearby Tabar Islands and at its Bullago prospect in the highlands of mainland New Guinea. Elsewhere on the mainland, the Nation's largest gold mine, the OK Tedi copper-gold mine at Mount Fubilan in the Star Mountains continued producing gold bullion and copper-gold concentrates for export. Despite interruptions by labor strikes and an invasion of protesting local tribesmen, Ok Tedi reportedly produced about 381,000 ounces of gold in copper concentrates and 200,000 ounces of raw gold during the year. Placer (P.N.G.) Pty. Ltd. reported that development at its Porgera gold project in the central highlands region had advanced to the development stage, and construction of its Misima Island gold and silver mine in Milne Bay moved toward its scheduled April 1989 startup. At Olipai, south of Wau, City Resources Ltd. continued drilling at its Lakekamu property. City also continued exploration at its Wild Dog Prospect on New Britain Island and at its Wapolu project on Fergusson Island. CRA, owned 49% by RTZ Corp. of the United Kingdom, continued exploration and development at its hard-rock and alluvial deposits at Mount Kare in the highlands, and geological studies and drilling at its Hidden Valley Prospect, near Wau. Byproduct gold production at CRA's 53.6%-held Bougainville copper mine on Bougainville Island, Papua New Guinea's second largest gold mine, amounted to about 462,400 ounces. A record, 99 million tons of gold-bearing copper ore was mined in 1988.

Gold mine production and development continued to expand in Indonesia. Exploration by Freeport Indonesia Inc. at its new Grasberg copper deposit, near its existing Ertsberg copper-gold mine in West Irian, resulted in adding nearly 5.0 million ounces of gold reserves to Freeport's West Irian copper-gold operations. Other principal Indonesian gold producers included state-owned P.T. Aneka Tambang, operator of the Cikotok Mine in West Java; P.T. Lusang Mining, operator of the Lebong Tandai Mine in South Sumatra; and P.T. Ampalit Mas Perdana, which began mining in central Kalimantan during 1988. Several mines were in late stages of development at yearend by various Australian, United States, and other foreign and domestic companies. Steps were taken by the Government of Indonesia during the year to remove illegal unlicensed miners poaching in areas under license to foreign companies. Problems remained however, with those unlicensed miners operating in the more remote areas of the country.

On the island of Viti Levu in Fiji, the Vatukoula Joint Venture, working both surface and underground ore at the Emperor gold mine, produced 77,000 ounces of gold during the fiscal year, compared with 102,000 ounces produced during the previous year. The nearby Tavua Basin Joint Venture, which began mining in 1987, produced 27,000 ounces in the fiscal year.

New Zealand's newest and largest gold mine, the old Martha Hill Mine at Waihi, was reopened as an open pit and began production in May, producing about 34,000 ounces by yearend. The Martha Hill property, owned by Waihi Gold Mining Co. Ltd., was expected to produce at an annual rate of 55,000 ounces over the next 12 to 15 years. BHP Gold Mines (New Zealand) and partner announced plans in late 1988 to proceed with development of their Macraes Flat project near Otago on New Zealand's South Island. The new open pit mine was expected to yield about 32,000 ounces of gold per year when production begins in late 1989. Also on the South Island, L & M Mining Ltd. poured its first gold in June at its Rimu placer project near Hokitika. L & M also operated three placer mines in the Central Otago area, two on the Shotover River and the other on the Kawarau River, for a combined fiscal year production of about 8,100 ounces. Unfortunately, unusual flooding along the Shotover capsized one of the company's floating recovery plants in September, and salvage operations could not be started until January 1989. Production was reportedly not expected to be resumed until April 1989. Many gold holdings throughout New Zealand's historic gold-producing districts were under study during the year.

Exploration for gold, and especially

gold deposits of the epithermal type, was continued in many areas of the South Pacific including the Solomon Islands, the Republic of Palau, on Yap and other islands in the Federated States of Micronesia, and elsewhere.

South Africa, Republic of

A decline in the average grade of ore milled during the year was offset by an increase in the quantity of ore milled. Declining gold prices toward yearend, combined with increased mining costs, forced some higher cost marginal operations to lay off workers, reduce the tonnage of ore processed, and to mine higher grade ores in order to maintain profitability.

Of the 19.9 million ounces of gold produced during the year, 19.2 million ounces was produced by the 33 mines that together represent the membership of the Chamber of Mines of South Africa. The remainder was recovered by small independent gold producers or as a byproduct of other mining sectors. Overall, 69 gold mines and byproduct gold producers and 16 retreatment plants were producing gold in 1988. The total ore milled by Chamber members, including ore milled by producers of byproduct and coproduct uranium, amounted to a record 124.2 million tons, averaging 0.16 ounce of gold per ton; in 1987, 118.7 million tons averaging 0.17 ounce per ton was milled. Working costs for South African gold mines in 1988 averaged $275.69 per ounce and ranged from $135.49 per ounce at the East Driefontein Mine to $577.91 per ounce at East Rand Proprietary.[14] Production by the six major mining groups was as follows, in million ounces: Anglo American Corp. of South Africa Ltd. (AAC). 8.0; Gold Fields of South Africa Ltd. (GFSA), 3.9; General Mining Union Corp. Ltd. (Gencor), 2.8; Rand Mines Ltd., 1.7; Anglovaal Ltd. (AVL) 1.4; and Johannesburg Consolidated Investment Co. Ltd. (JCI), 1.3.

In terms of individual mine output, the largest South African gold mines were, in million ounces, AAC's new Freegold Mine with 3.4, Vaal Reefs North and South lease areas with 2.6, Driefontein Consolidated with 2.0, Western Deeps with 1.3, Hartebeestfontein with 1.0, and Kloof with 0.93.

At AAC's huge Freegold complex, most of the higher grade Basal reef deposit was mined out, and operations were then concentrated on the lower grade Leader Reef. During 1988, Freegold was considering the feasibility of reopening the old Jeanette Mine and sinking a shaft on another nearby property. Gencor's Transvaal mines, as mainly high-cost producers, were under extreme pressure from lower gold prices during the year. In response to rising costs, the company laid off workers and embarked on a drive for higher grade ore, even at the expense of tonnage milled. The outlook was more favorable at several of Gencor's newer mines in the Orange Free State, especially the 5-year-old Beatrix Mine and the developing Oryx Mine, where mining on the Beisa Reef began in October.

Rand Mines, like Gencor's, also reduced tonnage milled to improve grades at several of its marginal operations, while moving ahead with the scheduled joint-venture development of its new Barbrook Mine in the Barberton area of the eastern Transvaal. Construction of its new mill was scheduled for completion in late 1989. In the Orange Free State, JCI's new H. J. Joel Mine, next to Gencor's Beatrix property, began production in midyear, 7 years after the first exploration drill arrived at the site. Joel is the first South African gold mine to utilize entirely trackless mining methods. Trackless mining is expected to result in a significant reduction in labor requirements.

Several small mines were under development or scheduled for reopening by independent gold mining companies. In December, the Knights Gold Mining Co., resumed gold production at its property, 66 years after the last closure. At full capacity, the newly rehabilitated facility will produce about 42,000 ounces of gold per year. The company was also reopening several other old gold mines.

Gold exploration continued at a brisk pace during the year throughout the Transvaal and the Orange Free State with the principal target areas as follows: the relatively unexplored areas of southern Orange Free State; existing goldfields within the State, such as the Bothaville Gap between Klerksdorp and the Orange Free State goldfield; the Transvaal Potchefstroom Gap area between Klerksdorp and Potchefstroom; the Orkney South and Vaal South Leeuddorn areas; the area south of Johannesburg, the so-called South Deep area near the Transvaal's Western Areas gold district; and finally, the Gerhardminnebronne area, southwest of Carletonville.

TECHNOLOGY

The Bureau of Mines issued a report on selective electrowinning as a method for removing the small quantities of mercury contained in many of the gold ores being mined in the western United States.[15] Cyanide leach liquors obtained from processing these ores may contain mercury in addition to the precious and base metals. Processing the leach liquors can result in the presence of mercury vapor in the refinery, creating potential pollution and health hazards. Bureau researchers found that selective electrowinning was a technique that could be used to remove mercury from gold-containing cyanide solutions, and that selection of the cathode material was critical in the electrowinning process.

Tests were performed by the Bureau of Mines on 14 precious metal ores to compare the dissoloution of gold and silver by acidic thiourea solution with that using alkaline cyanide solution.[16] The cyanide solutions at various concentrations extracted more gold than did thiourea from 10 ores and more silver from 4 ores; it was concluded that

TABLE 16

GOLD: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Troy ounces)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina	22,120	28,357	30,350	31,572	31,000
Australia	[3]1,295,963	[4]1,881,491	2,413,842	3,558,954	4,887,000
Bolivia	40,827	[e]30,000	24,531	88,575	[5]157,185
Botswana[e 6]	480	340	675	850	900
Brazil[e 7]	[r]1,980,000	[r]2,320,000	[r]2,170,000	[r]2,690,000	3,220,000
Burkina Faso	22,000	[e]50,000	56,000	[r e]87,000	90,000
Burundi	1,115	829	980	836	1,000
Cameroon	[e]250	215	248	[e]250	250
Canada	2,682,786	2,815,118	[e]3,364,700	3,724,000	[5]4,110,000
Central African Republic	6,953	6,033	[e]6,000	7,181	[5]12,268
Chile	541,064	554,278	576,719	547,655	640,000
China[e]	1,900,000	1,950,000	2,100,000	2,300,000	2,500,000
Colombia	730,670	1,142,385	1,285,878	853,600	[5]933,000
Congo	101	515	[e]500	[e]500	500
Costa Rica	[e]35,000	[8]15,997	[8]11,600	[8]9,645	[5]10,075
Dominican Republic	338,272	328,046	[e]282,990	[e]246,000	[5]186,000
Ecuador	280,000	300,000	317,327	305,432	305,000
El Salvador	285	—	—	—	—
Ethiopia[e]	15,000	15,000	15,000	[5]20,651	20,000
Fiji	48,515	60,707	94,902	95,230	[5]137,380
Finland	28,067	19,130	37,680	[r e]58,000	65,400
France	70,279	[r]68,385	76,582	71,535	70,000
French Guiana	10,127	8,005	10,481	[e]11,000	11,000
Gabon	1,325	1,608	2,000	2,529	2,500
Germany, Federal Republic of[e]	1,500	1,200	1,200	850	500
Ghana	287,000	299,363	287,127	327,958	[5]372,979
Guinea	—	—	—	[9]2,380	10,300
Guyana	11,131	10,323	14,035	21,425	21,000
Honduras	2,784	5,023	2,018	4,222	[5]3,945
Hungary[e]	20,000	20,000	18,000	18,000	18,000
India[10]	65,234	58,771	60,250	59,929	60,000
Indonesia[11]	78,677	[r]84,687	102,820	114,433	146,000
Ivory Coast	—	—	161	218	300
Japan	103,519	170,525	330,515	276,166	[5]235,022
Kenya	600	442	2,339	8,939	5,000
Korea, North[e]	160,000	160,000	160,000	160,000	160,000
Korea, Republic of[10]	79,156	77,258	149,436	244,345	250,000
Liberia[e 12]	10,500	4,900	20,100	15,000	[5]21,753
Madagascar[e]	130	130	130	[5]1,289	[5]2,894
Malaysia	89,527	90,304	87,026	111,673	98,000
Mali	16,075	16,075	19,500	22,500	[5 13]85,000
Mexico	270,998	265,693	250,615	256,822	[5]296,689
Namibia	6,302	6,237	5,916	5,530	5,100
New Zealand	21,605	45,011	[e]46,000	[e]45,000	55,000
Nicaragua	25,316	24,491	28,664	30,486	[5]28,237

See footnotes at end of table.

TABLE 16—Continued

GOLD: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Troy ounces)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Papua New Guinea	[e]835,000	1,186,618	1,127,686	1,069,011	[5]1,225,874
Peru	187,406	212,870	284,373	179,787	[5]163,583
Philippines	827,149	1,062,997	1,296,367	1,048,081	[5]1,134,920
Portugal	6,205	9,259	6,144	10,336	9,000
Romania[e]	65,000	65,000	60,000	60,000	60,000
Rwanda	240	238	208	325	300
Sierra Leone[14]	18,223	19,004	12,000	[e]15,000	13,000
Solomon Islands	2,572	2,100	3,150	[e]4,000	[5]1,511
South Africa, Republic of	21,860,933	21,565,230	20,513,665	19,176,500	[5]19,881,126
Spain	123,330	185,524	167,184	160,996	165,000
Sudan[e]	1,500	1,500	1,600	[5]2,734	2,500
Suriname[e]	[5]322	500	600	700	700
Sweden	141,600	148,900	[e]130,000	[re]130,000	135,000
Taiwan[10]	37,794	30,633	29,270	17,152	[5]7,584
Tanzania	2,680	1,776	2,735	[e]3,000	3,000
U.S.S.R.[e]	8,650,000	8,700,000	8,850,000	8,850,000	9,000,000
United States	2,084,615	2,427,232	3,739,015	4,947,040	[5]6,459,539
Venezuela	[e]50,885	74,180	[e]82,800	124,100	150,000
Yugoslavia	125,130	[e]110,000	115,195	171,941	150,000
Zaire	117,115	63,022	167,827	140,561	140,000
Zambia	12,185	7,909	1,865	11,253	10,000
Zimbabwe	478,307	472,327	477,535	472,937	475,000
Total	**[r]46,929,444**	**[r]49,283,691**	**51,534,056**	**53,033,614**	**58,453,814**

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through June 7, 1989.

[2]Gold is also produced in Botswana, Burma, Cuba, Czechoslovakia, the German Democratic Republic, Norway, Senegal, Thailand, and several other countries. However, available data are insufficient to make reliable output estimates. Poland annually mines and processes copper ore estimated to contain about 1 million troy ounces of gold. Disposition of the gold byproduct is unknown.

[3]Excludes gold in bismuth concentrate.

[4]Excludes gold in gold ore and concentrate from South Australia.

[5]Reported figure.

[6]Only the combined total of gold and silver production is reported, which for this table is estimated to be divided thus: 83.5% gold-16.5% silver (the approximate ratio for combined 1982–83 production). However, for 1987, gold may have been as much as 98% (or 999 troy ounces).

[7]Officially reported figures are as follows, in troy ounces: Major mines: 1984—213,963; 1985—244,249; 1986—300,545; 1987—300,000 (estimated); and 1988—772,000 (estimated). Small mines (garimpos): 1984—982,623; 1985—709,760; 1986—475,059; 1987—500,000 (estimated); and 1988—1,770,000 (estimated).

[8]Gold purchased by Banco Central from placer deposits and mines; actual production estimated to be at least twice this amount.

[9]Excludes undocumented production from small artisanal production.

[10]Refinery output.

[11]Excludes production from so-called people's mines, estimated at 482,000 troy ounces per year during 1986–88, but includes gold recovered as byproduct of copper mining.

[12]These figures are based on gold taxed for export and include gold entering Liberia undocumented from Guinea and Sierra Leone.

[13]Exports; includes production from Kalana Mine (19,000 troy ounces), artisanal production and undocumented gold entering Mali.

[14]Data are based on official exports and do not reflect gold moved through undocumented channels.

thiourea will probably find applications as a leachant for gold only under special conditions.

The effectiveness of activated carbon as a gold adsorbent from a bi(thiourea) gold (I) chloride complex aqueous solution was investigated.[17] The amount of gold recovered was dependent upon several variable factors. The results suggested that the gold complex is adsorbed on the activated carbon without reduction to metallic gold.

Alternative procedures for the recovery of gold from sand dumps, with an emphasis on the use of heap leaching, were presented.[18] It was determined that desliming of the sands and/or agglomeration prior to heap leaching reduced channeling through the heaps and improved gold recovery while lessening reagent consumption. Agitation leaching of the separated slimes fraction enhanced overall recovery.

Laser-enhanced, maskless, selective gold deposition on oxide ceramics with possible applications in electrical contact technology and microelectronics was compared with deposits made without laser treatment. The laser-enchanced deposits were found to have smaller grain structure than those without laser treatment.[19]

Gold panners operating in the streets of Calcutta's jewelry districts reportedly recover minute flakes of gold from water-filled potholes where the gold, swept from nearby goldsmiths shops, has accumulated.[20] Gold thus recovered is sold back to the shops and reportedly earns the panners more than they would make working for the goldsmiths.

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Ounce refers to troy ounce.

[3] Federal Register. Environmental Protection Agency. Ore Mining and Dressing; Point Source Category; Effluent Limitations Guide-lines, Pretreatment Standards, and New Source Performance Standards; Final Rules. V. 53, No. 100, May 24, 1988, pp. 18764–18790.

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[11] Work cited in footnote 8.

[12] O'Connell, R. Annual Review of the World Gold Industry 1989. London Metals Research Unit, Shearson Lehman Hutton Inc., Feb. 1989, p. 73.

[13] Law-West, D. C. Precious Metals—Gold. Can. Min. J., v. 110, No. 3, Mar. 1989, pp. 31–35.

[14] Values have been converted from South African rands (R) to U.S. dollars at the rate of R1.00=US$0.4423 for 1988, as shown in Int. Financial Stat., v. 42, No. 4, Apr. 1989, p. 474.

[15] Sheya, S. A. N., J. H. Maysilles, and R. G. Sandberg. Selective Electrowinning of Mercury From Gold Cyanide Solutions. BuMines RI 9191, 1988, 13 pp.

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[17] Schmidt, R. Adsorption of Gold From Acidic Thiourea Solutions on Activated Carbon. Int. J. Min. Proc., v. 23, No. 3–4, July 1988, pp. 253–264.

[18] Van Staden, P. J., and P. A. Laxen. Process Options for Retreatment of Gold-bearing Material From Sand Dumps. J. So. Afr. Inst. Min. and Met. v. 88, No. 8, Aug. 1988, pp. 257–264.

[19] Khan, H. R., M. Kittel, and C. J. Raub. Laser-Enhanced Deposition of Gold on Oxide Ceramics. Surface Coating Technol., v. 35, No. 1–2, Oct. 1988, pp. 215–216.

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GRAPHITE

By Harold A. Taylor, Jr.[1]

Amorphous graphite was mined domestically in 1988. Domestic graphite supplies, particularly of fine crystalline flake, lagged behind industrial demand, which increased substantially from the previous year. Prices of the major imported graphites generally increased near the end of the year from those of 1987. Production of manufactured graphite and graphite fibers increased by 23% and 33%, respectively.

DOMESTIC DATA COVERAGE

Domestic production data for synthetic graphite are developed by the Bureau of Mines from a voluntary survey of domestic producers. Of the 32 operations polled, 97% responded. This represented 100% of the total production data shown in table 4, which excludes the nonrespondent.

LEGISLATION AND GOVERNMENT PROGRAMS

No acquisitions or disposal of graphite from the strategic and critical materials stockpile occurred in 1988.

The Occupational Safety and Health Administration (OSHA) proposed new limits for graphite dust exposure in the workplace on June 7. The limit for natural graphite was revised from 2.5 milligrams per cubic meter for the respirable fraction of graphite containing less than 1% quartz to the same number simply for respirable dust. The change will simplify monitoring of employee exposures. Synthetic graphite is now included with nuisance dusts. Its limit was separated out of the one for nuisance dusts and dropped from 15 milligrams per cubic meter to 10 milligrams per cubic meter. The final rule may set an even lower limit for synthetic graphite.[2]

DOMESTIC PRODUCTION

United Minerals Co. operated its Townsend, MT, mine in 1988. Output of manufactured graphite increased 23% to about 276,000 short tons, at 30 plants, with a likelihood of some unreported production for in-house use. Production of all kinds of graphite fiber and cloth increased 33% to 2,662 tons.

Union Carbide Corp. continued to operate its Puerto Rican graphite electrode plant in 1988, on an interim basis.

E.I. du Pont de Nemours Co. (Du Pont) began to manufacture pitch-based graphite fiber on an experimental scale at a plant at Chattanooga, TN. The manufacturing process is continuous and readily expandable to a much larger scale. The ultra-high-modulus product will be sold at premium prices. Some of the fiber will be used internally to manufacture composites, which Du Pont will also market.

Amoco Performance Products Inc. announced its intention to build a research center near Atlanta, GA, to work on graphite fiber and composites. Its expansion plans included adding a new 600-ton-capacity polyacrylonitrile-based (PAN) graphite fiber plant by 1990 at the site of its present plants in Greenville, SC.

A requirement that 50% of the PAN-based graphite fiber for defense applications be made from domestic PAN by 1992 was added to the 1988 budget bill for the Department of Defense. Industry had been expecting this requirement

TABLE 1

SALIENT NATURAL GRAPHITE STATISTICS

		1984	1985	1986	1987	1988
United States:						
Production	short tons	W	—	—	—	W
Apparent consumption	do.	W	44,380	35,036	34,871	47,178
Exports	do.	7,096	8,357	7,754	12,897	12,200
Value	thousands	$2,807	$3,125	$3,416	$6,218	$5,815
Imports for consumption	short tons	58,246	52,737	42,790	47,768	59,378
Value	thousands	$14,579	$16,186	$15,758	$17,654	$23,238
World: Production	short tons	r689,087	r669,550	725,704	p728,904	e741,220

e Estimated. p Preliminary. r Revised. W Withheld to avoid disclosing company proprietary data.

TABLE 2

U.S. GOVERNMENT STOCKPILE GOALS AND YEAREND STOCKS OF NATURAL GRAPHITE IN 1988, BY TYPE

(Short tons)

Type	Goal	National stockpile inventory
Madagascar crystalline flake	20,000	17,826
Sri Lanka amorphous lump	6,300	5,444
Crystalline, other than Madagascar and Sri Lanka	2,800	1,933
Nonstockpile-grade, all types	—	932

Source: General Services Administration, Inventory of Stockpile Materials as of Dec. 31, 1988.

and so was able to respond rapidly. Hercules Inc. planned to bring on-stream a large precursor plant in Decatur, AL. BASF Structural Materials Inc. was planning to produce melt-spun PAN precursor by early 1989 in a small plant. The firm will use a new process that is cheaper and makes a product capable of yielding fibers with a noncircular cross section. A much larger plant may follow, consonant with the firm's desire to have a 3,000-ton-per-year graphite fiber capacity by the early 1990's. Amoco Performance Products Inc. was planning a specialized PAN precursor plant to supply raw material for a new very-high-tensile-strength graphite fiber. Courtaulds Grafil Co. was planning to build a precursor plant using the present technology of its British precursor plant.

TABLE 3

PRINCIPAL PRODUCERS OF SYNTHETIC GRAPHITE IN 1988

Company	Plant location	Product[1]
Airco Carbon, a division of Airco, Inc.	Niagara Falls, NY	Anodes, electrodes, crucibles, motor brushes, refractories, unmachined shapes, powder.
Do.	St. Marys, PA	
Akzo-Enka America Inc., Fortafil Fiber Div.	Rockwood, TN	High-modulus Fibers.
Amoco Performance Products	Greenville, SC	Cloth, high-modulus fibers.
Ashland Petroleum Co., Carbon Fibers Div.	Ashland, KY	High-modulus fibers.
BASF Structural Materials Inc.	Rock Hill, SC	High-modulus fibers.
Fiber Materials, Inc.	Biddeford, ME	High-modulus fibers and cloth.
Fiber Technology Corp.	Provo, UT	
BF Goodrich Co., Engineered Systems Div., Super Temp Operation	Santa Fe Springs, CA	Other.
Great Lakes Carbon Corp.		
Do.	Morganton, NC	Anodes, electrodes, motor brushes, unmachined shapes, other, powder.
Do.	Niagara Falls, NY	
Do.	Ozark, AR	
Hercules Inc.	Salt Lake City, UT	High-modulus fibers.
HITCO Materials Group, British Petroleum Co. Ltd.	Gardena, CA	Cloth and high-modulus fibers.
Hysol Grafil Co.	Sacramento, CA	High-modulus fibers.
National Electrical Carbon Co.	Fostoria, OH	Motor brushes, unmachined shapes, cloth.
North American Carbon Inc.	Punxsutawney, PA	Other.
Pfizer Minerals, Pigments & Metals Div.	Easton, PA	Other.
Polycarbon Inc.	North Hollywood, CA	Cloth.
Showa Denko Carbon Inc.	Ridgeville, SC	Electrodes.
Sigri Carbon Corp.	Hickman, KY	Electrodes.
Stackpole Fibers Co. Inc.	Lowell, MA	High-modulus fibers.
The Stackpole Corp. Carbon Div.	St. Marys, PA	Motor brushes, unmachined shapes, powder.
Standard Oil Co., Specialty Graphite Metallics Div.	Sanborn, NY	Motor brushes, unmachined shapes, cloth.
Superior Graphite Co.	Russellville, AR	Anodes, electrodes, and powder.
Do.	Hopkinsville, KY	
Textron Corp., Avco Specialty Materials Div.	Lowell, MA	High-modulus fibers.
The Carbon/Graphite Group Inc.	Niagara Falls, NY	Anodes, electrodes, unmachined shapes, powder, other.
Do.	St. Mary's, PA	
Union Carbide Corp., Carbon Products Div.	Clarksburg, WV	Anodes, electrodes, unmachined shapes, powder, other.
Do.	Clarksville, TN	
Do.	Columbia, TN	
Do.	Yabucoa, PR	

[1] Cloth includes low-modulus fibers; motor brushes include machined shapes, crucibles include vessels.

TABLE 4

U.S. PRODUCTION OF SYNTHETIC GRAPHITE, BY USE

Use	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Products:				
Anodes	3,388	$9,431	7,525	$17,399
Cloth and fibers (low-modulus)	255	23,706	263	28,228
Crucibles, vessels, refractories	W	W	W	W
Electric motor brushes and machined shapes	W	W	W	W
Electrodes	153,847	312,907	198,501	359,138
Graphite articles[1]	—	30,084	—	35,656
High-modulus fibers	1,745	84,559	2,399	117,754
Unmachined graphite shapes	8,421	45,699	5,548	33,258
Other	[r]6,545	[r]42,012	7,211	47,881
Total	**174,201**	**548,398**	**221,447**	**639,314**
Synthetic graphite powder and scrap	[r]50,727	[r]26,290	54,481	28,328
Grand total	**[r]224,928**	**[r]574,688**	**275,928**	**667,642**

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1]Includes all items for which no quantity data is available.

TABLE 5

U.S. PRODUCTION OF GRAPHITE FIBERS

Year	Cloth and low-modulus fibers Quantity (short tons)	Cloth and low-modulus fibers Value (thousands)	High-modulus fibers Quantity (short tons)	High-modulus fibers Value (thousands)	Total Quantity (short tons)	Total Value (thousands)
1978	141	$8,720	149	$11,804	290	$20,524
1979	169	10,089	194	13,031	363	23,120
1980	169	11,254	306	17,379	475	28,633
1981	216	15,293	409	21,759	625	37,052
1982	212	17,706	605	30,091	817	47,797
1983	188	14,217	739	33,854	927	48,071
1984	223	17,979	1,160	56,436	1,383	74,415
1985	316	27,235	1,586	84,743	1,902	111,978
1986	164	17,895	1,513	76,622	1,677	94,517
1987	255	23,706	1,745	84,559	2,000	108,265
1988	263	28,228	2,399	117,754	2,662	145,982

BOC Group Inc. sold its Airco Carbon Div., thus abandoning its place in the domestic graphite electrode and synthetic graphite industry. The firm sold its 27,000-ton-capacity Ridgeville, SC, electrode plant to Showa Denko KK (Japan) for $79.5 million, including product inventories. The New York and Pennsylvania graphite plants and the Sea Drift needle coke facility in Texas were sold to a consortium of present management for $152 million.

A review examined the relationship of domestic raw material supply to the level of imports for natural graphite and graphite electrodes. A deposit-by-deposit examination of domestic natural graphite supplies demonstrated the lack of abundant, cheap, easy-to-mine graphite. The principal raw material for graphite electrodes, petroleum coke, was found to be readily available domestically and likely to continue to be so. Good raw materials availability has helped encourage a sizeable domestic electrode industry. Government policy options for dealing with the import dependency resulting from lack of domestic raw materials were discussed.[3]

CONSUMPTION AND USES

Reported consumption of natural graphite increased 9% to about 35,100 tons. The three major uses of natural graphite were refractories, brake linings, and foundries, which together accounted for 53% of reported consumption.

PRICES

Natural graphite prices are often negotiated between the buyer and seller and are based on purity and other criteria. Therefore, published price quotations such as those in Industrial Minerals are given as a range of prices. Another source of information for graphite prices is the average customs

TABLE 6

U.S. CONSUMPTION OF NATURAL GRAPHITE, BY USE

Use	Crystalline		Amorphous[1]		Total[2]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1987:						
Batteries	W	W	W	W	1,102	$1,702
Brake linings	1,627	$1,408	2,643	$2,745	4,270	4,153
Carbon products[3]	361	868	219	270	580	1,138
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	1,506	1,411
Foundries[4]	436	281	4,345	1,321	4,781	1,602
Lubricants[5]	805	789	3,606	2,296	4,411	3,085
Pencils	1,857	2,047	271	164	2,129	2,211
Powdered metals	461	848	121	190	582	1,038
Refractories	W	W	W	W	8,300	3,682
Rubber	130	152	279	141	409	293
Steelmaking	167	111	1,369	538	1,536	649
Other[6]	73	163	2,487	2,750	2,560	2,913
Withheld uses	6,559	5,828	4,348	967	—	—
Total[2]	**12,475**	**12,494**	**19,690**	**11,383**	**32,165**	**23,876**
1988:						
Batteries	W	W	W	W	886	1,340
Brake linings	1,960	1,666	3,656	3,389	5,616	5,055
Carbon products[3]	349	879	256	374	605	1,253
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	1,809	1,818
Foundries[4]	513	283	4,307	1,247	4,820	1,530
Lubricants[5]	1,232	1,395	3,203	1,623	4,435	3,018
Pencils	1,666	1,746	334	174	2,000	1,920
Powdered metals	1,598	1,472	55	84	1,653	1,556
Refractories	W	W	W	W	8,137	4,352
Rubber	105	128	373	324	478	452
Steelmaking	207	116	1,271	1,405	1,478	1,521
Other[6]	147	303	3,002	4,177	3,149	4,480
Withheld uses	8,010	6,848	2,822	663	—	—
Total[2]	**15,787**	**14,836**	**19,279**	**13,460**	**35,066**	**28,294**

W Withheld to avoid disclosing company proprietary data; included with "Withheld uses."
[1] Includes mixtures of natural and manufactured graphite.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes bearings and carbon brushes.
[4] Includes foundry facings.
[5] Includes ammunition, packings, and seed coating.
[6] Includes paints and polishes, antiknock and other compounds, soldering and/or welding, electrical and electronic products, mechanical products, magnetic tape, small packages, industrial diamonds and drilling mud.

value per ton of the different imported classes. However, these mainly represent shipments of unprocessed graphite. A third source for natural graphite prices is the amount paid per ton at the point of consumption.

The price for crystalline graphite at the point of consumption—mostly crystalline flake, some crystalline dust, and a little lump graphite—dropped by 6% to $940 per ton. The price for amorphous graphite (including small amounts of amorphous-synthetic graphite mixtures) rose by 21% to $698 per ton.

FOREIGN TRADE

Total exports of natural and artificial graphite increased by 55%. Exports of graphite electrodes totaled 61,284 tons valued at $111.0 million, of which 9,361 tons ($15.7 million) went to Japan, 7,071 tons ($11.9 million) to Venezuela, 7,018 tons ($11.0 million) to Brazil, 6,240 tons ($11.9 million) to the U.S.S.R., 4,322 tons ($8.4 million) to the Federal Republic of Germany, 3,132 tons ($10.7 million) to Canada, and the balance to other destinations.

Imports of natural graphite increased 24% from those of 1987. Imports of natural graphite from Canada, China, Madagascar, Mexico, the Netherlands, and Sri Lanka rose substantially.

Imports of all kinds of graphite fiber, including tows, yarns, textiles, preox fiber, and carbon fiber, but not precursor, were estimated to be 940 tons, worth about $55 million in 1988. Almost all of this was from Japan, but Israel, and the United Kingdom, (transshipment) supplied minor amounts.

WORLD CAPACITY

The data in table 12 are rated annual capacity for mines or plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant or mine, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating facilities and facilities temporarily closed that in the judgment of the author can be brought into production within a short period with minimum capital expenditure.

The highest production or estimated production in the last 5 years were considered to be equal to rated capacity for all countries in table 12.

WORLD REVIEW

World demand for graphite was up significantly in 1988, while supply was probably affected by a drop of unknown size in exports from China. This resulted in sizable price increases being posted towards the end of the year.

A comprehensive benchmark review of natural graphite markets worldwide appeared at the end of the year. Covering major end uses and all major producers, it concluded that certain grades of crystalline flake graphite were in short supply. The increase in prices of flake graphite was expected to continue as a result of a major drop in Chinese graphite exports because of mine closure,

TABLE 7

REPRESENTATIVE YAEREND GRAPHITE PRICES

(Per short ton)

	1987	1988
Industrial Minerals:		
Crystalline large flake, 85% to 90% carbon	$572–$907	$744–$1,179
Crystalline medium flake, 85% to 90% carbon	445– 780	699– 1,016
Crystalline small flake, 80% to 90% carbon	272– 726	490– 816
Powder (200 mesh), 95% to 97% carbon	499– 680	699– 907
Powder (200 mesh), 97% to 99% carbon	680– 907	907– 1,179
Amorphous powder, 80% to 85% carbon	159– 318	200– 400
Custom Value, at foreign ports:		
Flake	712	673
Lump and chip, Sri Lankan	811	765
Amorphous, Mexican	52	48

Source: Industrial Minerals, No. 243, Dec. 1987, p.102, and No. 255, Dec. 1988, p.82.

TABLE 8

INDEXES OF UNIT VALUE OF GRAPHITE FIBER PRODUCED IN THE UNITED STATES[1]

(1973 = 100)

Year	Cloth and low-modulus fibers	High-modulus fibers
1977	124	74
1978	117	66
1979	114	56
1980	125	50
1981	129	46
1982	146	48
1983	129	45
1984	146	43
1985	149	50
1986	176	51
1987	153	50
1988	179	57

[1] The indexes were calculated from company data most representative of the industry and are not based solely on data shown in table 5.

TABLE 9

U.S. EXPORTS OF NATURAL AND ARTIFICIAL GRAPHITE, BY COUNTRY

Country	Natural[1] Quantity (short tons)	Natural[1] Value	Artificial Quantity (short tons)	Artificial Value	Total Quantity (short tons)	Total Value
1987:						
Brazil	12	$83,880	67	$55,762	79	$139,642
Canada	7,672	2,384,595	8,693	523,209	16,365	2,907,804
Germany, Federal Republic of	—	—	1,211	560,386	1,211	560,386
Italy	166	72,201	256	109,363	422	181,564
Japan	1,677	1,875,353	2,795	1,580,820	4,472	3,456,173
Mexico	399	185,097	168	97,456	567	282,553
United Kingdom	1,289	621,874	554	455,489	1,843	1,077,363
Venezuela	194	123,492	1	1,605	195	125,097
Other	1,488	871,453	4,377	2,276,049	5,865	3,147,502
Total	**12,897**	**6,217,945**	**18,122**	**5,660,139**	**31,019**	**11,878,084**
1988:						
Brazil	19	5,524	313	330,791	332	336,315
Canada	6,602	2,093,978	13,415	638,990	20,017	2,732,968
Germany, Federal Republic of	17	3,735	2,234	737,953	2,251	741,688
Italy	22	23,518	184	197,891	206	221,409
Japan	1,653	1,314,394	4,450	3,201,325	6,103	4,515,719
Mexico	1,276	526,572	510	245,695	1,786	772,267
United Kingdom	362	276,731	1,867	1,195,560	2,229	1,472,291
Venezuela	556	382,071	247	140,754	803	522,825
Other	1,693	1,188,192	12,509	7,323,521	14,202	8,511,713
Total	**12,200**	**5,814,715**	**35,729**	**14,012,480**	**47,929**	**19,827,195**

[1] Amorphous, crystalline flake, lump or chip, and natural, not elsewhere classified.

Source: Bureau of the Census.

drought, and increased consumption in China. Simultaneously, flake demand rose somewhat to reflect greater use in refractories caused by high steel production worldwide. The situation will ease shortly when new or expanded crystalline flake capacity comes on-stream, principally in Canada and Norway. Amorphous graphite, on the other hand, has no availability problem and its prices remain relatively stable. Sri Lankan lump graphite exports increased substantially, because problems with worn machinery, equipment failure and hydroelectric power rationing had been overcome.[4]

Canada

In November, Stratmin Inc. of Montreal agreed to lease Asbury Graphite Inc.'s mine and mill in Quebec and to operate them for 15 years. It agreed to produce 10,000 tons per year of concentrate from a new mine and mill to be built at Lac-des-Isles, Quebec. If feasible, it would come on-stream by yearend 1989. The latter property was said to have reserves of 26 million tons averaging at least 7.2% carbon. Asbury Graphite agreed to buy the entire first-year production of 10,000 tons and a minimum of 5,500 tons per year for at least 5 additional years from the leased property. It will also buy the first-year production of 5,500 tons from the Lac-des-Isles operation. Asbury will be the sole purchaser for North America. C. Itoh Ceramics Corp. of Japan agreed to buy 5,500 tons per year of graphite concentrate for 5 years with additional automatic 5-year renewals. It will be sole purchaser for Japan, the Republic of Korea, and Taiwan.

Stewart Lake Resources Ltd. studied the feasibility of developing its graphite property north of Kingston, Ontario. Mazarin Inc. examined graphite prop-

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY

Country	Crystalline flake		Lump or chippy dust		Other natural crude and refined		Amorphous		Total[1]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1986	4,821	$3,122	2,054	$1,914	18,115	$9,796	17,800	$925	[2]42,790	[2]$15,758
1987:										
Austria	—	—	—	—	—	—	82	37	82	37
Belgium-Luxembourg	—	—	—	—	37	13	—	—	37	13
Brazil	1,019	622	—	—	4,763	2,754	—	—	5,782	3,376
Canada	977	554	—	—	1,152	548	—	—	2,129	1,102
China	1,827	963	—	—	9,096	3,222	741	80	11,664	4,265
France	—	—	—	—	108	163	—	—	108	163
Germany, Federal Republic of	22	99	—	—	269	761	—	—	291	860
Hong Kong	—	—	—	—	—	—	59	8	59	8
India	39	15	—	—	348	284	—	—	387	299
Japan	83	295	—	—	403	780	—	—	486	1,075
Madagascar	2,519	2,086	—	—	1,325	975	—	—	3,844	3,061
Mexico	—	—	—	—	1,392	683	19,321	998	20,713	1,682
Netherlands	—	—	—	—	20	28	—	—	20	28
Seychelles	—	—	—	—	20	13	—	—	20	13
South Africa, Republic of	—	—	—	—	176	89	—	—	176	89
Sri Lanka	—	—	1,402	1,137	—	—	—	—	1,402	1,137
Sweden	—	—	—	—	([3])	3	—	—	([3])	3
Switzerland	—	—	—	—	20	33	—	—	20	33
United Kingdom	8	9	—	—	244	262	—	—	252	271
Venezuela	—	—	—	—	44	16	—	—	44	16
Zimbabwe	—	—	—	—	172	84	—	—	172	84
Other	82	39	—	—	([3])	1	—	—	82	40
Total[1]	**6,574**	**4,683**	**1,402**	**1,137**	**19,589**	**10,710**	**20,203**	**1,123**	**47,768**	**17,654**
1988:										
Austria	38	25	—	—	—	—	67	39	105	64
Brazil	2,293	1,607	—	—	2,917	2,064	—	—	5,210	3,671
Canada	2,443	1,533	—	—	2,749	1,188	—	—	5,192	2,721
China	1,307	613	—	—	15,159	6,051	152	25	16,618	6,689
France	20	22	—	—	30	78	—	—	50	100
Germany, Federal Republic of	([3])	1	—	—	273	624	—	—	273	624
Hong Kong	—	—	—	—	—	—	144	53	144	53
India	—	—	—	—	243	207	—	—	243	207
Japan	21	83	—	—	247	635	—	—	268	718
Madagascar	2,882	2,169	—	—	1,468	1,032	—	—	4,350	3,201
Mexico	—	—	—	—	1,771	869	20,717	1,000	22,488	1,869
Netherlands	—	—	—	—	7	65	—	—	7	65

TABLE 10—Continued

U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY

Country	Crystalline flake		Lump or chippy dust		Other natural crude and refined		Amorphous		Total[1]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
South Africa, Republic of	—	—	—	—	375	188	—	—	375	188
Sri Lanka	—	—	3,107	2,376	—	—	—	—	3,107	2,376
Sweden	—	—	—	—	1	1	—	—	1	1
Switzerland	—	—	—	—	131	108	—	—	131	108
Taiwan	—	—	—	—	15	3	—	—	15	3
United Kingdom	88	63	—	—	1	1	—	—	89	64
Zimbabwe	—	—	—	—	699	410	—	—	699	410
Other	1	4	—	—	12	101	—	—	13	105
Total[1]	**9,093**	**6,120**	**3,107**	**2,376**	**26,098**	**13,625**	**21,080**	**1,117**	**59,378**	**23,238**

[1] Data may not add to totals shown because of independent rounding.
[2] Data do not include artificial graphite.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

erties near Fermont, Quebec, north of Sept Isles. Cal Graphite Corp. was waiting for its permit to be approved by the Ontario Ministry of the Environment before proceeding with its proposed operation. Princeton Resources Corp. completed a pilot plant run that yielded 33 tons of crystalline flake graphite. It had tried to interest end-users in its product and had looked for financing.

Japan

According to Government statistics, production of graphite fiber in 1988 was 3,881 tons, and exports were 2,360 tons.

Mexico

The Government of Mexico has decided to sell Grafito de Mexico, S.A., its crystalline flake graphite producer in Oaxaca State. Any foreign bidder would be allowed no more than a 34% stake. Private-sector firms expressed interest in bidding. At yearend, work was under way to double the operation's production capacity. Minerales No Metalicos S.A. studied the feasibility of building an 11,000-ton-per-year-capacity plant near its crystalline flake graphite deposit in Oaxaca. The firm stated that 9.1 million tons of reserves averaging 3.9% to 4.5% carbon had been delineated. The total project was estimated to cost $4.7 million.

Norway

A/S Skaland Grafitverk expected to be back on-stream in 1989 with a new 11,000-ton-per-year capacity plant that will produce a 98% carbon content product.

WORLD RESERVES

The Bureau of Mines evaluated the availability of crystalline flake and high-crystalline (lump) graphite from 4 domestic and 25 foreign deposits. The deposits were found in 11 countries including Brazil, Madagascar, and Mexico. With a 15% discounted-cash-flow rate of return, around 2 million tons of graphite A product would be available at $660 per ton or less. Graphite A was defined as plus-100-mesh crystalline flake. With the same rate of return, more than 1 million tons of graphite B product would be available at $220 per ton or less and around 2 million tons at $360 per ton or less. Graphite B was defined as less-than-100-mesh crystalline flake. No domestic resources were economic at present prices.[5]

The Bureau of Mines and the mineral resources agencies of six countries made a comprehensive inventory of the major world graphite deposits. It included such major producers as Brazil, China, Madagascar, Mexico, and the U.S.S.R., and all types of natural graphite, including amorphous. This study showed that the world's demonstrated economically exploitable resources of crystalline graphite would last more than 50 years at present mining rates. With the demonstrated and inferred reserve bases added in, supplies would last more than a millenium. Demonstrated economically exploitable resources of amorphous graphite would last about 25 years at present mining rates. Including the demon-

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF ARTIFICIAL GRAPHITE AND GRAPHITE ELECTRODES, BY COUNTRY

Country	Artificial graphite		Graphite electrodes	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1987:				
Australia	4	$47	—	—
Austria	—	—	(1)	$6
Belgium	(1)	2	1,192	1,862
Brazil	—	—	130	35
Canada	1,492	767	5,828	7,161
China	75	18	48	71
Denmark	—	—	1	26
Finland	—	—	(1)	2
France	759	2,523	4,124	4,990
Germany, Federal Republic of	967	2,426	2,176	4,296
Italy	239	308	5,557	7,214
Japan	1,017	6,175	26,574	38,623
Korea, Republic of	—	—	139	551
Netherlands	6	47	1,459	1,269
Norway	—	—	(1)	65
Spain	—	—	2,005	2,922
South Africa, Republic of	—	—	(1)	2
Sweden	(1)	3	(1)	135
Switzerland	4,547	9,603	102	159
Taiwan	—	—	213	213
United Kingdom	4	8	986	1,020
Other	61	56	1	3
Total[2]	**9,170**	**21,983**	**50,535**	**70,625**
1988:				
Belgium	—	—	388	676
Brazil	—	—	206	56
Canada	1,750	599	10,931	12,606
China	—	—	284	376
France	848	3,326	1,648	1,983
Germany, Federal Republic of	707	2,997	5,664	7,906
Italy	224	411	5,321	7,477
Japan	1,104	8,418	24,073	33,245
Mexico	—	—	9,072	9,734
Spain	—	—	1,156	1,791
Sweden	—	—	1	75
Switzerland	5,048	9,352	550	905
Taiwan	—	—	258	267
United Kingdom	8	101	2,980	3,919
Other	4	48	234	293
Total[2]	**9,693**	**25,751**	**62,766**	**81,309**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

strated and inferred reserve bases, supplies would last for several millennia.[6]

World reserves, reserve base, and resources are shown in table 14. Crystalline flake graphite reserves are heavily concentrated in China, Madagascar, and the U.S.S.R. all of which are major producers. The crystalline flake reserve base is concentrated in China, Czechoslovakia, and the U.S.S.R., and the inferred reserve base is mostly in Madagascar. Amorphous graphite reserves are concentrated in equal amounts in China, the Republic of Korea, and Mexico, with much smaller amounts found in five other nations. The amorphous graphite reserve base is immense and heavily concentrated in China.

[1] Physical scientist, Branch of Industrial Minerals.

[2] Federal Register. Occupational Safety and Health Administration. Proposed Rules: Graphite, Natural; Graphite, Synthetic. V. 53, No. 109, June 7, 1988, pp. 21074, 21128.

[3] Taylor, H. A., Jr. Impact of Imports on the Graphite Industry. Government's Role in Reducing Dependency on Graphite Imports. American Ceramic Society Bulletin, V. 67, No. 5, May 1988, pp. 862–865.

[4] Russell, A. Graphite Current Shortfalls in Flake Supply. Ind. Miner. (London), No. 255, Dec. 1988, pp. 23–43.

[5] Fogg, C. Y., and E. H. Boyle, Jr. Flake and High-Crystalline Graphite Availability—Market Economy Countries. BuMines IC 9122, 1987, 41 pp.

[6] Krauss, V. H., H. W. Schmidt, H. A. Taylor, Jr., and D. M. Sutphin. International Strategic Minerals Inventory Summary Report-Natural Graphite. U.S. Geological Survey Circular 930-H, 1988, 29 pp.

TABLE 12

WORLD GRAPHITE CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

	Capacity
North America:	
Canada	5
Mexico	43
United States	W
Total	**W**
South America: Brazil[1]	34
Europe:	
Austria	44
Czechoslovakia	65
Germany, Federal Republic of	14
Norway	10
Romania	14
U.S.S.R.	95
Total	**242**
Africa:	
Madagascar	17
Zimbabwe	16
Total	**33**
Asia:	
China[e]	200
India	30
Korea, North[e]	30
Korea, Republic of	120
Sri Lanka	10
Other	10
Total	**400**
World total[2]	**757**

W Withheld.
[e] Estimated.
[1] Does not include product sold directly without benefication.
[2] Excluding U.S. production, which was quite small.

TABLE 13

GRAPHITE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina	[r]17	35	44	220	110
Austria	48,269	33,911	39,867	43,421	44,000
Brazil (marketable)[3]	[r]33,121	[r]30,026	31,511	33,069	33,000
Burma[4]	258	258	796	([5])	—
China[e]	204,000	204,000	204,000	204,000	220,000
Czechoslovakia[e]	55,000	65,000	65,000	61,000	61,000
Germany, Federal Republic of	13,620	14,107	14,587	10,903	8,000
India (mine)[6]	42,975	30,134	42,342	29,612	28,000
Korea, North[e]	28,000	28,000	28,000	28,000	28,000
Korea, Republic of:					
Amorphous	62,014	77,026	106,458	117,404	[7]115,064
Crystalline flake	2,541	1,766	707	924	1,100
Madagascar	15,403	15,400	17,843	14,516	14,000
Mexico:					
Amorphous	43,923	36,892	39,619	40,426	43,600
Crystalline flake	1,855	2,105	2,026	1,970	2,000
Norway	11,097	[e]2,500	—	—	—
Romania[e]	13,700	13,200	13,200	13,200	13,200
Sri Lanka	6,198	8,171	8,216	10,362	10,000
Turkey	[e]5,500	[e]5,500	3,953	12,963	[7]14,146
U.S.S.R.[e]	88,000	90,000	91,000	92,000	92,000
United States	W	—	—	—	W
Zimbabwe	13,596	11,519	16,535	14,914	14,000
Total	**[r]689,087**	**[r]669,550**	**725,704**	**728,904**	**741,220**

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.
[1] Table includes data available through May 17, 1989.
[2] In addition to the countries listed, Namibia may have produced graphite during the period covered by this table, but output is unreported and available general information is inadequate for formulation of reliable estimates of output levels.
[3] Does not include the following quantities sold directly without beneficiation, in short tons: 1984—2,902; 1985—18,105; 1986—21,025; 1987—22,000 (estimated); and 1988—22,000 (estimated).
[4] Data are for fiscal year beginning Apr. 1 of that stated.
[5] Revised to zero.
[6] Indian marketable production is 10%-20% of mine production.
[7] Reported figure.

TABLE 14

WORLD GRAPHITE RESOURCES

(Thousand tons[1] of recoverable flake or crystalline concentrates or of amorphous graphite.)

Country	Type	Reserves	Reserve base[2]	Inferred reserve base
Austria	amorphous	55	50	1,102
Brazil	flake	551	1,102	3,087
Canada	flake	40	299	3,307
China	amorphous	3,307	330,693	
do.	flake	2,756	8,267	4,409
Czechoslovakia	flake	992	2,557	
Germany, Federal Republic of	flake	143	243	661
India	flake	811	811	11,464
Korea, North	amorphous	1,102	12,125	22,046
do.	flake	772	1,102	1,102
Korea, Republic of	amorphous	3,307	22,046	27,558
do.	flake	176	236	683
Madagascar	flake	1,080	1,080	198,416
Mexico	amorphous	3,307	3,307	11,023
do.	flake	117	117	355
Norway	flake	221	221	44
Romania	amorphous	331	331	—
Sri Lanka	crystalline[3]	55	55	165
U.S.S.R.	amorphous	1,102	23,149	595,247
do.	flake	1,984	4,189	5,512
United States	amorphous	—	1,102	22,046
do.[4]	flake	—	828	441
Zimbabwe	flake	661	661	1,323
Other	flake	311	333	992
	Total amorphous	**12,511**	**392,808**	**679,023**
	Total flake	**10,615**	**22,046**	**231,796**
	Total crystalline	**55**	**55**	**165**

[1] This is the exact short ton equivalent of an estimate in metric ton(ne)s.
[2] The reserve base includes reserves; the inferred reserve base does not include the reserve base.
[3] Known as high crystalline or lump, comprising crystalline lump and amorphous lump.
[4] Reserve base is Alabama only, inferred reserve base is Alaska plus New York.

GYPSUM

By Lawrence L. Davis[1]

Demand for gypsum products remained strong in 1988. New public and private housing unit starts, a major indicator of gypsum product demand, decreased 8% to 1.5 million units. The gypsum industry set new record-high levels for crude gypsum mined and shipments of prefabricated wallboard products, but calcined gypsum production decreased slightly.

Sales of gypsum products decreased 5% to 25 million short tons, and value decreased 8% to $2.1 billion. Increased competition caused lower prices for gypsum products.

Imports for consumption of crude gypsum remained about 9.7 million tons. Total value of gypsum product exports increased 12% to $36 million.

DOMESTIC DATA COVERAGE

Domestic production data for gypsum are developed by the Bureau of Mines from a survey of U.S. gypsum operations. Of the 119 operations to which the annual survey request was sent, 98 responded, representing 84% of the total crude gypsum production shown in tables 1 and 2. Nonrespondents were estimated from previous years data.

DOMESTIC PRODUCTION

The United States remained the world's leading producer of gypsum, accounting for 16% of the total world output.

Crude gypsum was mined by 34 companies at 64 mines in 21 States. Production increased slightly. Leading producing States, in descending order, were Oklahoma, Iowa, Michigan, Texas, California, Nevada, and Indiana. These seven States produced more than 1 million tons each and together accounted for 75% of total domestic production. Stocks of crude ore at mines and plants at yearend were 3.1 million tons.

Leading companies were USG Corp., 11 mines; National Gypsum Co., 7 mines; Georgia-Pacific Corp., 7 mines; Domtar Inc., 3 mines; Pacific Coast Building Products Inc. (PABCO) and Weyerhaeuser Co., 1 mine each. These 6 companies, operating 30 mines, produced 71% of the total crude gypsum.

Leading individual mines, in descending order of production, were USG's Plaster City Mine, Imperial County, CA; USG's Sweetwater Mine, Nolan County, TX; USG's Alabaster Mine, Iosco County, MI; National Gypsum's Tawas Mine, Iosco County, MI; USG's Shoals Mine, Martin County, IN; National Gypsum's Sun City Mine, Barber County, KS; USG's Sperry Mine, Des Moines County, IA; Weyerhaeuser's Briar Mine, Howard County, AR; Temple-Inland Forest Products Corp.'s, Fletcher Mine, Comanche County, OK; and National Gypsum's Shoals Mine, Martin County, IN. These 10 mines accounted for 40% of the national total. Average output for the 64 mines increased slightly to 256,000 tons.

Gypsum was calcined by 14 companies at 72 plants in 28 States, principally for the manufacture of gypsum wallboard and plaster. Calcined output decreased slightly in tonnage and value. Leading States, in descending order, were California, Texas, Florida, Iowa, and Nevada. These 5 States, with 25 plants, accounted for 40% of the national output.

Leading companies were USG, 20 plants; National Gypsum, 18 plants; Georgia-Pacific, 10 plants; Domtar, 8 plants; and Celotex, 4 plants. These 5 companies, operating 60 plants, accounted for 85% of the national output.

Leading individual plants were, in descending order of production, USG's Plaster City plant, Imperial County, CA; USG's Jacksonville plant, Duval County, FL; USG's Sweetwater plant, Nolan County, TX; USG's Baltimore plant, Baltimore County, MD; National Gypsum's Tampa plant, Hills-

TABLE 1

SALIENT GYPSUM STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Active mines and plants[1]	113	116	113	109	112
Crude:					
Mined	14,319	14,414	15,403	15,612	16,390
Value	$113,671	$111,785	$99,570	$106,977	$109,205
Imports for consumption	8,904	9,922	9,559	9,717	9,679
Byproduct gypsum sales	780	779	653	688	733
Calcined:					
Produced	15,450	15,982	17,061	17,592	17,274
Value	$320,518	$366,581	$310,353	$321,645	$313,251
Products sold (value)	$2,274,261	$2,418,296	$2,514,432	r$2,278,822	$2,090,786
Exports (value)	$29,852	$26,419	$28,805	$32,061	$36,413
Imports for consumption (value)	$169,667	$155,422	$181,168	$163,581	$158,169
World: Production	r94,559	r95,905	98,362	p99,634	e104,928

e Estimated. p Preliminary. r Revised.

[1] Each mine, calcining plant, or combination mine and plant is counted as one establishment; includes plants that sold byproduct gypsum.

borough County, FL; Weyerhaeuser's Briar plant, Howard County, AR; USG's Stony Point plant, Rockland County, NY; USG's Shoals plant, Martin County, IN; USG's Empire plant, Pershing County, NV; and PABCO's Las Vegas plant, Clark County, NV. These 10 plants accounted for 29% of the national production. Average calcine production for the 72 U.S. plants was 239,900 tons, a slight decrease.

The following companies sold a total of 733,000 tons of byproduct gypsum, valued at $3.7 million, principally for agricultural use, but some for gypsum wallboard manufacturing: General Chemical Corp. and J.R. Simplot Co., both in California; Occidental Petroleum Corp. in Florida; Kemira Inc. in Georgia; SCM Pigments Div. of SCM Corp. in Maryland; Texasgulf Inc. in North Carolina; and Texas Utilities Co. in Texas. Approximately 67% was of nonphosphogypsum origin compared with 55% in 1987. Some byproduct gypsum obtained from SCM Corp.'s SCM Pigments Div.'s plant in Baltimore, MD, was mixed with natural gypsum and commercially used in the manufacture of wallboard at USG's Baltimore plant. Byproduct gypsum from the Texas Utilities powerplant at Tatum, TX, was used exclusively as feed to Windsor Gypsum Co.'s plant.

According to the Gypsum Association, gypsum wallboard plant capacity for producing 1/2-inch regular wallboard decreased 4% to 24.08 billion square feet per year. Total wallboard shipments were 20.66 billion square feet, 86% of capacity.

USG permanently closed its wallboard plant in Philadelphia, PA. Markets previously served by the plant will be shared between USG's Baltimore, MD, and Stony Point, NY, plants. USG continued its $30 million expansion to double capacity at its wallboard plant at Sperry, IA.

Georgia-Pacific began operation of its new gypsum mine and wallboard plant in Las Vegas, NV. Plans for construction of a $20 million wallboard plant in Kentucky, using byproduct gypsum from a nearby powerplant, were put on hold.

Atlantic Gypsum Co. Inc. completed construction of its new wallboard plant at Port Newark, NJ. Production began in October using crude gypsum imported from Spain.

Domtar began construction of its $30 million wallboard plant at Newington, NH. The plant was expected to be operational in 1990, using crude gypsum imported from Domtar's Flat Bay quarry in Nova Scotia. Annual capacity of the plant was to be 540 million square feet.

South Florida Gypsum Co. began construction of a wallboard plant in Miami, FL. The plant, scheduled to begin operating in 1990, will use crude gypsum imported from Spain.

Centex-American Gypsum Co. was building a new wallboard plant outside of Albuquerque, NM. The plant was scheduled for startup in mid-1989.

Western Plains Materials operated three quarries in Oklahoma, mostly for the production of road aggregate. Rock for road construction was also produced by Winn Rock Inc. at its Winnfield Mine in Winn Parish, LA, the only anhydrite mine in the United States. Mines remaining idle during the year included Quad-Honstein Joint Venture's Woodham Mine in Larimer County, CO; E.J. Wilson & Sons' Lidy Hot Springs Mine in Lemhi County, ID; and Cox Enterprises Inc.'s Levan Mine in Sanpete County, UT.

TABLE 2

CRUDE GYPSUM MINED IN THE UNITED STATES, BY STATE

State	1987			1988		
	Active mines	Quantity (thousand short tons)	Value (thousands)	Active mines	Quantity (thousand short tons)	Value (thousands)
Arizona and New Mexico	7	582	$3,001	6	574	$2,956
Arkansas, Kansas, Louisiana	5	1,655	9,462	5	1,654	9,951
California	7	1,468	11,719	7	1,490	11,222
Colorado, Montana, South Dakota, Washington, Wyoming	9	671	5,095	9	676	5,085
Indiana, New York, Ohio, Virginia	5	2,241	14,750	5	2,239	14,067
Iowa	6	1,874	12,887	6	2,047	13,710
Michigan	5	1,977	12,190	5	1,958	11,630
Nevada and Utah	6	1,444	10,285	7	1,637	11,400
Oklahoma	5	1,828	13,336	8	2,173	13,393
Texas	6	1,874	14,254	6	1,943	15,790
Total [1]	**61**	**15,612**	**106,977**	**64**	**16,390**	**109,205**

[1] Data may not add to totals shown because of independent rounding.

TABLE 3

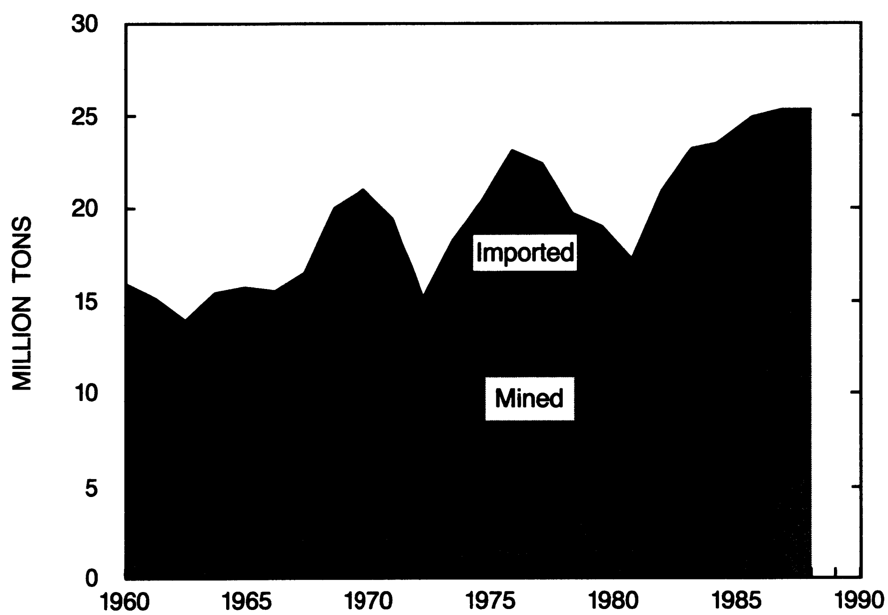
CALCINED GYPSUM PRODUCED IN THE UNITED STATES, BY STATE

State	1987 Active plants	1987 Quantity (thousand short tons)	1987 Value (thousands)	1988 Active plants	1988 Quantity (thousand short tons)	1988 Value (thousands)
Arizona, Colorado, New Mexico, Utah	6	785	$12,130	5	673	$10,001
Arkansas, Louisiana, Oklahoma	7	1,896	32,465	7	1,729	29,371
California	6	1,924	39,364	6	1,950	39,767
Delaware, Maryland, North Carolina, Virginia	6	1,690	31,269	6	1,681	30,538
Florida	3	1,308	27,362	3	1,309	27,001
Georgia	3	753	15,606	3	782	14,070
Illinois, Indiana, Kansas	6	1,529	25,573	6	1,524	25,143
Iowa	5	1,247	20,925	5	1,271	20,979
Massachusetts, New Hampshire, New Jersey, Pennsylvania[1]	5	911	17,959	5	825	16,451
Michigan	4	673	11,438	4	675	11,332
Washington and Wyoming	4	723	14,977	4	729	17,592
Nevada	3	1,071	18,045	4	1,228	20,590
New York	4	1,057	18,946	4	1,101	19,289
Ohio	3	460	10,868	3	485	11,194
Texas	7	1,562	24,718	7	1,312	19,932
Total[2]	**72**	**17,592**	**321,645**	**72**	**17,274**	**313,251**

[1] 1987 only.
[2] Data may not add to totals shown because of independent rounding.

FIGURE 1

SUPPLY OF CRUDE GYPSUM IN THE UNITED STATES



CONSUMPTION AND USES

Apparent consumption, defined as production plus net imports plus industry stock changes, of crude gypsum, including byproduct gypsum, increased slightly to 26.7 million tons. Net imports provided 36% of the crude gypsum consumed. Apparent consumption of calcined gypsum decreased 5% to 16.8 million tons.

Yearend stocks of crude gypsum at mines and calcining plants were 3.1 million tons. Of this, 55% was at calcining plants in coastal States.

Of the total gypsum products sold or used, 5.4 million tons, 21%, was uncalcined. Of the total uncalcined, 74% was used for portland cement manufacture and the remainder was used mainly in agriculture. Of the total calcined gypsum, 96% was used for prefabricated products and 4% for industrial and building plasters. Of the prefabricated products, based on surface square feet, 67% was regular wallboard; 22% was fire-resistant type X wallboard; 3% was water- and/or moisture-resistant board; and 3% was 5/16-inch mobile home board. Lath, veneer base, sheathing, predecorated, and other types made up the balance. Of the regular wallboard, 83% was 1/2-inch and 12% was 5/8-inch. In descending order, the leading sales regions for prefabricated products were the South Atlantic, Pacific, East North-Central, and Middle Atlantic. Together they accounted for 68% of the total.

PRICES

On an average value-per-ton basis, crude gypsum decreased slightly to $6.66, calcined gypsum decreased slightly to $18.13, and byproduct gypsum decreased to $5.06, 22% lower than the revised 1987 value of $6.48. The average value of gypsum products sold or used decreased 4% to $82.56 per ton. Prefabricated products were valued at $100.07 per ton, plasters at $124.26 per ton, and uncalcined products at $14.04 per ton.

FOREIGN TRADE

Imports for consumption of crude gypsum, which remained at 9.7 million tons, represented 36% of apparent consumption. Crude gypsum from Canada and Mexico was used mainly to feed wallboard plants in coastal cities. Imports from Spain, the other major source of imported gypsum, were used mostly for portland cement manufacture. Gypsum wallboard imports, principally from Canada, 98%, were 679 million square feet, a decrease of 11%.

TABLE 4

GYPSUM PRODUCTS (MADE FROM DOMESTIC, IMPORTED, AND BYPRODUCT GYPSUM) SOLD OR USED IN THE UNITED STATES, BY USE

(Thousand short tons and thousand dollars)

Use	1987		1988	
	Quantity	Value	Quantity	Value
Uncalcined:				
Portland cement	4,994	53,024	3,987	47,622
Agriculture and miscellaneous[1]	1,330	r23,920	1,388	27,851
Total	**6,324**	**r76,944**	**5,375**	**75,473**
Calcined:				
Plasters	777	95,492	792	98,411
Prefabricated products[2]	19,441	2,106,386	19,155	1,916,901
Total calcined[3]	**20,218**	**2,201,878**	**19,948**	**2,015,313**
Grand total[3]	**26,541**	**r2,278,822**	**25,323**	**2,090,786**

r Revised.
[1] Includes most of 688,000 tons of byproduct gypsum in 1987 and most of 733,000 tons in 1988.
[2] Includes weight of paper, metal, or other materials, and some byproduct gypsum.
[3] Data may not add to totals shown because of independent rounding.

FIGURE 2

SALES OF GYPSUM PRODUCTS, BY USE

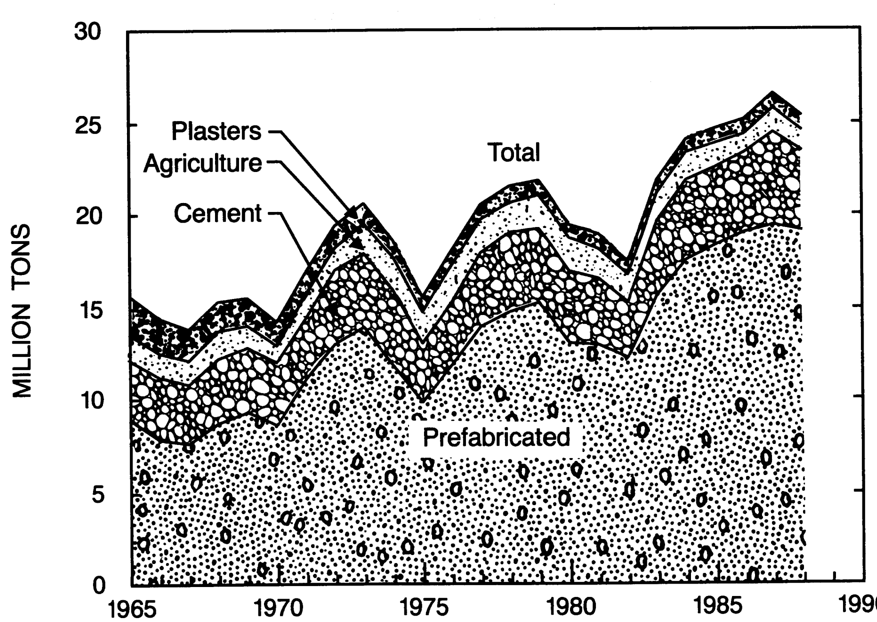


TABLE 5

PREFABRICATED GYPSUM PRODUCTS SOLD OR USED IN THE UNITED STATES

Product	1987 Thousand square feet	1987 Thousand short tons[1]	1987 Value (thousands)	1988 Thousand square feet	1988 Thousand short tons[1]	1988 Value (thousands)
Lath:						
3/8 inch	20,500	16	$3,484	18,447	14	$3,145
1/2 inch	700	1	121	376	([2])	65
Other	2,000	1	328	2,322	2	383
Total	**23,200**	**18**	**3,933**	**21,145**	**16**	**3,593**
Veneer base	479,310	484	53,893	472,127	473	47,931
Sheathing	312,690	300	46,513	311,264	299	43,008
Regular gypsumboard:						
3/8 inch	612,980	462	63,361	438,430	330	41,850
1/2 inch	11,455,627	10,265	1,024,974	11,503,724	10,184	935,825
5/8 inch	1,523,720	1,456	164,776	1,605,138	1,495	163,910
1 inch	85,050	149	20,074	30,597	37	6,495
Other[3]	242,730	154	17,824	309,780	202	32,490
Total[4]	**13,920,107**	**12,486**	**1,291,009**	**13,887,669**	**12,247**	**1,180,570**
Type X gypsumboard	4,488,857	4,945	505,042	4,583,338	4,922	445,572
Predecorated wallboard	127,760	122	42,489	132,008	125	43,582
5/16-inch mobile home board	597,780	466	56,463	604,988	474	55,208
Water/moisture-resistant board	556,930	523	85,310	549,814	504	76,325
Other	97,280	98	21,734	96,486	95	21,112
Grand total[4]	**20,603,914**	**19,441**	**2,106,386**	**20,658,842**	**19,155**	**1,916,901**

[1] Includes weight of paper, metal, or other material.
[2] Less than 1/2 unit.
[3] Includes 1/4-, 7/16-, and 3/4-inch gypsumboard.
[4] Data may not add to totals shown because of independent rounding.

WORLD CAPACITY

The data in table 9 are rated capacity for mines and plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

TABLE 6

U.S. EXPORTS OF GYPSUM AND GYPSUM PRODUCTS

(Thousand short tons and thousand dollars)

Year	Crude, crushed, or calcined: Quantity	Crude, crushed, or calcined: Value	Other manufactures, n.e.c.[1] (value)	Total Value
1986	155	15,481	13,324	28,805
1987	127	15,629	16,432	32,061
1988	271	19,362	17,051	36,413

[1] Includes gypsum or plaster building boards and lath (TSUS 245.7000) and articles, n.s.p.f., of plaster of paris (TSUS 512.4500).

Source: Bureau of the Census.

Domestic capacity of currently operating individual companies were estimated by assuming that the highest production in the last 5 years was 95% of capacity. Currently, idle capacity was added to the total if it operated in the last 2 years. Foreign capacity was estimated by country by assuming that the highest production in the most recent 5-year period was equivalent to that country's capacity.

WORLD REVIEW

Estimated world production of crude gypsum increased 5% to 105 million tons. Total world production figures are probably somewhat low because, in some countries, significant production was consumed captively and not reported. Also, production from small deposits in developing countries was intermittent and often unreported.

Australia

Prima Resources was raising funds to develop its large gypsum deposit at Lake Tay in Western Australia. Initially, at least, the gypsum will be exported to Indonesia.[2]

Canada

Domtar's quarry at Flat Rock, Newfoundland, closed since December 1987, was reactivated in May. The quarry will provide crude gypsum to Domtar's new wallboard plant in New Hampshire.

Louisiana-Pacific Panel Products Ltd., a subsidiary of Louisiana-Pacific Corp. of Portland, OR, announced it would begin construction early in 1989 of a fiber-gypsum board plant on Cape Breton Island, Nova Scotia. Annual capacity was expected to be 240 million square feet of board.[3]

The Gypsum Association in the United States, of which all Canadian gypsum wallboard manufacturers were members, announced that the yearend Canadian wallboard capacity was 3.72 billion square feet, a 4% decrease.

Ireland

North West Exploration PLC completed a review of its reserves at Glangevlin, County Cavan. North West Exploration was negotiating with international mining companies to develop production plans.[4]

United Kingdom

The Central Electric Generating Board (CEGB) applied for permission to add a desulfurization plant to its Drax power station in North Yorkshire. It would be the first flue gas desulfurization plant in the United Kingdom. CEGB expects it would produce over 1 million tons of byproduct gypsum per year.[5]

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Mining Journal (London). V. 310, No. 7965, Apr. 22, 1988, p. 327.

[3] Vagt, G. O. Construction Materials. Can. Min. J., Mar. 1989, p. 78.

[4] Industrial Minerals (London). No. 246, Mar. 1988, pp. 8–9.

[5] Page 13 of work cited in footnote 4.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF GYPSUM AND GYPSUM PRODUCTS

(Thousand short tons and thousand dollars)

Year	Crude		Ground or calcined		Alabaster manufactures[1] (value)	Plaster board[2] (value)	Other manufactures, n.s.p.f.[3] (value)	Total Value
	Quantity	Value	Quantity	Value				
1986	9,559	64,996	3	436	6,817	99,089	9,829	[4] 181,168
1987	9,717	59,171	2	384	6,080	82,220	15,726	163,581
1988	9,679	59,166	2	670	4,877	70,866	22,590	158,169

[1] Includes imports of jet manufactures, which are believed to be negligible.

[2] Includes gypsum or plaster building boards and lath (TSUS 245.7000).

[3] Includes statues and articles, n.s.p.f., of plaster of paris (TSUS 512.4100 and 512.4400) and gypsum cement (TSUS 512.3100 and 512.3500).

[4] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF CRUDE GYPSUM, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1987 Quantity	1987 Value	1988 Quantity	1988 Value
Australia	58	370	23	178
Canada[1]	6,166	38,486	6,229	39,256
China	233	1,234	232	1,235
Dominican Republic	([2])	1	14	113
Germany, Federal Republic of	—	—	12	48
Greece	67	1,254	—	—
Jamaica	23	117	—	—
Mexico	2,022	10,931	2,177	11,170
Morocco	12	86	51	711
Spain	1,135	6,662	936	6,221
Other	([2])	30	4	233
Total[3]	**9,717**	**59,171**	**9,679**	**59,166**

[1] Includes anhydrite.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

TABLE 9

WORLD GYPSUM ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

Country	Rated capacity[e] [1]
North America:	
Canada	9,800
Mexico	3,300
United States	16,500
Other	700
Total	**30,300**
South America:	
Argentina	500
Brazil	1,000
Chile	300
Colombia	400
Venezuela	300
Other	200
Total	**2,700**
Europe:	
France	6,100
Germany, Federal Repulic of	2,800
Italy	1,600
Poland	1,300
Romania	1,900
Spain	6,200
United Kingdom	3,600
Other	4,700
Total	**28,200**
Africa:	
Egypt	1,000
Morocco	500
South Africa, Republic of	600
Other	700
Total	**2,800**
Asia:	
China	7,900
Iran	11,000
Japan	7,200
Thailand	3,400
U.S.S.R.	5,600
Other	4,900
Total	**40,000**
Oceania:	
Australia	2,200
Other	100
Total	**2,300**
World total	**106,300**

[e] Estimated.
[1] Includes capacities of operating plants as well as plants on standby basis.

TABLE 10

GYPSUM: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

	1984	1985	1986	1987[p]	1988[e]
Afghanistan[e]	3	3	3	3	3
Algeria[e]	275	275	303	303	303
Angola[e]	22	22	22	22	22
Argentina	625	508	509	618	550
Australia	2,129	1,923	1,842	1,742	1,760
Austria[2]	816	765	773	732	730
Bolivia[e]	1	1	1	1	1
Brazil	544	617	777	908	[3]802
Bulgaria	433	428	435	337	385
Burma[4]	30	43	43	26	28
Canada (shipments)[2]	8,550	9,311	9,704	9,980	[3]9,394
Chile	185	216	213	258	259
China[e]	5,300	6,300	7,200	7,900	8,900
Colombia	287	276	325	[e]330	330
Cuba[e]	145	145	145	145	145
Cyprus	24	18	33	50	50
Czechoslovakia	928	851	819	850	825
Dominican Republic	[e]230	342	146	65	169
Ecuador	236	349	320	281	289
Egypt	[e]800	927	[e]1,000	1,200	1,200
El Salvador[e]	5	5	5	[r]5	5
Ethiopia[e 5]	[r]8	[r]8	[r]8	[3]2	[3]3
France[2]	5,954	5,827	5,797	5,962	5,900
German Democratic Republic[e]	397	397	375	[r]353	353
Germany, Federal Republic of (marketable)[2]	2,493	2,609	2,090	1,882	1,875
Greece	642	516	[e]720	[e]720	720
Guatemala	28	19	31	26	[3]38
Honduras[e]	25	25	25	25	25
Hungary[e 2]	33	33	33	33	33
India	1,519	1,389	1,707	1,900	[3]1,737
Iran	10,655	9,242	[e]9,300	[e]9,300	9,300
Iraq[e]	330	330	330	390	390
Ireland	358	335	318	313	330
Israel[e]	[3]51	50	50	50	50
Italy	1,393	1,390	1,373	[e]1,360	1,430
Jamaica	199	197	129	194	[3]160
Japan[e 6]	6,700	6,900	7,000	[r]6,600	6,900
Jordan	123	101	77	[e]77	[3]94
Kenya[2]	[e]2	[e]2	12	43	[3]42
Korea, Republic of	558	873	—	—	—
Laos[e]	[3]90	120	140	155	88

See footnotes at end of table.

TABLE 10—Continued.

GYPSUM: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

	1984	1985	1986	1987[p]	1988[e]
Lebanon[e]	6	3	3	3	3
Libya[e]	200	200	200	200	200
Luxembourg[e]	([3] [7])	([7])	([7])	([7])	([7])
Mauritania	[e]1	[e]6	20	22	22
Mexico	[r]4,696	[r]5,074	4,666	5,044	5,000
Mongolia[e]	35	35	35	35	35
Morocco[e]	500	500	500	500	500
Nicaragua	[e]10	9	[e]9	8	8
Niger[e]	3	3	3	—	3
Pakistan	413	451	411	[r] [e]495	520
Paraguay	7	3	3	3	[3]4
Peru	74	32	190	157	154
Philippines[6]	124	[e]124	138	138	141
Poland[e] [2]	1,300	1,070	[r]1,220	[r]1,220	1,200
Portugal	251	267	[e]250	[e]265	276
Romania[e]	1,820	1,790	1,760	[r]1,650	1,760
Saudi Arabia	406	451	411	[e]411	413
Sierra Leone	4	[e]4	[e]4	—	—
South Africa, Republic of	590	505	446	385	[3]426
Spain	5,914	6,090	[e]6,060	[e]6,100	6,060
Sudan[2]	9	7	[e]8	[e]8	8
Switzerland[e]	240	240	220	[r]250	250
Syria	88	177	[e]176	[e]176	176
Taiwan[6]	2	2	2	2	[3]3
Tanzania[e]	13	[3]16	16	16	16
Thailand	1,224	1,404	1,836	3,340	[3]5,014
Tunisia[e]	95	100	110	110	110
Turkey	64	86	141	333	[3]275
U.S.S.R.	[r] [e]4,600	4,655	5,070	5,270	5,300
United Kingdom[2]	3,459	3,515	3,765	[e]3,530	3,900
United States[8]	14,319	14,414	15,403	15,612	[3]16,390
Uruguay[e]	[3]82	110	110	110	110
Venezuela	158	147	[e]275	272	[3]277
Vietnam[e]	30	30	30	30	30
Yemen Arab Republic	27	[e]27	58	[e]58	66
Yugoslavia[e]	[3]669	670	680	[r]640	660
Total	**[r]94,559**	**[r]95,905**	**98,362**	**99,634**	**104,928**

[e]Estimated [p]Preliminary. [r]Revised.

[1] Table includes data available through July 5, 1989.

[2] Includes anhydrite.

[3] Reported figure.

[4] Data are for years beginning Apr. 1 of that stated.

[5] Reported in cubic meters and estimated at 2.0 short tons per cubic meter.

[6] Includes byproduct gypsum. (In the case of Japan, byproduct gypsum was virtually all gypsum consumed during 1984–88.)

[7] Less than 1/2 unit.

[8] Excludes byproduct gypsum.

HELIUM

By William D. Leachman[1]

Grade-A helium (99.995% or better) sales volume in the United States by private industry and the Bureau of Mines was 1,911 million cubic feet (MMcf) in 1988.[2] Grade-A helium exports by private producers were 663 MMcf, for total sales of 2,574 MMcf of U.S. helium. The price of Grade-A helium, f.o.b. plant, was about $37.50 per thousand cubic feet (Mcf) for both the Bureau and private industry. The Bureau price for bulk liquid helium was $45.00 per Mcf with additional costs for container services and rent. The liquid helium price of private industry was also about $45.00 per Mcf with some producers posting surcharges to this price.

DOMESTIC DATA COVERAGE

Domestic production data for helium are developed by the Bureau of Mines from records of its own operations as well as the "High-Purity Helium" survey, a single, voluntary canvass of private U.S. operations. Of the seven operations to which a survey request was sent, all responded, and those data plus data from the Bureau's operations represent 100% of the total production shown in table 2.

LEGISLATION AND GOVERNMENT PROGRAMS

The Government's program for storage of private crude helium in the Government's helium storage facilities at the Cliffside Field near Amarillo, TX, once again was vital in supplying helium for the private helium market. Excess helium production from private industry was obtained from natural gas supplying fuel markets in the winter and was stored by the Government under contract. This privately owned crude helium is returned to the owners for purification as needed to provide for private industry demand. Privatization of all the Government's helium program, except the conservation storage operation, is currently under consideration.

DOMESTIC PRODUCTION

In 1988, 12 privately owned domestic helium plants were operated by 9 companies. Seven of these and one Bureau of Mines plant extracted helium from natural gas. Both private and Bureau plants use cryogenic extraction processes. The volume of helium recovered from natural gas increased 16% in 1988 because all crude helium production plants remained operational throughout the year. All natural gas processed for helium recovery came from gasfields in Kansas, New Mexico, Oklahoma, Texas, and Wyoming.

Pressure-swing adsorption is used for helium purification at four of the private helium plants and at the Bureau's plant. Cryogenic purification is used by the other producers. The Bureau and all seven private plants that produce Grade-A helium also liquefy helium. The plant operators and locations are Air Products and Chemicals Inc., Hansford County, TX; Navajo Refined Helium Co., Shiprock, NM; Kansas Refined Helium Co., Otis, KS; Exxon Company, U.S.A., Shute Creek, WY; and Union Carbide Corp., Linde Div., Bushton, Elkhart, and Ulysses, KS. Linde's helium plant at Ulysses, KS, which was shut down for modification in 1987, was reactivated in 1988. This resulted in the suspension of operations at Linde's Elkhart plant in 1988 and the "mothballing" of its helium purification equipment.

TABLE 1

OWNERSHIP AND LOCATION OF HELIUM EXTRACTION PLANTS IN THE UNITED STATES IN 1988

Category and owner or operator	Location	Product purity
Government-owned:		
Bureau of Mines	Masterson, TX	Crude and Grade-A helium.[1]
Private industry:		
Air Products and Chemicals Inc.	Hansford County, TX	Grade-A helium.[1]
OXY Cities Service Cryogenics Inc.	Scott City, KS	Crude helium.[2]
OXY Cities Service Helex Inc.	Ulysses, KS	Crude helium.
Exxon Co. U.S.A.	Shute Creek, WY	Grade-A helium.[1]
Kansas Refined Helium Co.	Otis, KS	Do.
Navajo Refined Helium Co.	Shiprock, NM	Do.
Enron Helium Co.	Bushton, KS	Crude helium.
Phillips Petroleum Co.	Dumas, TX	Do.
Do.	Hansford County, TX	Do.
Union Carbide Corp.,		
Linde Div.	Bushton, KS	Grade-A helium.[1]
Do.	Elkhart, KS	Deactivated.
Do.	Ulysses, KS	Grade-A helium.[1]

[1] Including liquefaction.
[2] Output is piped to Ulysses, KS, for purification.

TABLE 2

HELIUM RECOVERY IN THE UNITED STATES[1]

(Thousand cubic feet)

	1984	1985	1986	1987	1988
Crude helium:					
Bureau of Mines Total storage:	**-314,969**	**-411,681**	**-379,827**	**-289,085**	**-359,409**
Private industry:					
Stored by Bureau of Mines	506,092	487,576	431,917	730,360	630,748
Withdrawn	-605,935	-956,462	-980,209	r-697,266	-551,997
Total private industry storage	**-99,843**	**-468,886**	**-548,292**	**r33,094**	**78,751**
Total crude helium	**-414,812**	**-880,567**	**-928,119**	**r-255,991**	**-280,658**
Stored private crude helium withdrawn from storage and purified by the Bureau of Mines for redelivery to industry	-49,057	-5,339	-18,658	-6,765	-11,920
Grade-A Helium:					
Bureau of Mines Sold	294,460	397,446	333,447	266,594	316,954
Private industry Sold	1,342,961	1,485,662	1,607,963	1,963,750	2,256,997
Total sold	**1,637,421**	**1,883,108**	**1,941,410**	**2,230,344**	**2,573,951**
Total stored	**-463,869**	**-885,906**	**-946,777**	**r-262,756**	**-292,578**
Grand total recovery	**1,173,552**	**997,202**	**994,633**	**r1,967,588**	**2,281,373**

r Revised.

[1] Negative numbers denote net withdrawal from the Government underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.

CONSUMPTION AND USES

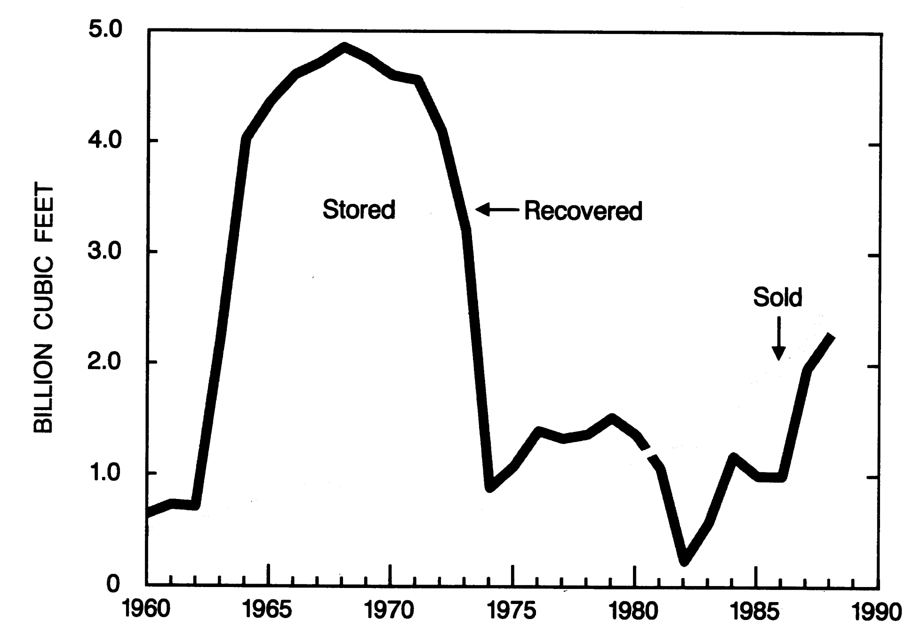
The major domestic end uses of helium were cryogenics, welding, and pressurizing and purging. Minor uses included synthetic breathing mixtures, chromatography, leak detection, lifting gas, heat transfer, and controlled atmospheres. The Pacific and Gulf Coast States were the principal areas of helium consumption.

Bureau sales to Federal agencies and their contractors totaled 317 MMcf in 1988, which is an increase of about 19% when compared with last year's. This increase was due largely to the National Aeronautics and Space Administration's (NASA) resumption of space shuttle flights and associated projects that require large volumes of helium. Sales to the U.S. Department of Defense also increased slightly, but U.S. Department of Energy sales continued to decline.

The Federal agencies purchase their

FIGURE 1

HELIUM RECOVERY IN THE UNITED STATES, 1960-88



major helium requirements from the Bureau of Mines. Direct helium purchases by Defense, NASA, Energy, and the National Weather Service constituted most of the Bureau's Grade-A helium sales. All remaining helium sales to Federal agencies were through Bureau contract distributors, who purchased equivalent volumes of Bureau helium under contracts described in the Code of Federal Regulations (30 CFR 602). Some of the contract distributors also have General Services Administration helium supply contracts. These contracts make relatively small volumes of helium readily available to Federal installations at lower freight charges by using the contractors' existing distribution systems.

STOCKS

The volume of helium stored for future use in the Bureau of Mines helium conservation storage system, which includes the conservation pipeline network and the Cliffside Field near Amarillo, TX, totaled 35.6 billion cubic feet (Bcf) at yearend. The conservation storage system contains crude helium purchased by the Bureau under contract, Bureau helium extracted in excess of sales, and privately owned helium stored under contract. During 1988, 631 MMcf of private helium was delivered to the Bureau's helium conservation storage system and 564 MMcf was withdrawn, for a net increase of 67 MMcf of private helium in storage.

RESOURCES

Domestic measured and indicated helium resources as of January 1, 1988, the latest figures available, are estimated to be 534 Bcf. The total identified helium resources are about 5 Bcf more than reported in 1987. The increase is attributed to the reevaluation

TABLE 3

SUMMARY OF BUREAU OF MINES HELIUM PLANT OPERATIONS

(Thousand cubic feet)

	1986	1987	1988
Grade-A supply:			
Inventory at beginning of period[1]	3,173	17,784	38,899
Helium recovered: Exell plant[2]	366,716	294,474	325,912
Total	**369,889**	**312,258**	**364,811**
Grade-A disposal:			
Sales	333,447	266,594	316,954
Redelivered to private producers	18,658	6,765	11,920
Inventory at end of period[1]	17,784	38,899	35,937
Total	**369,889**	**312,258**	**364,811**

[1] At Amarillo and Exell Helium Plants.
[2] Includes 18,658 Mcf purified for private industry in 1986, 6,765 Mcf in 1987, and 11,920 Mcf in 1988.

FIGURE 2

MAJOR U.S. HELIUM-BEARING NATURAL GASFIELDS

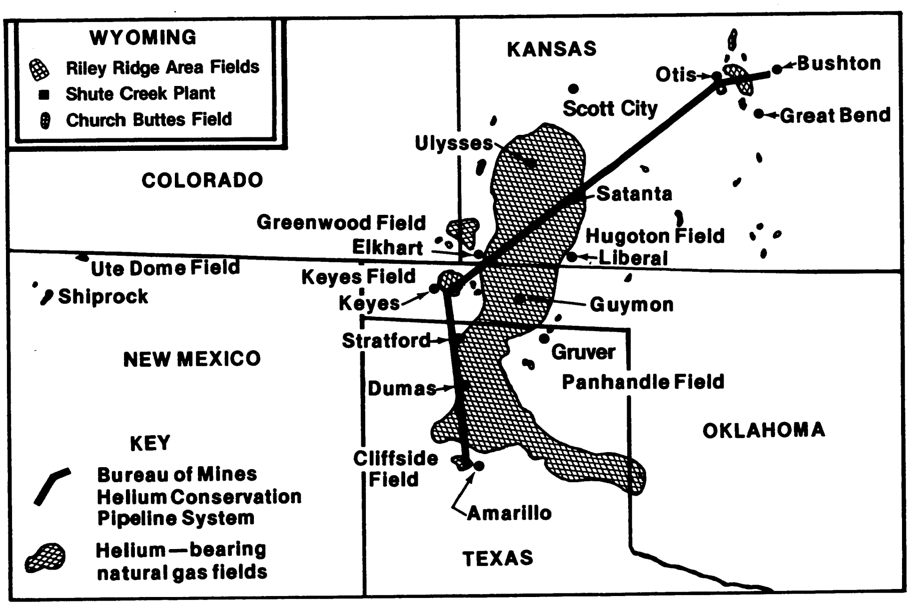


TABLE 4

TOTAL SALES OF GRADE-A HELIUM IN THE UNITED STATES

(Million cubic feet)

Year	Volume
1984	1,245
1985	1,444
1986	1,509
1987	1,736
1988	1,911

of the helium reserves of the Riley Ridge area in Sublette County, WY. The resources included measured reserves and indicated resources estimated at 256 and 29 Bcf, respectively, in natural gas with a minimum helium content of 0.3%. The measured reserves included 36 Bcf stored by the Bureau in the helium conservation storage system. Measured helium resources in natural gas with a helium content of less than 0.3% are estimated to be 46 Bcf. Indicated helium resources in natural gas with a helium content of less than 0.3% are estimated to be 203 Bcf. Approximately 176 Bcf, or 96%, of the domestic helium resources under Federal ownership are in the Riley Ridge area and the Church Buttes Field in Wyoming and in the Cliffside Field in Texas.

Most of the domestic helium resources are in the midcontinent and Rocky Mountain regions of the United States. The measured helium reserves are in approximately 95 gasfields in 12 States. About 91% of these reserves are contained in the Hugoton Field in Kansas, Oklahoma, and Texas; the Keyes Field in Oklahoma; the Cliffside and Panhandle Fields in Texas; and the Riley Ridge area in Wyoming. The Bureau of Mines analyzed a total of 213 natural gas samples from 21 States and 2 foreign countries during 1988 in conjunction with its program to survey and identify possible new sources of helium.

TABLE 5

BUREAU OF MINES SALES OF GRADE-A HELIUM, BY PURCHASER[1]

(Thousand cubic feet)

	1986	1987	1988
Federal agencies:			
Department of Defense	95,444	95,386	96,934
Department of Energy	41,275	27,497	23,088
National Aeronautics and Space Administration	45,684	17,504	49,654
National Weather Service	729	766	841
Other	4,827	7,223	4,557
Total	**187,959**	**148,376**	**175,074**
Federal agency sales supplied by private contract helium distributors[2]	140,071	117,052	140,944
Commercial sales	5,417	1,166	936
Grand total	**333,447**	**266,594**	**316,954**

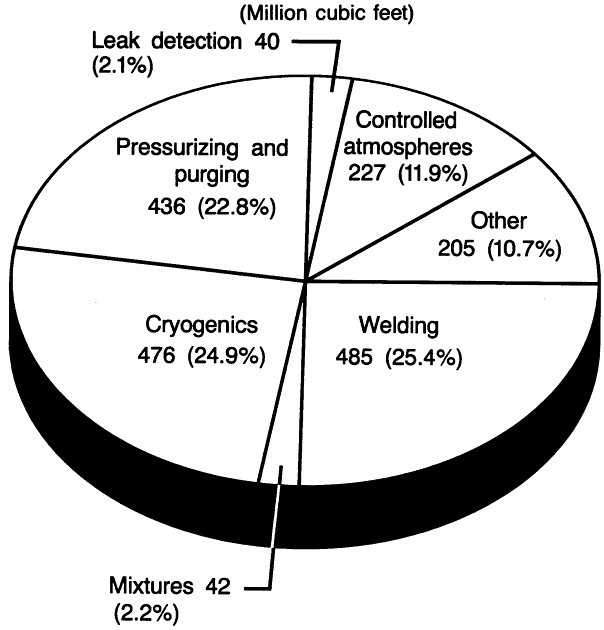
[1] Table identifies Federal purchaser, who might redistribute the helium to another Federal helium user.

[2] Purchased from the Bureau of Mines by commercial firms and redistributed to Federal installations under contract authority of 30 CFR 602.

FIGURE 3

ESTIMATED HELIUM CONSUMPTION BY END USE IN THE UNITED STATES IN 1988

(Million cubic feet)



ESTIMATED TOTAL HELIUM USED

1,911 MILLION CUBIC FEET

TRANSPORTATION

All Grade-A gaseous helium sold by the Bureau was shipped in cylinders, special railway tank cars, or highway tube semitrailers. Liquid helium was shipped in dewars and semitrailers from the Exell helium plant. Private industrial gas distributors shipped helium primarily as a liquid. Most of the private helium was transported in liquid form by semitrailers to distribution centers where some of it was gasified and compressed into trailers and small cylinders for delivery to the end user.

PRICES

The Bureau of Mines price, f.o.b. plant, for Grade-A helium has been maintained at $37.50 per Mcf since October 1, 1982, when it was raised from the $35.00 per Mcf price established in 1961. The price for Grade-A helium from private producers is also about $37.50 per Mcf. The Bureau's trailer-load liquid helium price was $45.00 per Mcf during all of 1988 with additional charges for container services and rent. The typical private industry price for liquid helium was also $45.00 per Mcf gaseous equivalent plus surcharges.

FOREIGN TRADE

Exports of Grade-A helium, all by private industry, increased by 34% in 1988 to 663 MMcf (table 7). Over 51% of the exported helium was shipped to Europe. Belgium-Luxembourg, France, and the United Kingdom collectively, received more than 97% of the European helium imports. About 36% of the U.S. helium exports went to Asia, with Japan taking about 85% of this helium. Other exports were as follows: over 4% to South America; more than 3% to North America; over 2% to Australia/New Zealand; 1% each to Central America, Africa, and the Middle East; and less than 0.5% to the Caribbean. The shipments of large volumes of helium to Western Europe were attributed to helium use in cryogenic research and superconducting equipment. Significant volumes are also being used in breathing mixtures for diving, welding, and as a lifting gas. Although no helium was imported in 1987, import tariffs on helium remained at the 3.7% rate established on January 1, 1987. No further decreases in import tariffs are currently scheduled.

TABLE 6

SUMMARY OF BUREAU OF MINES HELIUM CONSERVATION STORAGE SYSTEM OPERATIONS[1]

(Thousand cubic feet)

	1986	1987	1988
Helium in conservation storage system at beginning of period:			
Stored under Bureau of Mines conservation program	34,784,996	34,405,169	34,116,084
Stored for private producers under contract	2,340,395	1,773,445	1,799,774
Total	**37,125,391**	**36,178,614**	**35,915,858**
Input to system:			
Net deliveries from Bureau of Mines plants[2]	-379,827	-289,085	-359,409
Stored for private producers under contract	431,917	730,360	630,748
Total	**52,090**	**441,275**	**271,339**
Redelivery of helium stored for private producer under contract[2]	-998,867	-704,031	-563,917
Net addition to system[2]	-946,777	-262,756	-292,578
Helium in conservation storage system at end of period:			
Stored under Bureau of Mines conservation program	34,405,169	34,116,084	33,756,675
Stored for private producers under contract	1,773,445	1,799,774	1,866,605
Total	**36,178,614**	**35,915,858**	**35,623,280**

[1] Crude helium is injected into or withdrawn (–) from the Government underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.
[2] Negative numbers denote net withdrawal from storage.

TABLE 7

U.S. EXPORTS OF GRADE-A HELIUM

(Million cubic feet)

Year	Volume
1984	392
1985	439
1986	432
1987	494
1988	663

Source: Bureau of the Census.

WORLD REVIEW

World production of helium, excluding the United States, was estimated to be 250 MMcf, most of which was extracted in Poland and the U.S.S.R. The remainder was produced in small plants in China and India.

TECHNOLOGY

Until recently, all superconductors required liquid helium (−452° F) to reach superconducting temperatures. Current research on superconductors has resulted in the discovery of superconducting materials that operate above liquid nitrogen temperatures (−320° F). These new superconductors have physical limitations such as brittleness and poor current-carrying capacities, which have limited their use in various superconducting applications. If these problems are solved, the new materials could replace liquid helium-cooled superconductors and adversely affect the liquid helium market. Most researchers seem to think it will be at least 5 to 10 years before the new materials affect liquid helium demand.

Meanwhile, technology that uses liquid helium to produce superconducting temperatures continues to be developed and operated. Liquid helium continues to be used at Fermi National Accelerator Laboratory for Tevatron/Tevatron 1, which is the first superconducting particle accelerator. The liquid helium-cooled superconducting magnets used in this accelerator provide an intense and extremely steady magnet field with only a fraction of the energy required by conventional electromagnets. The Tevatron is presently the highest energy particle accelerator in the world (1.6 trillion electron volts). In addition, the Department of Energy has already selected the magnets it proposes to use in the Superconducting Supercollider (SSC). The magnets will be similar to those used at Fermi, which are liquid helium-cooled, because they have been proven and tested in operation. When completed, the SSC will have about 10 times the power of the Tevatron (20 trillion electron volts). The proposed Texas site for the SSC was selected by Energy this year.

Testing of the six liquid helium-cooled electromagnets supplied for the Large Coil Task continued at Oak Ridge National Laboratory. These six magnets each incorporate slightly different designs, which are being tested to determine the best configuration for the confinement of fusion systems for the production of clean nuclear energy. Although these magnets are the largest ever tested (8 tesla, or 160,000 times as strong as the magnetic field of Earth), they are only one-third to one-half the size of those needed for proposed fusion reactors.

Liquid helium use in magnetic resonance imaging (MRI) continues to increase as the medical profession accepts and develops new uses for the equipment. This equipment is providing accurate diagnosis of problems where exploratory surgery has been required previously. Another medical application being developed uses MRI to determine by blood analysis if a patient has any form of cancer.

Lifting gas applications are increasing. Many companies, besides Goodyear, are now using "blimps" for advertising. The U.S. Navy and U.S. Air Force are investigating the use of airships to provide early warning systems to detect low-flying cruise missiles. The Drug Enforcement Agency is proceeding with the installation of radar-equipped blimps along the southern border of the United States to detect drug smugglers. In addition, NASA is now using helium-filled balloons to sample the atmosphere in Antarctica to determine what is depleting the ozone layer that protects Earth from harmful ultraviolet radiation. Similar work is also under way in the Arctic.

Helium is being used to develop several Strategic Defense Initiative (SDI) applications such as the antisatellite (ASAT) rocket, the chemical laser, and the rail gun. The ASAT rocket uses liquid helium-cooled infrared sensors for target location and guidance. Gaseous helium is used in the lasing gas mixture of the chemical laser, and liquid helium is used to cool the tracking telescope. The telescope is used to locate and focus the laser beam on the target. High-pressure gaseous helium provides the initial push that inserts the projectile into the bore of the rail gun at a velocity of about 1,100 miles per hour. Electromagnetic energy applied along the bore accelerates the projectile to a final velocity of about 9,000 miles per hour.

Superconducting magnetic energy storage (SMES) is also being investigated to provide power for laser systems. SMES allows the accumulation and storage of electrical energy over the long term (hours) and discharges it in minutes.

Other evolving technologies that require the unique properties of helium are (1) metastable helium for energy storage, which involves raising helium electrons to an excited energy state and then stabilizing the atom there; (2) fiber-optic production, where an ultrapure atmosphere is required; (3) helium-filled plastic pillows, where low density is required to simulate a precur-

TABLE 8

WORLD GRADE-A HELIUM PRODUCTION CAPACITY, DECEMBER 31, 1988

(Million cubic feet)

	1988
United States	[1]3,000
Rest of World[e]	250
Total[e]	**3,250**

[e]Estimated.
[1]Includes capacity of operating plants as well as plants on standby.

sor wave from a nuclear blast; (4) helium ion tumor treatment, where large inert particles are required; (5) liquid helium-cooled superconducting microswitches, called Josephson junctions, which are much faster than conventional semiconductors and use less power; (6) "Aneutronic" nuclear fusion where nuclear energy is produced by fusion of deuterium and helium-3, which produces few or no neutrons; and (7) new helium-hydrogen breathing mixtures that enable deep-sea divers to reach depths below 1,700 feet.

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[1] Chemical engineer, Helium Field Operations, Amarillo, TX.

[2] All helium volumes herein reported are at 14.7 pounds per square inch absolute and 70° F.

IODINE

By Phyllis A. Lyday[1]

Three producers of crude iodine supplied less than one-half of domestic demand; the remainder was imported. The major world producer, Japan, produced iodine from brines associated with gas production. The second largest producer, Chile, produced iodine as a coproduct of sodium nitrate.

DOMESTIC DATA COVERAGE

Domestic production data for iodine are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the three operations to which a survey request was sent, two responded, representing an estimated 33% of the total production shown in table 5.

LEGISLATION AND GOVERNMENT PROGRAMS

The National Defense Stockpile contained 6.4 million pounds of crude iodine valued at $56 million in inventory at yearend. The stockpile goal remained at 5.8 million pounds. The Defense Logistic Agency (DLA) of the U.S. Department of Defense announced that offers for the purchase of various quantities of iodine to a maximum of 480,000 pounds would be considered during fiscal year 1989. Commencing November 28, 1988, DLA received and considered offers submitted by Billiton Metals Inc. and Elkem Metals Co. to purchase excess iodine as payment materials. The iodine was in exchange or "payment" for upgrading contracts to upgrade ferrochrome and ferromanganese from chrome and manganese ore, respectively. The Annual Materials Plan for fiscal year 1989 provided for a maximum disposal of 480,000 pounds of iodine. The maximum quantity offered for sale in any 1 month was limited to 100,000 pounds. At yearend, 200,000 pounds was disposed of; it was valued at $1.6 million.

On November 18, the President issued Executive Order 12657 that directed the Federal Emergency Management Agency to take over emergency planning, including the storage and distribution of potassium iodide, from State and local officials.

The Food and Drug Administration continued to list Red No. 3 dye, erythrosine, on the provisional list of color additives. Red No. 3 contains 58% iodine by weight and has a grapelike color used in carbonated soft drinks, powdered drinks, gelatin desserts, icings, and pet foods.

DOMESTIC PRODUCTION

IoChem Corp., 2 miles east of Vici, OK, produced iodine by the blowing-out process in a plant with a design capacity of 1 million pounds per year. The company planned to be producing 700,000 pounds per year by mid-1989.[2] The source of iodine was underground brines of the Morrowan Formation of Pennsylvanian age, 10,000 feet beneath the surface. The plant employed 25 people, 20 of whom were hired locally. IoChem marketed the iodine to Schering AG, Federal Republic of Germany, for use in radiopaque media.

North American Brine Resources operated two miniplants at Dover and Hennessey in Kingfisher County, OK. The plants were at oilfield reinjection disposal sites where iodine concentrations ranged up to 1,200 parts per million. Iodine of 95% purity was produced. North American was a joint venture among Beard Oil Co., 40%; Godoe USA Inc., a wholly owned subsidiary of United Resources Industry Co., 50%; and Inorgchem Development Inc., a wholly owned subsidiary of Mitsui & Co. Ltd. (United States), 10%. North American began drilling wells during the year to evaluate the reserves available to build a plant using the blowing-out process. The company expected the new plant to increase capacity from about 110,000 pounds to about 450,000 pounds per year.[3]

Woodward Iodine Corp., a subsidiary of Asahi Glass Co. of Japan, produced iodine from brines using the blowing-out process. Production of iodine was from underground brines at Woodward, OK, and from the Morrowan Formation, 7,500 feet beneath the surface. The iodine concentration averaged 300 parts per million. Plant capacity was reported at 2 million pounds per year of iodine of greater than 99.8% purity.

CONSUMPTION AND USES

Uses of iodine were in animal feed supplements, catalysts, inks and colorants, pharmaceuticals, photographic equipment, sanitary and industrial disinfectants, stabilizers, and other uses. Other uses included production of high-purity metals, motor fuels, iodized salt, and lubricants. Iodine also had application in cloud seeding and radiopaque diagnosis in medicine.

The U.S. International Trade Commission (ITC) publication, "Synthetic Organic Chemicals, 1987" reported that three companies produced roentgenographic contrast media, iohexol, meglumine iothalamate, and sodium diatrizoate containing between 47% and 60% iodine by weight. Mallinckrodt Medical Products Co. received approval from the FDA for Optiray, an ioversol that is a nonionic contrast medium for radiology and cardiology X-ray procedures. The U.S. market for X-ray contrast media was estimated at $500 million and may reach $1 billion by 1993.[4] The new contrast agents cost up to $100 a bottle compared to $6 a bottle for the older media, but are considered five times safer in terms of adverse reactions.[5]

The ITC reported in Synthetic Organic Chemicals, 1987 that Red No. 3 dye was produced by H. Kohnstamm & Co. Inc., which was owned by Warner-Jenkinson Co.

Domestic demand for hydriodic acid was about 400,000 pounds per year, of which approximately 70% was used in sanitizers and disinfectants. Between 10% and 15% of consumption was used in pharmaceuticals.

PRICES

The average declared c.i.f. value for imported crude iodine was $7.92 per pound. The average declared c.i.f. value for imported crude iodine from Japan averaged $7.86 per pound. The average declared c.i.f. value for iodine imported from Chile was $7.91 per pound. Government releases of iodine during the year had an average value of $8.12 per pound. Resublimed iodine, primarily from Japan, had an average declared c.i.f. value of $7.67 per pound.

Quoted yearend U.S prices for iodine and its primary compounds were as are shown in table 2.

TABLE 1

U.S. CONSUMPTION OF CRUDE IODINE, BY PRODUCT

Product	1987[r] Number of plants	1987[r] Consumption (thousand pounds)	1988 Number of plants	1988 Consumption (thousand pounds)
Reported consumption:				
Resublimed iodine	8	207	7	189
Hydriodic acid	([1])	([1])	4	93
Potassium iodide	7	1,546	7	1,956
Sodium iodide	7	136	5	391
Other inorganic compounds	10	1,452	13	2,267
Ethylenediamine dihydroiodide	4	861	5	861
Other organic compounds	13	1,627	10	541
Total	**[2]25**	**5,829**	**[2]29**	**6,298**

[r] Revised.
[1] Included in "Other organic compounds."
[2] Nonadditive total because some plants produce more than one product.

TABLE 2

YEAREND 1988 PUBLISHED PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

	Per pound[1]
Calcium iodate, FCC drums, f.o.b. works	$5.50
Calcium iodide, 50-kilogram drums, f.o.b. works	$10.73–11.63
Iodine, crude, drums	8.62– 9.07
Iodoform, N.F., 300-pound drums, f.o.b. works	24.00
Potassium iodide, U.S.P., drums, 5,000-pound lots, delivered	9.15
Iodine, U.S.P.	17.00
Sodium iodide, U.S.P., crystals, 5,000 pound lots drums, freight equalized	10.15

[1] Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Source: Chemical Marketing Reporter. V. 234, No. 26, Dec. 26, 1988, pp. 26–34.

FOREIGN TRADE

The U.S. Department of the Treasury continued charging duty on iodine of 99.9% or greater purity, which included resublimed iodine and some iodine classified as crude before 1984. The duty for resublimed iodine was 6 cents per pound. The U.S. Government anticipated adoption of the Harmonized Commodity Description and Coding System (Harmonized System) as the basis for its export and import tariff and statistical classification systems. The system is intended for multinational use as a basis for classifying commodities in international trade for tariff, statistical, and transportation purposes. The Harmonized System as proposed includes resublimed and crude iodine under the same code, and the duty rate is free.

WORLD CAPACITY

The data in table 4 are rated annual capacity for plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF CRUDE IODINE, BY TYPE AND COUNTRY

(Thousand pounds and thousand dollars)

Country	1987 Quantity	1987 Value[1]	1988 Quantity	1988 Value[1]
Iodine, crude:				
Belgium	—	—	24	256
Canada	([2])	5	([2])	5
Chile	1,423	9,669	1,748	13,828
Japan	1,119	7,921	994	7,812
United Kingdom	—	—	5	43
Total	**2,542**	**17,595**	**2,771**	**21,944**
Iodide, potassium:				
Belgium	5	16	—	—
Germany, Federal Republic of	50	29	([2])	6
India	76	496	62	478
Italy	—	—	6	11
Japan	2	18	1	10
Sweden	—	—	([2])	3
United Kingdom	2	56	5	138
Total	**135**	**615**	**[3]75**	**646**
Iodine, resublimed:				
Canada	—	—	([2])	2
Finland	([2])	1	([2])	3
Germany, Federal Republic of	—	—	([2])	1
Japan	4,388	30,992	4,346	33,326
Sweden	([2])	1	—	—
Total	**4,388**	**30,994**	**[3]4,347**	**33,332**
Grand total	**7,065**	**49,204**	**[3]7,193**	**55,922**

[1] Declared c.i.f. valuation.
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.
Source: Bureau of the Census.

within a short period of time with minimum capital expenditure.

Mine capacity for iodine is based on rated capacity as reported by the company, by another Government agency, or another published source.

WORLD REVIEW

Chile

Sociedad Química y Minera de Chile (SOQUIMICH), the largest producer of iodine in Chile, became privately owned in February with workers owning 20% of the company's common stock. In 1988, the dividends from these shares equaled more than 22% of the average worker's income. The María Elena and Pedro de Valdivia plants produced iodine, sodium nitrate, potassium nitrate, and sodium sulfate. SOQUIMICH increased iodine production during the year by opening a new plant at Puelma and implementing new technology at the existing two plants.

Hydrocyclone systems to improve the iodine recovery were installed in the María Elena and Pedro de Valdivia iodine plants. At Puelma, a salt solution is allowed to leach iodine from tailings by using a sprinkler system. A $1 million expansion was planned at Puelma to increase production by 450,000 pounds per year. SOQUIMICH also planned to invest in a nitrate and iodine project in the Nebraska, Perdiz, and Pissis mines. The project was planned to produce 300 tons per year of nitrate and 1,100 tons per year of iodine. A feasibility study for a joint-venture project with Ise Chemical Industry Co. Ltd. and the Mitsubishi Corp. of Japan was in development.

Other companies producing iodine during the year included a joint venture between the Sociedad Contractual Minera Lagunas and the Amsterdam Pharmaceutical Co. (ACF) of the Netherlands, ACF Minera, at a plant in the Salar de Lagunas and the Compania de Salitre y Yodo de Chile (COSAYACH) at two small plants at the site of the Former Pinto and Prat Nitrate Companies.

Other plants were expected to be operational in 1989. Compañiá Minera del Alba, a joint venture with Brazil, was constructing a plant at Salar de Bellavista at the site of the former Salinitas Nitrate Co. Merck Pharmaceutical Co. of the Federal Republic of Germany planned a 100,000 pound-per-year-plant at the site of abandoned nitrate tailings near Huara. Approximately 200 Chilean investors planned to produce 100,000 pounds of iodine per year at an abandoned nitrate tailings site of the former San Francisco Nitrate Co. North Lily Mining Co. of the United States and Zurfund International of Canada formed a joint venture to develop the Yolanda Deposit. A group of Swiss and Chilean investors planned a plant at the site of the former Moreno Nitrate Co. In addition, AMAX Inc. of the United States was investigating the possibility of extracting iodine from a deposit near Aguas Blancas. Total production of iodine

TABLE 4

WORLD IODINE ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand pounds)

Country	Rated capacity[2]
North America: United States	2,600
South America: Chile	8,600
Europe: U.S.S.R.	4,400
Asia:	
China	1,000
Indonesia	10
Japan	15,800
Total	**16,810**
World total	**[3]32,400**

[1] Actual capacity limited by brine supply.
[2] Includes capacity at operating plants as well as at plants on standby basis.
[3] Data do not add to total shown because of independent rounding.

TABLE 5

CRUDE IODINE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand pounds)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Chile	5,866	6,658	6,781	6,867	8,600
China[e]	1,000	1,000	1,000	1,000	1,000
Indonesia	55	29	13	18	22
Japan	16,098	15,986	16,290	15,463	16,000
U.S.S.R.[e]	4,400	4,400	4,400	4,400	4,400
United States	W	W	W	W	2,200
Total	**[3]27,419**	**[3]28,073**	**[3]28,484**	**[3]27,748**	**32,222**

[e] Estimated. [p] Preliminary. W Withheld to avoid disclosing company proprietary data.
[1] Table includes data available through June 14, 1989.
[2] In addition to the countries listed, New Zealand also produces elemental iodine, but data are not available and available information is inadequate for formulation of reliable estimates of output levels.
[3] Excludes U.S. production.

was expected to reach 13.6 million pounds during 1989, primarily from SOQUIMICH.[6]

Hungary

Iodine occurred in mineral waters produced from a depth of 6,000 feet at Rabasomjen. The iodine concentration was reported at 24 parts per million. Annual production was estimated at 1,300 pounds.[7]

Iceland

Small amounts of iodine were produced in Iceland as a byproduct of the largest seaweed drying plant in the world.[8]

Indonesia

The only producer of crude iodine was the state-owned pharmaceutical firm, P. T. Kimia Farma at Watudakon near Mojokerto, East Java. Iodine occurs with trace amounts of bromine in brines associated with oil.

TECHNOLOGY

By using a membrane and strip solutions, iodine in low concentrations could be recovered from industrial aqueous solutions. The process was a new separation technique using liquid film pertraction. Iodine is insoluble in the organic membrane, thereby resulting in the complete removal of iodine from the solution.[9]

An efficient method was announced for the preparation of methyl iodide for isotopic labeling used in research and medicine. The process minimized the number of radioactive intermediates, thus simplifying the production process.[10]

Research was performed on the Chemical Oxygen Iodine Laser (COIL) as a high-powered laser in the infrared region and a possible fusion driver.[11]

[1] Physical scientist, Branch of Industrial Minerals.
[2] Chemical Marketing Reporter. Iodine Mart in Growth Mode: Domestic Suppliers Expand. V. 234, No. 20, 1988, pp. 22, 23.
[3] Work cited in footnote 2.
[4] ———. Specialties News Front. V. 235, No. 2, 1989, p. 26.
[5] Wall Street Journal. Doctors Debate Use in Tests of Safer but Costlier Dyes. V. 212, No. 108, 1988, p. B-1.
[6] U.S. Embassy, Santiago, Chile. Chile's Increased Iodine Production Revitalizes Traditional Nitrate Industry. State Dep. Telegram 1533, Apr. 12, 1989, 3 pp.
[7] Roskill Information Services Ltd. (London). The Economics of Iodine. 1989, 88 pp.
[8] Work cited in footnote 7.
[9] Boyadzhiev, L., and E. Bezenshek. Liquid Film Pertraction. Recovery of Iodine From Iodine-Containing Aqueous Solutions. J. of Membrane Sci., v. 37, 1988, pp. 277-285.
[10] Chemical & Engineering News. Meeting Briefs From Dallas. V. 67, No. 17, 1989, p. 42.
[11] Bacis, R., and S. Churassy. Chemical Oxygen-Iodine Laser Mechanisms and High Resolution Spectroscopy Studies. Gas Flow and Chemical Lasers. Proceedings of the Sixth International Symposium. Jerusalem, Sept. 8-12, 1987, pp. 142-155.

IRON ORE

By Peter H. Kuck[1]

About 98% of the demand for iron ore came from the iron and steel industry. In 1988, world production of crude steel reached 780 million metric tons (Mmt),[2] setting a new record and stimulating demand for ore and agglomerates. Pig iron production was also at an alltime high, with blast furnaces in the market economy countries operating at rates not seen since the peak year of 1979. The increased demand for ore gave encouragement to mine operators in the private sector, who had been battered by 8 years of shrinking sales, a worldwide oversupply of sinter fines, and weak prices. Seaborne trade in iron ore continued to recover from the 1986 downswing and reached a new high for the decade. Ocean freight rates, which reversed their long-term decline in early 1987, fluctuated widely, but continued to climb upward.

In the United States, a strengthening of demand for finished steel products caused shipments from domestic mines to jump 19%. U.S. production of pig iron was at its highest level in 7 years. Pellet production at mines in the Lake Superior district was 21% greater than that of 1987 because of the increased blast furnace activity. Utilization of installed pelletizing capacity improved substantially. Two of the six active taconite plants on the Mesabi Range restarted pelletizing lines that had been idle for 6 years. Two of the other four plants set new records for pellet production. On the Marquette Range, $29 million was spent to revitalize the Tilden Mine and to convert it from a hematite to a magnetite operation. Fluxed pellets accounted for one-fourth of total pellet production. The new pellets were more expensive to make, but they reduced operating costs at the blast furnace. Congress passed legislation that restructured the Nation's system of tariffs and, in the process, established an identical eight-category classification series for imports and exports of iron ore. Future tariff schedules must now conform to an international harmonized system of classifying products.

Iron ore companies in both the United States and Canada continued to restructure and recapitalize. The Federal Governments of the two countries concluded a free trade agreement that should further strengthen ties between iron ore and steel operations on opposite sides of the Great Lakes. All-rail shipments of ore and agglomerates in the two countries were the highest ever recorded. USX Corp. spun off its lake shipping, railroad, and barging subsidiaries to Transtar Inc., a new transportation company formed with risk capital, but retained a minority interest in the joint venture. Dofasco Inc. took steps to acquire the Quebec Cartier Mining Co. (QCM) from USX and announced that it would close two smaller pelletizing operations in northern Ontario, Canada. The M. A. Hanna Co. severed its last ties to the U.S. iron ore industry. However, the conglomerate retained its equity in the Iron Ore Co. of Canada (IOC) and still managed the IOC mining complex in Labrador. Hanna decided to focus its resources on producing plastics and advanced materials, ending over a century of involvement in the Lake Superior district. LTV Corp. and the Wheeling-Pittsburgh Steel Corp. still operated under chapter 11 of the Federal Bankruptcy Code, but made significant headway in settling with their partners in three U.S. and Canadian mining ventures.

DOMESTIC DATA COVERAGE

U.S. production data for iron ore are developed by the Bureau of Mines from two separate voluntary surveys of domestic operations. The annual "Iron Ore" survey (1066-A) provides the basic data used in this report. Of 32 addressees to whom the 1066-A form was sent, 31 responded, representing 99.98% of total production shown in tables 1 through 4. Production for nonrespondents to the annual survey can be estimated from monthly surveys (1066-M), from railroad reports, or from reported production levels in prior years. This information may be supplemented by employment data, mine-inspection reports, and information from consumers.

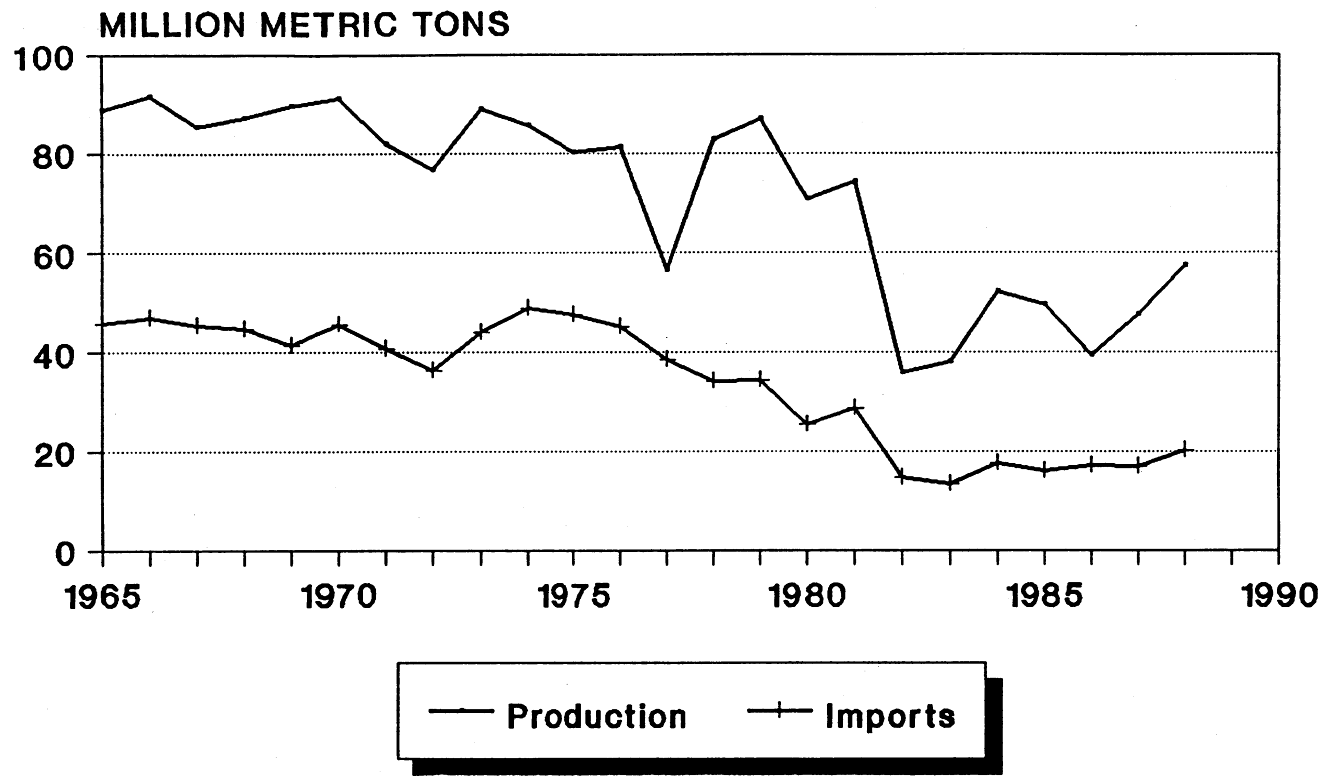
Data on consumption and stocks of iron ore and agglomerates at iron and steel plants were provided by the American Iron Ore Association (AIOA). AIOA also provided data on ore shipments from loading docks on the upper Great Lakes as well as receipts at transfer docks and furnace yards nationwide. The dock and steel plant data were compiled jointly by AIOA and the American Iron and Steel Institute (AISI). The Bureau discontinued its own annual "Blast Furnace and Steel Furnace" survey (1067-A) in 1988. Data on consumption of iron ore for nonsteel end uses were compiled from information gathered from other Bureau surveys.

LEGISLATION AND GOVERNMENT PROGRAMS

On January 2, 1988, the United States and Canada concluded a bilateral free trade agreement that will affect the economic relationship between the two countries for years to come. Under the United States-Canadian Free Trade Agreement (FTA), all bilateral tariffs are to be eliminated within 10 years. The FTA, which will take effect on January 1, 1989, also reduces or eliminates many nontariff barriers and is expected to liberalize trade in numerous areas, including minerals, metals, energy, and industrial investment. The trade pact will have a substantial impact on North American iron ore producers, even though iron ore has entered the two countries duty free for most of this century. The creation of new business opportunities should spur demand for advanced steels and im-

FIGURE 1

U.S. IRON ORE PRODUCTION AND IMPORTS FOR CONSUMPTION



prove the economic viability of the entire iron and steel sector. At the same time, mine operators on both sides of the border are expected to profit from lower costs for energy, transportation, mining and processing equipment, vehicles, and tools.[3]

Congress enacted the Omnibus Trade and Competitiveness Act (Public Law 100–418) on August 23, 1988, to enhance the competitiveness of the Nation's industries and to improve the management of U.S. trade strategy. This comprehensive act, included among other items, provisions modifying U.S. customs laws and tariff schedules. Subtitle B of the new law requires that all tariff schedules after January 1, 1989, conform to the nomenclature of the internationally established Harmonized System—a global system of classifying products for tariff purposes that had been adopted earlier by many major trading countries.

The new law restructured both the import and export classification systems. The new schedule B classification is now based on the organizational framework of the Tariff Schedule of the United States Annotated (TSUSA). That is, equivalent import and export items are assigned the same 10-digit classification code. In the case of iron ore, seven subheadings replaced the two less definitive ones in use since September 1963.

All of the iron ore trade statistics collected by the Bureau of the Census are now being compiled and published in *metric* units. The Bureau of Mines has decided to henceforth publish its iron ore statistics in *metric* units. To convert from metric tons to long tons, multiply by 0.984207. The Bureau has converted all numbers in its Iron Ore tables to metric tons, unless otherwise stated.

The Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, extended an administrative stay on the regulation governing exposure to the nonasbestiform varieties of actinolite, anthophyllite, and tremolite until November 30, 1990, while it continued to study the economic impact of the regulation on mining and construction industries.

The 1986 OSHA regulation established an exposure limit of 0.2 fiber per cubic centimeter of air for the nonasbestiform varieties of the three amphiboles and required producers to label all products containing more than 0.1 weight-percent of the three minerals as a potential carcinogen. Rules governing occupational exposure to asbestos and the asbestos varieties of the three amphiboles are already in effect.[4] Promulgation of the regulations pertaining to the nonasbestiform varieties was not expected to drastically change operations of most iron mines for two reasons. First, OSHA has no jurisdiction over mines and mills. Second, at least 96% of the usable ore shipped in the United States is pelletized. Any trace amphiboles present in the green balls are fused together with the iron minerals and bentonite binder during firing. The regulation, though, could indirectly impact a few producers of concentrates and/or direct-shipping ore. Of more importance would be a decision by either the Environmental Protection Agency or the Mine Safety and Health Administration (MSHA) to follow OSHA's lead. If the OSHA standard for nonasbestiform varieties of amphiboles were to be applied to blasting, mucking, and crushing operations, all nine of the Nation's taconite mines would be impacted. Cummingtonite-grunerite, the iron-rich analogue of anthophyllite, is one of the more abundant silicates in the Precambrian iron formations of North America. Actinolite is also frequently present, but in lesser amounts.

EMPLOYMENT

Statistics on employment and productivity in the U.S. iron ore industry in 1988, shown in table 2, were derived from quarterly employment data supplied by MSHA and from production data derived from Bureau of Mines surveys. Both sets of data were obtained from producers' reports.

The statistics include production workers employed at mines, concentrators, pelletizing plants, and in repair and maintenance shops, but do not include 594 persons engaged in management, research, or office work at mines and plants. Employees engaged in ore preparation, such as sintering, at blast furnace sites are not included. An additional 195 individuals were engaged in the secondary beneficiation of iron ore for heavy media and other nonsteel uses.

Because employment data reported to MSHA are primarily for safety analysis, hours spent by salaried employees in mines or plants may be included by operators in the total number of hours worked at individual mines or plants. This has resulted in the understatement of calculated productivity by 10% to 25% for some operations, but its effect on others is not known. If company reporting practice is consistent, however, comparison of productivity from one year to the next should be reasonably valid.

Average quarterly employment was 21% more than that of 1987, with mine operators calling back laid-off workers to meet increased pellet demand from domestic steel producers. The additional personnel enabled the iron ore industry to boost its output of usable ore by an identical 21%.

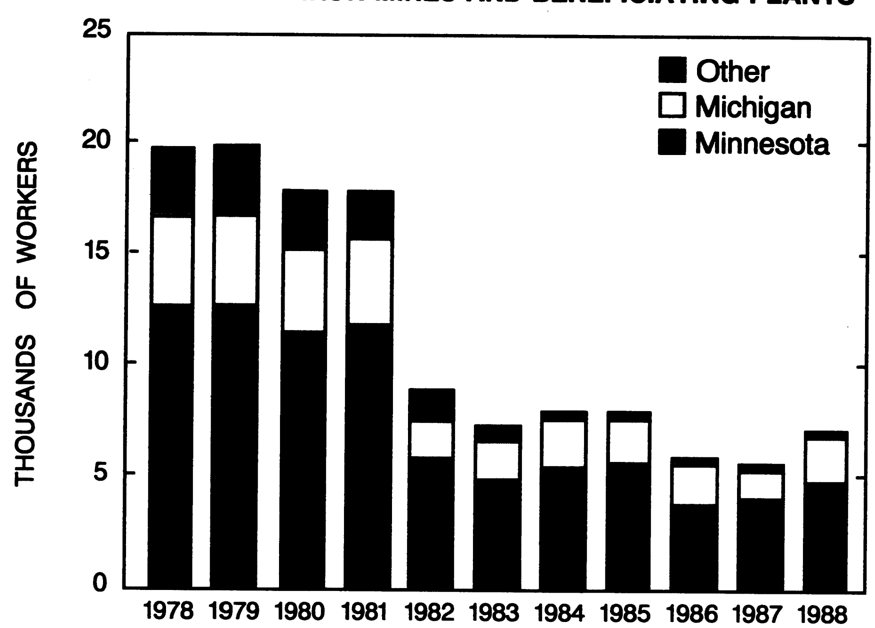
Total hours worked jumped 22% because of the recall and increased level of production. The increase in demand came at a time when at least three operations in the Lake Superior district were about to switch over to fluxed pellet production or make other major technological improvements. The timing of the increase in demand adversely affected productivity by forcing some producers to reallocate workers and slow or temporarily postpone scheduled improvements. Consequently, average productivity for usable ore in the Lake Superior district was about 4% lower than that of 1987. Because the district accounts for the bulk of U.S. output, the average productivity for the entire industry dropped about 3%.

DOMESTIC PRODUCTION

The outlook for the domestic iron ore industry has changed dramatically since the disastrous summer of 1986 when monthly pellet production dropped be-

FIGURE 2

EMPLOYMENT AT IRON MINES AND BENEFICIATING PLANTS



low the 3.5-Mmt level. At that time, USX was shut down by a nationwide work stoppage, and LTV had just filed for reorganization under chapter 11 of the Federal Bankruptcy Code. However, by reducing costs, recapitalizing, adopting new technologies, and improving pellet quality, the iron ore industry was able to extricate itself from a difficult situation that skirted total economic collapse. A strengthening of demand for finished steel products, in the wake of these improvements, caused domestic iron ore shipments to jump 19%, reaching a level unseen since 1981. Two taconite operations set new records for pellet production. Total output of usable ore was equivalent to about 69% of installed production capacity on January 1. This percentage was a considerable improvement over that of 1987 and 1986, when the utilization factors were 55% and 46%, respectively. Secondary factors contributing to the turnaround were the weak U.S. dollar, which made the importation of some steels less attractive and increased exports of goods fabricated from steel; higher prices for quality steel scrap; increased demand for steel worldwide; and the Federal Voluntary Restraint Arrangements program, which reduced steel imports to a little more than 20% of the U.S. market.

Iron ore was produced by 20 open pit mines and 1 underground mine. Thirteen mines produced ore for the iron and steel industry, while the remainder shipped ore mainly to cement plants. One taconite mine and its associated pelletizing plant remained idle throughout the year. Installed production capacity for usable ore at yearend was estimated at 83 Mmt per year, including 79 Mmt of capacity for pellets. Effective production capacity for pellets was at least 12 Mmt less than installed capacity. Only four of the nine active pelletizing plants utilized more than 85% of their installed capacities, despite the upswing in demand.

An average of 3.2 tons of crude ore was mined in 1988 for each ton of usable ore produced. This ratio does not take into account the tonnage of waste rock or overburden removed. The ratio of total materials mined to usable ore produced was probably greater than 5:1. Low-grade ores of the taconite type mined in Michigan and Minnesota accounted for 99% of total crude ore production. U.S. production of pellets totaled 55.79 Mmt, 97% of usable ore output. The average iron content of usable ore produced was 63.4%.

The iron ore industry of the United States and Canada launched a major restructuring in 1986 aimed at lowering operating costs and improving competitiveness. Many of the organizational changes were still being implemented in 1988. A few companies, like Cleveland-Cliffs Inc. (CCI), initiated new restructuring and recapitalization programs during the year. However, the bankruptcy filings of LTV and Wheeling-Pittsburgh made it difficult for their venture partners to refinance and modernize jointly owned operations.

Several steps were taken during 1988 to solve some of the problems created by the Wheeling-Pittsburgh bankruptcy. In late August, the West Virginia steel producer intensified its efforts to reorganize under chapter 11 of the Federal Bankruptcy Code. The company had operated under the protection of the U.S. Bankruptcy Court since April 1985. A major hurdle was overcome when agreements-in-principle were signed with all five North American mining partnerships in which it had partial ownership. The five had filed claims against the steel producer after it had entered chapter 11 and had defaulted on its ore purchase contracts.

IOC was the first partnership to settle with Wheeling-Pittsburgh under the terms of an agreement reached on August 24. The steel producer surrendered its 4.86% interest in the Canadian mining operation and admitted to a general unsecured claim of $46 million. A similar settlement was reached on the same day with the defunct Butler Taconite project of Nashwauk, MN. Again, Wheeling-Pittsburgh agreed to surrender its interest in the mining complex and admit to an unsecured claim of $25 million.

The agreements with the three partnerships managed by CCI were more complicated. Under the terms reached on September 28, Wheeling-Pittsburgh assumed its 10% interest in the Empire Iron Mining Partnership of Palmer, MI, on January 1, 1989, but discontinued its 4% interest in the neighboring Tilden Mining Co. In exchange, CCI was allowed an unsecured creditor claim of $100 million for damages resulting from the steel producer's rejection of its Tilden obligations. Wabush Mines of Labrador and Quebec was allowed a similar claim of $58 million, but two lesser claims filed by Wabush were still being disputed.

LTV Corp. and its subsidiary, LTV Steel Co., still operated under the protection of chapter 11. In May, the parent company submitted a proposed plan of reorganization to its creditor groups and made considerable progress in that part of the settlement negotiations. Emergence from chapter 11 was impeded by pension litigation. In January 1987, the Pension Benefit Guaranty Corp. (PBGC), an agency of the Federal Government, terminated and assumed responsibility for three of the steelworkers' pension plans. However, 8 months later, the PBGC attempted to restore the three plans to LTV. In June 1988, a Federal district court overruled the PBGC's decision and returned the pension plans to the Government agency. The PBGC then appealed the entire matter to the United States Court of Appeals for the Second Circuit, where a hearing was to be held in January 1989.

Minnesota

Minnesota produced 72% of the national output of usable ore in 1988. Production of pellets totaled 40.62 Mmt, equivalent to 75% of installed production capacity of the State's six active taconite plants. Utilization of active pelletizing capacity by the six, though, was 91%. The remainder of the output consisted of hematite concentrates produced by LTV Steel from natural ores. A seventh taconite plant—the E. W. Davis Works at Silver Bay—was left idle throughout the year by the bankruptcy filings of LTV and the Reserve Mining Co.

All of LTV's natural ore production came from its McKinley Extension Mine north of Aurora. In July 1987, Rhude & Fryberger Inc. stopped processing ore at its Rana Mine on the outskirts of Kinney and suspended all shipments 3 months later. The company had already halted operations at its Plummer-Diamond property in 1986. The Pittsburgh Pacific Co. was in the process of being liquidated and shipped only 113 metric tons (mt) of concentrates stockpiled at the Connie Mine in Wuori Township. The two closures left LTV the only active supplier of beneficiated natural ore in the Lake Superior district. Part of the demand for concentrates and direct-shipping ore in 1988 was eventually met by shipments of reclaimed or diverted material from three of the district's taconite operations.

According to officials of LTV Steel, reserves of natural ore at the company's Donora pit will be exhausted by 1993 if mining continues at the present rate of 600,000 to 800,000 mt per year. The 1,200-acre pit is the principal ore body of the McKinley Extension Mine, 4 kilometers (km) north of Aurora. The mine, operated by LTV's Northwest Ore Div. under a lease from USX, shipped 670,000 mt of beneficiated sinter fines and 20,000 mt of 1- by 4-inch coarse ore in 1988.[5] The bulk of the sinter fines contained 54.9% iron (Fe) and 7.2% silica (SiO_2) on a wet basis and went either to LTV's steelworks at Indiana Harbor, IN, or to USX's neighboring steelworks at Gary, IN. The lump ore was being added by LTV and outside customers to their electric arc furnaces to assist in the oxidation of impurities and to serve as a coolant. The Donora pit was reopened by LTV in the spring of 1983 when reserves at the adjacent Stephens pit became depleted. The Stephens pit produced more than 52 Mmt of natural ore between 1903 and 1987, but only 20,000 mt remained at the beginning of 1988. These last few ore pockets were removed during the final cleanup operations. The McKinley Extension had 79 hourly and 20 salaried employees.

Electric power rates for taconite mining operations on the Mesabi Range were reduced by about 4.5% because of a decision reached by the Minnesota Public Utilities Commission on February 17.

National Steel Pellet Co. (NSPC) produced 4.68 Mmt of standard pellets, containing 65.10% Fe, 4.92% SiO_2, and 0.010% phosphorus (P) on a wet basis. Because of improvements in productivity, the Keewatin mining and pelletizing complex had an effective pellet production capacity of 4.8 Mmt. The concentrator, which had 10 grinding circuits, had a higher output of 5.9 Mmt per year. Three-quarters of the production was being railed to Burlington Northern's Allouez terminal at Superior, WI, and then loaded onto vessels for delivery to the Great Lakes steelworks of National Steel Corp. (NSC) in Detroit. The remaining quarter was being hauled in 160-car unit trains to NSC's smaller steelworks at Granite City, IL.

The M.A. Hanna Co.'s decades long role in the U.S. iron ore industry came to an abrupt end on December 31, 1988. At midnight, NSPC assumed managerial control of the Keewatin complex from Hanna. Hanna had been sole manager of the operation since production began in 1967 and even held a 15% interest in the property until 1982 when it sold out to NSC. Hanna will continue to manage the parent company's 1,000-foot ore carrier, the *George A. Stinson*. NSPC reportedly did not renew the Keewatin contract with Hanna in a move to cut costs. The taconite facility employed about 640 people and had an additional 2.8 Mmt per year of obsolete pelletizing capacity, which was written off in 1983.

Hanna had been in the U.S. iron ore industry for at least 90 years, either as an owner or manager. In 1952, Hanna was second only to United States Steel Corp. (USS) as the largest iron ore producer in Minnesota. However, Hanna sustained its first corporate losses in 1982, when the entire U.S. iron ore industry suffered a severe setback. Since then, Hanna successfully diversified into an entirely new field—polymers. Hanna currently has over 80% of its assets in formulated polymers, but still holds a 27% share in IOC.

Hanna continued to operate its wholly owned research center near the former Butler taconite mine at Nashwauk. Hanna and NSPC are involved in a long-term project to produce fluxed pellets for NSC. A 5-week test run was completed in March at Keewatin, using a 1% dolomite-limestone additive and a Peridur binder.[6] The 400,000 mt of fluxed pellets from the test run was shipped to both Detroit and Granite City for blast furnace trials.

LTV Steel Mining Co. (formerly Erie Mining Co.) had its best year since 1981, even though its parent, LTV Corp., was still tied up in chapter 11 proceedings. Pickands Mather & Co., a subsidiary of CCI, continued to manage the 11-Mmt-per-year complex at Hoyt Lakes for LTV. The Hoyt Lakes operation produced 8.03 Mmt of pellets and 211,000 mt of chips in 1988 and shipped 7.26 Mmt of pellets and chips through the port of Taconite Harbor. On a normal day, at least 22 of the 27 shaft furnaces ran in the pelletizing plant.

Several improvement projects were begun during the year at Hoyt Lakes. A \$1.5 million computerized truck and train dispatching system was being installed to improve haulage efficiency. The system should be of considerable help because three to four pits in the area of the pelletizing plant were being mined simultaneously. Another pit was active in Area 8, 32 km to the northeast, between the Dunka River and Birch Lake. Several shovels and haulage trucks were added to the production fleet to take advantage of the new dispatching system. One of the additions was a new Wiseda KL2450, a truck with a carrying capacity of 218 mt—the largest in the Lake Superior district.

Hourly employees at Hoyt Lakes ratified a new 25-month labor contract on February 26 that reduced wages and benefits by $2.19 an hour. However, the 1,170 employees should be able to recover part of the lost income through profit-sharing and stock-option plans that were incorporated into the agreement. In return for the wage and benefit concessions, restrictions were placed on the amount of work that the company could contract out to nonunion workers. LTV Steel Mining was the last of the six active taconite operations on the Mesabi Range to come to terms with the United Steelworkers of America (USWA). The old contract, a master agreement covering all of the steelworkers on the range, expired on July 31, 1986, but was extended for the bargaining period. The new contract, which was approved by a 4-to-1 margin, expires in April 1990. Negotiations were lengthy and difficult because the parent company filed for bankruptcy 2 weeks before the old contract expired and has been under court supervision ever since.

The Hibbing Taconite Co. (Hibtac) produced a record high 8.79 Mmt of acid pellets. All three of the plant's indurating machines were in operation, making pellets that averaged 64.77% Fe, 4.82% SiO_2, and 0.011% P on a wet basis. Natural gas was used to fuel the three Dravo-Lurgi traveling grate systems. The concentrator and pelletizing plant were upgraded in 1979 from 5.5 Mmt to 8.2 Mmt, but never operated above the 6.9 Mmt level until 1987. During the last few years, improvements in the milling part of the operation have enabled the company to increase the effective capacity of the mining complex to 9.2 Mmt per year. The adoption of better blasting techniques and the installation of an automated system to control coarse crusher operations were expected to further improve productivity.

Hibtac's biggest customer was Bethlehem Steel Corp., which owned 70.3% of the joint venture. The remaining equity was divided between CCI, (15.0%), which managed the complex, and Stelco Inc. (14.7%). Bethlehem's part of the production was being railed 170 km on the Burlington Northern to the Allouez Terminal at Superior, WI, where it was loaded onto U.S.-flag vessels for delivery to the steelmaker's C and D blast furnaces at Burns Harbor, IN.

Minntac, the largest iron mine in the United States, produced 8.9 Mmt of standard acid pellets and 3.3 Mmt of fluxed pellets.[7] The output from the complex at Mountain Iron was 56% more than the 7.8 Mmt produced in 1987, but still far short of its installed capacity of almost 19 Mmt. Minntac is owned and operated by the USS steel segment of USX, the largest integrated steel producer in the country.

The beneficiation facilities were switched over from acid to fluxed pellet production in July at a cost of more than $8 million. However, because of improvements in productivity, overall production costs actually have been lowered by 50% since 1982. The new limestone-dolomite fluxed pellet contained 61.54% Fe, 4.05% SiO_2, and 0.014% P on a wet basis. In 1987, a silica flotation circuit was added to the concentrator. This flotation circuit of forty 500-cubic-foot Denver cells became fully operational in 1988 and was largely responsible for USX's success in lowering the silica content of its pellet from 5.20% to 4.05%. The upgrading left the concentrator with 16 grinding lines, one of which was reserved for the 50–50 fluxstone blend and one of which was used to regrind flotation concentrate.[8] Two grinding lines had to be decommissioned to make room for the flotation circuit. An additional 2-Mmt-per-year pelletizing line, idle since 1982, was readied for startup in August 1989 because of increased demand from the blast furnaces of USS at Gary, IN, and Braddock, PA, together with the resumption of hot-metal production at its recently modernized Fairfield works in Alabama. Pellets were also shipped to the company's integrated steelworks at Lorain, OH, which was placed in mid-1989 under the operational control of a joint partnership with Kobe Steel Ltd.

The output of Eveleth Mines was the highest since 1982. The joint venture produced 4.29 Mmt of partially fluxed pellets, 20% more than in 1987. The magnetite concentrate from the taconite was mixed with Peridur and a 1% limestone additive to make a pellet averaging 64.49% Fe, 4.95% SiO_2, 0.017% P, and 0.76% lime (CaO) on a wet basis. Eveleth is managed and partly owned by the Oglebay Norton Co., which has an 18.5% equity in the venture. The remaining equity is divided between Armco Inc. (35.1%), the Rouge Steel Co. (31.7%), and Stelco (14.7%).

In May, Eveleth revised its 1988 production goal upward by more than 25% because of increased demand from Armco and Rouge. To meet the new goal of 4.5 Mmt, management recalled 80 employees in June and reactivated the second of two pelletizing lines at its Fairlane plant, 11 km south of the city of Eveleth. This older line, which had been idle since July 1982, gave Fairlane a total effective capacity of 6.2 Mmt per year. At yearend, Eveleth employed about 685 hourly and 215 salaried personnel.

In late 1987, Oglebay Norton filed an environmental assessment plan with the Minnesota Department of Natural Resources, seeking approval to expand the north pit of the Thunderbird Mine toward the city of Virginia. Under the long-term plan, Eveleth would expand the pit by 400 acres and create three new stockpiles. One of these stockpiles would be in the old Rouchleau Pit on the southeastern edge of the city of Virginia. Development of the Spruce Hill reserve was well underway, with production scheduled to begin in 1989. The highway between Leonidas and West Eveleth had to be relocated because of the Spruce Hill project. The reserve is near the old Spruce Mine on the northwest edge of the south Thunderbird pit. Eveleth also renewed its efforts to improve pellet quality and planned to modernize the ore screening system at the Fairlane plant. The upgraded system should help lower the silica content of the concentrate.

Inland Steel Mining Co. produced a record high 2.44 Mmt of fluxed pellets at its Minorca Mine, 2 km northeast of the city of Virginia.[9] An additional 32,000 mt of acid pellets was produced during cleanup operations in the wake of the 1987 switchover to fluxed production. The mining company is a wholly owned subsidiary of the Inland Steel Co., which is owned in turn by Inland Industries Inc. The bulk of the fluxed pellets were being used in the mammoth No. 7 blast furnace at Inland Steel's Indiana Harbor Works in East Chicago, IN. The average daily output of the blast furnace was up more than 15% following its relining in 1987.

The Minorca Mine was using a fluxstone blend of 55% dolomite and 45% limestone. The fluxstone was being supplied by another Inland division, Inland Lime & Stone Co., and shipped in self-unloaders from the blending facility near Gulliver, on the Upper Peninsula of Michigan, to the docks at Duluth. The stone was then being hauled on the Duluth, Missabe, and Iron Range Railway to the pelletizing plant.

At the end of July, the State of Minnesota renewed its efforts to find a buyer for the defunct operations of Reserve. The Peter Mitchell Mine near Babbitt and the E.W. Davis pelletizing plant at Silver Bay had been shut down since July 1986 when LTV, the parent company of one of the two partners in Reserve, filed for bankruptcy. Armco, the other partner, was unable to carry the operation by itself and was forced to put Reserve into bankruptcy a month later. At the time of the shutdown, the mining complex employed about 800 workers and had a designed annual production capacity of 8.4 Mmt of standard pellets. However, in the ensuing 2 years, the bankruptcy trustee had sold some of the silica flotation cells and other equipment so that the effective capacity of the cannibalized operation at yearend was only about 4 Mmt per year.

On August 5, the Governor of Minnesota and other State officials met in Denver with executives of Cyprus Minerals Co. to explore ways of reopening the mining complex. CCI, Northfield Mining Inc., and at least two other parties also expressed an interest in acquiring or managing Reserve. However, potential buyers were discouraged by several obstacles, including liabilities for the sprawling Milepost 7 tailings basin and related environmental problems; concerns about the economic viability of the mining operation if demand for pellets in North America should drop back to 1986 levels; problems in satisfying Reserve's creditors and the accompanying legal quagmire created by bankruptcy; and the deterioration, cannibalization, and sale of machinery and other equipment.

In mid-October, the State of Minnesota, Cyprus, and the bankruptcy trustee signed a tentative agreement that eventually led to the refurbishing of the mine and pelletizing plant. Under the agreement, Cyprus began winterizing key equipment at the mine in November, but was not obligated to buy Reserve's facilities. Cyprus started pumping water, which had built up in the deeper parts of the pit. It also started heating the mine's primary crusher so that ice would not form inside the unit and seriously damage critical components. These steps had to be undertaken before winter if there were to be any possibility of reopening the mine in 1989 or 1990. The winterizing measures were expected to cost at least $1.3 million. Under terms of the tentative agreement, Cyprus would be reimbursed for some of its expenditures if it bid at least $35 million for the facilities.

Michigan

Michigan produced 25% of the national output of usable ore in 1988. More than 98% of the production consisted of pellets produced from ores mined at the Empire and Tilden Mines near Ishpeming in Marquette County. Both mining ventures are managed and partially owned by CCI's Cleveland-Cliffs Iron subsidiary. The company's wholly owned Republic Mine remained idle throughout the year. Production of pellets totaled 14.42 Mmt, of which 7.54 Mmt was produced at the Empire plant and 6.88 Mmt was produced at Tilden. The Empire plant operated at 93% capacity, down slightly from the record 95% achieved in 1987 when it made 7.75 Mmt of pellets. Empire also shipped about 165,000 mt of siliceous and run-of-mine ores in 1988. Tilden has traditionally had higher operating costs than Empire and has been used as a swing producer in recent years. However, Tilden has been in continuous operation since the spring of 1987 and produced at 85% capacity in 1988.

In mid-1987, CCI began exploring ways of making Tilden more competitive. The economics of the operation was hobbled by the mineralogy of the ore body. The taconite being fed to the concentrator was a mixture of fine-grained martite and hematite. This type of taconite is more difficult to beneficiate than the magnetite-rich material found elsewhere in the Lake Superior district. The hematite-rich taconite must be ground finer than the magnetite-rich type. The hematite ore must be selectively flocculated to float siliceous slimes from the pulp and then passed through a series of cationic flotation cells to remove the coarser, residual silicates. It was the operation of this flocculation-flotation circuitry and the accompanying consumption of expensive flotation reagents that made Tilden a higher cost producer than the adjacent Empire Mine, which recovers only magnetite.

The hematite concentrate at Tilden also had a higher phosphorus content than the magnetite concentrate at Empire. Despite years of costly research and hard work, a significant fraction of the phosphorus was still carried over into the pellet, making Tilden pellets more difficult to market. In 1988, Tilden's new fluxed hematite pellet averaged 0.031% P on a wet elemental basis, significantly higher than the 0.014% value for Empire's fluxed equivalent.

Because of these beneficiation problems, Tilden's three solvent partners—the Algoma Steel Corp. Ltd., CCI, and Stelco—agreed to convert the concentrator so that it could handle magnetite feed instead of hematite. The more easily processed magnetite ore would come from reserves at Schoolhouse Lake, about 1 km north of the existing pit. Magnetic separation techniques would drastically reduce the operation's concentrating costs, but the development of the new pit and conversion of equipment would cost $29 million. By March 1988, the partners had formalized their plan. Development of the Cliffs Drive III ore body would enable Tilden to reduce its production costs by at least $3 per mt while improving pellet quality.

Conversion of the pelletizing plant would require $7.5 million; development of the new pit, about $6 million. The remaining $15 million would be used to buy new equipment and upgrade existing facilities. The costs would be shared among Algoma (50%), CCI (33.3%), and Stelco Coal Co. (16.7%). The new venture was to be called the Tilden Magnetite Partnership. The other three partners in the old Tilden Mining Co. were not in a position to participate, having all filed for protection under chapter 11. One of the three, Sharon Steel Corp., was to have an indirect interest in the magnetite project through a separate arrangement with CCI, which had managed the existing Tilden operation since its startup in 1974. The remaining two bankrupt partners, LTV Steel and Wheeling-Pittsburgh, were being reorganized. Both had defaulted earlier on their Tilden obligations and stopped taking pellets. A wage deferral agreement was originally set up with the USWA to help finance the project and make improvements at Empire. Because of the improved financial climate, the deferral program was canceled in late November, and the money was turned over to the workers.

Pellet production from the redesigned operation was to peak at 4 Mmt per year, which was one-half of Tilden's capacity of 8.1 Mmt per year. If this downsizing schedule is followed, the reserves of Cliffs Drive III should last about 14 years. After that, hematite production could be resumed at a relatively small cost. Modification of the concentrator began in October 1988. All of the existing flocculation and flotation equipment was left intact. Production of the pellets from the first magnetite concentrates was scheduled to begin in the second quarter of 1989. The joint venture also planned to produce 2.5 to 4.1 Mmt of pellets from hematite concentrates during the first half of 1989.

Excavation of the new pit required the draining of two lakes, Foster and Schoolhouse, and the damming of the southeastern end of Ogden Lake. All three lakes are part of the Lake Sally watershed, which is the primary source of drinking water for the city of Ishpeming. Ishpeming, the neighboring city of Negaunee, and the Michigan Department of Commerce were working with CCI to develop a replacement water source.

In mid-April, CCI raised its 1988 production goal for Tilden to meet increased pellet orders. Management decided to produce 6.9 Mmt of pellets instead of 4.8 Mmt as was originally planned. Recent steps taken to improve productivity and lower operating costs made Tilden's pellets more competitive. Two grades of fluxed pellets were made in addition to the traditional standard hematite pellet. To meet the revised goal, CCI recalled about 75 employees, bringing total employment to about 850. In 1988, 10 of the 12 grinding lines at the concentrator were on-stream, up from 6 at yearend 1987. One of the two remaining lines was being used to grind fluxstone. The second of two grate-kiln pelletizing lines was also put into operation.

Empire produced a record number of fluxed pellets in 1988 and began increasing production from its newly developed Cliffs Drive I ore body. Both the plant and main pit were operating wide open with 21 shifts per week. Most of Empire's fluxed pellets, about 44% of the pelletizing plant's total output, went to Inland Steel. The fluxed pellets were hauled 113 km on the Chicago and Northwestern Railway to Escanaba, where they were later transferred to vessels bound for Inland Steel's receiving docks at Indiana Harbor. Fluxed pellets also accounted for more than 60% of Tilden's output for the year.

Empire was using a 47–53 blend of dolomite and limestone made by Inland Lime & Stone Co. at its Gulliver, MI, quarry, although Tilden opted for a 70–30 blend from the Calcite and Cedarville quarries of the Michigan Limestone Operations Ltd. Partnership. The two fluxstone mixes were shipped in self-unloading vessels to the docks at Presque Isle and Marquette, where they could be stockpiled and later hauled to the pelletizing plants by truck. CCI was evaluating ways of more efficiently shipping and handling the growing tonnages of fluxstone. In recent months, the increased truck traffic had put a strain on portions of the road network in the Ishpeming area. Some of the Gulliver mix was delivered to Escanaba for loading into railcars returning to the Empire Mine.

Missouri

In Missouri, Pea Ridge Iron Ore Co., a wholly owned subsidiary of Fluor Corp., produced almost 800,000 mt of iron ore products at its underground mine near Sullivan. The bulk of the production consisted of more than 700,000 mt of olivine-enriched pellets made from magnetite concentrate containing 70% Fe and less than 1% SiO_2. The concentrate was made from crude ore averaging 46% magnetic iron. The olivine pellets averaged 64.34% Fe, 3.13% SiO_2, and 0.026% P on a wet basis. In 1986, the phosphorus was significantly higher and ran 0.034%. Company engineers were able to lower the phosphorus level by installing additional equipment in the concentrator.

The addition of 5% olivine increases the reducibility of the pellet while improving its high-temperature properties in the blast furnace and increasing its resistance to low-temperature breakdown. The olivine was imported from Norway and was ground on-site. Four of the five shaft furnaces operated in the 1.65-million-ton-per-year pelletizing plant. Pea Ridge continued to ship pellets on the Union Pacific Railroad for a distance of 160 km to NSC's Granite City steelworks, across the Mississippi River from St. Louis. The mining complex operated continuosly throughout 1988.

Pea Ridge also produced heavy-medium magnetite for coal cleaning, as well as a variety of iron oxides for ferrites, pigments, and ceramic magnets. A hematite concentrate for use in well-drilling fluids was made when demand warranted. The company was one of the few sources of byproduct pyrite concentrate still operating in the United States.

Fluor Corp. completed an extensive restructuring of its natural resource investments in 1987, which resulted in the reconfiguration of its coal and lead subsidiaries and the sale of its gold and domestic zinc operations. As part of the restructuring, Fluor took steps to also divest itself of Pea Ridge and to set up the iron ore company as a quasi-independent subsidiary. At yearend, the California-based parent still owned the Missouri mining complex.

Other States

Geneva Steel of Utah continued to expand production at its open pit mines in the Iron Springs district of Iron County. The district, 24 km west of Cedar City, has provided magnetite and hematite ores for blast furnaces in the Rocky Mountain region on an intermittent basis since 1923. Coarse ore and fines were shipped 370 km on the Union Pacific Railroad to Geneva's integrated steelworks at Provo. The ore was hauled twice a week in 75-car unit trains.[10] The 100-ton railcars were originally built to carry pellets from USX's former Atlantic City Mine in Wyoming to Geneva. The actual mining was contracted out to the Gilbert Development Corp. Run-of-mine ore averaging 55.1% Fe, 6.7% SiO_2, and 0.27% P was crushed and screened at the Comstock Mine, a property leased by Geneva from CF&I Steel Corp. of Pueblo, CO. Gilbert Development also produced its own magnetically cobbed material from stockpiled ore at the old Iron Mountain Mine, 8 km to the southwest. This second material was averaging 58.7% Fe, 5.2% SiO_2, and 0.30% P. The Iron Mountain property was leased directly by Gilbert Development from CF&I. A total of 501,000 mt was shipped from the district in 1988. More than 50% of the material consisted of fines, which could not be charged directly into Geneva's three blast furnaces and had to be sintered.

At the end of September, Geneva and Gilbert Development announced the opening of two additional mines in the Iron Springs district. The new mines, the Excellsior and the Chesapeak, were also being leased from CF&I. The Excellsior Mine had reserves of 200,000 mt of mixed hematite and magnetite. The Chesapeak Mine had primarily hematite ore, with reserves of no more than 75,000 mt. The iron content of the ore from both mines was about 65%. The ores were to be trucked about 6 km to the railcar loading station at the Iron Mountain Mine.

In South Dakota, Pete Lien & Sons Inc. resumed mining of low-grade hematite after a hiatus of 9 years. The company produced direct-shipping ore averaging 32.0% Fe from the old CF&I pit near Nemo in Lawrence County. Production was limited by the relative remoteness of the Black Hills minesite from consumers. The bulk of the ore was shipped to the Dakota cement plant operated at Rapid City by the State Cement Commission.

CONSUMPTION AND USES

Consumption of iron ore rose about 18%, owing to increased demand from the iron and steel industry. Consumption for ironmaking and steelmaking totaled 72.31 Mmt, including 63.17 Mmt in blast furnaces, 8.38 Mmt in sintering plants, 0.44 Mmt for production of direct-reduced iron (DRI), and 0.28 Mmt in steelmaking furnaces. An additional 30,000 mt was used by the industry for miscellaneous and unspecified purposes. Monthly consumption of pellets, direct-shipping ore, and merchant sinter by the industry averaged 5.99 Mmt, compared with 5.09 Mmt in 1987. Reported consumption of iron ore for manufacture of cement, heavy-medium materials, animal feed, ballast, ferrites, pigments, and other nonsteel products was 1.29 Mmt.

The near-term outlook for the iron and steel industry improved considerably since 1986. U.S. production of pig iron totaled 50.70 Mmt in 1988, 15% more than in 1987 and the largest tonnage since 1981. Pig iron production was extremely stable throughout the year, averaging 4,225 mt per month. The deviation from the mean was never more than 6% for any one month. Monthly iron ore consumption statistics reflected this stability, which developed after overall demand for steel mill products had strengthened in the fall of 1987. Increased shipments of steel mill products to the automotive industry, the construction industry, and steel service centers accounted for almost one-half of the growth. Consumption of pellets, direct-shipping ore, and merchant sinter for the first 6 months was 35.18 Mmt, a 22% increase from the same period in 1987. During 1988, the number of blast furnaces in operation ranged from 49 to 52. At yearend, 50 of the 84 blast furnaces available were on-line. This increase in utilization was a significant improvement over that of 1986, when the number of furnaces operating dropped from 50 to 31 over a 7-month period.

Consumption of iron ore and all types of agglomerates reported to the AISI by integrated producers of iron and steel totaled 81.96 Mmt. This included 61.11 Mmt of pellets; 15.50 Mmt of sinter, briquettes, etc.; and 5.35 Mmt of natural coarse ore. Of the primary ore consumed, 73% was of domestic origin, 13% came from Canada, and 14% came from other countries. Other materials consumed in sintering plants included mill scale, flue dust, limestone and dolomite, slag and slag scrap, and coke breeze. Other iron-bearing materials charged to blast furnaces included steel-furnace slag, mill scale, and slag scrap.

STOCKS

Stocks of iron ore and agglomerates reported at U.S. mines, docks, and consuming plants had been gradually dropping for more than 30 years. This trend reversed itself in 1988. At yearend, total industry stocks were 23.50 Mmt, up 12% from that of 1987. The increase was due primarily to a buildup of domestic ore stocks at furnace yards. Even with the buildup, furnace yard stocks stood at only 18.00 Mmt, a 55% drop from the 39.93 Mmt reported at yearend 1978. Combined stocks at furnace yards and receiving docks included 14.44 Mmt of domestic ores, 2.04 Mmt of Canadian ores, and 3.71 Mmt of other foreign ores. Mine stocks at yearend were 23% more than those of 1987, despite the exhaustion of pellets at Reserve and Butler in 1987.

End-of-month stocks reported at mines peaked at 10.56 Mmt in March and declined to 3.30 Mmt at yearend, while stocks of ore at consuming plants ranged from a low of 9.39 Mmt in March to a high of 18.00 Mmt in December. As in previous years, these variations were principally caused by the seasonal nature of ore shipping on the Great Lakes.

Stocks of unagglomerated concentrates reported at pelletizing plants totaled 1.14 Mmt at yearend. This material is not included in mine stocks of usable ore reported in the accompanying tables because it is considered an intermediate product. Also, mine stock data after 1983 do not include byproduct ore owing to the change in classification reported in this publication in 1983. Data for previous years remain unchanged to avoid disclosing company proprietary information.

TRANSPORTATION

Vessel shipments of iron ore from U.S. ports on the upper Great Lakes totaled 52.76 Mmt, about 10% more than those of 1987. Nearly 90% was destined for U.S. consumers, with the rest going to Canada. Shipments of iron ore through the St. Lawrence Seaway to U.S. ports on the Great Lakes totaled 3.76 Mmt and accounted for about 19% of U.S. imports. The balance of imports, 16.42 Mmt, was shipped primarily through ports on the east and gulf coasts.

Ore shipments from four of the seven U.S. ports on the upper Great Lakes increased from the levels of 1987, with the largest increase at Two Harbors, MN. Tonnage shipped from each port in 1988 is shown in the text table.

Port	Date of first shipment	Date of last shipment	Total tonnage (thousand metric tons)
Duluth, MN	Apr. 2	Dec. 24	7,030
Two Harbors, MN	Mar. 24	Jan. 14	10,982
Silver Bay, MN[1]	—	—	—
Taconite Harbor, MN	Apr. 1	Jan. 4	7,842
Superior, WI	Mar. 28	Jan. 9	12,189
Marquette, MI	Mar. 27	Jan. 17	8,054
Escanaba, MI	Mar. 25	Jan. 7	6,660
Total[2]			**52,757**

[1] Operations ceased after LTV Steel Co., the co-owner of Reserve Mining Co., filed for bankruptcy on July 17, 1986. All of the stockpiled pellets that remained at Silver Bay were shipped out Oct.–Nov. 1987.
[2] Covers the 1988 navigation season, which extended from Mar. 24, 1988 to Jan. 17, 1989.

Source: Lake Carriers' Association, 1988 Annual Report.

No shipments were made from the dock at Silver Bay after November 1987 because of the closure of Reserve. The number of vessel shipments from the other six ports totaled 1,535, indicating an average cargo of 34,370 mt. Individual cargoes of 55,000 mt or more were loaded at five of the ports during the year, although the average shipment from individual ports ranged from 23,012 mt at Marquette to 46,960 mt at Taconite Harbor, MN.

The average shipment from all U.S. ports on the Lakes was only 34,370 mt, 6% less than in 1987. The dropoff was the result of drought conditions, which caused water levels on some of the Great Lakes to recede as much as 4 feet between the fall of 1986 and the summer of 1988. Any lowering of water levels on the Great Lakes reduces the carrying capacity of the bulk cargo fleet because of restrictions placed on individual vessels by channel and harbor depths. A reduction in draft of 1 inch on a 1,000-foot ore carrier equates roughly to a loss of 267 long tons in carrying capacity.[11] If the vessel made 45 trips during the season and its draft was reduced by only 12 inches, it would forfeit 146,000 mt of ore for the season.

In November 1987, the Great Lakes shipping industry dramatically lowered freight rates for self-unloaders hauling iron ore and established discounts to encourage the use of Class X vessels (i.e., vessels with hulls greater than 1,000 feet in length). These rates remained in effect until October 13, 1988, when an across-the-board hike of 10% was instituted for Class X vessels. Ore moving in smaller vessels was subjected to hikes of 6.3% to 6.7%. The different rates are compared in the text table.

The two principal issues concerning U.S. lake shipping in 1988 continued to be the proposed construction of a second Poe-class lock at Sault Ste. Marie and the question of sharing domestic lake and coastal trade with Canadian vessels. The latter issue was rejuvenated in 1987 during the FTA negotiations with Canada, causing the Reagan Administration to review the justifications for existing cabotage laws.

At the present time, the Poe Lock is the only one at Sault Ste. Marie that can handle vessels with a length greater than 680 feet. Of the 60 dry-bulk cargo vessels registered in the U.S. Great Lakes fleet, 29 must use the Poe Lock to transit the St. Marys Falls Canal. These 29 vessels account for more than 69% of active carrying capacity.[12] A lengthy shutdown of the Poe Lock could seriously disrupt lake shipping and sharply increase haulage costs in the region for iron ore and at least five other bulk commodities.

The Water Resources Development Act of 1986 (Public Law 99-662) authorized construction of a second Poe-sized lock, but differences over the cost-sharing arrangement dictated by the act have stalled the project.[13] Under the new law, a local sponsor must pay part of the costs of any port or harbor improvement, with the percentage determined by the project's depth. If the lock were treated as a port or harbor, a local sponsor would have to pay 35% of the estimated $247 million construction costs. One of the key parts of the problem was that there was neither a readily identifiable sponsor nor clear beneficiaries. Although the Soo Locks are physically in the State of Michigan, only 13% of the traffic originated from or was destined for Michigan. Michigan and the other States bordering the Great Lakes argued that foreign shipping would also use the proposed lock and, therefore, the Federal Government should bear the entire cost of the project. About 30% of the cargoes transiting the locks went to Canada or overseas. The Great Lakes States further argued that interior States such as Montana, the Dakotas, and West Virginia also benefit from the locks. The position taken by the Lake Carriers' Association (LCA) is that the national defense role of the Soo Locks alone justifies full Federal funding. If Congress were to appropriate all of the necessary funds in 1991, groundbreaking could not take place until 1994 and the project could not be completed before 2003.

From	To	Dollars per long ton[1] Nov. 10, 1987 Class X	Nov. 10, 1987 Other	Oct. 13, 1988 Class X	Oct. 13, 1988 Other
Head of the Lakes	Lower lake ports	4.50	5.25	4.95	5.60
Marquette	do.	—	4.40	—	4.69
Escanaba	Lake Erie ports	3.40	3.95	3.74	4.20
Do.	Lower Lake Michigan ports	2.70	3.00	2.97	3.19

[1] Excludes winter surcharges for shipments after Dec. 15 and before Apr. 15.

Sources: Cleveland-Cliffs Inc., Interlake Steamship Co., and Skillings' Mining Review.

Published bulk vessel freight rates from the Gulf of St. Lawrence to Lake Erie and Lake Michigan were $5.00 and $7.00 per ton, respectively. Freight rates for self-unloading vessels were $1.50 per ton higher. These rates may include toll charges on the St. Lawrence Seaway, which amount to about $1.24 per ton.

The cabotage issue is a complex one with serious long-term implications for the U.S. Great Lakes fleet. The United States has had cabotage laws since 1789 to ensure a reliable domestic shipping service and to be able to rapidly expand the Nation's maritime capabilities in the event of a national emergency. One of the key cabotage laws is section 27 of title I of the Merchant Marine Act of 1936. This section, known as the Jones Act, mandates that all domestic waterborne commerce be conducted in U.S.-built, -owned, and -crewed vessels.

The Government of Canada wanted these cabotage restrictions waived as part of the FTA. In exchange, U.S. vessels would have been allowed to carry cargo between Canadian ports. If approved, Canadian ore carriers would have been able to haul pellets from Duluth to Cleveland. U.S. and Canadian iron ore shipments on the Great Lakes for 1983 through 1988 are compared in the following text table.

The members of the LCA and other

Loading district	United States and Canadian iron ore shipments on the Great Lakes (thousand metric tons)					
	1983	1984	1985	1986	1987	1988
Lake Superior	35,619	38,765	37,962	31,677	41,835	46,098
Lake Michigan	7,535	8,757	7,503	7,497	[r]6,032	6,660
Lake Huron	175	221	—	—	—	—
Eastern Canada	9,592	10,441	7,542	7,108	8,109	9,209
Total[1]	**52,921**	**58,184**	**53,008**	**46,282**	**[r]55,976**	**61,966**
U.S. flag fleet shipments[2]	NA	NA	44,027	39,457	[r]48,952	55,028
Percent carried by U.S. fleet	NA	NA	83	85	87	89

[r]Revised. NA Not available.

[1]Includes transshipments. Data may not add to totals shown because of independent rounding.

[2]Includes mill scale, scarfer ore, and slag, in addition to iron ore.

Source: Lake Carriers' Association Annual Reports.

maritime groups have strongly opposed the Canadian proposal because the Federal Government in Ottawa heavily subsidized its shipbuilding industry in the 1970's and has continued to contribute to the pension and health programs of the Canadian merchant marine. Because of these and related arguments, the U.S. and Canadian negotiators decided to remove the maritime provisions from the final agreement. This issue has also been raised in trade negotiations with other seafaring countries and could complicate the upcoming talks being held in Uruguay to improve the General Agreement on Tariffs and Trade.

The State of Wisconsin, the city of Superior, and the Burlington Northern Dock Corp. were still locked in litigation over a taconite tax passed by the State legislature in 1977. During the last 11 years, the railroad subsidiary had been required to pay a 5-cent-per-ton tax on pellets railed from the western half of the Mesabi Range to the company's Allouez terminal. Burlington Northern had protested the tax since its inception and had brought several suits against the city of Superior, which collects the dock tax and retains 70% of the monies. The remaining 30% is sent to the State treasury.

In its original suit, Burlington Northern claimed that the dock tax was unconstitutional and violated the commerce clause of the U.S. Constitution by discriminating against ore mined outside of Wisconsin. In June 1986, the Wisconsin Supreme Court declared the tax, as originally conceived, was indeed unconstitutional and ordered Superior to pay back the $5.4 million collected between 1977 and 1985, plus interest. In January 1987, this ruling was upheld by the U.S. Supreme Court. However, in 1985, the Wisconsin legislature had rewritten the tax law and removed the part that the State Supreme Court had found objectionable, allowing the city to reimpose its dock tax. In May 1987, Burlington Northern sued the city again, claiming that the redrafted tax was also unconstitutional. The railroad filed yet another lawsuit in December 1988, even though the 1987 suit was still pending. In this latest suit, Burlington Northern sought the return of $394,122 paid under protest in 1986, again arguing that the tax interfered with interstate commerce.

On December 28, USX announced the formation of Transtar Inc., a joint venture with Blackstone Capital Partners L.P. and Blackstone Transportation Partners L.P. USX sold 56% of its extensive transportation holdings to Transtar for about $600 million. The USX railroad lines involved in the transaction included the Duluth, Missabe and Iron Range Railway Co.; Bessemer & Lake Erie Railroad Co.; Birmingham Southern Railroad Co.; Elgin, Joliet, and Eastern Railway Co.; The Lake Terminal Railroad Co.; Union Railroad Co.; and McKeesport Connecting Railroad. The new transportation company also acquired USX's lake shipping and river barging operations, including the USS Great Lakes Fleet Inc., Warrior & Gulf Navigation Co., and the Pittsburgh & Conneaut Dock Co. Stock in the new company is shared between the Blackstone Group (51%), USX (44%), and senior management of the transportation companies (5%). USX will use most of the proceeds from the transaction to reduce its debt.

All-rail shipments of iron ore and agglomerates in the United States and Canada totaled 7.14 Mmt, compared with 4.56 Mmt in 1987. This was the highest tonnage ever reported for the two countries. Separate statistics for the United States are not published to protect proprietary company information. All-rail shipments of pellets from Minnesota by the Duluth, Missabe and Iron Range Railway Co. and connecting lines amounted to 1.32 Mmt, substantially more than the 438,000 mt hauled in 1987.[14] Shipments from USX's Minntac Mine at Mountain Iron to the reactivated Geneva Works in Utah accounted for the bulk of the tonnage. Shipments of pellets and small quantities of natural ore to the ports of Duluth and Two Harbors totaled 17.86 Mmt for a total ore movement on the railway of 19.18 Mmt during the 1988–89 shipping season. More than 1 Mmt of pellets was also hauled all-rail via the Burlington Northern to NSC's two blast furnaces at Granite City, IL.

Published railway freight rates for pellets from mines to upper lake shipping ports were unchanged in Minnesota in 1988. The volume rate for pellets from the western Mesabi Range to the Allouez docks at Superior remained at $5.01 per long ton. For pellets from the Marquette Range of Michigan, the rate to Presque Isle remained at $2.15 per long ton. However, on October 1, the rate to Escanaba was raised from

$2.90 to $3.03. Escanaba has also had a handling charge of 3.5 cents per long ton since 1980.

Rail rates from lower lake ports to a number of consuming points were raised between 3% and 9% on January 1, 1988. These increases erased the rollbacks won by the integrated steel producers in November 1986. At that time, the railroads agreed to the rollbacks because consumption of ore and agglomerates had fallen steadily over a 7-month period to 3.8 Mmt. Most ore transfer charges were also increased slightly at the beginning of 1988. At Lake Erie ports, ore transfer charges from rail-of-vessel or dock-receiving areas direct into railway cars ranged from $1.00 to $1.20 per long ton. Key rail rates for 1986–88 are compared in the text table.

From	To	Type of rate[1]	Dollars per long ton Jan. 1, 1986	Nov. 17, 1986	Jan. 1, 1988	Jan. 16, 1989
Lake Erie ports	Pittsburgh district	Multiple car	10.74	10.62	11.07	12.42
Do.	Steubenville, OH, and Weirton, WV	do.	9.33	9.60	10.00	10.37
Baltimore, MD	Pittsburgh district	do.	11.68	11.49	12.51	12.98
Do.	do.	Single car	15.77	15.77	16.82	16.82
Philadelphia, PA	do.	do.	16.48	16.48	17.57	17.57
Mesabi Range	Granite City, IL	Multiple car	19.07	19.07	19.69	19.69
Mobile, AL	Birmingham district	do.	10.02	9.91	10.33	10.33
Pea Ridge, MO	do.	do.	6.41	6.41	6.41	6.41

[1] As a result of the Staggers Rail Act of 1980, which partially deregulated the railroads, it has become difficult to obtain accurate freight rate data. Published tariff rates are only suggested rates and may be significantly higher than the actual contract rates.

Sources: Cleveland-Cliffs Inc., Minnesota Mining Directory, and Skillings' Mining Review.

Published nominal ocean freight rates for iron ore from eastern Canada to U.S. mid-Atlantic ports were $3.50 to $3.75 per deadweight cargo ton (dwt), but spot rates quoted for cargoes of 60,000 to 110,000 dwt ranged from $2.75 to $3.75 per dwt. A few shipments reported from Brazil to east coast ports indicated freight rates of $4.50 to $4.95 per dwt.

PRICES

Very few published prices for domestically produced pellets changed in 1988. CCI and Oglebay Norton were both still quoting a price of 72.45 cents per *long ton unit* (ltu) of iron, natural, for their standard grades of Lake Superior pellets. The quotation included delivery to rail-of-vessel at *lower* lake ports. The Eveleth special grade of Oglebay Norton was listed slightly higher at 74.00 cents per ltu. Mineral Services Inc. continued to quote its lower price of 58.00 cents per ltu set in August 1985. At that time, Pickands Mather and Inland abandoned the traditional lower lake pricing base and began quoting 59.40 cents per ltu for pellets delivered to hold of vessel at *upper* lake ports. At yearend 1987, Inland dropped the price of its Minorca pellets to 46.84 cents per ltu, but Pickands Mather refused to follow. USX also decided to retain its 1987 quotation. The price for Minntac acid pellets was left at 37.344 cents per *dry* ltu of iron, delivered into railcars at the Minnesota mine. This price equated to about $23.83 per long ton of undried pellets containing 63.82% Fe and 2.51% moisture. The range of all of the above prices was approximately equivalent to $34.50 to $46.37 per long ton of pellets containing 64% Fe, delivered rail-of-vessel at lower lake ports.

Published prices for Lake Superior ores, per long ton, basis 51.5% Fe, natural, delivered rail-of-vessel at lower lake ports, remained as follows: Mesabi non-Bessemer ore, $30.03 for coarse ore and $31.53 for fines; and manganiferous ore, $32.78. These prices were not very significant in 1988 because most Mesabi non-Bessemer ore was produced and consumed by LTV Steel, and none of the manganiferous ore was mined. Pellets made up more than 98% of ore shipped from the Lake Superior district.

Prices for most Canadian and other foreign ores marketed in the United States were not available. The published price of Wabush pellets, f.o.b. Pointe Noire, Quebec, remained at 63.5 cents per ltu. The average f.o.b. value of all Canadian ores imported by the United States, as determined from data compiled by the Bureau of the Census, was $31.23 per mt. Data from this source indicated average f.o.b. values of $11.40 per mt for Liberian ores and $15.83 per ton for Brazilian ores. Other sources indicated that most imported Canadian ore consisted of pellets, Liberian ores consisted of fines and washed lumpy ore, and about two-thirds of the ore imported from Brazil consisted of pellets. F.o.b. value data for Venezuelan ores were not determinable because much of the ore was apparently valued on a c.i.f. basis.

Published f.o.b. prices for DRI were also unchanged from those quoted in 1987, and were as follows, per mt: at Georgetown, SC, $125 to $135; at Contrecoeur, Quebec, $115; and at Point Lisas, Trinidad and Tobago, $120. The apparent f.o.b. value of some shipments of DRI imported from Venezuela since 1987 ranged from about $84 to $115 per mt.

FOREIGN TRADE

U.S. exports of iron ore were slightly higher than those of 1987 despite a leveling off of demand from the Canadian steel industry. Virtually all exports consisted of pellets and concentrates shipped via the Great Lakes to Canadian steel companies that are partners in U.S. taconite projects in Minnesota and Michigan. Consumption of iron ore at Canadian blast furnaces totaled 13.22 Mmt, an amount almost identical to that of 1987. U.S. material accounted for 4.74 Mmt, or 36% of the blast furnace total. An additional 148,000 mt of U.S. material was consumed at Canadian sintering plants.

U.S. imports for consumption of iron ore jumped 20% to 20.18 Mmt as a result of the pickup in blast furnace activity. Total tonnage for 1988 was 25% greater than the mean of the previous 5 years, 16.16 Mmt, and was equivalent to about 28% of consumption. Sharp increases of imports into the Baltimore, Philadelphia, and Mobile customs districts (30%, 32%, and 50%, respectively) offset small drops at lower lake ports. Canadian ores accounted for 45% of total U.S. imports; however, in recent years, Canada had to struggle to maintain its 12% to 23% share of the increasingly competitive U.S. market. Brazil, the next largest supplier after Canada, increased its share to 6.9% from 6.1% in 1987. Venezuela was close behind with a 5.0% share and was expected to become more competitive with the placing and operation of its transfer vessel at the mouth of the Orinoco River. (See World Review.)

As a result of the passage of the Omnibus Trade and Competitiveness Act in August, much more detail will be available on iron ore entering the United States after January 1, 1989. The eight new classification categories and their accompanying TSUSA numbers are listed in the text table.

TSUSA No.	Description
Oxides	
2601.11.0030	Concentrates.
2601.11.0060	Coarse ores.
2601.11.0090	Fine ores.
2601.12.0030	Pellets.
2601.12.0060	Briquettes.
2601.12.0090	Sinter and other agglomerates.
Sulfides	
2601.20.0000	Roasted pyrites.
2502.00.0000	Unroasted pyrites.

WORLD CAPACITY

Integrated iron ore operations have become extremely complex and resemble medium-sized towns in some cases. The production capacity of an operation of this magnitude is determined by equipment limitations at several stages of recovery. To simplify analysis and make comparisons of individual mines easier, data were collected that represent the rated or design capacity at three key points in the recovery process: crusher-screen output, concentrator output, and furnace output. These three points were chosen because they serve to readily separate the mining, beneficiating, and agglomerating stages of the operation. At the first two points, the iron ore is already in a marketable form and can be diverted for sale if bottlenecks occur downstream or the economics of the process change. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operation rate, based on the physical equipment of the plant, and given acceptable operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Table 14 shows world pelletizing capability at the close of 1988. The data represent the rated capacities of 81 plants in 25 countries. Five of the plants were near or part of integrated steelworks and had no captive iron mines. A sixth, the natural-gas-based merchant operation in Bahrain, was also dependent on imported feed. A significant part of the data was collected by the International Iron and Steel Institute in 1987. The table excludes plants that have not produced since 1982. Four of these idled plants are identified in the table footnotes because they could be reactivated in some realistic scenarios. Table 14 also excludes all of the world sintering plants. Similar tables were being developed by the Bureau of Mines that list world crude ore production capability and world concentrating capability.

WORLD REVIEW

At least 47 countries mined iron ore during the year, producing a total of 916 million *metric tons*. The U.S.S.R.

was the largest producer, with an output of 180.7 Mmt of concentrate and 69.0 Mmt of pellets. Soviet production accounted for about 26% of the world's marketable output in terms of metal content. World production of pig iron, which directly reflects ore consumption, increased almost 6% to 532 million *metric* tons.

The world ore trade was estimated at 401 Mmt, of which about 84% was oceanborne.[15] Brazil, the leading exporter, shipped 105.3 Mmt to world markets in 1988, an increase of 8%. The top three customers of the Latin American giant were the European Community (EC), Japan, and the Republic of Korea. Australian shipments, in second place, rose from 80.6 to 98.3 Mmt primarily because of increased imports by Japanese steelmakers who increased pig iron production 8%. Australian exports to Europe also improved dramatically, reaching a record 24.63 Mmt. The recently expanded EC received a total of 132.5 Mmt of ore and agglomerates, again edging out Japan as the world's principal importer. Japanese imports increased 10% from 112.0 Mmt to 123.4 Mmt.

World production of pellets was estimated at 226 Mmt, about 85% of rated capacity. Preliminary data suggest that pelletizing plant output was 9% more than the 208.5 Mmt reported for 1987. Most plants in Brazil, Canada, Sweden, and the U.S.S.R. were operating close to capacity. Producers in India, Peru, and the United States considered reopening facilities idled in the wake of the 1981 downturn. More and more customers asked plant managers to switch to self-fluxed or olivine-base pellets. Dolomite-limestone fluxed pellets were being made in record amounts in Australia, Canada, Japan, and the United States.

World output of DRI was estimated by Midrex Corp. at 14.16 Mmt, about 58% of installed capacity.[16] The low utilization rate was due more to startup delays at new plants and other technical problems than to market factors. At seven gas-based plants, production actually exceeded rated capacity. Hot-briquetted iron (HBI), an enhanced form of DRI, was in considerable demand throughout 1988. Merchant DRI remained in direct competition with high-quality home scrap (i.e., scrap internally generated within the steelworks). The long-term outlook for DRI was favorable because of the rapid dropoff in the generation of home scrap since the advent of continuous casting. Efficiency improvements at rolling mills have made the home scrap dropoff even more pronounced.

New plants were brought on-line in Iraq and Mexico, raising global DRI capacity from 22.4 Mmt to 24.4 Mmt. The improved utilization of existing gas-based facilities in Egypt and the U.S.S.R. was largely responsible for the 4% increase in world DRI production between 1987 and 1988. About 44% of the total output for 1988 was produced in Mexico, Venezuela, and other countries in Latin America.

In the past, iron ore exporters normally completed their annual price negotiations in Europe before fixing prices in Japan. The tradition arose because European contracts are based on the calendar year, while Japanese contracts are on an April-to-March fiscal year. However, for the second consecutive year, Japanese ore buyers completed their price negotiations before their European counterparts. For the fourth year in a row, excess stocks of sinter fines overshadowed the negotiations, forcing prices for direct-shipping ore continually lower.

The Australians settled first. At least two Australian suppliers found themselves in a difficult position at the start of the negotiations and moved quickly to set prices. Hamersley Iron Pty. Ltd. took the initiative, signing with Japanese steelmakers on December 22, 1987, and with British Steel Corp. 2 days later. Hamersley had several reasons to be concerned: the company's ore stockpile at the port of Dampier had grown excessively to 17 Mmt; ocean freight rates had trended upward since February 1987, making Australian ore less competitive in Western Europe than ore from Canada, Sweden, and other nearer suppliers; the Australian dollar was strengthening against the U.S. dollar; and state-operated mines in some of the developing countries were becoming more competitive.

Hamersley agreed to cut the price of its fines in the Japanese market by 4.01%; Mount Newman Mining Co. Pty. Ltd. and several smaller competitors immediately followed suit. By mid-April, Japanese steelmakers had settled essentially all of their contracts for fines and lump ore, winning f.o.b. price cuts of 4.0% to 5.9% for most fines. Lump ore prices were largely unchanged, with the premium over fines widening because of the drop in prices for fines. Prices negotiated under Japanese contracts for fiscal year 1988 were reported as shown in the text table (f.o.b., in U.S. cents per dry ltu of iron).

Pellet prices moved in the opposite direction, rising between 7.5% and 12.6%, because of growing demand worldwide and a shortage of modern sintering facilities in the EC. The price settlements in Europe were similar to those made in Japan. West German steelmakers had mixed reactions to a proposal by Luossavaara-Kiirunavaara AB (LKAB) to introduce nondollar pricing in Europe for long-term pellet contracts.

On an f.o.b. (shipping port) basis, most 1988 prices apparently ranged from about \$7.30 to \$19.60 per dry metric ton (dmt) for fines, \$14.65 to \$18.45 per dmt for lump, and \$17.80 to \$30.15 per dmt for pellets. Delivered prices (at receiving port) were about \$2 to \$14 higher, depending on ocean freight costs.

Seaborne trade in iron ore was at its highest level in more than 8 years.[17] The high shipping level was brought on by the worldwide upswing in pig iron production. World production of pig

Country and producer	Ore type	Prices (April 1–March 31) FY 1987	FY 1988
Australia:			
Hamersley Iron Pty. Ltd. and Mount Newman Mining Co. Pty. Ltd.	Lump ore	28.78	28.78
Do.	Fines	24.67	23.68
Robe River Iron Associates	do.	21.50	20.51
Savage River Mines Ltd.	Pellets	34.72	36.46
Brazil:			
Cia. Nipo-Brasileira de Pelotização (Nibrasco)	do.	35.29	38.54
Cia. Vale do Rio Doce (Carajás)	Fines	22.24	21.23
Cia. Vale do Rio Doce	Lump ore	22.24	22.24
Mineraçoes Brasileiras Reunidas S.A.	do.	22.24	21.77
Do.	Fines	22.76	21.73
Samarco Mineracão S.A.	Pellet feed	18.29	17.46
Canada: Iron Ore Co. of Canada (Carol Lake)	Concentrates	21.26	20.25
Chile:			
Minera del Pacifico S.A. (El Algarrobo)	Pellets	34.72	32.98
Minera del Pacifico S.A. (El Romeral)	Fines	17.30	16.44
India:			
Minerals and Metals Trading Corp. (Bailadila)	Lump ore	27.75	27.75
Do.	Fines	23.70	22.75
Liberia: LAMCO Joint Venture Operating Co.	do.	[1]20.13	18.58
Peru: Empresa Minera del Hierro del Peru S.A.	Pellets	27.59	27.59
South Africa, Republic of:			
South African Iron and Steel Industrial Corp. Ltd.	Lump ore	[2]22.34	[2]22.21
Do.	Fines	[2]19.15	[2]18.03

[1] Prices for fiscal year (FY) 1986 and FY 1987 were revised by Japanese analysts. The revised FY 1986 price was 21.42 cents.
[2] Price per dry metric ton unit.

Source: The TEX Report (Tokyo), v. 21, No. 4954, July 5, 1989, pp. 2–3.

iron was estimated to be 532 Mmt, an alltime high, with blast furnaces in the market economy countries operating at rates not seen since the peak year of 1979. The increase in iron ore trade came at a time when shipments of coking coal, grain, and several other major dry bulk commodities were also elevated. As a result, ocean freight rates were driven up significantly for iron ore. Freight rates for iron ore had already reversed their long-term decline in early 1987 and had risen more than 25% by the beginning of 1988. Rates continued to rise during the first half of the year, dropped somewhat during the summer because of the mine strikes in Australia and drought-related barging problems on the Mississippi River, but bounced back again in the fall. Published rates for spot charterings to the EC from Western Australia ranged from $6.75 to $9.70 per dwt for cargoes of 120,000 to 140,000 dwt, compared with $5.80 to $8.30 in 1987. The 1988 rate ranges for other shipments to the EC are shown in the text table.

Rates for cargoes of 120,000 to 150,000 dwt to Japan from Western Australia ranged from $3.95 to $5.25. Higher rates applied to Port Latta in Tasmania because it cannot accommodate vessels greater than 95,000 dwt and is farther from Japan. Rates to Japan from the Brazilian Port of Tubarão for cargoes of similar size were $7.50 to $11.75.

Australia

Preliminary reports put production of iron ore for ironmaking and steelmaking at 96.08 Mmt, about 6% less than the record high 101.75 Mmt of 1987. Planned cutbacks by Hamersley and labor disputes at the Mount Newman Joint Venture were primarily responsible for the drop in the national total. Pellet production increased slightly to an estimated 3.4 Mmt. There were two pellet producers: Savage River Mines Ltd. and a subsidiary of The Broken Hill Pty. Co. Ltd. (BHP), the BHP Steel International Group. Shipments of ore and pellets reported by individual companies were as follows, in Mmt: Hamersley, 41.07; Mount Newman Mining Co. Pty. Ltd., 32.02; Robe River Iron Associates, 19.28; Goldsworthy Mining Ltd. (GML), 4.80; BHP-Yampi Sound, 3.94; BHP-Middleback Ranges, 2.18; and Savage River Mines Ltd., 2.39. Exports of ore and pellets rose 21% between 1987 and 1988 because of increased sales to Japan, Western Europe, and the Republic of Korea. A large part of the increase was met by drawing down port stockpiles. Exports totaled 94.97 Mmt, with 58% of the tonnage going to Japan—Australia's principal market for more than 2 decades. The Australian industry recaptured part of the Japanese import market that it lost to Brazil and the Republic of South Africa in 1987. Australia supplied 45.0% of total Japanese imports, up from 41% in 1987.

Hamersley, the largest iron mining company in Australia, deliberately cut back production in 1988 to reduce its porthead stocks at Dampier in Western Australia. The company's mines at Mount Tom Price and Paraburdoo in the center of the Pilbara iron region produced a total of about 33 Mmt of hematite products, down 16% from that of 1987. In 1987, Tom Price shipped 22.9 Mmt of products by rail to

Country	Loading port	Cargo size (thousand deadweight tons)	Rate (dollars per deadweight ton)
Brazil	South Atlantic ports	100–150	4.90– 7.50
Do.	do.	200–220	5.50– 6.45
Canada	Sept-Iles or Port Cartier	100–140	4.20– 8.40
Liberia	Buchanan or Monrovia	60– 80	4.97– 8.50
Mauritania	Nouadhibou	80–130	3.90– 5.80
South Africa, Republic of	Saldanha Bay	100–150	6.30–10.25
Sweden	Narvik (Norway)	80–100	2.95– 4.00
Venezuela	Puerto Ordáz	40– 80	7.00–12.50

Sources: Drewry Shipping Consultants Ltd. (London), Maritime Data Network Ltd. (London), Simpson Spence & Young Shipbrokers Ltd. (London), and The TEX Report (Tokyo).

Dampier. The rail haul from the mine to the Indian Ocean port is about 288 km. Paraburdoo, 98 km farther south on the railway, shipped 16.5 Mmt that year.[18]

Hamersley's shipments from Dampier in 1988, in contrast, set a new record and were up 36% from that of 1987.[19] The ratio of fines to lump ore shipped was 52:48. Included in the shipments were 76,000 mt of pellets stockpiled at Dampier since 1980. As a result of the production cutback and record-high shipments, the company's stocks at Dampier plummeted from 17 Mmt to 9 Mmt, a level still excessive for filling spot purchase orders. At yearend 1988, the ratio of fines to lump in the stockpile stood at 8:1. In an attempt to restore the traditional 50:50 balance between lump and fines and still meet the growing demand for lump, Hamersley launched a project to recover lump from detrital scree deposits in the Mount Price area. The company planned to produce 1.5 Mmt of lump per year from these deposits beginning in 1989 and continuing through to 1992.

In line with past years, 42% of Hamersley's exports went to Japan. In fiscal year 1988 (April 1988–March 1989), the company supplied 17.2% of Japan's total import tonnage. Price negotiations for fiscal year 1989 were completed ahead of schedule in mid-December with Hamersley winning price hikes of 13.0% for its fines and 17.3% for its lump. The new prices in U.S. currency were 26.76¢ and 33.76¢ respectively, per dry ltu of iron f.o.b. In 1987, the lump ore averaged 65.0% Fe, 2.82% SiO_2, and 0.055% P. At yearend 1988, Japanese steelmakers and Hamersley were in the process of negotiating several long-term contracts for the 1990's.

In June 1987, Hamersley and the China Metallurgical Import & Export Corp. (CMIEC) agreed to jointly develop the Brockman deposit in the Channar mining area 20 km east of Paraburdoo.[20] Channar was the first overseas project in which China has taken a direct equity interest. Channar Mining Pty. Ltd., a Hamersley subsidiary, had a 60% equity in the venture, with CMIEC holding the remaining 40%. Mine construction began in early 1988 and was projected to cost US $180 million. Production was scheduled to start in late 1990 at a rate of 3 Mmt per year and would be gradually increased to 9 Mmt per year by 1997. Channar consists of five ore bodies having combined proven reserves of 290 Mmt of ore averaging 63.0% Fe and 0.006% P. The ore will be transported by conveyor to Paraburdoo for secondary crushing. When construction is completed, the mine will be placed under the control of the Paraburdoo general manager. Australian exports to China had increased substantially since 1984, with Hamersley supplying more than 70% of the 7.49 Mmt taken by China in 1987.

Mount Newman, the second largest iron ore operation in Australia, planned to operate close to full capacity in 1988 and produce 40 Mmt of hematite products. However, actual production fell considerably short of that goal because of a series of on-off strikes at its Mount Whaleback Mine, on the railway, and at Port Hedland. Union leaders called the strikes to protest management's planned overhaul of work practices. By the time the dispute was settled in late November, porthead stocks of fines had fallen to 1.5 Mmt. Lump ore stocks were almost nonexistent, and several vessels had to be reassigned to either Dampier or Cape Lambert. Mount Newman made important gains despite the difficult situation. In October, the company began producing scree ore at Ore Body 25, 17 km east of Mount Whaleback, at a rate of 1 Mmt per year. In addition, NKK Corp. of Japan agreed to take 1.8 Mmt of fines per year from the Marra Mamba Mine (Ore Body 29) during the next 4 years for use as pellet feed at its Fukuyama steelworks.

A 32-km spur line was built connecting the McCamey's Monster deposit to the main railway that runs between Mount Whaleback and Port Hedland. McCamey's Monster was being developed jointly by Hancock Mining Ltd. (HML) and BHP-Utah Minerals International Inc. At yearend 1988, HML began mining detrital scree ore, containing 62% Fe, from a valley south of the main minesite. The company planned to produce 750,000 to 1 million mt of scree ore in 1989. The scree was railed to Port Hedland, where it was blended with Mount Newman lump. A blend would be more marketable in Japan because the scree is higher in alumina and silica than the Mount Newman material.

The scree was turned over to Mount Newman under a complicated memorandum of agreement. In 1986, HML contracted to supply the Romanian purchasing authority, Mineral Import Export, with 53 Mmt of fines over a

15-year period. Sale agreements were later concluded with Czechoslovakia and Hungary for 500,000 mt per year each. The Romanian contract was then raised to 68 Mmt. In 1988, Mount Newman began shipping about 3 Mmt per year of fines to Romania in exchange for HML's lump and Romanian railroad ore car components. However, at some point in time, Mount Newman will begin receiving cash from trading houses that barter for East European goods. Mount Newman and HML were still studying the feasibility of developing a much larger and more permanent mining operation at McCamey's. The deposit had about 250 Mmt of reserves, averaging 62% Fe.

BHP Steel International announced plans in July to develop several deposits in the South Middleback Range of South Australia. The deposits were in the Iron Duke area, 33 km south of BHP Steel's existing Iron Baron and Iron Prince Mines. The new production would replace shipments of hematite ore from the Iron Baron, where the reserves are nearly exhausted. In 1988, the Iron Baron operations delivered 2.18 Mmt of pellet feed, lump, and fines to BHP Steel's Whyalla Steelworks. The 1.5-Mmt-per-year pelletizing plant at Whyalla had produced dolomite fluxed pellets since 1981. Most of the fluxed pellets were consumed in Whyalla's single 3,000-mt-per-day blast furnace. However, 150,000 mt of pellets was exported, of which almost three-fourths went to Bethlehem Steel's operations in the United States. An additional 400,000 mt of ore products was shipped in coastal vessels to BHP Steel's other steelworks at Port Kembla and Newcastle in New South Wales.

The Robe River project produced a record high 19.79 Mmt of sinter fines on a wet basis in 1988. The joint venture was managed by Robe River Mining Co. Pty. Ltd. for Peko-Wallsend Ltd. (53% equity) and the Australian affiliates of three Japanese steel companies. Pisolitic limonite ore was railed 185 km from the Eastern Deepdale Mine near Pannawonica to the project's Cape Lambert loading terminal at Port Walcott, where the ore was crushed and screened. Deposits K, L, and N at Eastern Deepdale were all being worked in anticipation of a third year of record sales. Deposit K, which had 67 Mmt of reserves averaging 57.5% Fe and 5.5% SiO_2, was brought into production in January 1988 to compensate for the depletion of reserves at L and N. The neighboring deposit M was expected to also come on-line sometime in 1990. Mining of the four deposits was scheduled to continue at the combined rate of 19 Mmt per year until 1995, when operations were to be shifted south of the Robe River to the much larger deposit J. Development of deposit J, which contains about 580 Mmt of pisolitic ore, was postponed in mid-1987 to reduce short-term costs at a time when market conditions were less buoyant. The J ore grade was almost identical to that being mined at Eastern Deepdale.

Shipments from Cape Lambert were up 13%, with about 73% of the tonnage exported going to Japan. On January 15, 1988, Robe River shipped its 200 millionth mt of ore from the terminal. The 4.8 Mmt-per-year pelletizing plant at Cape Lambert was dismantled in early 1986 and sold piecemeal to China's Anshan Iron and Steel Works. The pelletizing plant was closed in April 1980 because of rising fuel oil prices and other cost increases.

GML, the operating company for Mount Goldsworthy Mining Associates, continued to mine high-grade direct-shipping ore at Shay Gap and Sunrise Hill in the eastern Pilbara. The ore, averaging 62.2% Fe for fines and 62.9% Fe for lump, was being railed 180 km to the company's port at Finucane Island in Port Hedland for crushing, screening, and ship loading. The mining venture was owned 70% by Consolidated Gold Fields PLC and 30% by BHP-Utah Minerals. In December 1986, the two partners launched a 20-year project to extract 100 Mmt of lower grade ore, containing 55 to 56% Fe, from leases adjoining the existing operations. The partners planned to develop the Nimingarra and Sunrise Hill West deposits first, with operations shifting after about 15 years to Kennedy Gap and Yarrie, 25 km to the east. Since 1986, a new crusher, ore storage yards, and train-loading facilities have been built at Nimingarra. An 8-km spur line now connects the facilities to the existing Port Hedland rail line. Mining was to begin at Nimingarra in January 1989, with the lower grade ore being extracted and processed separately from the higher grade material.

A 3.0-Mmt-per-year beneficiation plant employing jigs and spirals was constructed at Finucane Island to upgrade the lower grade ore. The upgraded concentrates were being blended with the high-grade direct-shipping ore. The plant was expected to reach full production in April 1989. When the plant becomes fully operational, GML will have the capacity to ship 6.0 Mmt per year of lump ore, fines, and concentrates, an increase from 4.5 Mmt. The new facilities also were expected to improve significantly the quality of the company's products.

Savage River Mines produced 2.4 Mmt of pellets from magnetite ore mined near Mount Cleveland in northwest Tasmania. The ore, which contained 38% to 40% Fe, was crushed and concentrated on-site. The concentrate, which was upgraded by magnetic separation to 67.5% Fe, was then pumped as a slurry 85 km through a 230-millimeter-diameter pipeline to the joint venture's Port Latta pelletizing plant on the Bass Strait. The plant had five shaft furnaces with a combined annual capacity of 2.5 Mmt. Savage River was managed by CCI through its Pickands Mather subsidiary and the Northwest Iron Co. Pty. Ltd. CCI had a 36.2% equity in the project; the remaining equity was shared between Sumitomo Metal Industries Ltd. (17.4%), Nippon Steel Corp. (16.5%), six other Japanese companies (17.5%), and seven Australian companies (12.4%). Almost 80% of Savage River's production was exported to Japan, with the other 20% going to BHP Steel and smaller Australian consumers. About

3% of the pellet feed was sold as heavy medium.

On October 1, 1988, the partners placed the joint venture in a 2-year shutdown mode after operating expenses began to rise. Technical advisors recommended that Savage River be closed because the iron recovery factor had been dropping in recent years, the tonnage requirements of the Japanese partners had slackened, and the mining complex needed modernization. During the closedown period, attempts were to be made to find new customers for the mine's pellets and to reorganize the ownership structure. Proven reserves, equivalent to 15 Mmt of concentrate, were sufficient to allow the mine to operate at least until 1995. Confirmatory drilling was underway to better define the percent of reserves economically viable under current market conditions. The property had at least 87 Mmt of demonstrated resources.

Bahrain

The Kuwait Petroleum Co. (KPC) acquired the idle pelletizing plant in Bahrain from the bankrupt Arab Iron and Steel Co. (AISCO).[21] AISCO suspended operations in early 1986 because of financial and technical problems after producing less than 2 Mmt of pellets at the new facility. AISCO originally had planned to sell a significant part of its production to the Iraqi HYL DR plant at Khor Al-Zubair, but was unable to overcome the extraordinary marketing obstacles created in the Persian Gulf region by the Iran-Iraq war.

Creditor banks wrote off $146 million of AISCO debt in return for an immediate payment of $72 million from KPC. The Kuwaitis formed a new company, Gulf Industrial Investment Co. (GIIC), with $130 million of capital to operate the 4.0-Mmt-per-year facility. Technical assistance was provided by the Japanese Overseas Development Corp., an institution set up by the Government of Japan to promote industrialization in developing countries. Kobe Steel, the plant's original contractor, agreed to supply expertise through the framework of the development corporation and expressed an interest in building a Midrex-designed direct-reduction plant near the existing $310 million complex. GIIC had already signed long-term contracts for pellet feed with Companhia Vale do Rio Doce (CVRD) and Minerações Brasileiras Reunidas S.A. of Brazil, Kudremukh Iron Ore Co. Ltd. (KIOCL) of India, and C.V.G. Ferrominera del Orinoco C.A. of Venezuela.

Brazil

Brazil continued to be the largest exporter of iron ore products in the world. Shipments from the country's five loading ports reached an alltime high of 109.88 Mmt in 1988 and were up 9.3% over that of 1987.[22] Exports accounted for 104.63 Mmt or 95% of the shipment total. The port figures do not include iron ore products trucked or railed directly to Brazilian consumers from the mines and beneficiation plants. Tubarão was the busiest terminal, accounting for 52.2% of the total tonnage. The other half of the shipments was divided between Ponta de Madeira (26.6%), Sepetiba (13.2%), Pontu Ubu (7.5%), and Rio de Janeiro (0.5%).

The largest exporter, CVRD, shipped 29.50 Mmt of ore and pellets to domestic steelworks and exported 62.68 Mmt for combined sales of 92.18 Mmt. Material was shipped to 28 countries, of which the five largest importers were Japan (34%), the Federal Republic of Germany (12%), the Republic of Korea (7%), Poland (5%), and the United States (5%). The state-owned company set a new production record of 97.64 Mmt, an 11% increase over that of 1987.

CVRD divided its mining and transportation activities into two operational regions to better manage the giant and remote Carajás project. The Southern System operated the Caue, Conceicao-Dois Corregos, Periquito, and Caraca Mines in the Iron Ore Quandrangle of Minas Gerais. It also managed the Timbopeba-Capanema Complex near the Minas Gerais town of Ouro Preto. Timbopeba was wholly owned by CVRD, but Capanema was a joint venture between CVRD with 51% equity and a consortium of Japanese companies. Part of the production from the Minas Gerais mines was fed to the pelletizing complex at Tubarão in Espírito Santo. The complex consisted of six pelletizing plants with a combined production capacity of 17 Mmt per year. Two of the six plants were wholly owned by CVRD; the other four were joint ventures with Italian, Japanese, or Spanish companies. The Southern System shipped 37.32 Mmt of ore and pellets from Tubarão during the year. In addition, CVRD exported 20.02 Mt through the port for other companies, including 7.48 Mt of pellets for the three Tubarão joint ventures, 7.03 Mmt of lump and fines for Ferteco Mineração S.A., and 5.50 Mmt of lump and fines for S.A. Mineração da Trindade (SAMITRI).

The Northern System shipped 29.22 Mmt of sinter fines and natural pellet ore from Carajás through its new terminal at Ponta da Madeira in Maranhão. Since the startup of production at Carajás in 1985, CVRD rapidly increased its exports of fines from Ponta da Madeira while slowing down its expansion and development programs in Minas Gerais. The company had to accelerate its development of Carajás to quicken the payback on the $3.2 billion project. The loan payments on Carajás started to strain CVRD's financial resources and were largely responsible for the company's $190 million loss in 1987.

Several factors contributed to the company's financial problems despite record sales. First, world prices for iron ore were significantly lower than were forecast in the Carajás feasibility study. Second, the U.S. dollar weakened against the Japanese yen and the West German mark. This currency realignment adversely affected CVRD's cash-flow because the company's export revenues were largely tied to the dollar, although several of its Carajás loans were negotiated on a yen or mark basis. Third, the original short-term forecast of Carajás sales was overly optimistic. Restrained demand for fines throughout the world forced CVRD to limit the output of Carajás in 1988 to 29 Mmt per year instead of the planned 35 million mt. Despite these problems, CVRD showed a profit of about $210 million in 1988.

The production buildup at Carajás upset the company's traditional balance between lump ore, pebble ore, sinter fines, and pellet feed. Carajás had been producing about 20 times as much fines as lump. In addition, more and more soft itabirite (50% to 53% Fe) was being mined in Minas Gerais in place of the hard type of hematite (64% to 68% Fe). These two operational changes led to a leveling off of lump ore production and made it increasingly difficult for CVRD to fully satisfy the upswing in demand from European and Japanese steelmakers for lump. On October 21, an arm on one of two stacker and reclaimer units at Ponta da Madeira collapsed and killed four people. However, emergency measures taken by CVRD permitted the terminal to operate at about 85% of capacity for the remainder of the year. The terminal was designed to handle 30 to 35 Mmt per year of ore, so the company was expected to meet its 1989 shipment schedule. CVRD planned to have the reclaimer repaired by June 1989.

Canada

Six mines shipped a total of 40.7 Mmt of iron ore products on a wet basis, part of which came from stockpiles. Production was estimated at 39.8 Mmt, about 80% of active capacity. Canadian iron and steel plants consumed 14.3 Mmt of ore and agglomerates, slightly less than the tonnage reported for 1987. In contrast, exports rose from 29.7 Mmt to 31.1 Mmt on a wet basis because of increased sales of concentrates to Western Europe. In 1987, Canada's three largest customers were the 12-member EC (57.2%), the United States (29.9%), and Japan (7.4%). Pellets made up 59.4% of the tonnage exported that year; concentrates, 39.7%; and direct-shipping ore, 0.9%.

IOC shipped 14.8 Mmt of iron ore products from its docks at Sept-Iles, Quebec. The total, which was 12% more than that of 1987, included 7.9 Mmt of standard pellets, 2.0 Mmt of fluxed pellets, 4.1 Mmt of Carol Lake concentrates, and 0.8 Mmt of blended Schefferville ores and Carol Lake concentrates. At yearend, the company had only 200,000 mt of Schefferville direct-shipping ore left in its Sept-Iles stockpile. The Schefferville operation was closed in 1982. All of the crude ore that was mined in 1988 came from the Humphrey Mines at Carol Lake near Labrador City. The Carol Lake beneficiation complex was capable of producing 10.2 Mmt of pellets and an additional 8.8 Mmt of concentrates annually. The pellets and concentrates had to be railed 423 km from Labrador City to the Sept-Iles terminal, which could load two 250,000-dwt carriers at a rate of 7,000 mt per hour.

The Quebec Cartier Mining Company (QCM) shipped 8.51 Mmt of concentrate and 8.33 Mmt of pellets during 1988 from its terminal at Port Cartier. The company's Mount Wright mining complex, 415 km north of Port Cartier, was capable of producing about 18.4 Mmt of concentrate from specularite ore averaging 31.4% Fe. The concentrate typically contained 66.3% Fe, 5.0% SiO_2, and 0.015% P. Almost one-half of the Mount Wright concentrate recovered in 1988 went to the company's 6.0-Mmt-per-year pelletizing plant at Port Cartier. The Port Cartier plant operated at 130% of designed capacity, making more than 8.0 Mmt of pellets. The plant, which QCM had leased since 1985 from Sidbec-Normines Inc., produced custom-tailored low-silica pellets in addition to several types of standard and fluxed pellets. Most of the low-silica pellets went to the DRI plants of Sidbec at Contrecouer, Quebec, and Georgetown Steel Corp. at Georgetown, SC.

The restructuring of USX triggered a series of of events that eventually led to the sale of QCM to Dofasco Inc. At yearend, QCM still remained a wholly owned subsidiary of USX, but was under the control of the parent company's divestment group, USX Holdings Inc. The situation was complicated further because QCM's lease with Sidbec was scheduled to expire in January 1990.

Wabush Mines shipped 6.04 Mmt of pellets in 1988 from its docks on the north shore of the St. Lawrence River at Pointe Noire, Quebec. Wabush's Pointe Noire pelletizing plant operated at its rated capacity of 6.1 Mmt. Production was running 16% ahead of 1987 levels when an 8-week strike interrupted operations in the spring. The company produced three new grades of pellets in addition to the traditional standard pellet containing 2% manganese (Mn) that was sold in 1987. The three new pellet grades were created to satisfy customer requests for both fluxed pellets and pellets with no more than 1% Mn. Both the high and low-manganese concentrates for Pointe Noire came from the company's Scully Mine at Wabush, Labrador. The low-manganese requirement was met by selectively mining zones of manganese-poor ore and segregating that ore from the normal run-of-mine material. In both cases, the primary ore mined was specular hematite. As did IOC, Wabush shipped its concentrates on the Quebec North Shore & Labrador Railway to Sept-Iles. The railway was wholly owned by IOC, but operated as a common carrier and was required by law to haul the concentrates of IOC's competitor.

In late August, Dofasco, the second largest steelmaker in Canada, acquired Algoma of Sault Ste. Marie, Ontario. Both steel companies had extensive iron ore holdings in North America. Algoma was a major partner in the Tilden Mine near Ishpeming, MI, and sole owner of the George W. MacLeod Mine at Wawa, Ontario. Dofasco was sole owner of the Adams Mine at Kirkland Lake, Ontario, and had equities in three other Canadian operations: the Sherman Mine (90%), Wabush Mines (16.4%), and IOC (6.07%). Algoma's management and union officials all supported the takeover, which cost Dofasco about $485 million in stock and cash. The acquisition of Algoma made Dofasco the fourth largest steelmaker in North America, following USX, LTV, and Bethlehem Steel.

Algoma's steelworks at Sault Ste. Marie received 2.4 Mmt of pellets from Tilden in 1988. Algoma also produced 1.09 Mmt of superfluxed sinter at its own Wawa operations. The sinter was railed 295 km along the eastern shore of Lake Superior to Sault Ste. Marie. The sinter was made from 1.32 Mmt of siderite ore, 0.19 Mmt of limestone, 0.09 Mmt of rollscale, and 0.04 Mmt of miscellaneous oxides and subgrade fines.[23] All of the siderite came from the nearby MacLeod Mine. The underground mine was connected to the sintering plant by a 4.6-km-long cable belt system. The petroleum coke, limestone, and rollscale consumed in the sintering were discharged from vessels docking in Michipicoten Harbor.

The Adams and Sherman Mines in northern Ontario both produced fluxed pellets for Dofasco's steelworks at Hamilton. Their combined output was about 11% less than 1987 levels because of a month-long strike that began on March 26 and operational cutbacks later in the summer. The Adams Mine shipped 1.00 Mmt of pellets; the Sherman Mine at Temagami, 0.85 Mmt. Each complex had a rated annual capacity of 1.1 Mmt and employed about 340 people. Both were managed by Cliffs of Canada Ltd., a subsidiary of CCI, and both have been in highly unfavorable cost positions since 1985.

A major restructuring of the Canadian iron ore industry was underway at yearend. Dofasco took steps to close its two mines in Ontario at the same time that USX was seeking buyers for QCM. Both Elders Resources North America (a subsidiary of an Australian investment group) and Dofasco were interested in acquiring equity in the Quebec operation. A switchover to QCM pellets would solve several of Dofasco's raw material problems. The Adams and Sherman Mines were having difficulty competing with the much larger operations in Quebec, Michigan, and Minnesota. The Ontario operations were at a disadvantage because of their relatively small size, low ore grades, and the high cost of shipping pellets by rail more than 540 km from Kirkland Lake and Temagami to Dofasco's steelworks in Hamilton. Hamilton's 2-Mmt annual requirement could be easily met by hauling pellets in 222-meter-long, 25,000-dwt self-unloaders up the Saint Lawrence Seaway from QCM's terminal at Port Cartier.

Chile

Cía. Minera del Pacífico S.A. (CMP) produced a total of 7.28 Mmt of iron ore products, an increase of 19%. The Huasco pellet plant set a new production record, making 3.80 Mmt of self-fluxing pellets for blast furnaces and 0.27 Mmt of pellets for DRI plants. The 4.0-Mmt-per-year pelletizing facility also generated 327,000 mt of special pellet feed and 55,000 mt of pellet chips. CMP, a wholly owned subsidiary of Cía. de Acero del Pacífico S.A. de Inversiones (CAP), was planning to raise Huasco's capacity to 4.5 Mmt by making several design and process improvements. As in past years, the bulk of the preconcentrate feed for Huasco came from the beneficiation plant at the El Algarrobo Mines, an 85-km rail haul.

CAP purchased the El Algarrobo Mines in 1959 from Mijnen NV of the Netherlands. The mines, 48 km southwest of the city of Vallenar, had 107 Mmt of reserves, averaging 54% Fe, and a dry magnetic concentrator capable of processing 5.5 Mmt of ore per year. Mining was scheduled to resume at the Los Colorados deposit, northwest of Vallenar, in 1990. Los Colorados, idle since 1986, had 78 Mmt of reserves and a concentrator that can process 610,000 mt of ore per year. Huasco, El Algarrobo, and Los Colorados were all within Region III.

CMP also supplied 1.50 Mmt of sinter fines to the Japanese steel industry in 1988 as part of a 3-year contract. An additional 56,000 mt of fines was shipped for the first time to the Baoshan steelworks in China. In both cases, the sinter fines came from the El Romeral Mines, which produced 1.45 Mmt of fines and 1.32 Mmt of lump ore during the year. The El Romeral Mines, near La Serena in Region IV, had 237 Mmt of reserves, averaging 55% Fe. The fines and lump were hauled 38 km by rail to the port of Guayacan, which could accommodate 220,000-dwt vessels.

CMP began production at its new El Laco Mine high in the Andes near the Argentine border. The mine lies at elevations of 4,800 to 5,500 meters and could only be worked from November to March because of severe winter weather conditions. The company had a 5-year contract to deliver a total of 360,000 mt of lump ore to the Argentine steelworks of Establecimiento Altos Hornos Zapla. The magnetite ore was trucked to Olacapato in Argentina and transferred to railcars for shipment to the steelworks at Palpala, north of Salta in Jujuy Province.

CMP exported 6.40 Mmt of iron ore products. Shipments from the port of Guacolda in Huasco Bay consisted of 3.55 Mmt of pellets, 326,000 mt of pellet feed, and 55,000 mt of chips. The No. 2 berth at Guacolda could accommodate vessels of up to 270,000 dwt without using tugboats. The remaining 2.66 Mmt included 1.56 Mmt of fines and 911,000 mt of lump loaded at Guayacan. An additional 1.22 Mmt of products went to CAP's blast furnaces at Huachipato. Occasionally, El Romeral concentrates were also shipped from Guayacan to Guacolda for use in the Huasco plant.

Finland

Rautaruukki Oy, the state-controlled steel conglomerate, closed its Rautuvaara iron-copper mine in Lapland in December after 13 years of operation. The underground mine had been unprofitable in recent years because of depressed world prices for fines. In 1988, 1.07 Mmt of crude ore was hoisted to the surface. Rautuvaara produced 555,600 mt of iron ore concentrates and 7,900 mt of byproduct copper concentrates from the crude, setting new production records for both. The mining operation shipped 556,900 mt of concentrates averaging 67% Fe to Rautaruukki's steelworks at Raahe on the Gulf of Bothnia. The closure of Rautuvaara made Rautaruukki's steelmaking operations totally dependent on imported ores and agglomerates. Rautaruukki closed Otanmäki, its other underground iron mine, in mid-1985. For 1989, the steel conglomerate was planning to import about 2.5 Mmt of fines and pellets for Raahe and 0.7 Mmt for its smaller Koverhar works at Dalsbruk, west of Helsinki. A large part of the tonnage was being supplied by LKAB. The land and buildings at Rautuvaara were leased to Outokumpu Oy, who was using the site to process gold ore from its new Saattopora open pit, 55 km away. The equipment used to crush and concentrate the iron-copper ore was sold outright to Outokumpu. The recent discovery of the Karhujapukka vanadium-rich iron deposit in the Kolari area, 40 km south of Rautuvaara, could conceivably alleviate the long-term supply situation for Rautaruukki. However, exploration was still at a very preliminary stage.

India

India moved from fifth to fourth place in the list of major exporting countries. Based on preliminary data, production of ore and agglomerates rose only slightly, but exports increased 11% to 32.25 Mmt. Domestic consumption was estimated at 17.1 Mmt. Exports included 21.77 Mmt to Japan, 3.38 Mmt to the Republic of Korea, and 1.67 Mmt to Romania. Goan exports through the Port of Mormugao totaled 13.28 Mmt, with 64% going to Japan. The three largest Goan shippers were Chowgule & Co. Pvt. Ltd. (2.36 Mmt), V. M. Salgaocar & Bros. Pvt. Ltd. (2.27 Mmt), and Sesa Goa Ltd. (2.19 Mmt). Included in the Goan total were 2.38 Mmt moved through the port by the State-owned Minerals and Metals Trading Corp. (MMTC), but only two-thirds of this material was of Goan origin.

KIOCL has steadily built up an export market for its concentrates and pellets. The details of this buildup are shown in the text table.

	Gross weight (thousand dry metric tons)	
	Concentrates	Pellets
Financial year (April to March)		
1981-82	503	—
1982-83	1,029	—
1983-84	1,137	—
1984-85	1,572	—
1985-86	2,060	—
1986-87	3,362	155
1987-88	3,045	825
1988-89	2,963	1,640
Calendar year: 1988	3,277	1,486

Sources: Skillings' Mining Review, v. 77, No. 24, June 11, 1988, p. 4; and v. 78, No. 26, July 8, 1989, p. 5. The TEX Report (Tokyo), v. 21, No. 4949, June 28, 1989, p. 11.

KIOCL's export earnings have improved substantially since 1985 when the company first began shipping concentrates to Japan. The Japanese steel industry has been KIOCL's main customer ever since and took 2.33 Mmt of concentrates on a dry basis in Indian fiscal year 1988-89, which began on April 1. The remaining 632,000 mt was shared between Australia, Bahrain, China, Czechoslovakia, and Yugoslavia.

The Kudremukh Mines have been in operation since 1981 and are in the Chikmagalur district of Karnataka State. In Indian fiscal year 1988-89, the complex produced 13.83 Mmt of crude ore, averaging 41.2% Fe. Both magnetite and hematite were mined, but the two were treated separately at the concentrator. The soft, more friable hematite occurs in the upper, weathered portions of the banded iron formation and tapers off with depth. In contrast, the magnetite becomes increasingly abundant deeper in the pits where there has been little or no oxidation.

Weak sales have kept the concentrator from operating anywhere close to its full capacity of 7.5 Mmt per year. The facility was built with the understanding that the bulk of the concentrate would go to the Iranian steel industry. However, these sales never materialized because of the Iranian revolution and the subsequent Iran-Iraq war. In Indian fiscal year 1988-89, the facility produced 4.61 Mmt of concentrate, averaging 67.74% Fe and 2.76% SiO_2. The increased output was a significant improvement over the early years of operation. Utilization of the concentrator had risen steadily from 22% in 1984-85 to 61% in 1988-89. The concentrate was being slurried and pumped through a 67-km-long pipeline to the Port of Mangalore on the Arabian Sea.

In April 1986, KIOCL commissioned a 3-Mmt-per-year pelletizing plant at Mangalore and began commercial production 1 year later. The plant was built at a cost of about $87 million with technical assistance from Lurgi Chemie und Huettentechnik GmbH. Since then, KIOCL has built up the plant's output to more than 1.8 Mmt per year. About 44% of the plant's 1988-89 production was shipped to blast furnaces in Eastern Europe, although the facility was originally designed to make high-quality pellets for gas-based DRI plants in the Middle East and Southeast Asia. The remainder of the 1988-89 pellet production went to a wide spectrum of countries, including the Federal Republic of Germany, Qatar, Turkey, and the United States.

National Mineral Development Corp. Ltd. (NMDC) had three mining complexes in operation: Bailadila-

14/11C and Bailadila-5 in the Bastar district of Madhya Pradesh and Donimalai in the Bellary district of Karnataka. The largest shipper was Bailadila-14/11C, which produced 2.35 Mmt of lump and 1.54 Mmt of fines during the 1988 calendar year. Bailadila-11C was commissioned in October 1987 to supplement and eventually replace the main Bailadila-14 mine. Bailadila-14 had been in production since April 1986, and its reserves were being rapidly depleted. NMDC had three other projects under consideration to extend the life of Bailadila-14. The first project involved making the pit 72 meters deeper so that ores on the lowest levels could be recovered more easily. This additional production could be used either to feed the new integrated steelworks being built at Visakhapatnam on the coastal side of the Eastern Ghats or exported through Visakhapatnam Outer Harbor. The port can accommodate vessels up to 135,000 dwt. The second project called for the mining and handling of "blue dust," a powdery form of hematite that occurs in the upper levels of the mine and has been difficult to process and market in the past. The initial production level was to be 0.7 Mmt per year. Bailadila-14 had reserves of at least 22 Mmt of blue dust. The third project involved the construction of a mechanized facility capable of handling and loading 2.8 Mmt of fines per year into railcars for delivery to the classification yards at the harbor in Visakhapatnam.

A similar mechanized handling system was completed at Bailadila-5 in July 1987 and was undergoing trials. Mine shipments from Bailadila-5 for the 1988 calendar year were about 9% less than those from Bailadila-14/11C. However, Bailadila-5 made 2.50 Mmt of lump and 1.61 Mmt of fines, outproducing 14/11C. Like 14/11C, Bailadila-5 rails its ore 470 km over mountainous terrain to Visakhapatnam via Jagdalpur. The port facility at Visakhapatnam loaded 4.95 Mmt of lump and 1.55 Mmt of fines for a total of 6.50 Mmt. Donimalai produced 1.16 Mmt of lump and 1.45 Mmt of fines during the calendar year and shipped 2.37 Mmt from Madras on the Coromandel coast.

Liberia

Bong Mining Co. (BMC) had two pelletizing plants, but the older one had been idle since 1980. The No. 2 plant had a capacity of 2.8 Mmt per year and produced 3.18 Mmt of pellets in 1988. The pellets contained 64.6% Fe and 6.5% SiO_2; however, BMC planned to lower the silica to 4.0% in the near future. The company also produced 3.92 Mmt of sinter feed for export to Italy and the Federal Republic of Germany.

The BMC operation, a 50–50 joint venture between the Liberian Government and four European steel companies, had relatively high production costs because its ores averaged only 37% Fe and required intensive beneficiation. The company recently made several modifications to its 11-line concentrator to adjust for changing crude ore characteristics and to satisfy customer desires for lower silica and alkalis.[24]

When BMC started up in 1965, two types of ore were mined initially: (1) a soft, completely weathered, coarse hematitic ore that averaged 39.1% Fe and 9.3% magnetite, and (2) a partially weathered, transitional ore that averaged 37.4% Fe and 18.1% magnetite. The hematite was recovered first with Humphrey's spirals; the magnetite was then pulled from the spiral tails with a cobber magnetic separator. As the pit deepened, the company began mining a third, less weathered type of ore composed of much finer grained magnetite and considerably harder to grind. This third type of ore, which averaged 35.8% Fe and 35.0% magnetite, constituted 71% of BMC's remaining reserves, but the ore contained significant amounts of troublesome amphiboles and mica. Because its reserves of softer ores would be exhausted by 1995, BMC took steps to improve the efficiency of both its primary grinding section and its magnetic separation section. In March 1988, the company converted one of its primary cascade mills from autogenous to semiautogenous grinding. Plans were also made to convert two other cascade mills and to add a quaternary stage to the magnetic separation section. The plant was capable of producing more than 7 Mmt of concentrate per year.

Mauritania

Société Nationale Industrielle et Minière (SNIM) produced 9.52 Mmt of usable ore and shipped 10.00 Mmt from the Atlantic Port of Nouadhibou to 11 countries. About 92% of the exported material went to seven members of the EC. The three largest buyers were Belgium (28%), Italy (23%), and France (19%). The tonnage was 11% more than that of 1987, when the company exported 7.89 Mmt of direct-shipping ore and 1.12 Mmt of Guelb concentrates. Belgian steelmakers were also the largest buyers in 1987, contracting for four different ore grades, totaling 2.51 Mmt. In the 1988 European price negotiations, the price of Tazadit fines was reduced by 3.5% to 25.10 cents per dry mtu of iron f.o.b. The price for Guelb concentrate dropped slightly less, going from 24.90 cents to 24.40 cents. As a result of the successive price cuts in 1988, 1987, and 1986, SNIM's prices were lower in real terms than they were in 1975. More than one-half of the Guelb concentrate was used as sinter feed at steelworks in Western Europe and Japan.

The management of SNIM examined ways of increasing its market share in Europe and finding new customers in the United States and Asia. To become more cost competitive with Brazilian producers, the parastatal company froze salaries in early 1987 at their 1986 levels and put a ceiling on hiring. In 1986, SNIM had a staff of 5,875, making it the largest employer in Mauritania. In April 1987, about 1,000 workers were laid off to cut costs further.

SNIM was negotiating with General Motors Corp. for additional locomotives for its 650-km-long railway from the mines near Zouerate to Nouadhibou. In July 1986, Mauritanian ore entered the United States for the first time ever as part of an earlier barter transaction for locomotives. Two unit trains haul ore daily through inhospitable desert terrain to the coast.[25] This route parallels the border with Western Sahara. The unit trains are some of the longest in the world and frequently extend for more than 2.2 km. A typical train consists of 220 cars and can haul as much as 22,000 mt of ore when pulled by five locomotives. Maintenance of the rail line and rolling stock accounted for a significant portion of SNIM's operating costs in 1988. Drifting sand and the heat were continual headaches, causing excessive abrasion of parts and an abnormally high number of derailments. About one-fourth of SNIM's employees work on the railway.

SNIM sought financial assistance to upgrade both the railway and port facilities at Nouadhibou, which had an ore storage capability of about 1.8 Mmt. The company also needed funds to resolve technical problems at the new 6.0-Mmt-per-year Guelbs ore beneficiation plant, which used an unconventional dry magnetic separation process. Reserves at the four existing hematite mines in the Kedia D'Idjil (Tazadit, Rouessa, F'Derik, and Segaza'u), which totaled about 58 Mmt, were projected to be exhausted by 1998.[26] To replace these high-grade reserves, SNIM planned to develop new mines at Oum Arwagen and Mhaoudat, which are east of the existing new El Rhein Guelb Mine. The feasibility study on developing the 6-Mmt-per-year Mhaoudat Mine was being funded in part by the European Investment Bank. The mine would produce predominantly lump ore containing 64% to 68% Fe and would cost $70 to $100 million. The reserves of the eastern Guelbs group (El Rhein, Oum Arwagen, and Mhaoudat) consist of 500 to 700 Mmt of ore averaging 38% Fe. The rest of the Tiris region, which included both Zouerate and the Guelbs, contained a minimum of 1 billion additional mt of resources.

SNIM also investigated the possibility of constructing a 2- to 4-Mmt-per-year pelletizing plant at Nouadhibou.[27] The prefeasibility study was supported by Société Nationale de Siderurgie of Algeria and the Misurata Iron and Steel Works of Libya. The pellets would go to the DRI plants at Misurata, Bellara in Algeria, and El Dikheila in Egypt.

SNIM's three principal problems have been declining prices for its ores, a $350 million debt incurred to develop the Guelbs project, and dependence on imported oil for energy. The iron mines were vital to the economy of Mauritania and the second biggest source of foreign exchange earnings after fishing.

Mexico

A 2-Mmt-per-year gas-based DRI plant was commissioned in mid-November at the steelworks of Siderúrgica Lázaro Cárdenas-Las Truchas S.A. (Sicartsa). The steelworks is in the State of Michoacán at the mouth of the Balsas River. Sicartsa is part of the State-controlled SIDERMEX Group and has financial ties to Altos Hornos de México S.A. de C.V. The DRI plant was a key part of SIDERMEX's stage 2 expansion program for the steelworks. Most of the DRI will be used as feed for Sicartsa's four new electric arc furnaces and the older, lone blast furnace built during stage 1. The remainder will be employed as a cooling charge in the complex's two basic oxygen furnaces. The steelworks also had a 1.85-Mmt-per-year pelletizing plant equipped with a Lurgi traveling grate. Ore for the DRI and pelletizing operations was coming from Ferrotepec and several smaller open pits in the Las Truchas district, less than 30 km away in the Pacific coastal hills.

The new DRI plant is the first to employ the HYL III process, and consists of four 500-mt-per-year reactors in a cube formation with common mineral charge and product discharge facilities.[28] The reactors were designed to operate in pairs, sharing the same natural gas reformer, reducing gas heaters, and related equipment. Only one-half of the plant's capacity (i.e., one module of two reactors) will be utilized until the new meltshop becomes fully operational.

New Zealand

New Zealand Steel Mining Ltd. produced iron sand concentrate at two locations on the western coast of North Island. The first operation, Waikato North Head, pumped its entire output through a 20-km-long slurry pipeline to the Glenbrook steelworks of the company's parent, New Zealand Steel Ltd. At Glenbrook, the concentrate was reduced to hot metal in a 750,000-mt-per-year ironmaking plant equipped with four SLRN kilns and two Elkem electric arc furnaces. The second mining operation, Taharoa, exported all of its production and was the sole source of iron sand for the Japanese steel industry. New Zealand's other supplier, Waipipi Iron Sands Ltd., closed in November 1987 after 17 years of operation. Waipipi had been using two dredges and a floating concentrator to mine an area of sandhills behind the beaches at Waverley.

In 1988, the dune operation at Waikato North Head produced 760,000 mt of titanomagnetite concentrate and pumped 870,000 mt to Glenbrook, with the difference coming out of the mine's stockpile. The recent expansion of the Glenbrook facilities increased the steelmaking capacity of New Zealand Steel more than fivefold and required Waikato to correspondingly raise its concentrating capacity from 300,000 mt per year to 1.5 Mmt. Glenbrook was expected to consume about 1.1 Mmt of concentrate in 1989 and 1.3 Mmt in 1990.

The Taharoa dune operation produced 1.48 Mmt of titanomagnetite concentrate during 1988 and sold 1.58 Mmt, delivered in 14 shipments. The bulk of the Taharoa material was hauled to Japan in three specially designed, 120,000-dwt vessels: the *Slurry Express, Taharoa Maru,* and *Taharoa Enterprise.* Japanese steelmakers used the iron sand concentrate, which averaged 56.5% Fe and 8% TiO_2, to protect the refractory linings of their blast furnaces and prolong furnace life. The concentrate is first sintered with other iron ore. The relatively lightweight, titaniferous sinter is then carefully charged into the blast furnace so that it falls outward toward the refractory-lined walls during its descent into the bosh. This action enables the titanium in the sinter to more easily form a protective coating on the refractory.

In the last few years, improved technology enabled Japanese steelmakers to reduce the amount of titanium needed to produce a ton of pig iron. At the same time, relatively high phosphorus and alumina levels of the New Zealand concentrate [0.17% P and 3.7% alumina (Al_2O_3)] have encouraged the Japanese to substitute high-titanium lump from the Republic of Korea [48% Fe minimum and 15% titanium (Ti) minimum] for iron sand. The net result was a drop in sales volume for the New Zealanders. However, the 13% to 20% loss in contract volume between fiscal years 1988 and 1989 was offset by a 13% price hike to 16.689 cents per dry ltu of iron f.o.b.[29] The iron sand was still inexpensive compared to alternatives. In addition, its titanium is more evenly distributed through the furnace burden than that of the lump ore because the sintered sand has a lower and more uniform concentration of titania.

Chinese steelmakers recently expressed an interest in New Zealand iron sand and requested delivery of trial amounts to Baoshan in late 1989.

Norway

Exports totaled 1.7 Mmt, down almost one-third from the 2.53 Mmt in 1987. The largest producer, A/S Sydvaranger, loaded 1.26 Mmt of standard pellets and 68,900 mt of concentrate at the Arctic Port of Kirkenes. Most of the pellets were shipped to British Steel PLC and Peine Salzgitter AG, with the balance going to ferrosilicon producers in south-central Norway. All of the concentrates went to the United States. British Steel paid Sydvaranger 42.75 cents per dry mtu f.o.b. for the pellets, 9.9% more than in 1987. The Sydvaranger operation had high operating costs, but enjoyed the support of the Norwegian Government because of the mine's remote location in the Sor-Varanger area, 350 km north of the Arctic Circle. In 1987, Sydvaranger produced 1.45 Mmt of concentrate from 3.39 Mmt of crude ore averaging 29.29% magnetic iron.[30] The bulk of the concentrate went to produce 1.46 Mmt of pellets at the company's two grate-kiln plants near Kirkenes. The two plants had a combined pelletizing capacity of 2.4 Mmt per year, but the older of the two was only used as backup. Sydvaranger considered converting the older plant to metallurgical coke production and using the byproduct gas as fuel for the newer plant. The ore mined in 1987 came from four open pits: Bjornevatn North (47.8%), Bjornevatn East (21.2%), Tverrdalen (15.6%), and Jerntoppen (15.4%). The development of the new Jerntoppen pit allowed Sydvaranger to halt mining of the lower grade Tverrdalen deposit in June 1987. This changeover raised the iron content of the mill feed by 5% to 7%.

Two other Norwegian companies mined iron ore during 1988. Norsk Jernverk AS shipped 1.04 Mmt of concentrate, down from 1.29 Mmt in 1987. The company exported 500,000 mt, with France taking 218,000 mt and Czechoslovakia taking 120,000 mt. The remaining 544,000 mt was consumed at the company's Mo i Rana integrated steelworks on the Ranen Fjord. Norsk Jernverk also had an ore beneficiation complex and a shipping terminal at Mo i Rana. The crude ore was hauled 37 km from the Ortfjell Mine in the Dunderland Valley to Mo i Rana, where it was crushed, screened, and eventually fed through a high-intensity magnetic separator. Until last year, the coarser concentrates went to an agglomerating facility where they were made into pellets for Mo i Rana's electric pig iron furnaces. However, pelletizing was halted in January 1987 when two of the electric furnaces were shut down because of low prices for semifinished steel.[31] All of the concentrates were exported "as is" or upgraded into a 71% Fe superconcentrate, which was then shipped to Sweden for iron powder production.

In July 1986, a $7 million shipping terminal capable of handling vessels up to 80,000 dwt was commissioned adjacent to the beneficiation complex. In February 1987, an underwater landslide extensively damaged the new deepwater wharf. Norsk Jernverk received a second setback when prices for its concentrates began declining 6 months later. Because of the low prices, management decided to cut back concentrate production from 1.6 Mmt per year to the present 1.0 Mmt. Since 1986, the number of employees in the Mining Div. had been reduced from 410 to 325.

The third company, Fosdalens Bergverks A/S, produced 196,000 mt of magnetite concentrates in 1988 at its mines in Malm. The underground mines are near the northern head of the Trondheimsfjord, about 85 km northeast of the city of Trondheim. Fosdalen exported 175,000 mt of concentrates, averaging about 65.5% Fe, from its loading dock on the fjord, leaving the company with yearend stocks of 32,000 mt. The Malm mines have operated continuously since 1906 and also have produced concentrates of pyrite and chalcopyrite.

Peru

Empresa Minera del Hierro del Perú (Hierro Perú) produced 4.16 Mmt of pellets and fines on a dry basis, a drop from 5.10 Mmt in 1987. Production included high-grade sinter feed (45%), blast furnace pellets (35%), pellet feed (13%), and low-silica pellets for direct reduction (7%). The 18% drop in production was the result of two nationwide mining strikes, which seriously crippled most of the industry for a total of 87 days. Nonunion members of Hierro Perú's staff were able to keep the No. 2 pelletizing plant operating at about 50% of capacity throughout both strikes. The two strikes had a minimal effect on exports of fines because 2 months of stocks were on hand at the Port of San Nicolás. Exports totaled 4.52 Mmt on a dry basis, with 57% going to the Republic of Korea, 24% to Japan, and 12% to Yugoslavia. In addition to exports, coastal vessels carried about 400,000 mt from San Nicolás to the Chimbote steel mill operated by Empresa Siderúrgica del Peru S.A.

Because of the improved demand for pellets in Europe and parts of Asia, Hierro Perú took steps to restart its No. 1 pelletizing plant, which had been idle for 10 years. Pohang Iron and Steel Co. Ltd. (Posco) of the Republic of Korea spurred the startup by agreeing to increase its contract purchases for Kwangyang from 2.9 to 3.15 Mmt per year. About two-thirds of the South Korean purchases were to be sinter feed. When the 1.2-Mmt-per-year plant resumes full scale production in mid-1989, Hierro Perú will have a total annual pelletizing capacity of about 3.4 Mmt. Steps were also taken to acquire five 120-ton dump trucks for the Marcona pit and to modernize the existing berth at San Nicolás to accommodate vessels of 200,000 to 250,000 dwt. A new loader with a 20-meter-high clearance will be installed by the Hyundai Group so that vessels larger than 160,000 dwt can take full advantage of the 18-meter-deep berth. The existing loader has a clearance of only 12.65 meters.

South Africa, Republic of

South African mines shipped an estimated 23 Mmt of lump ore, sinter fines, and concentrates in 1988. The bulk of the shipments came from the Sishen and Thabazimbi Mines operated by the Iron and Steel Corp. of South Africa Ltd. (Iscor). At least six other mines had primary production.[32] The largest of the six was the Mapochs Mine of Highveld Steel and Vanadium Corp. Ltd. at Roossenekal in the eastern Transvaal. Mapochs provided magnetite lump for the pig iron plant at Highveld's Witbank steelworks as well as magnetically upgraded fines for the company's Vantra roast-leach vanadium plant. The Witbank plant smelted the lump in electric arc furnaces after prereduction in rotary kilns. Three additional operations mined titaniferous magnetite solely for the extraction of vanadium. Titaniferous magnetite was also recovered as a byproduct concentrate by Palabora Mining Co. Ltd. during the beneficiation of copper and phosphate ores at the Phalaborwah carbonatite complex near Kruger National Park.

Exports accounted for almost one-half of the country's total shipments. Overseas sales rose from 8.80 Mmt to 11.1 Mmt between 1987 and 1988, even though economic sanctions had been imposed by some traditional trading partners. During the 5-year period from 1984 to 1988, South Africa exported 50.9 Mmt of iron ore products. On a tonnage basis, 55% went to Japan, 34% to the EC, and 11% to Turkey and three other countries.

The sanctions issue complicated contract negotiations between the Japanese steel industry and the Republic of South Africa's two principal exporters of iron ore, Associated Manganese Mines of South Africa Ltd. (ASSMANG), and Iscor. Iscor's 12-year contract with the Japanese expired in March 1988, leaving 18 Mmt of the contracted 77 Mmt unshipped. The contract expired when the Japanese Ministry of International Trade and Industry was reevaluating its South African trade policies and encouraging Japanese blast furnace operators to exercise self-control in importing iron ore and coking coal from the Republic of South Africa. Japanese imports of South African iron ore declined from 5.58 Mmt to 4.90 Mmt between 1987 and 1988.

The Sishen open pit mine in the Griqualand West district of Cape Province made about 15 Mmt of marketable products from run-of-mine, Lake Superior-type hematite ore containing 57% to 66% Fe. Sishen also maintained a 150-Mmt stockpile of lower grade ore containing 50% to 60% Fe. All of the high-grade crude ore was beneficiated in Iscor's 18-Mmt-per-year North Sishen plant. The ore must be upgraded because it is highly laminated and has interbedded bands of shale.[33] Three products were recovered utilizing different stages of crushing, wet and dry screening, heavy-medium separation, and blending: lump ore (−25 + 8 millimeters) averaging 66.4% Fe, 3.03% SiO_2, and 0.043% P; intermediates for direct blast furnace reduction (−13 + 5 millimeters); and fines (−5 + 0.2 millimeters) averaging 65.4% Fe. Atomized ferrosilicon was used as the separating medium in both the drum and cyclone circuits. Iscor had a second beneficiation plant with a product capacity of 9.0 Mmt per year, but the facility has been shut down since 1984 because of production cutbacks. Iscor railed more than 7 Mmt of Sishen products to its steelworks in the Transvaal (689 km) and northwestern Natal (998 km). The parastatal company had four blast furnaces at Vanderbijlpark south of Pretoria and one at Newcastle. The remaining 10 Mmt was railed 861 km to the deepwater Atlantic Port of Saldanha Bay for export. The ore terminal at Saldanha Bay was capable of handling vessels up to 285,000 dwt at a rate of 8,000 mt per hour. The Bruce Mine at the southern edge of the Sishen property was idle throughout 1988. Iscor had been operating the iron mine for its owner, ASSMANG, and beneficiating its ores at Sishen until June 1986. At that time, ASSMANG decided not to renew its agreement with Iscor and chose instead to increase production at its wholly owned and operated Beeshoek Mine.

Iscor's Thabazimbi Mine in the northwestern Transvaal was producing about

1.6 Mmt of run-of-mine ore per year from its Donkerpoort open pit and about 1.0 Mmt from its East underground operation.[34] Like Sishen, the ore was composed largely of hematite derived from a Lake Superior-type banded ironstone. The Thabazimbi ores averaged about 63% Fe and are slightly lower grade than those at Sishen. Drilling, blasting, and caving must be carefully controlled because of the extreme variability in ore hardness created by secondary enrichment. The ore from both operations was fed to a heavy-medium separation plant for washing, screening, and upgrading. The plant produced two fractions of lump ore averaging 64.0% Fe, 6.0% SiO_2, and 0.03% P. Sinter fines (-6+0.07 millimeters) made up about one-half of the plant's output. All of Thabazimbi's production was railed to Iscor's steelworks.

ASSMANG's Beeshoek open pit mine in northern Cape Province was capable of producing 5 Mmt per year of run-of-mine ore. However, the operation, 6 km west of Postmasburg, produced and shipped only 1.48 Mmt of lump ore and fines in 1988. The lump ore averaged about 66.4% total Fe and 0.05% P. Most of the production was bought by Sumitomo Metal Industries Ltd. and three other Japanese steelmakers. The geological setting and ores were very similar to those at Sishen, but Beeshoek had much larger reserves. One major difference was that conglomeratic ore predominated over laminated ore at Beeshoek. After washing, screening, and blending, the products were railed to Saldanha Bay.

Iscor started up its novel COREX ironmaking plant at the Pretoria steelworks on August 19, 1988, after 3 years of construction and testing.[35] The facility was the first commercial plant to employ the direct-reduction process developed by Korf Engineering GmbH (now Deutsche Voest-Alpine Industrieanlagenbau). It was designed to produce 300,000 mt per year of hot metal for Pretoria's three steelmaking furnaces. The COREX or KR process uses low-ranked coal, which is abundant in the Republic of South Africa, and eliminates the need for environmentally troublesome coke ovens and sintering plants. A COREX plant can be regarded as a miniblast furnace, but is more flexible than a blast furnace because the operator can choose from a wider selection of iron ore products. The addition of the small, efficient, and cost-effective swing producer will enable Iscor to optimize the operating conditions of its two conventional blast furnaces.

Sweden

Total shipments of iron ore products increased 5% to 21.5 Mmt, of which 3.4 Mmt went to the Swedish steel industry and 18.1 Mmt was exported. Yearend stocks of ore dropped from 2.2 Mmt in 1987 to 1.4 Mmt.

LKAB's mines and plants in Lapland accounted for 19.20 Mmt, or about 89% of total Swedish shipments. The Kiruna operation, which included the Svappavaara pelletizing plant, shipped 5.84 Mmt of pellets and 6.84 Mmt of lump ore and sinter feed. All of the Kiruna material was sold abroad. An additional 3.20 Mmt of pellets and 3.32 Mmt of lump and fines came from the Malmberget operation. Almost 60% of the Malmberget material was exported. About 83% of the total 16.59 Mmt exported by LKAB was railed to the Port of Narvik in Norway. The remainder went to the Port of Luleå on the Gulf of Bothnia.

LKAB produced 18.43 Mmt of marketable products during the year, of which 9.1 Mmt was pellets. Pellet production reached record-high levels and was divided almost evenly between Kiruna (35%), Svappavaara (30%), and Malmberget (35%). More than 100,000 mt of dolomite from Masugnsbyn and 100,000 mt of olivine from Purnu were consumed in the production of fluxed pellets. In December 1987, LKAB announced plans to increase the capacity of each of its pelletizing plants by 700,000 mt per year. Since then, the capacity of the Svappavaara plant, a grate-kiln system, was increased from 2.8 to 3.5 Mmt per year. A similar expansion was underway at Malmberget and was to have been completed by August 1989. Malmberget had a traveling grate system with a capacity of 3.0 Mmt per year. When the entire expansion program is finished in 1990, LKAB is expected to have an overall pelletizing capacity of more than 11 Mmt per year.

About 78% of Malmberget's olivine pellet production was consumed domestically with a significant fraction going to the Luleå steelworks of Svenskt Stål AB (SSAB). Luleå's two blast furnaces operated entirely on Malmberget pellets and had a combined hot-metal capacity of 1.44 Mmt per year. The Luleå steelworks traditionally made sections for the Swedish shipbuilding industry, but expanded recently into the machinery manufacturing and general construction sectors.

In central Sweden, Grängesberg Gruvor AB produced 1.24 Mmt of iron ore products, including 0.62 Mmt of granulated fines. Lump ore averaging 60.0% Fe, fines averaging 62.7% Fe, and three types of concentrate composed the other half of the tonnage. Production peaked at 3.2 Mmt in 1969 and has been in decline since the 1974 oil crisis. Grängesberg and the smaller Dannemora Mine, north of Uppsala, were both high-cost, underground operations. Dannemora Gruvor AB produced 605,000 mt of lump ore, sinter fines, and concentrate in 1988. The two mining operations were scheduled to close at the end of 1991, and all exploratory work was halted. Both were completely taken over by the Swedish Government in 1987 and were being operated as subsidiaries of the mining division of SSAB.

Venezuela

Shipments of iron ore products by C.V.G. Ferrominera del Orinoco C.A. (FMO) increased for the fifth consecutive year, reaching 17.37 Mmt. Exports through the Orinoco River Ports of Puerto Ordáz and Palua totaled 12.29 Mmt, consisting of 8.16 Mmt of sinter fines and 4.13 Mmt of lump ore. The remaining 5.08 Mmt was consumed primarily by the Matanzas steelmaking complex of C.V.G. Siderúrgica del Orinoco C.A., another subsidiary of the State-owned Corporacíon Venezolana de Guayana (CVG).

FMO produced 18.22 Mmt of usable ore in 1988. The bulk, 13.61 Mmt of hematite or martite fines and 2.25 Mmt of lump, came from the San Isidro and Cerro Bolívar Mines in the Piar district of Bolívar State. The ores from the two mines were railed about 150 km to the Puerto Ordáz loading yards, where they were blended to improve their marketability. The Cerro Bolívar ore had relatively high phosphorus (0.11% P), whereas the San Isidro ore (0.07% P) was more friable and dusty. The new San Isidro Mine, which opened in September 1985, was operating at the 9-Mmt-per-year level. The adjacent Los Barrancos Mine was scheduled to start production in 1990. The production from Los Barrancos and the increased output at San Isidro were expected to help offset the impending closure of the El Pao Mine. The older El Pao Mine produced 1.21 Mmt of lump and 1.14 Mmt of fines in 1988. At this rate, El Pao's reserves should be depleted by 1992. FMO also decided to build a 3.3-Mmt-per-year pelletizing plant at Puerto Ordáz to take advantage of the improved market in Europe and the United States for pellets and other direct-charged products. The pelletizing plant was to use undersize fines from the blending operation. When these processing and adjunct storage improvements are completed in 1992, FMO should have a total annual production capacity of 25 Mmt.

For years, the meandering and heavily sedimented Orinoco River had been a problem for FMO because of its numerous sandbars and widely fluctuating flow. However, in October 1988, an ore transfer vessel was permanently anchored 100 km offshore at the mouth of the river. This new facility overcame many vessel loading problems. The 227,588-dwt transfer vessel was remodeled at the Tsu shipyard of NKK Corp. in Japan and renamed the *Boca Grande*. The *Boca Grande* transfer vessel was designed to (1) load 150,000- to 200,000-dwt ore carriers that are too large to transit the Orinoco and (2) to top off smaller carriers that can only be partially loaded in Puerto Ordáz. The transfer station became operational on December 20 and was capable of loading carriers at the rate of 6,000 mt per hour. The *Rio Orinoco*, a 86,868-dwt vessel with a draft of only 13.7 meters, was acquired to shuttle ore 300 km downriver from Puerto Ordáz to the transfer station. This second vessel was also capable of topping off carriers. The transfer station was initially only being used for shipments that were fully controlled by FMO, but the company was considering opening the station to carriers loading on an f.o.b. basis.

Venezuela was the largest producer of DRI in the world with 18% of world capacity. Production of DRI in 1988 was 2.73 Mmt, a decrease of 13% from the previous year. Two natural-gas-based DRI modules were scheduled for startup near Puerto Ordáz in 1990. Siderúrgica Venezolana S.A. (SIVENSA), Voest-Alpine AG, and Midrex Corp. began construction of a 400,000-mt-per-year plant in February 1988 at Matanzas to produce HBI from San Isidro fines. About one-half of the HBI was meant to go to SIVENSA's adjacent steelworks. SIVENSA would operate the direct-reduction plant under the name Siderúrgica del Caroní S.A.

The second DRI project was less straight forward. CVG and Kobe Steel, the parent company of Midrex, began renovation of the idle direct reduction plant owned by Minerales Ordáz C.A. The plant was closed in 1982 because of technical problems with its fluidized-bed reactors. Midrex was in the process of installing a 1-Mmt-per-year shaft furnace, the largest ever designed by the North Carolina-based company. Lump ore from San Isidro and oxide pellets from FMO's proposed plant would be used as feed. The renovated direct-reduction plant was expected to produce 830,000 mt per year of HBI for the export market and would be operated by a Venezuelan subsidiary of Kobe Steel under a 9-year lease from CVG.

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[1] Physical scientist, Branch of Ferrous Metals. The author was assisted in preparation of this chapter by Cheryl M. Cvetic, physical scientist, and Sarah P. Guerrino, supervisory program specialist.

[2] Unless otherwise specified, the unit of weight used in this chapter is the metric ton. To convert from metric tons to long tons, multiply the published number by 0.984207.

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[5] Skillings' Mining Review. LTV Steel Company Ships 678,939 G.T. of Natural Ore in 1988. V. 78, No. 2, Jan. 14, 1989, p. 60.

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TABLE 1

SALIENT IRON ORE STATISTICS

(Thousand metric tons and thousand dollars unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Iron ore (usable,[1] less than 5% manganese):					
Production	52,092	49,533	39,486	[r]47,648	57,515
Shipments	51,700	50,204	41,991	[r]47,983	57,113
Value	$2,247,686	$2,076,730	$1,472,511	$1,503,087	$1,716,661
Average value at mines, dollars per ton	$43.48	$41.37	$35.07	$31.33	$30.06
Exports	5,073	5,114	4,553	5,093	5,285
Value	$239,257	$240,557	$204,738	$198,254	$193,796
Imports for consumption	17,463	16,024	17,011	16,849	20,183
Value	$529,065	$452,267	$460,643	$408,783	$484,543
Consumption (iron ore and agglomerates)	73,678	71,708	62,097	67,768	[2]83,694
Stocks, Dec. 31:					
At mines[3]	5,349	6,046	3,307	[r]2,402	2,957
At consuming plants	24,403	21,631	17,439	16,565	18,005
At U.S. docks	2,989	2,442	2,019	2,056	2,537
Manganiferous iron ore (5% to 35% manganese):					
Shipments	80	18	13	W	W
World: Production	[r]829,349	[r]862,158	868,360	[p]890,137	[e]916,431

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Direct-shipping ore, concentrates, agglomerates, and byproduct ore.

[2]Consumption data for 1988 are not entirely comparable to those of previous years owing to changes in data collection.

[3]Excludes byproduct ore. These stocks are not comparable to those of 1982 and earlier years owing to the reclassification of some stocks from the usable to the byproduct category.

TABLE 2

EMPLOYMENT AT IRON ORE MINES AND BENEFICIATING PLANTS, QUANTITY AND TENOR OF ORE PRODUCED, AND AVERAGE OUTPUT PER WORKER HOUR IN THE UNITED STATES IN 1988, BY DISTRICT AND STATE

District and State	Average number of employees	Worker hours (thousands)	Production (thousand metric tons)			Iron content (natural) (percent)	Average per worker hour (metric tons)		
			Crude ore	Usable ore	Iron contained (in usable ore)		Crude ore	Usable ore	Iron contained
Lake Superior:									
Michigan	2,090	4,023	44,317	14,590	9,063	62.1	11.02	3.63	2.25
Minnesota	4,706	9,816	137,225	41,449	26,508	64.0	13.98	4.22	2.70
Total[1] or average	**6,796**	**13,839**	**181,542**	**56,038**	**35,572**	**63.5**	**13.12**	**4.05**	**2.57**
Other States[2]	210	389	1,624	1,477	896	60.7	4.18	3.80	2.30
Grand total[1] or average	**7,006**	**14,229**	**183,166**	**57,515**	**36,468**	**63.4**	**12.87**	**4.04**	**2.56**

[1] Data may not add to totals shown because of independent rounding.
[2] Includes California, Missouri, Montana, New Mexico, South Dakota, Texas, and Utah.

TABLE 3

CRUDE IRON ORE[1] MINED IN THE UNITED STATES IN 1988, BY DISTRICT, STATE, AND MINING METHOD

(Thousand metric tons, unless otherwise specified, and exclusive of ore containing 5% or more manganese)

District and State	Number of mines	Open pit	Underground	Total quantity
Lake Superior:				
Michigan	2	44,317	—	44,317
Minnesota	7	137,225	—	137,225
Total	**9**	**181,542**	**—**	**181,542**
Other States:				
Missouri	1	—	1,075	1,075
Other[2]	11	549	—	549
Total	**12**	**549**	**1,075**	**1,624**
Grand total	**21**	**182,091**	**1,075**	**183,166**

[1] Excludes byproduct ore.
[2] Includes California, Montana, New Mexico, South Dakota, Texas, and Utah.

TABLE 4

USABLE IRON ORE PRODUCED IN THE UNITED STATES IN 1988, BY DISTRICT, STATE, AND TYPE OF PRODUCT

(Thousand metric tons and exclusive of ore containing 5% or more manganese)

District and State	Direct-shipping ore	Concentrates	Agglomerates	Total quantity
Lake Superior:				
Michigan	([1])	—	14,590	14,590
Minnesota	—	825	40,624	41,449
Total[2]	**([1])**	**825**	**55,213**	**56,038**
Other States:				
Missouri	—	50	744	794
Other[3]	683	W	—	683
Total	**683**	**50**	**744**	**1,477**
Grand total[2]	**683**	**875**	**55,957**	**57,515**

W Withheld to avoid disclosing company proprietary data; included with "Direct-shipping ore."
[1] Included with "Agglomerates" to avoid disclosing company proprietary data.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes California, Montana, New Mexico, South Dakota, Texas, and Utah.

TABLE 5

SHIPMENTS OF USABLE IRON ORE[1] FROM MINES IN THE UNITED STATES IN 1988

(Exclusive of ore containing 5% or more manganese)

District and State	Gross weight of ore shipped (thousand metric tons)				Average iron content (natural) (percent)	Value (thousands)
	Direct-shipping ore	Concentrates	Agglomerates	Total		
Lake Superior:						
Michigan	165	—	14,458	14,623	62.1	W
Minnesota	—	760	39,975	40,735	64.0	$1,134,539
Total reportable or average	**165**	**760**	**54,433**	**55,358**	**63.5**	**1,134,539**
Other States:						
Missouri	—	51	765	816	66.1	W
Other[2]	615	324	—	939	57.0	17,341
Total reportable or average	**615**	**375**	**765**	**1,755**	**61.2**	**17,341**
Total withheld	**—**	**—**	**—**	**—**	**—**	**564,782**
Grand total or average	**780**	**1,135**	**55,198**	**57,113**	**63.4**	**[3]1,716,661**

W Withheld to avoid disclosing company proprietary data; included in "Total withheld."
[1] Includes byproduct ore.
[2] Includes California, Montana, New Mexico, New York, South Dakota, Texas, and Utah.
[3] Data do not add to total shown because of independent rounding.

TABLE 6

USABLE IRON ORE PRODUCED IN THE U.S. LAKE SUPERIOR DISTRICT, BY RANGE

(Thousand metric tons and exclusive after 1905 of ore containing 5% or more manganese)

Year	Marquette	Menominee	Gogebic	Vermilion	Mesabi	Cuyuna	Spring Valley	Black River Falls	Total[1]
1854–1981	531,510	334,629	325,474	105,189	3,391,584	71,465	8,280	9,624	4,777,756
1982	6,984	—	—	—	24,281	—	—	245	31,511
1983	9,489	—	—	—	26,676	—	—	—	36,165
1984	13,190	—	—	—	37,286	—	—	—	50,476
1985	12,679	—	—	—	35,470	—	—	—	48,148
1986	10,727	—	—	—	27,476	—	—	—	38,203
1987	12,491	—	—	—	[r]34,265	—	—	—	[r]46,756
1988	14,590	—	—	—	41,449	—	—	—	56,038
Total[1]	**611,661**	**334,629**	**325,474**	**105,189**	**3,618,488**	**71,465**	**8,280**	**9,869**	**5,085,054**

[r] Revised.
[1] Data may not add to totals because of independent rounding.

TABLE 7

AVERAGE ANALYSES OF TOTAL TONNAGE[1] OF ALL GRADES OF AGGLOMERATES SHIPPED FROM MINES IN THE UNITED STATES

Year	Quantity (thousand metric tons)	Content (percent)[2]					
		Iron	Phosphorus	Silica	Manganese	Alumina	Moisture
				SINTER[3]			
1979	398	44.45	0.150	15.73	0.14	9.00	2.00
1980	533	44.04	.136	13.66	.18	6.04	2.00
1981	423	44.57	.166	13.84	.19	6.34	NA
1982	254	45.94	NA	12.99	NA	6.40	NA
				PELLETS OF ALL TYPES			
1979	79,268	63.07	.029	6.05	.16	.36	2.30
1980	63,819	63.42	.022	5.65	.14	.32	2.35
1981	66,994	63.59	.019	5.48	.12	.32	2.38
1982	33,950	63.76	.018	5.38	.10	.30	2.40
1983	43,865	63.64	.018	5.26	.10	.27	2.41
1984	49,549	63.83	.018	5.15	.11	.31	2.47
1985	47,182	63.91	.016	5.12	.10	.28	2.45
1986	40,645	63.90	.015	5.14	.09	.28	2.44
1987	46,337	63.86	.014	5.02	.09	.22	2.04
				STANDARD PELLETS			
1988	41,349	64.17	.015	5.08	.11	.21	2.20
				FLUXED PELLETS[4]			
1988	13,618	60.71	.017	4.52	.21	.24	2.10

NA Not available.
[1] Railroad weight—gross metric tons.
[2] Natural basis.
[3] Sinter has not been produced at U.S. mines since 1982.
[4] Ratio of $(CaO + MgO)/(SiO_2 + Al_2O_3)$ is 0.6 or greater.
Source: American Iron Ore Association.

TABLE 8

CONSUMPTION OF IRON ORE[1] AT U.S. IRON AND STEEL PLANTS

(Thousand metric tons)

Year	Iron ore originating areas					Total[2]
	United States ores		Canadian ores		Foreign ores	
	Great Lakes	Other U.S.	Great Lakes	Other Canada		
1979	67,140	10,030	2,264	21,177	16,248	116,860
1980	54,851	8,430	1,390	16,167	9,993	90,832
1981	61,279	7,207	656	18,377	8,963	96,482
1982	35,789	3,446	76	10,967	5,840	56,119
1983	40,344	2,246	123	11,612	7,876	62,202
1984	44,384	1,680	109	12,130	8,747	67,049
1985	45,089	1,438	1	9,138	9,012	64,678
1986	39,881	1,164	401	7,818	6,905	56,170
1987	44,004	710	—	8,686	7,651	61,051
1988	51,048	1,242	—	9,453	10,122	71,865

[1] Excludes dust, mill scale, and other revert iron-bearing materials added to sinter.
[2] Data may not add to totals shown because of independent rounding.

Source: American Iron Ore Association.

TABLE 9

CONSUMPTION OF IRON ORE AND AGGLOMERATES AT U.S. IRON AND STEEL PLANTS, BY TYPE OF PRODUCT

(Thousand metric tons)

Type of Product	1984	1985	1986	1987	1988
Blast furnaces:					
Direct-shipping ore	NA	2,904	1,893	2,696	5,155
Pellets	53,296	51,698	43,610	49,500	61,025
Sinter[1]	17,152	16,182	13,221	14,420	15,497
Total[2]	**70,448**	**70,784**	**58,725**	**66,616**	**81,676**
Steelmaking furnaces:					
Direct-shipping ore	NA	90	65	123	194
Pellets	51	62	31	44	88
Sinter[1]	34	82	25	42	—
Total[2]	**84**	**233**	**122**	**209**	**282**
Grand total[2]	**70,533**	**71,017**	**58,846**	**66,824**	**81,958**

NA Not available.
[1] Includes briquettes, nodules, and other.
[2] Data may not add to totals shown because of independent rounding.

Source: American Iron and Steel Institute.

TABLE 10

U.S. CONSUMPTION OF IRON ORE AND AGGLOMERATES, BY END USE

(Thousand metric tons and exclusive of ore containing 5% ore more manganese)

Year	Blast furnaces	Steel furnaces	Sintering plants[1]	Miscellaneous[2]	Subtotal Integrated iron and steel plants[3]	Direct-reduced iron for steelmaking[4]	Nonsteel end uses[5]	Total
1979	95,019	943	20,680	218	116,860	NA	1,017	117,877
1980	74,593	492	15,617	130	90,832	NA	1,151	91,983
1981	80,022	343	16,028	87	96,482	NA	1,421	97,903
1982	45,898	248	9,062	911	56,119	NA	1,084	57,203
1983	51,610	225	10,134	234	62,202	—	848	63,050
1984	56,072	380	10,353	245	67,049	179	1,222	68,450
1985	55,589	184	8,440	465	64,678	224	1,147	66,049
1986	48,539	97	7,424	110	56,170	244	1,099	57,513
1987	54,614	144	6,270	23	61,051	325	1,049	62,425
1988	63,172	282	8,381	30	71,866	443	1,293	73,602

NA Not available.
[1] Excludes dust, mill scale, and other revert iron-bearing materials.
[2] Sold to nonreporting companies or used for purposes not listed.
[3] Data from American Iron Ore Association.
[4] Bureau of Mines estimates based on production reports compiled by Midrex Corp.
[5] Includes iron ore consumed in production of cement and iron ore shipped for use in manufacturing paint, ferrites, heavy media, cattle feed, refractory and weighting materials, and for use in lead smelting. Data from Bureau of Mines surveys.

TABLE 11

U.S. EXPORTS OF IRON ORE, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value
Canada	4,551	204,600	5,091	198,108	5,277	193,249
India	([1])	17	—	—	([1])	25
Mexico	1	45	1	42	1	62
Netherlands	([1])	17	—	—	([1])	3
Venezuela	([1])	39	1	95	4	348
Other	([1])	20	([1])	9	3	109
Total[2]	**4,553**	**204,738**	**5,093**	**198,254**	**5,285**	**193,796**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF IRON ORE, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value
Australia	10	86	194	5,141	1,076	16,780
Brazil	3,752	71,045	3,698	64,820	4,935	78,092
Canada	8,836	311,757	7,981	246,181	9,157	285,961
Chile	94	2,126	636	12,601	139	2,772
India	—	—	—	—	126	2,820
Liberia	1,511	21,855	994	13,707	128	1,460
Mauritania	66	1,158	412	6,403	522	7,864
Peru	92	2,429	84	1,691	181	2,939
Philippines[1]	56	1,504	59	1,575	239	5,432
Spain	—	—	1	27	—	—
Sweden	106	2,473	139	3,334	88	4,678
Venezuela	[2]2,346	[2]42,126	[3]2,622	[3]52,889	3,568	75,443
Other	140	4,083	29	413	[4]24	[4]301
Total[5]	**17,011**	**460,643**	**16,849**	**408,783**	**20,183**	**484,543**

[1] Sinter made from raw materials supplied by Australia, Brazil, and other countries.
[2] Excludes approximately 84,300 metric tons of sponge iron valued at $8,340,609, originally reported as iron ore.
[3] Excludes 18,370 metric tons of sponge iron valued at $1,849,584, originally reported as iron ore.
[4] Excludes 28,923 metric tons of crude iron sulfate crystals valued at $318,651, originally reported as iron ore from the Federal Republic of Germany.
[5] Data may not add to totals shown because of independent rounding.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF IRON ORE, BY CUSTOMS DISTRICT

(Thousand metric tons and thousand dollars)

Customs district	1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value
Baltimore	5,656	144,725	5,975	125,887	7,759	183,932
Buffalo	([1])	25	([1])	30	([1])	14
Chicago	1,562	37,958	2,007	40,224	1,837	28,820
Cleveland	1,734	67,123	1,490	54,551	1,401	41,315
Detroit	388	17,798	637	27,196	520	19,607
Houston	42	745	9	177	62	1,115
Mobile	2,473	64,317	1,063	22,645	1,595	40,708
New Orleans	1,594	31,052	1,530	27,230	1,496	22,673
Philadelphia	3,289	90,592	3,809	103,101	5,031	135,335
Other	271	6,308	328	7,743	482	11,024
Total[2]	**17,011**	**460,643**	**16,849**	**408,783**	**20,183**	**484,543**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

TABLE 14

IRON ORE: WORLD PELLETIZING CAPACITY, BY CONTINENT AND COUNTRY

	Number			Rated capacity (million metric tons, gross weight)
	Sites	Plants[1]	Units	
North America:				
Canada	5	6	13	26.44
Mexico	5	6	6	9.50
United States[2]	10	18	50	66.55
Total	**20**	**30**	**69**	**102.49**
South America:				
Argentina	1	1	4	1.00
Brazil	3	8	8	24.30
Chile	1	1	1	4.00
Peru	1	2	2	3.20
Venezuela	1	1	2	6.60
Total	**7**	**13**	**17**	**39.10**
Europe:				
Belgium-Luxembourg[3]	1	1	1	.80
Czechoslovakia	1	1	1	.25
Netherlands[3]	1	1	1	3.80
Norway[4]	2	3	3	3.20
Sweden[5]	3	3	3	10.10
Turkey	1	1	1	1.30
U.S.S.R.[6]	7	13	NA	80.00
Yugoslavia[7]	1	1	1	.60
Total	**17**	**24**	**NA**	**100.05**
Africa:				
Liberia[8]	1	1	1	3.00
Morocco[9]	1	1	1	.85
Nigeria[3]	1	1	1	1.45
South Africa, Republic of	1	1	1	.60
Total	**4**	**4**	**4**	**5.90**

See footnotes at end of table.

TABLE 14—Continued

IRON ORE: WORLD PELLETIZING CAPACITY, BY CONTINENT AND COUNTRY

	Number			Rated capacity (million metric tons, gross weight)
	Sites	Plants[1]	Units	
Asia:				
Bahrain[3]	1	1	1	4.00
China[6]	4	4	NA	2.50
India[10]	1	1	1	2.00
Japan[3]	1	2	2	4.40
Total	**7**	**8**	**NA**	**12.90**
Oceania: Australia[11]	2	2	6	4.00
World total	**57**	**81**	**NA**	**264.44**

NA Not available.
[1] Staged additions are treated at some mining complexes as if they were separate plants. Site data exclude plants that have had no production since 1982. Plants that produced after 1979, but have been continuously idle since 1982, are cited in the footnotes because they could be reactivated at some reasonable cost.
[2] The total for the United States includes the newer part of the E. W. Davis Works at Silver Bay, MN, but not the idled plant owned by Cleveland-Cliffs Inc. at Republic, MI. Cyprus Minerals Co. acquired the cannibalized Silver Bay facility in Aug. 1989 and was expected to resume production in early 1990. Cleveland-Cliffs has been considering reopening its 1.3-Mmt-per-year Republic plant, which has been on care and maintenance since 1981.
[3] Pellets produced from imported direct-shipping ores and/or concentrates.
[4] The older of the two plants operated by A/S Sydvaranger at Kirkenes has been idle since 1986. In addition, the 0.50-Mmt-per-year plant operated by Norsk Jernverk at Mo-i-Rana was shut down in Jan. 1987 for an indefinite period, leaving only one plant in Norway on-line.
[5] In early 1988, the capacity of the Svappavaara plant was upgraded from 2.8 to 3.5 Mmt per year.
[6] Based on incomplete information.
[7] The Skopje plant operated by Rudnici i Zelezara was recently idled.
[8] Excludes the No. 1 pelletizing plant (capacity of 2.4 Mmt per year) of the Bong Mining Co. The No. 1 plant has been idle since 1980.
[9] The Nador plant operated by Société d'Exploitation des Mines du Rif (SEFERIF) was recently idled.
[10] There is an additional plant with a capacity of 1.8 Mmt per year at Mandovi in Goa, but it has been closed since 1982. The owner planned to reopen the facility in Dec. 1989, using high-grade blue dust from the Bellary Hospet area of Karnataka as feed.
[11] There is an additional plant with a capacity of 3.0 Mmt per year at Dampier in Western Australia, but it has been closed since 1980.

Sources: Association of Iron Ore Exporting Countries (Geneva, Switzerland), Commodities Research Unit Ltd. (London, United Kingdom), International Iron and Steel Institute (Brussels, Belgium), Metal Bulletin Books Ltd. (Surrey, United Kingdom), Roskill Information Services Ltd. (London, United Kingdom), United Nations Commission on Trade and Development (UNCTAD), UNCTAD Trust Fund Project on Iron Ore Information, and Bureau of Mines.

TABLE 15

IRON ORE, IRON ORE CONCENTRATES, AND IRON ORE AGGLOMERATES: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country[2]	Gross weight[3]					Metal content[4]				
	1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987[p]	1988[e]
Albania[e 5]	[6]1,080	1,130	1,150	1,200	1,200	360	376	380	400	400
Algeria	3,664	3,376	3,359	3,382	[6]3,118	1,869	1,705	1,679	1,691	[6]1,559
Argentina	572	639	810	567	[6]583	346	389	514	360	[6]370
Australia	[r]89,046	[r]97,447	94,015	101,748	[6]96,084	[r]56,885	62,042	60,082	64,798	[6]61,494
Austria	3,600	3,270	3,120	3,061	[6]2,301	1,138	1,019	976	954	[6]727
Bolivia	14	—	11	7	[6]34	9	—	7	5	21
Brazil	112,132	128,251	132,288	134,105	[6]145,040	72,890	[e]87,210	[e]89,960	91,200	[6]98,600
Bulgaria	2,063	1,985	2,179	1,857	[6]1,826	622	607	661	559	600
Canada[7]	[r]39,930	39,502	36,167	37,702	[6]38,742	26,076	25,130	23,002	23,882	24,300
Chile	6,685	6,534	6,981	6,637	[6]7,866	3,991	3,967	4,197	4,078	[6]4,801
China[e 8]	75,000	80,000	90,000	100,000	105,000	37,500	40,000	45,000	50,000	52,500
Colombia	441	447	653	615	666	198	201	[e]235	[e]277	300
Czechoslovakia	1,869	1,859	1,784	1,798	[6]1,773	481	477	458	462	440
Egypt	1,901	1,950	2,135	2,048	2,000	950	975	[e]1,065	[e]1,100	1,000
Finland[9]	1,231	[e]1,200	[e]600	896	556	788	[e]750	[e]390	588	360
France	14,839	14,447	12,436	10,852	10,650	4,680	4,536	3,861	3,255	3,195
German Democratic Republic[10]	36	30	—	—	—	20	[r]15	—	—	—
Germany, Federal Republic of	977	1,034	717	247	[6]70	293	309	212	68	[6]10
Greece[5]	1,929	2,245	1,197	1,082	1,100	810	943	502	[e]443	460
Hungary	383	311	—	—	—	92	75	—	—	—
India	41,026	42,545	47,800	51,018	[6]52,322	25,682	26,633	29,923	[r e]31,937	[6]32,754
Indonesia	83	131	153	194	[6]203	48	76	89	113	[6]118
Iran[e 11]	2,711	2,799	2,800	2,800	2,800	950	1,550	1,600	1,600	1,600
Japan	324	338	291	266	[6]96	202	212	182	166	[6]61
Korea, North[e]	8,000	8,000	8,000	8,000	9,000	3,200	3,200	3,200	3,200	3,600
Korea, Republic of	625	542	582	470	[6]390	350	304	326	263	[6]218
Liberia	15,100	15,318	15,295	13,742	[6]12,767	9,360	9,420	9,480	[e]8,520	7,910
Malaysia	194	182	208	161	[6]132	119	111	127	98	[6]81
Mauritania[12]	9,527	9,333	8,929	9,002	[6]10,004	5,754	6,066	5,804	5,851	6,500
Mexico[13]	8,317	7,820	7,298	[r e]7,523	[6]8,431	5,489	5,161	4,817	4,965	[6]5,564
Morocco	163	191	196	210	[6]114	101	118	123	128	70
New Zealand[14]	2,414	2,520	[e]2,580	2,290	[6]2,240	1,376	1,425	[e]1,425	[e]1,300	[6]1,266
Norway	3,837	3,468	3,659	3,141	2,700	2,501	2,254	2,378	2,042	1,755
Peru	3,979	4,892	5,230	5,224	[6]4,159	[r]2,740	[r]3,421	3,473	3,358	3,070
Poland	11	11	9	6	6	3	3	2	2	2
Portugal[15]	36	73	51	27	[6]23	12	11	19	[e]15	[6]8
Romania	1,916	2,287	2,431	2,281	2,300	[r]498	[r]595	632	595	596
Sierra Leone	355	[e]70	—	—	—	223	[e]40	—	—	—
South Africa, Republic of[16]	24,647	24,414	24,483	22,008	[6]25,248	15,749	15,076	15,424	13,865	15,906
Spain[17]	7,261	6,463	6,089	4,700	4,200	3,558	3,189	2,778	2,300	2,000

See footnotes at end of table.

TABLE 15—Continued

IRON ORE, IRON ORE CONCENTRATES, AND IRON ORE AGGLOMERATES: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country[2]	Gross weight[3]					Metal content[4]				
	1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987[p]	1988[e]
Sweden	18,123	20,454	20,489	19,627	20,440	11,180	13,500	[e]13,520	12,267	12,670
Thailand	61	94	37	97	[6]99	33	52	21	54	55
Tunisia	308	309	311	295	[6]325	166	166	[e]167	159	175
Turkey	4,037	3,994	5,249	5,366	[6]5,693	2,192	2,163	2,843	2,906	3,100
U.S.S.R.	247,104	247,639	249,959	250,874	251,000	134,809	136,000	137,000	138,000	138,000
United Kingdom	403	274	289	269	260	85	60	[e]64	[e]60	60
United States[17]	52,092	49,533	39,486	47,648	[6]57,515	33,339	31,798	25,295	30,526	[6]36,468
Venezuela	13,054	16,228	19,125	17,782	[6]18,789	8,093	10,061	[e]11,840	[e]11,006	[6]12,500
Yugoslavia	5,321	5,478	6,618	5,983	5,545	1,837	[e]1,800	[e]2,000	[e]1,800	1,800
Zambia	1	1	1	1	1	([18])	1	([18])	1	1
Zimbabwe	927	1,100	1,110	1,328	[6]1,020	575	682	688	824	610
Total	**[r]829,349**	**[r]862,158**	**868,360**	**890,137**	**916,431**	**[r]480,222**	**[r]505,874**	**508,421**	**522,041**	**539,655**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 19, 1989.
[2]In addition to the countries listed, Cuba and Vietnam may produce iron ore, but definitive information on output levels, if any, is not available.
[3]Insofar as availability of sources permits, gross weight data in this table represent the nonduplicative sum of marketable direct-shipping iron ores, iron ore concentrates, and iron ore agglomerates produced by each of the listed countries. Concentrates and agglomerates produced from imported iron ores have been excluded under the assumption that the ore from which such materials are produced has been credited as marketable ore in the country where it was mined.
[4]Data represent actual reported weight of contained metal or are calculated from reported metal content. Estimated figures are based on latest available iron content reported, except for the following countries for which grades are Bureau of Mines estimates: Albania, China, Hungary, and North Korea.
[5]Nickeliferous iron ore.
[6]Reported figure.
[7]Series represent gross weight and metal content of usable iron ore (including byproduct ore) actually produced, natural weight.
[8]Bureau of Mines estimates of China's usable iron ore production are normalized to an ore grade of 50% Fe to provide a series approximately comparable with world marketable production. In actuality, run-of-mine ore in China averages only about 30% Fe. Production of crude ore, as reported by the UNCTAD Trust Fund, was as follows in thousand metric tons: 1984—121,900; 1985—131,500; 1986—142,480; 1987—157,000; and 1988—164,000.
[9]Includes magnetite concentrate, pelletized iron oxide (from roasted pyrite), and roasted pyrite (purple ore).
[10]Includes "roasted ore," presumably from pyrite, not separable from available sources.
[11]Data are for year beginning Mar. 21 of that stated.
[12]Gross weight is exported iron ore (Mauritania exports all of its iron ore).
[13]Gross weight calculated from reported iron content based on grade of 66% Fe.
[14]Concentrates from titaniferous magnetite beach sands.
[15]Includes manganiferous iron ore.
[16]Includes magnetite ore as follows, in thousand metric tons: 1984—3,481; 1985—3,607; 1986—4,000 (estimated); 1987—4,979; and 1988—4,991.
[17]Includes byproduct ore.
[18]Less than 1/2 unit.

IRON OXIDE PIGMENTS

By Donald P. Mickelsen[1]

U.S. mine production of crude iron oxide pigments decreased slightly in 1988, while shipments and value increased. Total domestic shipments and value of natural and synthetic finished iron oxide pigments increased over 1987 levels. Unit value for most categories of finished iron oxides increased. Synthetic iron oxides comprised 64% of all shipments. An announced purchase of Pfizer Pigments Inc., by the Cambrex Corp. was abandoned. Columbian Chemicals Co. created a new Mapico Div. to handle their pigment operations. Foote Mineral Co. was purchased by the Cyprus Minerals Co. Pigment operations are being operated by a subsidiary named Cyprus Specialty Metals Co.

Construction materials was the largest end use for iron oxide pigments, followed, in order of rank, by paints and coatings; colorants for ceramics, glass, paper, plastics, rubber, and textiles; foundry sands; industrial chemicals; ferrites; animal feed and fertilizer; and other end uses.

Domestic list prices for iron oxide pigments increased during the year, with list prices for natural iron oxides increasing slightly from those in 1987, and synthetic iron oxides increasing moderately. Price increases reflected higher costs for labor, operations, and raw materials.

The United States imported 77% more iron oxide pigment in 1988 than it exported, although exports of pigment-grade iron oxides increased substantially compared with those of 1987. This was attributed to a tightened worldwide market for pigments and the decline in the value of the dollar against foreign currencies. U.S. imports for consumption of natural iron oxide pigments decreased while synthetic imports increased, resulting in total iron oxide pigment imports remaining practically unchanged. Imports of natural crude umber decreased significantly, while imports of synthetic black and the other synthetic grades category increased. World mine production of natural iron oxide pigments in reporting countries decreased slightly in 1988.

DOMESTIC DATA COVERAGE

Mine production and sales data for crude iron oxide pigments and sales data for finished iron oxide pigments and iron oxides from steel plant wastes were compiled from voluntary responses received in an annual survey of U.S. producers conducted by the Bureau of Mines. Responses for crude iron oxide mine production and sales data were received from five companies representing 100% of all iron oxide pigment producers known to mine or ship crude iron oxide pigments in the United States as shown in table 1. Of the 20 operations canvassed for finished iron oxide pigment sales data in 1988, all responded. They represent 100% of the total production shown in table 2. Of the six companies canvassed for sales data for iron oxide recovered from steel plant wastes, including steel plant dust and regenerator oxide, 100% responded, and they represent 53% of the estimated production shown in the text discussion under "Domestic Production." Remaining data were estimated through analysis of industry trends and practices.

DOMESTIC PRODUCTION

Mine production of crude iron oxide pigments decreased slightly from that of 1987, while shipments increased 2% in quantity and 6% in value. Four companies mined and shipped various grades. One company in Georgia mined and shipped ocher; magnetite was mined and shipped by a company in Missouri; and of two companies in Virginia, one mined and shipped sienna, umber, and ocher, and the other shipped umber. In addition, Cleveland-Cliffs Iron Co., which permanently closed its Mather Mine in northern Michigan in 1979, continued to ship hematite from stockpiles.

Total domestic shipments of finished natural and synthetic iron oxide pigments, excluding regenerator oxide, steel plant waste, and magnetic iron oxide, increased only slightly in quantity when compared with those of 1987 but increased 5% in value. Synthetic iron oxides comprised over two-thirds of total shipments, but remained practically unchanged in quantity while increasing 5% in value from 1987 levels. Increases in shipments of synthetic brown and red iron oxides were offset

TABLE 1

SALIENT U.S. IRON OXIDE PIGMENTS STATISTICS

		1984	1985	1986	1987	1988
Mine production	short tons	29,307	32,234	33,889	35,071	33,893
Crude pigments sold or used	do.	53,017	46,585	40,987	42,773	43,774
Value	thousands	$2,819	$2,826	$2,908	$3,598	$3,815
Finished pigments sold	short tons	129,492	126,822	128,357	137,010	139,597
Value	thousands	$122,620	$122,716	$126,388	$136,427	$143,546
Exports	short tons	32,428	29,720	28,841	22,249	24,213
Value	thousands	$31,832	$27,574	$30,830	$31,689	$33,014
Imports for consumption	short tons	38,239	39,799	36,773	42,322	42,912
Value	thousands	$21,523	$22,565	$21,517	$20,680	$27,128

by decreases in synthetic yellows. Natural iron oxide pigment shipments increased slightly in quantity and nearly 7% in value when compared with those of 1987. Shipments of natural iron oxides were influenced mainly by an increase in the red iron oxide category, which accounted for more than one-half of the natural iron oxides shipped in 1988. Total values for both synthetic and natural iron oxides increased in 1988 with notable increases in value of 14% for synthetic brown iron oxides and 13% for natural red iron oxides.

Pigment-grade iron oxides for use in magnetic applications were produced domestically in 1988, but are not shown in table 2. Production and shipment data for magnetic iron oxides were unavailable because of their proprietary nature.

An estimated 42,000 short tons[2] of steel plant byproduct iron oxides, in the form of regenerator oxide and steel plant wastes and dust, was shipped in 1988. Of the six plants canvassed, representing 53% of estimated shipments with a value of $2.2 million, all but one plant showed increases. Data on the remaining steel plant wastes were unavailable and were estimated based on known plant capacities.

In 1988, Cambrex announced an agreement in principle with Pfizer Pigments to purchase their pigments business. Pfizer Pigments is one of the top three domestic iron oxide pigment producers, with annual sales of over $100 million. The sale, which would have practically doubled the size of Cambrex, was terminated presumably because of market conditions.[3] Columbian Chemicals, another large iron oxide pigment producer, announced the creation of a new division to operate their iron oxide manufacturing facilities. The new Mapico Div. would produce and market the Columbia Chemicals pigment line.[4] Foote Mineral, a smaller producer of iron oxide pigments, formerly owned by the Newmont Mining Corp., was sold to Cyprus Minerals in 1988.[5]

TABLE 2

FINISHED IRON OXIDE PIGMENTS SOLD BY PROCESSORS IN THE UNITED STATES, BY KIND

Kind	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Natural:				
Black: Magnetite	6,332	$1,142	6,982	$1,228
Brown:				
Iron oxide	W	W	W	W
Umbers:				
Burnt	W	W	W	W
Raw	W	W	W	W
Red:				
Iron oxide[1]	24,259	3,612	25,935	4,064
Sienna, burnt	W	W	W	W
Yellow:				
Ocher	W	W	W	W
Sienna, raw	W	W	W	W
Undistributed	18,517	7,852	17,427	8,141
Total	**49,108**	**12,606**	**50,344**	**13,433**
Synthetic:				
Brown: Iron oxide[2]	24,287	34,340	26,735	39,018
Red: Iron oxide	36,816	52,901	37,568	56,503
Yellow: Iron oxide[3]	26,799	36,579	24,950	34,592
Other: Speciality oxides	([4])	([4])	([4])	([4])
Mixtures of natural and synthetic iron oxides	([4])	([4])	([4])	([4])
Total[5]	**87,902**	**123,821**	**89,253**	**130,113**
Grand total[5]	**137,010**	**136,427**	**139,597**	**143,546**

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1] Includes pyrite cinder.
[2] Includes synthetic black iron oxide.
[3] Includes other speciality oxides and mixtures of natural and synthetic iron oxides.
[4] Included with synthetic yellow iron oxide to avoid disclosing company proprietary data.
[5] Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Iron oxide pigments were consumed mainly as an ingredient in construction materials; in coatings; and as colorants for ceramics, glass, paper, plastics, rubber, and textiles. End-use data shown in table 4 were based on data reported by the producers to the Bureau of Mines.

Iron oxide pigment consumption in construction increased 11% in quantity to become the largest end use for the second year in a row over the use for coatings, the traditional leader. Coatings consumption dropped 12% in quantity from that in 1987. Construction materials consumption accounted for over one-third of iron oxide usage in 1988 and totaled 49,000 tons, increasing significantly over the 1987 level of 43,000 tons. According to F. W. Dodge, the Information Systems Div. of McGraw-Hill Co., newly started construction declined slightly to a value of $253.1 billion. This occurred after

TABLE 3

PRODUCERS OF IRON OXIDE PIGMENTS, REGENERATOR IRON OXIDES, AND SPECIALITY IRON OXIDES IN THE UNITED STATES IN 1988

Producer	Mailing address	Plant location
Finished pigments:		
American Minerals Inc.	Box 677 Camden, NJ 08101	Camden, NJ.
Blue Ridge Talc Co. Inc.	Box 39 Henry, VA 24102	Henry, VA.
Columbian Chemicals Co.	303 Hofmeister St. Louis, MO 63125	St. Louis, MO, and Monmouth Junction, NJ.
Cyprus Specialty Metals Co.	301 Lindenwood Dr., Suite 301 Malvern, PA 19355	Frazer, PA.
DCS Color & Supply Co. Inc.	2011 South Allis St. Milwaukee, WI 53207	Milwaukee, WI.
Hilton-Davis Co.	2235 Langdon Farm Rd. Cincinnati, OH 45237	Cincinnati, OH.
Hoover Color Corp.	Box 218 Hiwassee, VA 24347	Hiwassee, VA.
Mobay Corp., Inorganic Chemicals Div.	Mobay Rd. Pittsburgh, PA 15205	New Martinsville, WV.
New Riverside Ochre Co.	Box 387 Cartersville, GA 30120	Cartersville, GA.
Pea Ridge Iron Ore Co.	Route 4 Sullivan, MO 63080	Sullivan, MO.
Pfizer Pigment Inc.	640 North 13th St. Easton, PA 18042	Emeryville, CA; East St. Louis, IL; Easton, PA.
Prince Manufacturing Co.	700 Lehigh St. Bowmanstown, PA 18030	Quincy, IL, and Bowmanstown, PA.
Solomon Grind-Chem Services Inc.	Box 8288 Springfield, IL 62791	Springfield, IL.
Crude pigments:		
Cleveland-Cliffs Iron Co., Mather Mine and Pioneer plant (closed July 31, 1979; shipping from stockpile).	1100 Superior Ave. Cleveland, OH 44114	Negaunee, MI.
Hoover Color Corp.	Box 218 Hiwassee, VA 24347	Hiwassee, VA.
New Riverside Ochre Co.	Box 387 Cartersville, GA 30120	Cartersville, GA.
Pea Ridge Iron Ore Co.	Route 4 Sullivan, MO 63080	Sullivan, MO.
Virginia Earth Pigments Co.	Box 1866 Pulaski, VA 24301	Hillsville, VA.
Regenerator and Specialty Iron Oxides:		
Armco Inc.	Box 191 Ashland, KY 41101	Ashland, KY.
Chesapeake Specialty Products	5055 North Point Blvd. Baltimore, MD 21219	Baltimore, MD.
Gulf States Steel Inc.	174 South 26th St. Gadsden, AL 35904	Gadsden, AL.
Petco Inc.	200 So. 600 East Lehi, UT 84043	Lehi, UT.
Shance Chemical Corp.	1 Depot Plaza Mamaroneck, NY 10543	Philadelphia, PA.
Weirton Steel Corp.	400 Three Springs Rd. Weirton, WV 26062	Weirton, WV.

record-high starts of $254.7 billion in 1987. Construction starts varied by region with the West being the only region showing a gain in 1988. Residential building was the strongest sector during the year; valued at $120.9 billion, virtually the same as that in 1987. Nonbuilding construction, including public works and utilities, also remained practically the same as in 1987, valued at $45.5 billion. Nonresidential building construction dropped 5% to $86.8 billion. Cutbacks in commercial and institutional building were identified as causes.[6]

Coatings, the second largest use for iron oxide pigments, accounted for one-quarter of the iron oxide pigment consumption in 1988, decreasing sharply to 34,647 tons from 39,720 tons in 1987. Shipments of lacquer, paint, and varnish, as reported by the U.S. Department of Commerce,[7] totaled about 1.1 billion gallons of coatings valued at $11 billion, up slightly in volume and 10% in value over those of 1987. Architectural coatings comprised 49% of all shipments and totaled 532 million gallons; product coatings (original equipment manufacture) was 36% of shipments, or 393 million gallons; and special purpose coatings was 15%, or 162 million gallons.

Of all iron oxides, 17% or 23,000 tons, was consumed as colorants for plastics, glass and ceramics, paper and textiles, and rubber, in order of rank. This amounted to a 39% increase in quantity over that consumed in 1987. Iron oxide pigments were popular for these uses because of their low cost, coloring effectiveness in thermoplastics and thermosets, and acceptance by the Food and Drug Administration for food contact and medical applications.

The remaining 23% of reported iron oxide pigment consumption, in order of rank, was for use in foundry sands, industrial chemicals, ferrites, the manufacture of animal feed and fertilizers, and other end uses, including cosmetics, magnetic tape and magnetic ink, and polishing agents.

Regenerator oxide, steel plant dust, and specialty oxides not accounted for in table 4 were consumed mainly for use in foundry sands and in the manufacture of ferrites, with lesser amounts used as colorants for cements and construction materials and in fertilizers. An estimated 42,000 tons was shipped for consumption in 1988.

Magnetic iron oxides, also not included in table 4, were used mainly in the manufacture of ferromagnetic ceramics, magnetic media such as magnetic tapes and floppy disks, and in magnetic inks and toners. Ferromagnetic ceramics, which are advanced ceramics having magnetic properties, were manufactured using iron oxides in ferrite compounds and have become an important basic component of the electronics industry. According to the U.S. Advanced Ceramic Association, domestic electronic ceramic consumption in 1987 included $140 million in soft ferrite materials and $190 million in hard ferrite materials. This was 15% of the total U.S. electronic ceramic consumption in 1987, and it was expected to grow 9% or greater in 1988. Iron oxides were combined with barium and/or strontium to produce hard ferrite materials that were used in small motor magnets, loudspeakers, and business equipment. Soft ferrite materials are iron oxides combined with, among others, manganese-zinc and nickel-zinc compounds. Soft ferrite materials were used as cores for transformers and to suppress electrical noises. Applications included use in electronic recording heads, electromagnetic interference (EMI) filters, and microwave materials.[8]

PRICES

Domestic list prices for iron oxide pigments remained stable for the first half of the year. During the second quarter, one major producer announced price increases of approximately 5 cents per pound for its line of synthetic iron oxides, effective July 1, 1988. Other major synthetic producers showed initial reluctance, but followed with similiar price increases by the end of September. Reasons cited for the increases were higher costs for labor, operations, and raw materials. During the third quarter, price increases by major producers were also announced for natural iron oxide pigments, resulting in slightly increased prices for some grades. Following these announced increases, list prices for natural and synthetic grades of iron oxide pigments sold by major domestic producers remained unchanged for the remainder of 1988.[9]

Prices for imported iron oxide pigments increased in 1988 because of a strong worldwide demand. Western Europe, in particular, showed strong growth in its construction sector, and that, with unseasonably mild winters in 1987 and 1988, in which building continued unabated, had depleted European stocks of iron oxide pigments.[10] As shown by the American Paint and Coatings Journal, list prices for Italian burnt sienna advanced from 45 to 73 cents to 50 to 78 cents per pound; Turkish burnt umber from 43.5 to 52 cents to 47.5 to 56 cents per pound; vandyke brown from 44.5 to 46.5 cents per pound; and Spanish red from 29.5 to 33.5 cents per pound.

TABLE 4

ESTIMATED IRON OXIDE PIGMENT CONSUMPTION,[1] BY END USE, AS A PERCENTAGE OF REPORTED SHIPMENTS

End Use	All iron oxides		Natural iron oxides		Synthetic iron oxides	
	1987	1988	1987	1988	1987	1988
Coatings (industrial finishes, trade sales: lacquers, paints, varnishes)	29	25	19	16	34	30
Construction materials (cement, mortar, preformed concrete, roofing granules)	32	35	24	29	36	39
Colorants for ceramics, glass, paper, plastics, rubber, textiles	12	17	13	18	12	16
Foundry sands	6	6	17	17	—	—
Industrial chemicals (such as catalysts)	5	5	W	W	W	W
Ferrites	W	W	W	W	W	W
Animal feed and fertilizers	4	4	9	9	W	W
Other (including cosmetics, magnetic tape and magnetic ink, and polishing agents)	[2]12	[2]8	[3]18	[3]11	[4]18	[4]15
Total	**100**	**100**	**100**	**100**	**100**	**100**

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Data do not include magnetic iron oxide usage.
[2] Includes ferrites iron oxide usage.
[3] Includes industrial chemicals and ferrite iron oxide usage.
[4] Includes ferrites, animal feed and fertilizers, and industrial chemicals iron oxide usage.

FOREIGN TRADE

The United States imported 77% more iron oxide pigments than it exported in 1988 as shown by the U.S. Department of Commerce. This trade imbalance represented a decrease of 13% from that of 1987 and was the result of a tight worldwide market and the decline in the value of the U.S. dollar against foreign currencies. These data refer to quantities only because the iron oxide pigment material ex-

TABLE 5

PRICES QUOTED ON FINISHED IRON OXIDE PIGMENTS, PER POUND, BULK SHIPMENTS,[1] DECEMBER 31, 1988

Pigment	Low	High
Black:		
Natural	$0.1000	$0.3000
Synthetic	.6500	.7900
Micaceous	—	[2].6875
Brown:		
Ground iron ore	.0600	.1600
Metallic	.1950	.3500
Pure, synthetic	.6500	.8650
Sienna, domestic, burnt	—	.5400
Sienna, domestic, raw	.5200	.6200
Sienna, Italian, burnt	.4500	[2].7300
Umber, Turkish, burnt	.4350	[2].5200
Vandyke brown	—	[2].4450
Red:		
Domestic primers, natural, micronized	—	.1100
Pure, synthetic	.6000	.8700
Spanish	—	[2].2950
Yellow:		
Synthetic	.6100	.8100
Ocher, domestic	.1200	.1650

[1] Prices shown represent the best information available from responding companies but are not to be considered definite or necessarily reflect contract prices.
[2] American Paint and Coatings Journal.

ported by the United States is generally a higher valued product and ultimately results in a trade surplus for this commodity. Total value of U.S. exports of iron oxide pigments was $33 million, or $5.9 million greater than that of U.S. imports.

U.S. exports of pigment-grade iron oxides and hydroxides increased 9% in quantity and 4% in value compared with those of 1987. These exports went to 48 countries, principally in Europe, North America, and Asia. Chief destinations for pigment-grade iron oxide pigments, in order of rank, were the Federal Republic of Germany, Canada, Japan, the United Kingdom, Hong Kong, and the Republic of Korea. Exports to the Federal Republic of Germany increased 11% in quantity and 29% in value from those of 1987 and had an average value of 38 cents per pound, an increase of 5 cents per pound. Exports to Canada decreased slightly in quantity, with the average unit value also declining from 79 to 73 cents per pound, while exports to Japan increased 37% in quantity and the average unit value jumped from 50 to 62 cents per pound. Exports of other grades of iron oxides and hydroxides increased 18% in quantity and 17% in value compared with those of 1987. Main destinations, in order of rank, were the Republic of Korea, Mexico, Japan, Australia, the Federal Republic of Germany, India, and Canada.

U.S. imports for consumption of iron oxide pigments remained virtually the same in quantity as those of 1987, but increased 31% in value. Imports were received from 18 countries in 1988, down from 30 in 1987. Imports of synthetic iron oxide pigments increased 5% in quantity and 37% in value. Synthetic iron oxides comprised over three-quarters of all imports received. Synthetic black and other synthetic grades increased in quantity, while synthetic red and yellow grades remained at practically the same levels as those of 1987. Synthetic iron oxides were received chiefly from Canada, the Federal Republic of Germany, Mexico, and Japan, in order of rank, with the remainder received from other countries. Data on synthetic iron oxides imported from Canada were as reported by Commerce. It is likely, however, that a portion of the material reported as a synthetic iron oxide pigment was misclassified and was actually a regenerator or steel plant waste iron oxide. This was apparent, since one of the two Canadian companies exporting iron oxide material into the United States was a steel plant operator, not a pigment producer.

U.S. imports of natural iron oxide pigments decreased 12% in quantity and 13% in value compared with 1987 levels. The most sizable decrease was in crude umber, which fell 18% below its 1987 level and was mainly responsible for the overall decrease in natural imports. Unit values for crude sienna, finished umber, and both the crude and finished other grades increased, while all other natural iron oxide pigment grades decreased in value. Cyprus, the Federal Republic of Germany, Spain, Canada, and Japan, in order of rank, supplied 98% of all imports of natural iron oxides with the remaining 2% coming from other countries. Imports received from Cyprus were primarily of crude and finished sienna and crude umber grades; from the Federal Republic of Germany were primarily vandyke brown; and from Japan were primarily crude ocher. The United States also received 37 tons of micaceous iron oxide from Austria. Minor amounts of natural crude and synthetic iron oxides were received and stored in bonded warehouses for future consumption.

Periodically, iron oxide pigments also enter the United States under the combined classification "Iron compounds, other." In 1988, iron oxides, including regenerator and steel plant waste iron oxides, were received from Canada and other countries in unknown amounts.

WORLD REVIEW

World mine production of natural iron oxide pigments for reporting countries decreased slightly in 1988, totaling 299,000 tons, down from 309,000 tons in 1987. In addition to the countries listed in table 9, other countries, including the centrally planned economy countries, produced natural iron oxide pigments in 1988. Production data, however, were not available. Natural red iron oxide was produced primarily by India and Spain; yellow ocher by Spain, the United States, Brazil, and the Republic of South Africa; and si-

TABLE 6

U.S. EXPORTS OF IRON OXIDES AND HYDROXIDES, BY COUNTRY

Country	1987				1988			
	Pigment grade		Other grade		Pigment grade		Other grade	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Algeria	—	—	169	$156	—	—	—	—
Argentina	8	$28	20	71	13	$19	20	$64
Australia	173	468	393	783	317	463	614	893
Belgium-Luxembourg	9	12	403	647	66	244	428	685
Brazil	28	81	384	1,177	41	91	260	925
Bulgaria	—	—	24	81	—	—	45	139
Canada	3,920	6,186	304	493	3,787	5,549	398	522
Chile	1	6	2	5	11	46	—	—
China	82	291	15	60	18	100	—	—
Colombia	42	38	146	156	118	146	140	172
Costa Rica	—	—	12	18	5	8	—	—
Cyprus	—	—	—	—	5	8	—	—
Denmark	24	277	135	473	60	120	18	20
Dominican Republic	135	147	—	—	8	8	3	5
Ecuador	17	35	1	2	8	13	5	10
Egypt	—	—	2	19	—	—	43	57
El Salvador	([1])	4	40	59	—	—	—	—
Finland	—	—	10	15	10	16	—	—
France	386	1,415	126	274	477	1,639	144	284
Germany, Federal Republic of	10,205	6,705	90	184	11,307	8,642	549	1,715
Greece	—	—	—	—	—	—	21	29
Guatamala	—	—	—	—	23	20	—	—
Honduras	19	36	—	—	6	10	8	16
Hong Kong	1,032	2,972	153	623	725	1,771	288	1,117
India	1	9	133	662	44	111	487	2,318
Indonesia	12	20	40	50	32	116	12	30
Ireland	90	211	5	12	63	109	4	6
Israel	—	—	—	—	([1])	2	6	3
Italy	508	2,173	1	2	505	2,050	5	14
Japan	2,697	2,721	369	757	3,706	4,601	793	758
Korea, Republic of	379	560	3,407	12,105	610	856	3,183	12,605
Malaysia	2	3	57	103	32	35	15	17
Mexico	456	531	1,594	2,433	347	588	1,447	1,914
Netherlands	121	260	118	188	292	529	195	418
Netherlands Antilles	—	—	11	49	—	—	—	—
New Zealand	2	3	4	9	15	16	3	8
Pakistan	—	—	—	—	—	—	59	149
Peru	5	7	—	—	22	29	2	13
Philippines	107	146	22	21	116	127	128	199
Singapore	10	20	91	225	18	66	132	377

TABLE 6—Continued

U.S. EXPORTS OF IRON OXIDES AND HYDROXIDES, BY COUNTRY

Country	1987				1988			
	Pigment grade		Other grade		Pigment grade		Other grade	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
South Africa, Republic of	39	$120	—	—	40	$244	—	—
Spain	40	106	72	$246	24	50	82	$86
Sweden	16	236	4	9	—	—	5	13
Switzerland	1	3	—	—	49	161	4	15
Taiwan	244	590	51	83	98	313	74	70
Thailand	236	194	26	27	125	367	97	136
Trinidad	13	3	14	28	(1)	6	—	—
Turkey	7	13	—	—	(1)	4	—	—
United Kingdom	1,059	4,799	219	340	959	3,542	358	655
U.S.S.R.	—	—	(1)	3	—	—	110	60
Venezuela	114	227	20	86	106	161	15	42
Yugoslavia	—	—	—	—	—	—	33	50
Other	10	33	3	6	5	17	4	9
Total[2]	**22,249**	**31,689**	**8,691**	**22,737**	**24,213**	**33,014**	**10,236**	**26,618**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

enna by Cyprus and Italy. Cyprus was the major umber producer, Austria was the principal micaceous iron oxide producer, and the Federal Republic of Germany was the main vandyke brown producer.

Synthetic iron oxides were one of the largest consumed colored inorganic pigments in the world. Their popularity was attributed to a performance-price relationship. Iron oxides exhibit high tinctorial strength and hiding power, chemical resistance, lightfastness, and weatherfastness at low pigmentation costs. Synthetic iron oxides have made continuous gains in total market share over natural iron oxides because of product consistency, higher tinting strengths, and more saturated color shades compared with natural grades. Principal world producers of synthetic iron oxides, in order of rank, included the Federal Republic of Germany, the United States, the United Kingdom, and Japan.

According to the Japan Inorganic Chemical Industry Association, sales of iron oxides in Japan were expected to decrease 5% in 1988, totaling 166,700 tons. This followed a 20% jump in sales from 1986 to 1987, the result of a higher than expected demand for iron oxides used for magnetic materials. It was estimated that magnetic material end uses would continue to dominate iron oxide sales, growing to over 83% of the total, or 138,500 tons. Other major end uses for Japanese-produced iron oxides were, in order of rank, paints, roads, printing inks, synthetic resins, construction, ceramics, paper manufacture, and other. In addition to iron oxides consumed domestically, 26,800 tons were estimated to be sold for export, down 10% from that in 1987.[11]

Kawasaki Steel Corp. consumed iron oxides in two new plants; one produced ferrite carrier and the other produced a toner magnetite. Each plant had an output capacity of 40 tons per month. The ferrite carrier plant used a single-stage process involving material adjustment, drying, granulation, and burning to produce a high-quality product in 22 grades, with an average particle diameter of 80–100 micrometers. Ferrite carriers were used by audio and video equipment makers. The magnetite toner produced had an average diameter of 0.3–0.5 micrometers and was used in electronic copiers.[12]

TECHNOLOGY

MPLC Laboratories Ltd., a subsidiary of Magnesium Laboratories Corp. in the United Kingdom, developed a technology to manufacture synthetic micaceous iron oxide (MIO). This technology will produce a synthetic iron oxide having the same lamellar characteristics as natural MIO, which impedes moisture penetration in paints and resists corrosion. The new process involves the oxidation of steel scrap at high temperatures to produce an iron oxide of high purity (97%), with control of flake size at a stable price. Flake size could be manufactured at the optimized range of 5-75 micrometers, which would result in smoother coating finishes, or be restricted to a smaller 15-micrometer maximum and used in primer paints. MPLC produced synthetic MIO at two pilot plants at Peterlee, County Durham, the United Kingdom.[13]

[1]Mineral industry specialist, Branch of Ferrous Metals.

[2]Unless otherwise specified, the unit of weight in this chapter is the short ton.

[3]Chemical Marketing Reporter. Pfizer Iron Oxides Won't Go To Cambrex. V. 235, No. 3, Jan. 1, 1989, p. 4.

[4]American Paint and Coatings Journal. Columbian Chemicals Announces Mapico Division Formation. V. 73, No. 27, Dec. 12, 1988, p. 14.

[5]Industrial Minerals (London). World of Minerals: Newmont Completes Foote Divestment. No. 246, Mar. 1988, p. 13.

[6]American Paint and Coatings Journal. Construction declined in '88. V. 73, No. 34, Feb. 6, 1989, p. 12.

[7]Bureau of the Census (Dep. Commerce). Paint, Varnish, and Lacquer. Rep. M28F(88)-12, 1988.

[8]Dwyer, T. J., and R. B. McPhillips. Electronics Ceramic Committee Promotes Market Growth. Am. Ceram. Soc. Bull. V. 67, No. 12, 1988, pp. 1894-1896.

[9]American Paint and Coatings Journal. The Markets. Various Issues.

[10]Benbow, J. Iron Oxide Pigments. Ind. Miner. (London). No. 258, Mar. 1989, pp. 21-41.

[11]Roskill Information Services Ltd. (London). Roskill's Letter From Japan. Strontium Carbonate, Barium Salts and Ferric Oxide; Results for 1987 and Forecasts for 1988. RLJ No. 148, Aug. 1988, pp. 4-10.

[12]Japan Chemical Week. Kawasaki Makes Ferrite Carrier, Copier Toner-use Magnetite. V. 29, No. 1478, Aug. 11, 1988, p. 3.

[13]Steel Times. Iron Oxide Paints Still Fight Corrosion. V. 216, No. 10, Oct. 1988, p. 539.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF SELECTED IRON OXIDE PIGMENTS, BY TYPE

Type	1987 Quantity (short tons)	1987 Value (short tons)	1988 Quantity (short tons)	1988 Value (short tons)	Major sources, 1988[1] (short tons)
Natural:					
Crude:					
Ocher	53	$91	371	$34	Japan 371.
Sienna	19	4	57	18	Cyprus 57.
Umber	5,667	915	4,667	738	Cyprus 4,667.
Other	753	557	559	568	Canada 470; Japan 49; Cyprus 19; West Germany 12; United Kingdom 9; Peru 1.
Total[1]	**6,491**	**1,566**	**5,655**	**1,358**	
Finished:					
Ocher	6	8	—	—	
Sienna	270	173	42	12	Austria 37; Cyprus 5.
Umber	456	143	307	111	Cyprus 220; United Kingdom 87.
Vandyke brown	1,576	342	1,633	314	West Germany 1,582; Canada 51.
Other	845	212	870	338	Spain 828; Netherlands 18; West Germany 10; United Kingdom 6; Canada 6; Japan 2.
Total[1]	**3,152**	**878**	**2,852**	**774**	
Synthetic:					
Black	4,726	718	5,632	1,430	Canada 5,103; West Germany 358; Japan 148; Mexico 20; United Kingdom 3.
Red	10,916	3,575	11,160	4,657	Canada 6,090; West Germany 2,676; Mexico 974; Japan 782; France 201; Belgium 183; Brazil 118; Spain 91; Republic of Korea 42; United Kingdom 2; Norway 2.
Yellow	11,225	6,843	11,152	7,849	West Germany 5,556; Mexico 2,595; Canada 1,409; Brazil 618; United Kingdom 599; Spain 336; Netherlands 20; Japan 16; Belgium 2.
Other[2]	5,811	7,100	6,461	11,061	Canada 2,512; Japan 1,891; West Germany 1,280; Netherlands 435; Belgium 143; Austria 116; Mexico 54; United Kingdom 22; Republic of Korea 7; Sweden 1.
Total[1]	**32,679**	**18,235**	**34,405**	**24,996**	
Grand total[1]	**42,322**	**20,680**	**42,912**	**27,128**	

[1] Data may not add to totals shown because of independent rounding.
[2] Includes synthetic brown oxides, transparent oxides, and magnetic and precursor oxides.
Source: Bureau of the Census.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF IRON OXIDE AND IRON HYDROXIDE PIGMENTS, BY COUNTRY

Country	Natural				Synthetic			
	1987		1988		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	79	$66	37	$10	40	$35	116	$119
Belgium-Luxembourg	113	14	([1])	3	196	98	328	142
Brazil	—	—	—	—	676	411	736	470
Canada	713	135	527	170	13,770	2,559	15,115	3,036
China	—	—	—	—	121	64	—	—
Cyprus	6,045	1,027	4,968	833	—	—	—	—
Denmark	—	—	—	—	4	7	—	—
France	45	21	([1])	2	—	—	201	477
Germany, Federal Republic of	1,504	460	1,604	417	9,549	6,934	9,870	8,522
Italy	146	78	([1])	1	—	—	([1])	8
Japan	66	335	422	272	2,724	4,505	2,837	8,493
Korea, Republic of	—	—	—	—	22	16	49	139
Mexico	220	12	([1])	3	3,230	1,938	3,643	2,363
Netherlands	—	—	18	6	961	439	455	247
Norway	—	—	—	—	20	52	2	3
Peru	4	112	1	151	—	—	—	—
Portugal	—	—	—	—	29	233	—	—
Spain	622	136	828	195	188	80	427	387
Sweden	—	—	—	—	4	26	1	19
Switzerland	([1])	2	—	—	([1])	9	([1])	2
United Kingdom	87	47	101	70	1,142	825	626	570
Other	([1])	([1])	—	—	1	4	([1])	1
Total [2]	**9,643**	**2,445**	**8,507**	**2,132**	**32,679**	**18,235**	**34,405**	**24,996**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 9

NATURAL IRON OXIDE PIGMENTS: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina	834	[r]4,431	1,132	1,212	1,100
Austria	[e]12,700	12,768	12,930	11,913	11,900
Brazil	4,689	5,106	3,891	[e]5,500	5,500
Canada[e]	3,100	2,200	2,200	2,200	2,200
Chile	17,762	9,065	4,854	8,978	7,700
Cyprus	14,440	13,448	11,023	13,778	11,000
France[e]	16,500	16,000	16,500	[r]16,500	16,500
Germany, Federal Republic of[3]	17,833	17,377	12,528	11,026	11,000
India	118,886	119,655	108,763	160,105	154,300
Iran[4]	10,031	4,740	[e]4,700	[e]4,700	4,700
Italy[e]	900	950	960	950	950
Pakistan (ocher)	1,153	610	670	1,975	2,100
Paraguay[e]	275	290	275	[r]300	275
South Africa, Republic of	1,092	829	1,655	847	[5]2,091
Spain:					
Ocher	11,371	11,346	[e]11,600	[e]11,600	11,600
Red iron oxide[e]	22,000	23,000	22,000	22,000	22,000
United States	29,307	32,234	33,889	35,071	[5]33,893
Zimbabwe[e]	1,100	1,100	[5]228	220	220

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through Apr. 12, 1989.

[2] In addition to the countries listed, a considerable number of others undoubtedly produce iron oxide pigments, but output is not reported, and no basis is available for formulating estimates of output levels. Such countries include (but are not limited to) China and the U.S.S.R. Because unreported output is probably substantial, this table is not added to provide a world total.

[3] Includes Vandyke brown.

[4] Iranian calendar year (Mar. 21 to Mar. 20), beginning in the year stated.

[5] Reported figure.

IRON AND STEEL

By Anthony T. Peters[1]

Although 1988 was another profitable year for the U.S. steel industry, its leaders pointed out that a year showing a profit of $2 billion following a year of $1 billion profits does not make up for the $12 billion lost during the period 1982-86. Production, capacity utilization, and shipments were higher than in the past several years in response to the increased demand. Consequently, prices firmed and discounting became uncommon until the last quarter of the year, when a softening of the market for most commodities became apparent.

The shrinking of U.S. steel capacity to 112 million raw steel tons in 1987 and 1988 from a peak of 160 million in 1977 stopped and reversed. During 1988, some existing facilities were upgraded, mainly from the standpoint of improved steel quality, but often with some increase in capacity. Also, four minimills either started up new units, restarted closed operations, or underwent acceptance testing. Production in 1988 was just short of 100 million tons, the highest since 1981.

Demand for steel was strong worldwide. New facilities were being built in developing countries despite an existing overcapacity. World steel production in 1988 reached 857 million tons compared with 808 million in the previous year. Significant increases were reported by the United States with an increase of 11 million tons; Japan with an increase of 7 million tons; and the European Community as a whole with an increase of 12 million tons. The developing countries increased production by 10 million tons. Nearly one-half of the latter increase came jointly from the Republic of Korea and Taiwan.

DOMESTIC DATA COVERAGE

Data regarding the domestic production of iron and steel and the respective raw materials consumption were developed from reports by the American Iron and Steel Institute (AISI). This organization covers approximately 85% of domestic production; data for the remainder of the industry were developed from many independent sources.

Numbers referring to imports, exports, and consumption of steel and its products were developed from information published by the Bureau of the Census.

LEGISLATION AND GOVERNMENT PROGRAMS

The U.S. Customs Service commenced demanding declarations of the point of actual production of imported steel, the so called "melt-and-pour" place. Importers complained that this was sometimes unknown and that the burden of proof was excessive; AISI welcomed this action as an insurance

TABLE 1

SALIENT IRON AND STEEL STATISTICS

(Thousand short tons unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Pig iron:[1]					
Production	51,961	49,963	44,287	48,308	55,745
Shipments:					
Steel production	45,282	49,547	43,312	47,413	54,833
Other uses	1,499	619	357	315	812
Exports[2]	57	32	41	50	[e]100
Imports[2]	702	338	295	355	[e]450
Steel:[1]					
Production of raw steel:[3]					
Carbon	79,918	76,699	71,413	77,976	86,823
Stainless	1,772	1,683	1,689	2,028	2,199
All other alloy	10,838	9,877	8,505	9,147	10,902
Total	**92,528**	**88,259**	**[4]81,606**	**89,151**	**99,924**
Capacity utilization, percent[5]	68.4	66.1	63.8	79.5	89.2
Net shipment of steel mill products	73,740	73,043	70,263	76,654	83,974
Annual average composite price for steel mill products[6]	27.3	27.6	24.8	25.4	25.4
Exports of major iron and steel products[2]	1,413	1,266	1,201	1,419	2,576
Imports of major iron and steel products[2]	27,488	25,707	22,145	21,534	22,310
Profits or (loss), Million dollars	($30.5)	($34.0)	($4,149.9)	$1,017.3	[7]$2,300
World production:[8]					
Pig iron	[r]545,971	[r]556,630	553,068	[p]566,520	[e]593,949
Raw steel	[r]783,951	[r]791,384	784,009	[p]808,198	[e]805,973

[e]Estimated. [p]Preliminary. [r]Revised.
[1]American Iron and Steel Institute (AISI).
[2]Bureau of the Census.
[3]Raw steel defined by AISI as steel solidified from liquid state.
[4]Data do not add to total shown because of independent rounding.
[5]Raw steel production capacity defined by AISI as the tonnage capability to produce raw steel for sustained full order book.
[6]Iron Age, cents per pound.
[7](558.9) after special charges and unusual expenses.
[8]Bureau of Mines, International Iron and Steel Institute.

against cheating on import quotas.

Two major bills became laws, but little can be said about their actual impact on the industry until the administrative rules are published. These bills were the Workers Retraining and Notification Act (WARN), Public Law 100-379, and the United States-Canadian Free Trade Agreement.

The steel industry objected to many provisions of the WARN act on two grounds. The first one was that the 60-day notice of major layoffs or plant closures was a period generally longer than the steel order acceptance time span, and mill scheduling was even shorter than that. The second was that such a long period of uncertainty would put a company into major commercial disadvantage, possibly to the point of having no work left well in advance of the announced closure or layoff. However, both provisions were retained in the bill.

The Steel and Aluminum Energy Conservation and Technology Competitiveness Act became Public Law 100-680, but administrative interpretations were not available. The act provided for public and private partnerships to develop science and technology in the production of aluminum and steel.

A little noted but important provision in the Omnibus Trade and Competitiveness Act of 1988 Public Law 100-418 called for Federal agencies to use the metric measuring system as long as its usage did not harm U.S. competitive interests. The conversion was to be completed by 1992. It should be noted that U.S. Armed Forces and many major corporations, including steel producers, routinely used the metric system. Orders for flat products and plates in millimeters were handled for several years without any problems.

DOMESTIC PRODUCTION

The capacity of the steel industry remained at 112.2 million tons, unchanged since 1987.

Production of raw steel and shipments of finished steel mill products, as shown in table 1, were the highest since 1981, at nearly 100 million and 84 million tons, respectively. Basic oxygen furnaces again produced about 58% of the total, although production of electric arc furnaces slipped slightly to 36.9% from the usual 37% to 38%; the electric arc steel tonnage produced actually increased from that of the previous year. The production of basic open hearth furnaces increased for the first time in many years to a little more than 5% of the total. Alloy steels other than stainless accounted for nearly 11%; stainless, more than 2%; and carbon steel, 87%.

The apparent average product yield dropped slightly from about 86% to 84% probably owing to the increased amount of steel made in open-hearth furnaces and cast into ingots. This old practice results in yield losses of 8% to 13% in comparison with continuous casting of semifinished sections. The proportion of cast steel increased to 61%; this was the first year that this proportion had exceeded 60%.

Capacity utilization was an unprecedented 89.2%, a result of consistently full order books throughout almost the entire year. Only toward yearend did a slight slackening of orders become apparent.

The State with the highest steel production was Indiana again with 21 million tons, followed by Ohio with about 17.7 million tons and Pennsylvania with 13.7 million tons.

Iron production was also much higher than in recent years, nearly 56 million net tons. Almost all of it was "basic" and consumed liquid in basic oxygen and basic open hearth steelmaking furnaces. The entire output came from only 45 blast furnaces, which averaged 1.2 million tons per year or about 3,200 tons per day. The three largest units each routinely make 9,000 to 10,000 tons per day. A few small furnaces made iron for remelting at foundries.

Northwest Indiana had 11 furnaces in blast, followed by Ohio with 10 and Pennsylvania with 8. Closure of blast furnaces seemed to have ceased but the number of operating furnaces leveled out at about 45 new or modernized units.

Table 2 summarizes some key data on industry modernization.

Excess steel capacity was shed mainly by closing down old and inefficient open-hearth furnaces. Although capacity utilization depended to a large extent on market conditions and thus also on import policies of the Government, the reduction of capacity resulted in an upward utilization trend. In 1988, the industry worked at an unprecedented 89% of capacity, occasionally touching 95%, a rate that is not sustainable for a prolonged period due to normal maintenance requirements.

More than 60% of the raw steel made was cast continuously into semifinished sections. This method replaces the old ingot pouring and rolling technique with its unavoidable high yield losses. The result was improved shipped product yield.

Credit must also be given to better sensors and computerized controls and to a simple but effective quality control technique used by the operators on the production floor. This technique is known as the Statistical Process Control (SPC). In this method, some selected process variables are frequently checked and charted. In this way undesirable trends in quality performance can be spotted early and corrected before a defective product is actually made. The minimizing of steel quality rejections contributed to increased process yield.

AISI estimated that its members spent about $18 billion on development and modernization during the past 10 years. Most of these expenditures occurred since 1984 in response to the promise of the industry to U.S. legislative and Government bodies to use the respite granted by the Voluntary Restraint

TABLE 2

EFFICIENCY TRENDS OF U.S. STEEL PRODUCTION

Year	Raw steel Capacity (thousand short tons)	Raw steel Utilization (percent)	Raw steel Continous cast (percent)	Average steel[1] Product yield, (percent)	Manpower[2] Input (hour/ shipped ton)
1988	112,200	89.2	61.3	84.0	5.7
1987	112,200	79.5	59.8	86.0	4.6
1986	127,000	63.8	55.2	86.1	5.1
1985	133,600	66.1	44.4	82.6	5.7
1984	135,300	68.4	39.6	79.7	6.4
1983	150,600	56.2	32.1	79.9	7.0
1982	154,020	48.4	29.0	82.6	8.5
1981	154,300	78.3	21.6	73.2	8.5
1980	153,700	72.8	20.3	75.0	9.0
1979	155,300	87.8	16.9	73.5	8.9

[1] 100 times shipped tons divided by raw steel tons.
[2] Hourly and salaried hours combined.

Sources: American Iron and Steel Institute and Bureau of Labor Statistics.

Agreements for these purposes. The AISI also estimated that $1 billion per year would be needed for several years to maintain this pace of modernization.

The almost halving of work force used per product ton was also assisted by better work organization. All recent labor contracts achieved improved utilization of personnel by simplifying work assignment rules and combining positions for better scheduling flexibility. For instance, in many cases fixed maintenance squads assigned to one facility were replaced by "flying groups" covering several similar production units. The resulting reduction of personnel was in almost every case achieved by attrition, early retirement, or internal reassignment within a plant, usually after some retraining.

The development paths of the major integrated steel companies, minimills, and specialty steel producers were quite different. The integrated majors reinvested a large part of their profits and realized tax investment credits in their facilities and borrowed some funds from banks. They also generated funds by selling unprofitable or unrelated parts of the business, by cancelling or selling contracts for expensive raw materials, and by entering into joint ventures with Japanese steel companies.

The concept of "vertical integration" means ownership of all sources of raw materials including iron ore, coking coal, limestone, etc., and the means of transportation to the point of use. Vertical integration was the principal mode of operation up to the early 1980's. Realization that high-quality raw materials were available from other countries at a lower cost resulted in many integrated mills shedding their domestic raw materials operations, mines, railways, and shipping lines. Even coke ovens were being replaced in favor of buying coke abroad, although some ovens were being refurbished. It was reported in the industry that the resulting savings amounted to $10 to $15 per steel ton.

There was a period, mainly in the 1970's, when integrated steel producers purchased, in the name of diversification, businesses unrelated or only barely related to steel. In the late 1980's, they were selling these units because, in almost every case, they had proven to be unprofitable. The change of U.S. Steel into a de facto energy company renamed USX Corp. was an extreme example, but it involved a complete change of company aims and policies.

A typical example of this new policy was Armco Inc. This company experienced severe financial problems after it bought an insurance company along with some commercial distributors. These were sold in 1987 and 1988. The latest sale was that of Armco Atlantic, a manufacturer of metal buildings; plans to sell the Armco Construction Products Div. and W. Smith Engineering were announced toward the end of 1988. LTV Steel Co. sold its Warren, OH, flat products plant to a newcomer in the steel industry, Renco Group, based in New York.

Even the successful minimill operation, Nucor Corp., sold its Research Chemicals Div., which produced rare earth alloys. Nucor had high expenses for startups of two new mills; the profit from this sale, about $40 million after taxes, contributed to the decision to sell.

The gains from sales contributed to the large profits of the industry in 1988, but the executives of the respective companies usually pointed out their nonrecurrent character. On the other hand, there was evidence of some interest in buying steel-using firms. Inland Steel Industries Inc. steel service subsidiaries, J. T. Ryerson Co., and J. M. Tull Metals Co. Inc. each bought another, smaller service chain. Acme Steel Co., a producer of steel strapping, bought a strapping manufacturer. Armco had bought a group of steel processors and service operations.

The third way of securing development capital practiced by the integrated mills and, in the minimills sector, by Nucor, was formation of joint ventures with Japanese steel companies. These often brought the enormous resources of Japanese banks and trading companies into the deal. However, contrary to Japanese practice, the management of the joint ventures was usually restricted to the steel people; the financiers were merely investors. The old arrangement between National Steel Corp. and Nippon Kokan Steel, where the latter bought a 50% interest in the U.S. producer of flat products, was almost reproduced by Armco in 1988. Forty percent of Armco's Eastern Steel Div., which made 70% of Armco's steel output, was sold to Kawasaki Steel. The price was reported to be approximately $350 million with Kawasaki having the right to purchase another 10% after 3 years. The cash was to be used for upgrading the operation.

Inland Steel announced in late 1988 that IN-Tek, a subsidiary held with Nippon Steel Corp. (a 60–40 split), would add a large galvanizing facility to the cold-rolling complex under construction in Northern Indiana. Both hot-dip and electrolytic coating lines were planned. Projected galvanizing capacity was 1 million tons per year. Wheeling-Pittsburgh Steel Co. had a very successful startup of its electrogalvanizing line jointly owned with Nisshin Steel Co. The large cold-rolling mill in Pittsburgh, CA, jointly (50–50) owned by U.S. Steel (now a subsidiary of USX) and the Korean Pohang Iron and Steel Co. Ltd, neared completion toward yearend.

Some recent developments in 1987 and 1988 put to rest the persistent rumors about liquidation of the respective mills or abandonment of their primary facilities. U.S. Steel reactivated the large 5,000-ton-per-day No. 8 blast furnace at the Fairfield, AL, works, upgraded the hot strip mill, and put a slab caster into operation. The capacity of these works was 1 million tons of flat products and 640,000 tons of seamless pipe.

Newport Steel started construction of a slab caster and improvements in its slab rolling facilities. When completed, these improvements would bring the existing finishing capacity to 540,000 tons per year of welded pipe. Bethlehem Steel announced a major upgrading of the 68-inch hot strip mill at Sparrows Point, MD. The $200 million project was to be completed in 1990.

Bethlehem Steel advertised that it was starting the production of aluminum-nickel electrolytic coating on a line jointly owned with Pre-Finish Metals Corp. and Inland Steel Co. Only Ford and the Japanese car makers in the United States were interested; the other American automobile companies continued to use straight zinc coated steel. However, the Zn-Ni coating was becoming increasingly popular in Europe and Japan owing to its better corrosion resistance and better formability and weldability.

Despite the apparent overcapacity for light plate, U.S. Steel and Feralloy Co. announced the construction of a light plate finishing line at the U.S. Steel Gary Works.

All integrated steelmakers either started up or were constructing ladle metallurgy stations to improve control of steel analysis and properties. These might indirectly increase the steelmaking capacity because of the relief of steelmaking furnaces from final steel refining.

Most integrated steel producers were also adding vacuum degassers to their basic oxygen furnace shops. The degassers were intended to improve steel properties. If equipped for oxygen blowing, they could produce steel with ultralow carbon levels below 0.01%. These steels showed excellent formability in all dimensions and hence were desired for deep drawing by automobile and appliance makers. Also, their magnetic properties are outstanding, making them highly attractive to makers of electrical machines. Inland Steel and the Burns Harbor mill of Bethlehem Steel started up their oxygen blown vacuum degassers, and U.S. Steel was building a degasser in Gary, IN. The LTV Corp. announced plans to construct a degasser at its Indiana Harbor works. All of these mills were in northwestern Indiana near Chicago. National Steel disclosed that it was to build similar units at its Great Lakes Div. near Detroit, MI, and at Granite City, IL, near St. Louis, MO.

Many forges and high quality steel foundries were using vacuum degassers in their old role of eliminating hydrogen to prevent "hydrogen cracking."

Minimills faced different problems. Their product mix seldom included high quality steel; hence, major expenditures aimed at improving steel quality were seldom needed. They were not large enough to enter into joint enterprises with Japanese steelmakers, with one important exception that is discussed later. They seldom had access to attractive financing for modernization or expansion. They competed not only with imported steel but increasingly among themselves. As scrap-based steel producers, they were at the mercy of fluctuating scrap prices. Yet they captured about 25% of the steel market, stepping in for commodities abandoned by the majors, who could not compete with cheap imports of reinforcing bars, structural sections, wire bars, etc.

As a result of activities by the minimills, most integrated steel plants either left the bar steel business, e.g., LTV and Armco, or restricted their production to specialty items, e.g., Bethlehem Steel, U.S. Steel, and Inland.

Some of the larger companies among the "minis," sometimes called "market mills," raised money by offering stock to the public. In no case, however, did the owners lose control. The most extensive issue offered covered only 45% of the ownership. None of these issues showed any significant gain, and, by yearend, most lost some of their original values. Several small mills either failed or were bought out by more successful competitors. Birmingham Steel Corp. expanded during the year by adding Mississippi Steel Div., Norfolk Steel Div., Salmon Bay Steel Div., and Barbary Coast Steel Div. (these are their new names) to their original mills in Birmingham, AL, and Kankakee, IL. In every case, Birmingham announced plans to upgrade the existing operations as wholly owned divisions.

Nucor expanded by building two large-size minimills from scratch. Nucor was a group operating four minimills, all built from the ground up. It produced a wide range of hot-rolled bar steels, including higher quality grades, with flats and beams up to 12 inches (305 millimeters) wide. These were wider than most minimills but narrower than those produced by the majors, where 24 inches (610 millimeters) was common and beams up to 36 inches (915 millimeters) were rolled by U.S. Steel and Bethlehem Steel. Nucor started a joint venture with the Japanese Yamato Steel Co. by building a minimill at Blytheville, AR, designed to roll beams up to 24 inches wide. The declared capacity was 650,000 tons per year.

Nucor scored another "minimill first" by entering the flat products market. This always was the domain of the integrated mills for two reasons: the heavy, multistand hot- and cold-rolling mills were beyond the financial possibilities of smaller operators; and electric furnace steel is inherently high in nitrogen, which is a very undesirable hardener, particularly in cold- rolled products.

Nucor got around the first problem, mainly financial, by designing the new mill around a "thin slab caster," a very new and almost untried technology imported from the Federal Republic of Germany. Casting 1.5- to 2-inch-thick (38- to 51-millimeter) slabs, rather than the usual 8 to 12-inch (203- to 305-millimeter) variety, enabled Nucor to use a light mill costing much less than the usual rolling train. Hence, Nucor was entering the hot-rolled strip and light plate market. The mill was in Crawfordsville, IN, and was rated for 800,000 tons per year. Cold rolling was to be added in 1990.

The closed Phoenix Steel Co. in Claymont, DE, a small producer of plates, was bought by Chinese interests and upgraded under the name of Citi Steel Co. The capacity was 400,000 tons per year. Some producers of light plate in the East and Midwest lowered their prices after this was announced. The Green River Steel Co. of Covington, KY, a small producer of bar steels, restarted its 150,000-ton-per-year operation in 1988.

Korf Engineering Co. bought two small failed minimills in New England, apparently as demonstration plants for the Korf Energy Optimizing Furnace (EOF). The EOF's seemed to be a combination of a steel and iron scrap melting cupola with limited refining possibilities. They did not use electric power, only oxygen and low-grade solid fuels, e.g.,injected coal, and they obtained their high energy utilization levels by careful secondary combustion and heat recirculation.

Many of the minimills upgraded their electric furnaces by installing computer controls, enlarging the hearths, and adding oxy-fuel burners to assist in the melting of scrap. Florida Steel, encouraged by the original results obtained by Nucor, which were mainly large savings in electrode costs, was building a fairly large, direct-current single-electrode furnace.

Some ownership changes took place in the stainless steels area. Cyclops Industries Inc., which manufactured high-alloy steels and superalloys, bought Eastern Stainless Corp. and announced plans to update it. Washington Steel Corp., another large producer, was bought by Mercury Stainless Corp., owner and operator of a cold-rolling and finishing mill and several high-alloy steel warehouses.

Four facilities owned by ALTech Specialty Steels Corp. and the Bar Products Div. of LTV Steel were put on the market. ALTech's operations included both bar and flat products, although LTV steel's operations produced stainless and superalloys bars only. Cyclops attempted to negotiate a sale of its Cytemp Specialty Steel Div. but the talks were broken off.

Producers of stainless flat products found it advantageous to send coils for polishing and other finishing operations to Mexico, Canada, and, in a few cases, Brazil. In most cases, the steel was returned to the United States. The value of steel converted abroad was nearly $100 million.

Castings

Production of the foundry industry showed little change from that of 1987. Shipments of steel castings increased from 0.8 to 1.0 million tons; almost all of this steel was made in small arc furnaces under 15-ton capacity with some alloy steels also made in coreless induction units. Gray iron shipments dropped from 5.7 to 5.3 million tons; nearly one-half of these shipments were pipe and fittings. Most of the gray iron was made in cupolas but some air furnaces and induction furnaces were also in use. Ductile iron castings increased from 2.9 to 3.2 million tons while malleable iron went from 0.3 to 0.4 million tons. Overall, ferrous casting shipments were 9.9 million tons.

CONSUMPTION AND USES

U.S. steel mills shipped 77.9 million tons of carbon steel, 4.5 million tons of alloy, and 1.6 million tons of stainless steels for a total of 84.0 million tons during 1988. Imports for consumption totaled 22.3 million tons. Because 2.1 million tons was exported, the apparent steel supply was 104 million tons; changes of stocks and in-process steels were negligible.

The pattern of consumption of steel made by the U.S. mills was little changed from previous years. Steel service centers and warehouses took 22.6%. The automotive industry, including spare parts manufacture, consumed 14.4%. Construction and contractors required 10.5%. The balance was widely distributed among the 18 consuming categories recognized by the

Bureau of Census and AISI. The final uses of steel bought by processors and distributors, i.e., by service centers and warehouses, was, of course, not known nor was the destination of imported steel available.

Producing mills reported steel stocks to be about 12 million tons, a little over a 1-month supply, but this number included steel earmarked for predictable repetitive future orders. Inventories at service centers and warehouses were about one-half of this number; some of these 6 million tons included slow moving, uncommon grades, and sizes.

There was no governmental stockpile of iron or steel.

PRICES

The published "basic" or "list" prices of steel products and the resulting indices may be misleading as indicators of actual price trends. Most rolled steel products were subject to various analysis, quality, and special steel processing extras, which may increase the actual price by 10% to 15% over list. In times of slack steel demand, steel was widely discounted up to 15%. These two opposing tendencies may make list and resulting index prices misleading at least for some steel products. It also should be remembered that an index may become misleading unless it is adjusted for inflationary changes and changing product mix. Few were so adjusted, thus prices in 1987 and 1988 were numerically higher than in the late 1970's, but correcting them for inflation showed them to be actually lower than prices were about 10 years earlier.

The market was strong for almost all steel commodities in the first half of 1988, a notable exception being oil country tubular goods. The market softened a little in the third quarter and dropped significantly for several commodities, e.g., light plates and medium to wide structurals, in the last quarter. It was widely accepted in the industry that the announced price increases for flat products and oil country tubular goods would be nullified by extensive discounting.

A definite and well understood price increase occurred in the high-alloy steel field. Many of these producers added the existing scrap cost "extra" into their basic lists, due to the persistently high prices of high quality scrap. The strong increases in the costs of alloying elements in 1988 caused all producers to publish new "analysis extras" for stainless, tool, and some other alloy steels.

These extras took the form of surcharges for chromium, nickel, and vanadium, either by the nominal content of these elements in the applicable steel grade, or by what often amounted to the same, actual steel analysis. These surcharges were adjusted several times according to the price movements of the metals per London Metals Exchange in the case of nickel, published ferrochrome price per American Metals Market or Metals Bulletin, prices of vanadium alloys as published by their makers or the metals publications. Only the chromium surcharge dropped slightly toward yearend, reflecting stabilization that was seen in a small drop in the price of chromium alloys from their record highs.

FOREIGN TRADE

The weakness of the dollar in 1988 and the success of sharp cost cutting by U.S. steelmakers caused a revival of recently weak export activities. While steel exports were still small, 2 million tons compared with the 22 million tons imported, U.S.-made steel was shipped to Europe, Canada, South America and Mexico, China, the Soviet Union, and elsewhere.

The unexpected reactivation of exports to Japan may be explained by high Japanese costs. Paine-Webber's World Steel Dynamics estimated the Japanese costs in 1988 to be the highest in the developed world, averaging $523 per shipped ton. Paine-Webber attributed this high level to the surge in the value of the yen, less severe cost cutting as elsewhere, high cost of electric energy, and high financial charges. The same source also estimated the lowest cost producers (apart from nonexporting China) to be Brazil, Taiwan, the Republic of Korea, and the United Kingdom; France and the Federal Republic of Germany followed, and the United States came next, all in the range of $450 to $480 per shipped ton. Furthermore, a few "reconstituted" U.S. mills, those operating in bankruptcy or reopened with new, or no, labor contracts and attractive new power contracts, may have had costs as much as $40 lower than the U.S. average of $480. Costs of low-grade bar and structural products made in small minimills were much lower.

Most large steelmakers had some export sales, but did not stress these markets having to satisfy the strong domestic demand. However, a few did make efforts in exporting. U.S. Steel reactivated its export division that had been closed for several years. The aim was to sell 1 million tons in 1989, mainly to China, Japan, South America, and the U.S.S.R., which buys large-diameter pipe and specialty steels.

The Geneva Steel Co., formerly the Columbia-Geneva Div. of the U.S. Steel Corp. announced an export goal of 250,000 tons, following acceptance of trial shipments in Europe, Japan, and South America. Other smaller mills took the same course.

Expanding U.S. steel exports was not easy because steel markets elsewhere remained relatively closed. In a presentation to the U.S. Department of the Interior in October 1988, the president of the U.S. Steel Div. of USX stated that, although the European Community and Japan each accounted for approximately 25% of the world's steel exports, they imported only 6% and 3%, respectively.

A detailed review of export tonnage by product category is presented in table 10.

Imports were, to a large extent, regulated by the Voluntary Restraint Agreements (VRA). These were treaties negotiated by the U.S. Government with 19 steel-producing countries, including the European Community, in the form of shares of U.S. apparent steel consumption. Quotas in tons often were referred to as Orderly Marketing Arrangements. Specialty steels were included only in a few of these pacts, because, for most countries, these steels had been included in previous separate agreements. The import agreements in force in 1988 are listed in table 12. These agreements resulted in steel imports stabilizing at about 20% of U.S. consumption rather than reaching 28% to 30%.

VRA's were scheduled to expire on September 30, 1989. The AISI and the steelworkers union were in favor of their extension and inclusion of specialty steels. The Steel Service Center Institute, an organization of about 400 companies handling 22 million tons of domestic and imported steel, proposed changes that would liberalize steel import rules in times of steel shortage, but in general was in favor of VRA retention.

The Institute for Imported Steel and a group of steel users opposed an extension, arguing that VRA's were supporting excessive steel prices in the United States. This organization would accept very loose rules, subject to voluntary acceptance by each country concerned, and would prohibit importation of semifinished steel.

Imports of lower quality steel grades, such as reinforcing bars or structural sections, shifted from VRA countries to smaller steel producers not covered by VRA's. Reinforcing bar was a typical example. Although before 1986, a large part of U.S. imports came from Brazil (44% of total), in 1987-88, most came from Indonesia, Norway, and Turkey. The probable reasons were the development of minimills in the non-VRA countries and preference of VRA signatories to ship higher grade products with higher profit margins.

Another often misunderstood aspect of imports was the importation of semifinished sections, slabs, blooms and billets, and occasionally unrolled ingots. In times of intense steel demand, steel mills with rolling capacity higher than their steelmaking capacity used this method to fill orders. Also, when a major interruption of ironmaking or steelmaking occurred, for instance before a blast furnace reline or a BOF vessel exchange, steel mills bought semifinished sections just to keep the rolling mills busy. Few companies have an excess of semifinished capacity and, in time of steel shortage, purchasing semifinished steel abroad was a way to satisfy the swollen order books.

Requests for importation of semifinished steel dropped to zero in the last quarter of 1988, indicating a balance between capacity and demand.

The greatest and possibly only permanent importer of semifinished steel as slabs, especially from Brazil and Japan, was California Steel Co., which was jointly owned by Brazilian and Japanese interests. This company took over the hot- and cold-rolling mills of the defunct Kaiser Steel Co., Fontana, CA, but had no steelmaking facilities.

WORLD CAPACITY

Some general trends of changes in steel production capacities were reported by the Steel Times in December 1988. According to this magazine, the following increases in million metric tons took place since 1985:

China	13.0
Korea, Republic of	5.4
Brazil	3.5
India	1.8

The following decreases in million metric tons occurred:

Japan	6.4
France	5.6
United States	5.4
Belgium	4.0
Australia	.8
Luxembourg	.8

Hence, as mentioned earlier, increases occurred in less well developed countries, while the developed countries decreased their capacity. However, a strong 1988 seemed to have arrested the last trend.

Since the definition of "capacity" was not firm, precise calculation of this number was not possible. AISI defined it as "production capability during a sustained full order book period using normal maintenance procedures;" but even this apparently clear definition was subject to fine interpretational differences.

The interpretation of this concept in various countries varied from "nameplate capacity," assuming an excellent raw material and product mix and no maintenance, to some extrapolations bordering on wishful thinking. Nevertheless, the estimates on table 15 were developed from various sources.

WORLD REVIEW

Some foreign developments of direct interest to the U.S. steel producers and users were:

Belgium

The ALZ Corp. in Genk started up a new melt shop for stainless steels; an oxygen-inert gas blowing converter of 100 tons capacity was fed by scrap and ferrochrome melted in a high-power arc furnace. The steel made was finished in a newly constructed vacuum-oxygen decarburization facility. The total output capacity, about 550,000 tons per year, was far in excess of both Belgian needs and marketing possibilities in the European Community.

Canada

Dominion Steel and Foundry Co. (Dofasco) acquired Algoma Steel Corp. Ltd. in Sault Ste. Marie, Ontario, for $470 million and became the fourth largest steel company in North America. Dofasco planned to operate Algoma as an independent subsidiary.

Korea, Republic of

The capacity of the new Kwangyang works of POSCO was doubled to 6.5 million tons during the year. The cost of this expansion was declared to be very low, only about $650 per ton, owing to long-term, favorable international loans and competitive international construction bidding.

Mexico

The World Bank approved a loan of $400 million for the modernization of the steel industry, provided the Mexican Government lifted steel price controls and steel subsidies and opened the country to competition.

United Kingdom

The sale of the stock of the British Steel Corp. (BSC) to the public ("privatization") was completed toward yearend. The receipts were $4.6 billion, and about 10% of this sum was obtained from the United States. The BSC, after years of losses, underwent a thorough reorganization and, in 1986–87 had a profit of $750 million.

Venezuela

The World Bank approved a loan of $78 million toward the reconstruction of a plant to make hot-briquetted (direct-reduced) iron. Most of the output was to be directed to Japan, although some may be exported to the United States.

TECHNOLOGY

A large part of the applied research on steel industry problems was financed and coordinated by AISI. In every case it was "applied research" with clearly stated objectives. It always involved the AISI member companies and universities and often also supply companies and governmental bodies.

In 1988, AISI undertook some major activities.[2]

AISI established a Refractories Research Center at the University of Missouri-Rolla. Although the original planning expected a group of about 10 sponsoring member companies, 23 actually signed up.

AISI made a study of electric furnace dust disposal, which is a "hazardous substance" due to zinc, lead, and cadmium contents. The study resulted in the development of a profitable method, for disposal of the dust, known as the Tectonics Bethlehem (the original sponsor) reduction process. The first commercial plant to utilize this process was under construction in 1989.

Other work completed in 1988 included a study of stresses in coke ovens, rapid in-furnace determination of steel analysis, measurement of temperature distribution within a solidifying steel body, in-line inspection of seamless tube blanks and detection of porosity in other hot semifinished products, improved zinc based steel coatings, and formability of sheet metal.

It was interesting that ongoing projects on the use of computers for planning and scheduling of production regarded the computers as tools assisting the human operator, but by no means were they viewed as on-line masters.

All these developments were handed over to the sponsoring companies for utilization or were subject to studies regarding their continuation.

[1] Physical scientist, Branch of Ferrous Metals.
[2] AISI, unpublished.

TABLE 3

MATERIALS CONSUMED IN BLAST FURNACES AND PIG IRON PRODUCED

(Thousand short tons)

Material	1984	1985	1986	1987	1988
Iron oxides: [1]					
Ores	2,247	3,201	2,087	2,972	5,682
Pellets	58,749	56,987	48,072	54,564	67,268
Sinter [2]	18,907	17,838	14,574	15,895	17,082
Total	**79,903**	**78,026**	**64,733**	**73,431**	**90,032**
Scrap [3]	1,944	2,381	2,079	3,389	3,007
Miscellaneous [4]	1,778	2,023	1,502	1,703	[e]1,900
Coke	28,014	26,564	22,573	24,031	29,442
Fluxes [5]	3,241	3,132	2,247	2,131	[e]2,100
Pig iron produced [6]	51,961	49,963	44,287	48,308	55,745

[1] American Iron and Steel Institute.
[2] Includes sintered ore and pellet fines, dust, mill scale, and other revert iron bearing materials; also some nodules.
[3] Mainly briquetted turnings and borings, shredded scrap, etc.; scrap produced at blast furnaces and remelted not included.
[4] Mainly revert materials not sintered.
[5] Includes fluxes used in sintering at the steel plant, but excludes fluxes consumed in agglomeration at the iron ore mine.
[6] For disposition of iron, see table 1; for consumption of energy, see tables 8 and 9.

TABLE 4

SPECIFIC CONSUMPTION OF MATERIALS IN BLAST FURNACES

(Pounds per ton)

Material	1984	1985	1986	1987	1988
Ores	87	118	94	123	204
Pellets	2,261	2,281	2,171	2,259	2,413
Sinter [1]	728	714	658	658	613
Total	**3,076**	**3,113**	**2,923**	**3,040**	**3,230**
Scrap [2]	75	95	94	140	108
Miscellaneous [3]	68	81	68	71	[e]68
Coke	1,078	1,063	1,019	995	1,056
Fluxes [4]	124	125	101	88	75

[e] Estimated.
[1] Includes sintered ore and pellets fines, dust, mill scale and other revert iron bearing materials; also some nodules.
[2] Mainly briquetted turnings and borings, shredded scrap, etc.; scrap produced at blast furnaces and remelted not included.
[3] Mainly revert materials not sintered.
[4] Includes fluxes used in sintering at the steel plant, but excludes fluxes consumed in agglomeration at the iron ore mine.

Source: American Iron and Steel Institute and the Bureau of Mines.

TABLE 5

U.S. STEEL PRODUCTION, BY TYPE OF FURNACE PROCESS

Year	Basic oxygen		Basic open hearth		Basic electric arc		Total
	(thousand short tons)	(percent)	(thousand short tons)	(percent)	(thousand short tons)	(percent)	(thousand short tons)
1988	57,960	58.0	5,118	5.1	36,846	36.9	99,924
1987	52,496	58.9	2,666	3.0	33,989	38.1	89,151
1986	47,885	58.7	3,330	4.1	30,390	37.2	[1] 81,606
1985	51,885	58.8	6,428	7.3	29,946	33.9	88,259
1984	52,822	57.1	8,336	9.0	31,370	33.9	92,528

[1] Data do not add to total shown because of independent rounding.

TABLE 6

CONSUMPTION OF SCRAP AND PIG IRON IN STEEL PRODUCTION, BY TYPE OF STEELMAKING FURNACE[1]

(Thousand short tons)

Year	Basic oxygen		Basic open hearth		Basic electric arc		Total	
	Scrap	Iron	Scrap	Iron	Scrap[2]	Iron	Scrap	Iron
1988	17,484	52,446	[e] 3,709	[e] 2,291	34,345	248	52,986	54,985
1987	15,230	47,525	992	2,057	32,009	30	48,321	49,612
1986	14,753	41,582	1,556	2,325	31,166	313	47,475	43,910
1985	15,339	44,515	2,411	4,737	32,252	503	50,002	49,257
1984	16,447	45,551	3,724	5,718	28,244	22	48,415	51,291

[e] Estimated.
[1] Pig iron mainly as liquid in basic oxygen and open hearth furnaces; for specific consumption, pounds per steel ton, see table 7; for energy consumption see tables 8 and 9.
[2] Consumption of scrap appears to be underreported.

TABLE 7

SPECIFIC CONSUMPTION OF SCRAP[1] AND PIG IRON

(Pounds per ton of steel)

Year	Basic oxygen		Basic open hearth	
	Scrap	Iron	Scrap	Iron
1988	603	1,810	[e] 1,454	[e] 898
1987	584	1,811	744	1,543
1986	616	1,737	935	1,396
1985	592	1,717	750	1,474
1984	623	1,725	893	1,372

[e] Estimated.
[1] Consumption of scrap, the almost exclusive charge of arc furnaces, appears to be underreported.

TABLE 8

CONSUMPTION OF PURCHASED OXYGEN AND FUELS

		1984	1985	1986	1987	1988
Oxygen:[1]						
Oxygen furnaces	million cubic feet	101,921	100,721	94,168	112,594	127,383
Blast furnaces	do.	24,271	18,031	22,077	31,953	44,334
Other uses	do.	50,245	44,737	37,380	41,043	49,925
Total	**do.**	**176,437**	**163,489**	**153,625**	**185,590**	**221,642**
Natural gas:						
Blast furnaces	do.	29,235	25,621	23,650	37,583	82,148
In process heating	do.	228,082	197,823	175,295	208,651	264,300
Other uses	do.	133,906	123,331	109,966	150,202	187,077
Total	**do.**	**391,223**	**346,775**	**308,911**	**396,436**	**533,527**
Fuel oil:[2]						
Blast furnaces	thousand gallons	131,437	99,674	149,364	140,225	127,013
Other uses	do.	190,463	133,723	156,411	118,381	183,030
Total	**do.**	**321,900**	**233,397**	**305,775**	**258,601**	**310,043**
Electric power:[3]	million kilowatt hours	56,077	52,880	49,164	52,157	[e]55,000

[1] Includes 10% to 20% of total produced by steelworks owned or leased oxygen separation plants.
[2] Mostly "Bunker C" grade and for injection into blast furnaces also high viscosity, high sulfur residual refinery oil.
[3] Includes 10 to 20% of total generated by integrated steelworks.

TABLE 9

SPECIFIC CONSUMPTION OF PURCHASED OXYGEN AND FUELS PER PRODUCT TON IN IRONMAKING AND STEELMAKING

		1984	1985	1986	1987	1988
Oxygen						
Blast furnaces	cubic feet per iron ton	467	361	498	661	797
Basic oxygen furnaces	cubic feet per raw steel ton	1,930	1,941	1,967	2,134	2,198
Natural gas						
Blast furnaces	cubic feet per iron ton	563	513	534	778	1,474
Fuel oil						
Blast furnaces	gallons per iron ton	2.5	2.0	3.4	3.0	2.3
Electric power[1]		NA	NA	NA	NA	NA

NA Not available.
[1] Typical usage is 460 to 530 kilowatt hours per raw steel ton.

Source: American Iron and Steel Institute.

TABLE 10

U.S. EXPORTS OF MAJOR IRON AND STEEL PRODUCTS

Product	1986		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Steel mill products:						
Ingots, blooms, billets, slabs, sheet bars	58,885	$18,812	73,543	$34,285	61,430	$34,637
Wire rods	6,206	9,195	8,850	15,200	10,768	17,405
Structural shapes, 3 inches and over	31,698	21,275	63,159	28,283	61,494	35,076
Structural shapes, under 3 inches	6,995	7,463	11,563	10,196	13,461	16,084
Sheet piling	5,729	6,136	2,552	1,637	428	369
Plates	69,565	55,709	96,538	67,655	119,393	104,591
Rails and track accessories	9,447	11,057	11,988	13,228	13,646	27,233
Wheels and axles	3,685	18,796	3,766	17,767	—	—
Concrete reinforcing bars	14,197	4,907	20,550	8,213	23,480	7,486
Bars, carbon, hot-rolled	19,561	9,572	40,675	18,272	45,305	21,645
Bars, alloy, hot-rolled	25,862	33,900	24,845	41,408	33,398	52,504
Bars, cold-finished	13,491	22,291	21,925	29,831	23,107	42,691
Hollow drill steel	790	1,730	1,677	2,850	2,102	3,402
Pipe and tubing	121,050	188,212	149,941	220,513	248,337	344,501
Wire	26,081	37,574	26,146	44,178	35,062	76,412
Nails, brads, spikes, staples	5,862	31,659	7,905	34,285	487	78,408
Blackplate	70,488	22,178	73,967	27,731	139,125	62,906
Tinplate and terneplate	214,122	71,312	172,842	71,794	301,392	147,875
Sheets, hot-rolled	75,906	46,204	80,001	67,933	419,037	197,935
Sheets, cold-rolled	37,672	130,547	46,685	45,866	102,965	119,155
Strip, hot-rolled	13,683	17,386	28,321	21,448	32,331	29,121
Strip, cold-rolled	20,863	32,574	15,838	45,802	55,676	76,458
Plates, sheets, strip, galvanized, coated or clad	74,685	59,896	110,705	81,222	323,529	206,391
Total[1]	**926,521**	**858,386**	**1,093,982**	**949,597**	**2,065,955**	**1,702,286**
Other steel products:						
Plates and sheets, fabricated	11,133	18,023	10,708	20,806	64,611	90,649
Structural shapes, fabricated	34,098	67,121	35,662	70,791	44,832	10,888
Architectural and ornamental work	2,552	7,171	1,472	5,532	33,101	63,481
Sashes and frames	4,242	16,765	5,462	20,639	2,485	4,993
Pipe and tube fittings	18,645	155,183	25,189	182,307	110,313	382,769
Conduit	2,883	4,930	5,631	6,376	—	—
Bolts and nuts	44,186	100,502	55,608	88,229	10,322	94,081
Forgings	46,649	67,505	78,202	83,824	107,522	60,407
Cast-steel rolls	1,243	2,582	1,880	2,700	2,907	10,820
Railway track material	2,812	4,272	5,774	1,259	4,648	5,023
Total[1]	**168,444**	**444,053**	**225,587**	**482,464**	**380,741**	**723,111**
Iron products:						
Cast-iron pipes, tubes, fittings	65,307	69,253	31,898	52,586	62,247	80,414
Iron castings	40,473	34,909	67,197	55,134	66,594	50,005
Total[1]	**105,780**	**104,161**	**99,095**	**107,719**	**128,841**	**130,419**
Grand total[1]	**1,200,744**	**1,406,601**	**1,418,665**	**1,539,781**	**2,575,537**	**2,555,817**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF IRON ORE, BY COUNTRY

(Thousand long tons)[1]

Country	1984	1985	1986	1987	1988
Brazil	2,533	2,540	3,693	3,640	4,760
Canada	11,190	8,557	8,696	7,854	8,946
Liberia	1,745	2,206	1,487	979	126
Venezuela	1,524	2,068	2,309	2,580	3,512
Other	195	400	558	1,530	2,436
Total	**17,187**	**15,771**	**16,743**	**16,583**	**19,780**

[1] Traditional iron ore trading unit, 2,240 pounds.

Source: Bureau of the Census.

TABLE 12

STEEL IMPORT AGREEMENTS

	Voluntary Restraint Agreement percent U.S. apparent consumption[1]	Orderly Marketing Agreement quota (short tons)[2]	Orderly Marketing Agreement semifinished steel quota (short tons)
Australia	0.24	—	50,000
Austria	.23	—	—
Brazil	1.24	—	700,000
China	—	77,400	—
Czechoslovakia	—	40,100	—
European Community	5.36	—	840,000
Finland	.23	—	15,000
German Democratic Republic	—	228,500	—
Hungary	—	33,300	—
Japan	5.93	—	100,000
Mexico	.42	—	100,000
Poland	—	87,200	—
Portugal	—	29,300	—
Romania	—	111,400	—
Korea, Republic of	1.82	—	50,000
Spain	.69	—	50,000
Trinidad and Tobago	—	43,500	—
Venezuela	—	143,900	71,225
Yugoslavia	—	20,900	—

[1] Includes semifinished steel.
[2] Includes semifinished steel, except for Venezuela.

Source: U.S. International Trade Commission.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF PIG IRON, BY COUNTRY

(Short tons)

Country	1984	1985	1986	1987	1988
Brazil	421,176	130,762	143,154	118,736	496,916
Canada	171,708	166,291	112,607	209,898	145,366
South Africa, Republic of	31,489	30,504	32,944	—	—
Other	77,982	10,701	6,252	26,078	10,273
Total	**702,355**	**338,258**	**294,957**	**354,712**	**652,555**

Source: Bureau of the Census.

TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF MAJOR IRON AND STEEL PRODUCTS

Product	1986		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Steel mill products:						
Ingots, blooms, billets, slabs, sheet bars	1,907,274	$391,269	2,101,145	$468,889	2,576,935	$704,264
Wire rods	1,367,221	472,387	1,471,949	501,989	1,499,307	577,257
Structural shapes, 3 inches and over	1,748,604	515,737	1,778,314	537,598	1,847,288	700,028
Structural shapes, under 3 inches	166,369	61,515	140,469	56,708	132,538	60,656
Sheet piling	107,013	40,047	109,705	42,712	112,067	46,186
Plates	1,593,056	457,362	1,676,588	857,523	2,003,838	771,543
Rails and track accessories	266,084	79,999	227,869	66,454	268,699	84,166
Wheels and axles	9,626	9,614	18,120	13,433	50,734	34,894
Concrete reinforcing bars	454,735	102,718	351,632	87,143	357,253	93,494
Bars, carbon, hot-rolled	419,699	135,123	441,858	148,977	475,547	141,729
Bars, alloy, hot-rolled	171,546	96,615	176,968	100,350	207,844	122,480
Bars, cold-finished	236,149	169,188	222,639	182,735	251,894	211,392
Hollow drill steel	1,378	1,530	2,050	2,383	2,038	2,376
Welded pipe and tubing	1,939,948	786,443	1,758,349	729,688	1,787,400	904,281
Other pipe and tubing	996,864	592,187	969,191	559,035	1,414,584	375,695
Wire	583,072	396,936	607,185	393,244	542,098	435,655
Wire nails	393,673	219,223	440,746	257,209	6,061	8,221
Wire fencing, galvanized	24,475	18,038	21,358	17,688	24,454	19,391
Blackplate	205,937	84,835	159,779	72,050	145,166	73,850
Tinplate and terneplate	380,268	199,484	363,524	193,110	329,743	185,259
Sheets, hot-rolled	2,101,876	594,816	2,134,221	666,220	2,211,961	820,016
Sheets, cold-rolled	2,764,195	1,175,118	2,329,020	1,102,208	2,185,632	1,208,855
Sheets, coated (including galvanized)	2,489,419	1,158,634	2,577,799	1,297,140	2,147,148	1,178,429
Strip, carbon, hot-rolled	43,557	15,486	18,130	9,341	49,554	20,688
Strip, carbon, cold-rolled	123,380	94,380	102,028	82,980	5,572	9,309
Strip, alloy, hot- or cold- rolled (including stainless)	49,846	81,192	28,083	50,821	27,479	74,156
Plates, sheets, strip, electrolytically coated (other than with tin, lead, or zinc)	131,379	69,596	122,097	69,538	111,878	68,006
Total[1]	**20,676,642**	**8,019,473**	**20,350,816**	**8,567,164**	**20,774,712**	**8,932,276**
Other steel products:						
Plates, sheets, strip, fabricated	47,822	22,459	84,076	40,705	139,732	74,007
Structural shapes, fabricated	352,500	278,020	214,208	162,846	162,798	126,909
Pipe fitting	92,218	142,322	67,948	133,544	115,703	203,896
Rigid conduit	19,491	11,376	4,910	3,399	4,021	4,394
Bale ties made from strip	752	616	437	384	271	178
Nails, brads spikes, staples, tacks, not of wire	50,823	70,083	53,861	95,393	42,089	58,653
Bolts, nuts, rivets, washers, etc.	647,002	748,820	565,651	682,007	718,543	1,082,123
Forgings	46,864	34,395	28,983	25,720	36,817	35,744
Total[1]	**1,257,473**	**1,308,091**	**1,020,073**	**1,143,999**	**1,219,974**	**1,585,904**
Iron products:						
Cast-iron pipes, tubes, fittings	57,799	59,808	60,220	59,606	68,931	74,124
Iron castings	152,632	92,222	103,173	102,062	246,794	207,388
Total[1]	**210,432**	**152,030**	**163,393**	**161,668**	**315,725**	**281,512**
Grand total[1]	**22,144,546**	**9,479,595**	**21,534,282**	**9,872,830**	**22,310,411**	**10,799,692**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 15

WORLD ANNUAL IRON AND STEEL PRODUCTION CAPACITY, DECEMBER 31, 1988

Country or area	Estimated capacity, 1988 (Million short tons)
North America:	
United States	[1]112
Canada	22
Mexico	12
Total	**146**
Europe:	
European Community	165
Other market economy countries	95
Total	**260**
U.S.S.R.	184
Other planned economy countries	60
Total	**274**
Africa	16
Asia:	
China	66
Japan	123
Korea, Republic of	24
Other	42
Total	**255**
Oceania	12
Total	**963**

[1] Source: American Iron and Steel Institute (AISI).

TABLE 16

PIG IRON: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria[e]	1,210	1,210	1,210	1,210	1,210
Argentina[3]	1,983	3,306	2,866	3,142	3,000
Australia	5,874	6,181	6,492	6,139	6,290
Austria	4,128	4,083	3,692	3,804	3,900
Belgium	[r]9,881	[r]9,617	8,876	9,087	10,010
Brazil[3]	18,960	20,911	22,432	23,710	[4]25,972
Bulgaria	1,739	1,876	1,760	1,821	1,800
Burma	9	—	3	—	—
Canada	10,629	10,654	10,195	10,472	10,500
Chile	655	639	651	680	[4]858
China[e]	[4]44,070	48,100	55,300	59,400	62,200
Colombia	278	258	349	[e]353	[4]341
Czechoslovakia	10,539	10,540	10,552	10,789	10,800
Egypt	248	175	[e]200	[e]220	220
Finland	2,242	2,084	2,190	2,274	2,300
France	16,578	17,004	15,412	16,305	14,800
German Democratic Republic[5]	2,598	2,842	3,018	3,085	3,200
Germany, Federal Republic of	33,293	34,757	31,987	31,435	[4]35,773
Greece[e]	152	154	180	180	180
Hungary	2,312	2,309	2,264	2,323	[4]2,307
India	10,342	10,841	11,584	12,007	[6]11,000
Iran[e 6]	276	276	276	276	276
Italy	12,818	[r]13,297	13,135	[e]11,500	[4]12,550
Japan	88,629	88,812	82,289	80,929	[4]87,408
Korea, North[e]	6,300	6,400	6,400	6,400	7,200
Korea, Republic of	9,660	9,737	9,940	12,188	[4]13,865
Luxembourg[5]	3,051	[r]3,036	2,921	2,541	[4]2,779
Mexico[3]	5,924	5,616	5,566	5,774	[4]4,035
Morocco[e]	17	17	17	17	17
Netherlands	5,430	5,312	5,101	6,035	[4]5,508
New Zealand[e 3]	190	190	220	220	220
Norway	602	[r]657	617	402	390
Pakistan	624	885	983	998	1,020
Paraguay	—	—	—	37	[4]89
Peru[3]	[r]68	[r]234	300	278	[4]279
Poland	11,002	10,810	11,626	11,548	11,600
Portugal	[r]421	[r]466	473	480	485
Romania	10,535	10,154	10,283	9,560	9,400
South Africa, Republic of	6,013	7,247	[e]7,500	[e]7,400	7,200
Spain	5,884	[r]6,015	5,291	5,363	5,300
Sweden[3]	2,561	2,811	2,897	2,666	2,900
Switzerland	60	73	87	77	77

See footnotes at end of table.

TABLE 16—Continued

PIG IRON: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Taiwan	3,704	3,780	[e]4,100	[e]4,190	6,300
Trinidad and Tobago	([7])	([7])	([7])	([7])	—
Tunisia[e]	[4]165	165	165	165	165
Turkey	3,199	3,520	4,041	4,892	5,350
U.S.S.R.[e]	121,600	120,600	124,800	[r]124,850	124,950
United Kingdom	10,458	11,443	10,676	13,246	[4]14,279
United States	51,961	49,963	44,287	48,308	[4]55,745
Venezuela[3]	3,511	3,391	3,758	3,951	[4]4,027
Yugoslavia	3,147	3,439	3,376	3,160	[4]3,214
Zimbabwe[e]	441	743	710	633	660
Total	**[r]545,971**	**[r]556,630**	**553,068**	**566,520**	**593,949**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table excludes ferroalloy production except where otherwise noted. Table includes data available through June 28, 1989.
[2] In addition to the countries listed, Vietnam and Zaire have facilities to produce pig iron and may have produced limited quantities during 1984-88, but output is not reported and available information is inadequate to make reliable estimates of output levels.
[3] Includes direct-reduced iron output.
[4] Reported figure.
[5] Includes blast furnace ferroalloys.
[6] Presumably from blast furnaces only. Although Iran has direct reduct ion iron plants attaining a reported 360,000 short tons per year capacity, no production data are available.
[7] Revised to zero. Data presented in previous editions of this table are for direct-reduced iron and are not comparable to the other figures presented here.

TABLE 17

DIRECT REDUCED IRON[1] WORLD PRODUCTION, BY COUNTRY

(Thousand short tons)

Country	1984	1985	1986	1987	1988
Argentina	992	1,100	1,006	1,014	1,066
Canada	550	820	760	801	767
Egypt	—	—	33	520	770
Indonesia	815	1,101	1,460	1,013	1,080
Malaysia	—	570	640	651	500
Mexico	1,620	1,770	1,500	1,720	1,620
Quatar	550	549	548	520	488
Saudi Arabia	800	1,100	1,290	1,450	1,080
South Africa, Republic of	300	460	870	930	730
Trinidad and Tobago	—	260	420	545	[e]600
U.S.S.R.[e]	400	460	830	1,390	1,600
Venezuela	2,750	2,910	3,240	3,438	2,983
Other	1,410	1,230	1,190	1,120	876
Total	**10,187**	**12,330**	**13,787**	**15,112**	**[2]14,160**

[e] Estimated.
[1] Iron obtained from ore by reduction of oxides to metal without melting.
[2] World capacity 26,885 metric tons.

Sources: International Iron and Steel Institute, Midrex Corp., and HYL S.A.

TABLE 18

RAW STEEL:[1] WORLD PRODUCTION, BY COUNTRY[2]

(Thousand short tons)

Country[3]	1984	1985	1986	1987[p]	1988[e]
Algeria	1,190	1,559	1,543	1,543	1,540
Angola[e]	11	11	11	11	11
Argentina	2,918	3,243	3,566	4,002	[5]3,967
Australia	6,948	7,251	7,389	6,756	[5]6,942
Austria	5,368	5,137	4,731	4,741	5,020
Bangladesh[4]	80	111	106	90	[5]77
Belgium	12,459	11,776	10,736	10,788	[5]12,342
Brazil	20,267	22,549	23,406	24,505	[5]27,046
Bulgaria	3,172	3,245	3,268	3,357	3,310
Canada	16,220	[r]16,094	15,543	16,204	[5]16,728
Chile	763	759	778	800	[5]987
China[e]	[r 5]47,807	51,500	57,400	61,700	65,018
Colombia	550	584	697	678	[5]678
Cuba	358	442	454	463	460
Czechoslovakia	16,348	16,574	16,658	16,992	16,500
Denmark	604	582	697	668	715
Dominican Republic	70	66	110	97	[5]83
Ecuador	20	20	19	28	[5]26
Egypt	[r]1,268	[r]1,047	1,102	1,764	[5]1,874
El Salvador	12	13	10	14	[5]12
Finland	2,901	2,776	2,850	2,942	[5]3,055
France	[r]20,953	20,759	19,427	19,540	[5]20,947
German Democratic Republic	8,348	8,656	8,782	9,086	9,260
Germany, Federal Republic of	43,419	44,640	40,933	39,957	[5]45,220
Greece	987	1,086	1,112	1,001	990
Guatemala	29	11	19	23	[5]25
Honduras[e]	—	21	8	8	8
Hong Kong[e]	130	130	130	130	130
Hungary	4,134	4,019	4,095	3,991	[5]3,950
India[6]	11,402	12,185	12,596	14,201	[5]15,651
Indonesia	1,100	1,323	1,653	1,653	2,260
Iran[e]	1,300	990	990	990	990
Ireland	183	224	229	243	220
Israel	101	110	121	128	130
Italy	26,484	26,173	25,212	25,184	[5]26,090
Japan	116,389	116,050	108,330	108,592	[5]116,493
Jordan[e]	150	150	150	[r]240	240
Kenya[e]	11	11	11	11	11
Korea, North[e]	7,200	7,200	7,200	7,200	8,800
Korea, Republic of	14,366	14,924	16,043	18,499	[5]21,069
Luxembourg	4,395	4,349	4,084	3,639	[5]4,033

See footnotes at end of table.

TABLE 18—Continued

RAW STEEL:[1] WORLD PRODUCTION, BY COUNTRY[2]

(Thousand short tons)

Country[3]	1984	1985	1986	1987[p]	1988[e]
Malaysia[e]	390	610	830	[5]827	600
Mexico	8,333	8,121	7,904	8,346	[5]8,591
Morocco[e]	7	7	7	7	8
Netherlands	6,326	6,081	5,824	5,602	[5]6,083
New Zealand	302	250	[e]316	[e]330	275
Nigeria	206	280	220	203	[5]212
Norway	1,014	1,056	922	923	[5]1,000
Pakistan[e]	670	770	880	[r]1,000	1,000
Paraguay	—	—	—	11	[5]68
Peru	371	438	537	553	540
Philippines	288	276	[e]276	[e]280	[5]331
Poland	18,224	17,776	18,898	18,902	18,700
Portugal	761	733	780	807	550
Qatar	527	588	559	542	[5]581
Romania	15,914	15,206	15,737	15,306	15,400
Saudi Arabia	928	1,219	[e]1,200	1,505	1,545
Singapore[e]	390	390	390	390	[5]468
South Africa, Republic of	8,628	9,460	[e]9,700	9,259	[5]9,480
Spain	14,864	15,691	13,201	12,887	13,200
Sweden	5,186	5,305	5,192	5,065	5,070
Switzerland	1,078	1,088	1,185	959	910
Syria[e]	[4]76	76	76	[r]77	77
Taiwan	5,758	5,871	6,260	6,558	9,150
Thailand	420	493	510	589	[5]608
Trinidad and Tobago	[r]206	[r]190	359	398	[5]398
Tunisia	186	187	200	[e]200	200
Turkey	4,773	[r]5,469	5,432	7,765	8,820
U.S.S.R.	170,018	170,492	176,976	178,450	179,500
United Kingdom	16,668	17,331	16,326	19,208	[5]20,958
United States	92,528	88,259	81,606	89,151	[5]99,924
Uruguay	45	43	44	33	[5]32
Venezuela[6]	3,241	3,710	3,822	4,102	[5]4,052
Vietnam[e]	110	120	120	120	125
Yugoslavia	4,669	4,938	4,981	4,814	[5]4,946
Zimbabwe[e]	[5]431	510	540	[r]570	[5]663
Total	**[r]783,951**	**[r]791,384**	**784,009**	**808,198**	**856,973**

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Steel formed in first solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

[2]Table includes data available through June 28, 1989.

[3]In addition to the countries listed, Burma, Ghana, Libya, and Mozambique are known to have steelmaking plants, but available data is insufficient to make reliable estimates of output levels.

[4]Data are for year ending June 30 of that stated.

[5]Reported figure.

[6]Includes steel castings except for India for 1988, which excludes steel castings.

IRON AND STEEL SCRAP

By Raymond E. Brown[1]

Brokers, dealers, and other outside sources supplied domestic consumers in 1988 with 47.1 million short tons[2] of all types of ferrous scrap at a delivered value of approximately $5.06 billion, while exporting 10.1 million tons (excluding rerolling material and ships, boats, and other vessels for scrapping) valued at $1.35 billion. In 1987, domestic consumers received 42.1 million tons at a delivered value of approximately $3.55 billion; exports totaled 10.4 million tons valued at $967 million.

DOMESTIC DATA COVERAGE

Domestic production data for ferrous scrap are developed by the Bureau of Mines from voluntary monthly or annual surveys of U.S. operations. Of the operations to which a survey request was sent, 58% responded, representing an estimated 73% of the total consumption shown in table 2 for three types of scrap consumers. Consumption for the nonrespondents was estimated using prior reports adjusted by industry trends. An estimation error is also contained in the difference between the reported total consumption of purchased and home scrap and the sum of scrap receipts plus home scrap production, less scrap shipments, and adjustments for stock changes. For scrap consumption data shown in table 2, this difference amounted to 1% for manufacturers of pig iron and raw steel and castings, 0.0% for manufacturers of steel castings, 1% for iron foundries and miscellaneous users, and 0.7% average for all types of manufacturers combined.

LEGISLATION AND GOVERNMENT PROGRAMS

The Institute of Scrap Recycling Industries, Inc. (ISRI), Washington, DC, was subpoenaed as part of an attempt by the U.S. Environmental Protection Agency (EPA) to determine the source of polychlorinated biphenyls (PCB) in shredder residue. Some scrap processors, primarily in the Northeast where landfill capacity is at a premium, have refused to accept household appliances (white goods) because of concerns over items with PCB-bearing capacitors. ICF Incorporated, Fairfax, VA, has been developing an economic profile of the scrap metal shredding industry for EPA's Office of Pesticides and Toxic Substances. A ruling by the EPA requiring pretreatment of nearly 30% of all regulated wastes prior to disposal could pose serious problems for steelmakers operating electric furnaces. At issue have been a series of regulations concerning electric-furnace dust. Under terms of the Resource Conservation and Recovery Act (RCRA) of 1984, steelmakers will have to recover or stabilize metals in sludges from electric arc furnaces and electroplating operations. Prior to the ruling, ISRI had asked the EPA to change its proposed standards on treatment of baghouse dust from electric arc steelmaking furnaces. The president of ISRI asked scrap processors and recyclers to discuss with members of Congress the inequities of the Compre-

TABLE 1

SALIENT U.S. IRON AND STEEL SCRAP AND PIG IRON STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
Stocks, Dec 31:					
Scrap at consumer plants	5,261	5,104	4,344	4,844	4,554
Pig iron at consumer and supplier plants	304	266	188	281	207
Total	**5,565**	**5,370**	**4,532**	**5,125**	**4,761**
Consumption:					
Scrap	65,702	70,493	65,856	68,303	76,822
Pig iron	53,202	51,411	45,604	50,030	59,047
Exports:					
Scrap (excludes rerolling material and ships, boats, and other vessels for scrapping)	9,498	9,950	11,704	10,367	10,098
Value	$917,981	$918,186	$1,053,849	$967,018	$1,351,955
Imports for consumption:					
Scrap (includes tinplate and terneplate)	577	611	724	843	1,038
Value	$47,427	$46,480	$49,073	$82,016	$133,577

hensive Environmental Response, Compensation, and Liability Act (Superfund). ISRI contended that it is an injustice to be held accountable in the future for something that it did in the past that was legal and consistent with good operating practice at that time.

The U.S. Office of Technology Assessment was developing a report on municipal solid waste tentatively entitled "The Nation's Trash: A Materials Use Strategy for Municipal Solid Waste." The Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, proposed a new standard "The Control of Hazardous Energy Sources (Lockout/Tagout)." ISRI informed its members that the proposed standard would require employers to develop formal procedures for deenergizing machinery and equipment before performing maintenance or service.

The Bureau of Mines and ISRI signed a "Memorandum of Agreement" on May 24. The agreement provided for a mutual exchange of information that would extend to 1990 and may be renewed at that time. The Bureau agreed to contribute statistical and technical information, and ISRI will provide data concerning scrap collection and recycling methods. On January 2, the President of the United States and the Prime Minister of Canada signed the United States-Canada Free-Trade Agreement (CFTA). The main objective of the CFTA was to eliminate barriers to trade in goods and services between the two countries. Ferrous scrap has continued to be a major trade item between the two nations. Based on an agreement between the Port Authority of New York and New Jersey and the New York State Legislative Commission on Solid Waste Management, the Port Authority conducted a study to assess the export market potential of post consumer secondary materials. The objectives of the study were to determine the material composition and waste generation rates for the States of New York and New Jersey and to identify export markets for post-consumer secondary materials for those States.

AVAILABLE SUPPLY, CONSUMPTION, AND STOCKS

Overall domestic demand for ferrous scrap by the iron and steel and the ferrous castings industries, the major consumers of this raw material, increased about 10% in 1988 compared with that of 1987. Domestic demand for ferrous scrap by producers of pig iron and raw steel was up by a larger quantity than that for the ferrous castings industry. However, domestic demand for ferrous scrap by producers of ferrous castings increased by a larger percentage than that for producers of pig iron and raw steel. Because of exceptionally strong worldwide demand for ferrous scrap in 1988, prices for most grades rose accordingly.

The Steel Can Recycling Institute (SCRI), Pittsburgh, PA, with funding from six major domestic tin mill producing firms, was formed on July 1. The major thrust of the organization, which plans to establish the recycling of steel containers as a practical alternative to that of aluminum, is expected to be a massive public relations campaign directed at municipal governments and consumers. The president of SCRI stated that steel producers need to promote public awareness for steel can recycling and to capitalize on legislative efforts that promote recycling, such as State laws that require residents to sort their trash and mandate recycling. About 30 billion steel cans are produced in the United States annually, representing about 5% to 7% by weight of the solid waste stream. However, less than 5% of these steel cans were recycled prior to 1988. On the other hand, aluminum has captured the bulk of the metal can market from steel, and about 50% of the aluminum cans are recycled. One major advantage that steel cans have over other containers is their unique magnetic property which allows for efficient separation of the steel cans from the solid waste stream.

Two major detinners, Proler International, Houston, TX, and AMG Resources Corp., Pittsburgh, PA, announced that they would expand their operations. Proler was planning to build a new 15,000-ton-per-month detinning plant on the Houston Ship Channel, and AMG would construct its first new tin can recycling plant in New Brunswick, NJ.

Domestic steel-producing companies, committed to steel can recycling: included Bethlehem Steel Corp.'s plant at Sparrows Point, MD, which has used steel cans that have been magnetically separated from household waste since 1977; Florida Steel Corp., which has used steel cans from a resource recovery operation near Miami at its Tampa and Jacksonville minimills; USX Corp., which has used bimetallic beverage cans at its basic oxygen steelmaking shop at Gary, IN; and Weirton Steel Corp., which has used detinned scrap at its plant in Weirton, WV. LTV Steel Co., Inc., headquartered in Cleveland, OH, and National Steel Corp. and Wheeling-Pittsburgh Steel Corp., both headquartered in Pittsburgh, PA, have also agreed to purchase steel can scrap. Additionally, in Canada, Dofasco Inc. and Stelco Inc. have been charging can scrap into their blast furnaces since 1983.

The CONSTEEL process involves scrap preheating by means of furnace off-gases along with continuous melting, refining, and periodic bottom tapping of the furnace. The inventor claimed that the process reduced electrical energy required to melt a ton of steel by up to 35%, significantly increased melt rate, and improved furnace arc stability. A CONSTEEL prototype for preheating scrap that was tested at Nucor Corp.'s Darlington, SC, plant was being installed on a new electric arc furnace at Florida Steel

Corp.'s Charlotte, NC, plant. North Star Steel Co. was planning to expand the 175,000-ton-per-year production capacity of its recently acquired Milton Division to between 250,000 and 300,000 tons per year during the next 3 years. The Milton Division, formerly Milton Mfg. Co., continued as a minimill steel-producing and fabricating operation in Milton, PA. The shareholders of Florida Steel Corp., Tampa, FL, and FLS Holdings Inc. approved the merger of FLS Acquisition Inc., a subsidiary of FLS Holdings, into Florida Steel. As a result, Florida Steel has become a wholly owned subsidiary of FLS Holdings.

USX Corp., the largest domestic steel producer, restarted a blast furnace at its Fairfield Works in Fairfield, AL, that had been idled since August 1986. This would add about 1.8 million tons per year of raw steelmaking capacity to the domestic market. The plant, which consumed significant quantities of scrap, was shut down originally due to a 6-month strike, but remained closed while extensive upgrading of equipment proceeded. Responding to increasing quality demands of American steel purchasers, LTV Steel Co., Cleveland, OH, announced on July 1 an unusual plan to give its customers the option of rejecting LTV products they judge unsatisfactory. LTV pledged to replace any flat-rolled products with no questions asked. However, the company would appreciate the customer's letting them know what was wrong with the steel shipment so that it could do a better job in the future. In the past, customers unhappy with LTV products had to negotiate with the steel company. This has remained a common practice among other steel producers.

A major concern of the entire scrap industry was the potential impact of environmental regulations on its ability to operate profitably, if at all. The problem of disposal of shredder residue that could contain PCB's has forced ISRI to recommend to its members that they should no longer process or handle certain items, such as appliances or fluorescent lighting fixtures, unless they were sure that the items did not contain PCB's. Decreasing availability of disposal sites and increasing costs of disposal, currently up to $40 per ton, have hurt many shredder operations. Automobile hulks continued as the predominate raw feed material for shredders. Each automobile shredded produced about 25% of nonmetallic "fluff," which must be disposed of in an acceptable manner. The use of hazardous substances in automobiles, such as cadmium, which was used as a color enhancer in seat covers and as an anticorrosion coating, were also concerns. In general, Superfund tended to make scrap processors consider the financial liability associated with the recycling of historically important feed materials.

A survey by Arthur D. Little, Inc., Cambridge, MA, revealed that a majority of steel producers were experiencing an increasing rate of scrap residuals and were expecting the problem to escalate by 1995. Preliminary analysis showed that scrap will play a more important role in a wider range of steel production. Steelmakers look to their suppliers in the scrap industry to resolve quality concerns.[3] Quality and demand trends, environmental problems affecting scrap processors, scrap-processing technology, outlook for future scrap management, and other issues were topics discussed at a symposium on "Scrap-Based Steelmaking Systems for the '90's," in Tarpon Springs, FL, that was sponsored by the Iron and Steel Society.[4] Some of these topics were also addressed at The Steel Industry Outlook Conference of Wharton Econometric Forecasting Associates in Pittsburgh, PA,[5] and in a publication by Charles River Associates Inc., Boston, MA.[6]

Imports of metallurgical-grade coke increased about 200% in 1988 to 2.69 million tons compared with the 1987 level. Metallurgical coke imports represented an astounding 8.1% of apparent consumption in 1988 compared with a much lower range of 0.1% to 3.1% for the period 1980 through 1987. Since 1986, the United States has become a net importer of metallurgical coke. A number of domestic coke ovens have been shut down over the last several years, and coke supplies have tightened. However, since 1980, domestic metallurgical coal exports have exceeded domestic consumption of this raw material.

Raw steel production was 99.9 million tons in 1988 compared with 89.2 million tons in 1987. The shares of raw steel produced by electric, basic oxygen, and open-hearth furnaces were, respectively, 36.9%, 58.0%, and 5.1% in 1988 and 38.1%, 58.9%, and 3.0% in 1987. Continuous cast steel production represented 61% of total raw steel production in 1988 compared with 60% in 1987. Raw steel capacity utilization was 89% in 1988 and 79% in 1987. Net shipments of all grades of steel mill products were 83.8 million tons in 1988 and 76.7 million tons in 1987. Imports of steel mill products increased from 20.4 million tons in 1987 to 20.9 million tons in 1988. Exports of steel mill products increased sharply from 1.13 million tons in 1987 to 2.07 million tons in 1988. The apparent supply of steel mill products increased from 95.9 million tons in 1987 to 102.7 million tons in 1988. Although imports of steel mill products increased in 1988, these imports represented a smaller share of the U.S. market. Steel mill processing yields decreased slightly from 86% in 1987 to 84% in 1988.

Iron castings shipments totaled 8.88 million tons in 1988 compared with 8.92 million tons (revised) in 1987. Steel castings shipments totaled 1.01 million tons in 1988 compared with 830,000 tons (revised) in 1987.

Steel mills accounted for 72.1% of all scrap received from brokers, dealers, and other outside sources; steel foundries received 3.7%; and iron castings producers and miscellaneous users received 24.2%. The apparent total domestic consumption of ferrous scrap in

1988, in million tons, was composed of 49.6 net receipts (total receipts minus shipments), 27.4 home scrap, and 0.3 withdrawals from stocks. The 1988 total was 77.3 million tons; the apparent total domestic consumption was 69.0 million tons in 1987. The total market for U.S. scrap (net receipts plus exports minus imports) was 59.0 million tons in 1988 compared with 54.6 million tons in 1987. Stocks of ferrous scrap held by steel mills and iron castings producers decreased, but those held by steel castings producers increased in 1988.

The percentage of scrap consumed in the United States to produce a ton of raw steel has increased from about 50% in 1978 to about 60% in 1988. Of the steel scrap consumed by domestic steel mills, about two-fifths was purchased from sources outside the steel plant in 1978 compared with about two-thirds in 1988. The two major factors that have influenced scrap consumption by domestic steel mills over the past 10 years were included 1) the increased proportion of raw steel produced in electric furnaces, which resulted in a need for more scrap, and 2) the increased adoption of continuous casters, which produced higher yields with a subsequent reduction in home scrap generation. Other technical advances that have altered scrap consumption patterns in steel mills included processing improvements, which have reduced the generation of home scrap.

PRICES

Based on average composite delivered prices per long ton quoted weekly and monthly by the American Metal Market (AMM), No. 1 heavy melting steel scrap cost $108.98 in 1988, ranging from a low of $99.72 in January to a high of $114.55 in February. Based on Iron Age data, No. 1 heavy melting steel scrap cost $109.21 in 1988, ranging from $99.08 in January to $115.83 in July. The average composite price for No. 1 heavy melting steel scrap in 1988 was 27% higher compared with that of 1987, based on both AMM and Iron Age data. Toward the end of May, reports were circulating of high-end offers for 18-8 grade stainless steel scrap at $1,450 per long ton delivered. Mills were paying more than twice as much for this material than they were the previous year. The 18-8 grade nominally contains 18% chromium plus 8% nickel. A severe shortage and overwhelming demand for nickel, and to a lesser extent for chromium, were the main contributors to escalating worldwide prices for 18-8 grade.

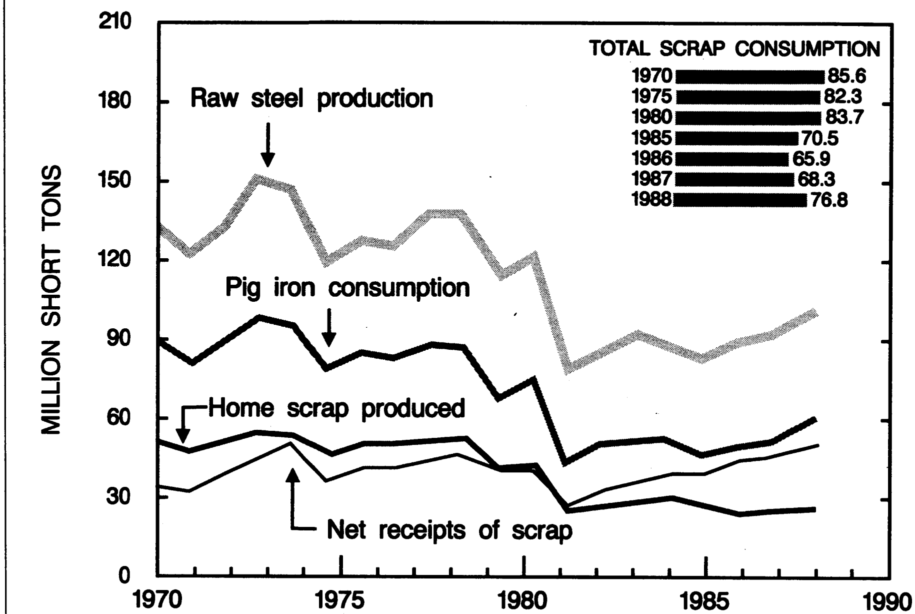
In 1988, the average price for total ferrous scrap exports increased 43% compared with that of 1987, to $133.99 per ton; that of total imports increased 32% to $128.71 per ton.

FOREIGN TRADE

The trade surplus in 1988 for all classes of ferrous scrap (including rerolling material and ships, boats, and other vessels for scrapping) was $1.27 billion in value and 9.43 million tons in quantity. This was an increase of 39% in value and a decrease of 4% in quantity, compared with the 1987 surplus of $914 million in value and 9.83 million tons in quantity. The balance of trade for all U.S. merchandise showed a deficit of $138 billion in 1988, down from

FIGURE 1

RAW STEEL PRODUCTION (AISI), TOTAL IRON AND STEEL SCRAP CONSUMPTION, PIG IRON CONSUMPTION, HOME SCRAP PRODUCTION, AND NET SCRAP RECEIPTS



a record deficit of $170 billion in 1987.

Total U.S. exports of ferrous scrap (excluding rerolling material; ships, boats, and other vessels for scrapping; stainless steel; and alloy steel) in 1988 went to 44 countries and totaled 9,491,483 tons valued at $1,042,615,275, which averaged $109.85 per ton. Six countries received 76% of the total quantity. The largest tonnages went to the Republic of Korea, 2,230,132 tons; Turkey, 1,979,882 tons; India, 904,053 tons; Mexico, 894,243 tons; Taiwan, 638,585 tons; and Canada, 551,969 tons. The value of scrap exports to these six countries was $792,403,056; 76% of the total.

Total U.S. exports of stainless steel scrap in 1988 went to 30 countries and consisted of 243,344 tons valued at $239,807,389 that averaged $985.47 per ton. Six countries received 84% of the total quantity. The largest tonnages went to Japan, 72,812 tons; Spain, 67,396 tons; Canada, 27,447 tons; the Federal Republic of Germany, 14,853 tons; the Republic of Korea, 10,957 tons; and Sweden, 10,882 tons. The value of stainless steel scrap exports to these six countries was $207,170,466; 86% of the total.

U.S. exports of alloy steel scrap (excluding stainless steel) in 1988 were shipped to 44 countries. The total comprised 362,730 tons valued at $69,532,334, which averaged $191.69 per ton. Six countries received 80% of the total quantity; the largest tonnages went to the Republic of Korea, 116,449 tons; Sweden, 54,329 tons; Canada, 48,638 tons; Japan, 26,262 tons; Taiwan, 24,064 tons; and Mexico, 21,902 tons. The value of alloy steel scrap to these six countries was $51,254,865; 74% of the total.

Total U.S. imports for consumption of iron and steel scrap were supplied by 26 countries in 1988. They contained 21,509 tons of tinplate waste or scrap valued at $1,929,623. The balance of imports consisted of 991,445 tons of iron and steel scrap, without dutiable alloys, valued at $114,342,071 and 24,867 tons of iron or steel waste and scrap valued at $17,305,261.

WORLD REVIEW

World demand for iron and steel scrap reached an alltime high in 1988. Demand for ferrous scrap, both on a quantity and a percentage basis, was higher in market economy countries than in countries with centrally planned economies. Most of the increase in demand, on a quantity basis, came from the United States. Countries with significant increases in demand, on a percentage basis, were Belgium, Brazil, the Federal Republic of Germany, Luxembourg, the Republic of Korea, Taiwan, Turkey, and the United States in the Western World and China outside the Western World.

The United States continued to be the leading exporting country of iron and steel scrap. The U.S.S.R. and the United Kingdom were also major exporters of ferrous scrap.

A shortage of old ships, rising scrapping costs, and pressure from environmentalists have combined to erode Taiwan's position since the 1970's as the world's largest shipbreaking nation. Taiwan scrapped about 3.6 million metric tons of ships in 1986. However, this figure dropped to about 2.5 million tons in 1987 and even further to about 1.0 million tons in 1988. Taiwanese shipbreakers have planned to relocate their labor-intensive operations across the straits of Taiwan to the Chinese mainland where scrap steel and new steel for rerolling were in strong demand.

TECHNOLOGY

Armco Inc., Parsippany, NJ, has been named the prime contractor for a continuing research contract with the U.S. Department of Energy to study process development of thin strip steel casting. With assistance from Westinghouse Corp., the research was to be conducted at a special facility near Armco's Research Center in Middletown, OH. The objective of the research was to establish feasibility of casting low-carbon steels on a single wheel caster at thicknesses principally between 0.030 inch and 0.125 inch. In a related matter, the 850,000-ton-per-year thin slab caster being installed at Nucor Corp.'s, Crawfordsville, IN, facility was slated to begin operations in the first half of 1989. In addition to substantial savings over more conventional routes, thin slab casting (near net shape) would likely improve steelmill processing yields with a corresponding reduction in home scrap generation.

The Iron and Steel Corp. of the Republic of South Africa (ISCOR) initiated startup of the world's first commercial direct-coal-reduction (Corex) process at its Pretoria Works. Annual capacity of the plant was about 300,000 metric tons of pig iron. The Corex process (previously known as KR for the Kohle Reduktion process) involved direct use of coal instead of coke to produce pig iron. Because coke ovens, sintering plants, and blast furnaces would be eliminated, capital costs would be reduced by as much as 50% compared with those of a conventional blast furnace operation. Reportedly, the Corex process also would reduce production costs, allow for greater flexibility in feed material, and have less impact on the environment than would conventional methods.[7] Voest-Alpine AG, an Austrian steel producer and equipment builder, has established a new subsidiary, Corex Limitada, in Rio de Janeiro, Brazil, to introduce the Corex process in Latin America. State officials of Minnesota also were attempting to have a demonstration plant built in their State.

The American Iron and Steel Institute has proposed a 4-year, $20 million development program aimed at achieving direct steelmaking. A direct steelmaking process would eliminate pellet plants, coke ovens, iron blast furnaces, and basic oxygen and open-hearth steelmaking furnaces. These facilities would be replaced by one major process and some auxiliary systems.[8]

There were at least three plasma processes either under development or being applied to industrial operations to melt scrap in 1988. The first process consisted of a complete 2-megawatt plasma unit purchased by Chaparral Steel Co., Midlothian, TX, from Plasma Energy Corp., Raleigh, NC. The system would fire plasma torches in transferred and nontransferred arc mode for use in applications requiring tight temperature control.[9] The second process involved combining energy from coal or hydrocarbon fuel combustion with energy from a nontransferred arc plasma generator to melt scrap. The scrap was melted in a shaft furnace that was similar to a hot-blast cupola. The system was developed by SKF Plasma Technologies AB, Hofors, Sweden.[10] The third process comprised a 1-megavolt-ampere plasma-smelting furnace purchased by Pohang Iron and Steel Co., Republic of Korea, from Davy McKee Ltd., Stockton-on-Tees, United Kingdom. The furnace was similar to the pilot furnace at Davy's research and development laboratory where plasma-melting technology has been developed. The process, called Hi Plas, employed by these furnaces incorporated both melting and smelting capabilities by means of a long arc technique, ensuring maximum exploitation of the energy consumed. Because of the unique design of a cyclone reactor in the Hi Plas furnace, it could process low-cost feedstocks such as metal fines and ore fines. Also, in the Hi Plas process, the superheated gas stabilized arc was discharged between a nonconsumable cathode and an anode-molten bath. This feature would reduce operating costs and preclude product contamination.[11]

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[1]Physical scientist, Branch of Ferrous Metals.

[2]All quantities are in short tons unless otherwise specified.

[3]Goldberg, D. Survey Shows Steelmakers Search for Scrap Solutions. Recycling Today, v. 26, No. 12, Dec. 1988, pp. 46-97.

[4]Iron and Steel Society-AIME. Scrap-Based Steelmaking Systems for the '90's—6th Advanced Technology Symposium (ISS-AIME, Tarpon Springs, FL, Oct. 16-18, 1988). AIME, Warrendale, PA, 1988.

[5]Wharton Econometric Forecasting Associates. The 4th Annual Steel Industry Outlook Conference (Pittsburgh, PA, Nov. 15, 1988). The WEFA Group, Bala Cynwyd, PA, 1988, 90 pp.

[6]Charles River Associates Inc. The Recovery of the Rust Belt. CRA Rev., Nov. 1988, 4 pp.

[7]Feichtner, H., W. Maschlanka, and F. Helten. The Corex Process. Skillings' Min. Rev., v. 78, No. 2, Jan. 14, 1989, pp. 20-27.

[8]T. P. McAloon. Direct Steelmaking Program Proposed for the United States. Iron and Steelmaker, v. 15, No. 7, July 1988, pp. 30-32.

[9]Industry News. Chaparral Buys Plasma Unit. Thirty Three Metal Producing, v. 27, No. 1, Jan. 1989, p. 8.

[10]Santen, S. O. and J. Feinman. Pilot Plant Studies of the Plasma Scrap Process. Iron and Steelmaker, v. 15, No. 8, Aug. 1988, pp. 24-28.

[11]Industry News. Pohang Orders 1 MVA Plasma Melting/Smelting Furnace. Thirty Three Metal Producing, v. 26, No. 9, Sept. 1988, p. 9.

TABLE 2

U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP AND PIG IRON IN 1988, BY GRADE

(Thousand short tons)

Grade	Receipts of scrap: From brokers, dealers, other outside sources	Receipts of scrap: From other own-company plants	Production of home scrap: Recirculating scrap resulting from current operations	Production of home scrap: Obsolete scrap (includes ingot molds, stools, scrap from old equipment, buildings, etc.)	Consumption of both purchased and home scrap (includes recirculating scrap)	Shipments of scrap	Ending stocks, Dec. 31
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS							
Carbon steel:							
Low-phosphorus plate and punchings	379	5	14	27	433	5	22
Cut structural and plate	1,213	201	417	25	1,803	31	169
No. 1 heavy melting steel	9,808	198	6,663	260	16,366	323	886
No. 2 heavy melting steel	3,552	148	936	2	4,622	16	357
No. 1 and electric-furnace bundles	6,109	153	1,113	2	6,665	675	456
No. 2 and all other bundles	901	74	114	—	1,057	42	72
Electric furnace, 1 foot and under (not bundles)	112	103	18	([1])	218	15	13
Railroad rails	343	19	32	—	390	—	17
Turnings and borings	951	96	181	([1])	1,202	16	61
Slag scrap (Fe content 70%)	1,046	10	2,099	1	2,830	269	159
Shredded or fragmentized	3,587	1,790	71	—	5,424	—	360
No. 1 busheling	1,884	253	106	([1])	2,186	80	141
All other carbon steel scrap	1,797	971	6,073	38	8,344	522	248
Stainless steel scrap	736	19	529	—	1,271	16	40
Alloy steel (except stainless)	128	153	735	—	1,003	54	107
Ingot mold and stool scrap	471	84	399	313	991	263	174
Machinery and cupola cast iron	92	1	4	—	50	3	47
Cast-iron borings	122	19	2	([1])	126	13	3
Motor blocks	—	—	—	—	—	—	—
Other iron scrap	483	95	444	1	890	118	141
Other mixed scrap	208	159	63	([1])	407	17	43
Total[2]	**33,921**	**4,551**	**20,011**	**670**	**[3]56,277**	**2,476**	**3,514**
MANUFACTURERS OF STEEL CASTINGS							
Carbon steel:							
Low-phosphorus plate and punchings	558	([1])	130	—	676	([1])	34
Cut structural and plate	240	5	20	([1])	266	—	20
No. 1 heavy melting steel	97	—	100	—	207	—	12
No. 2 heavy melting steel	180	—	1	—	167	—	26
No. 1 and electric-furnace bundles	10	—	1	—	10	—	1
No. 2 and all other bundles	—	—	—	—	—	—	—
Electric furnace, 1 foot and under (not bundles)	21	—	7	—	27	—	2
Railroad rails	7	—	1	—	8	—	1
Turnings and borings	18	—	11	—	27	2	2
Slag scrap (Fe content 70%)	([1])	—	—	—	([1])	—	([1])

See footnotes at end of table.

TABLE 2—Continued

U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP AND PIG IRON IN 1988, BY GRADE

(Thousand short tons)

Grade	Receipts of scrap: From brokers, dealers, other outside sources	Receipts of scrap: From other own-company plants	Production of home scrap: Recirculating scrap resulting from current operations	Production of home scrap: Obsolete scrap (includes ingot molds, stools, scrap from old equipment, buildings, etc.)	Consumption of both purchased and home scrap (includes recirculating scrap)	Shipments of scrap	Ending stocks, Dec. 31
Shredded or fragmentized	78	—	—	—	83	—	3
No. 1 busheling	57	—	—	—	56	—	1
All other carbon steel scrap	258	—	121	—	369	—	21
Stainless steel scrap	20	2	28	—	48	([1])	6
Alloy steel (except stainless)	76	([1])	147	—	214	4	44
Ingot mold and stool scrap	—	—	6	—	6	—	—
Machinery and cupola cast iron	38	—	3	—	41	—	6
Cast-iron borings	37	—	13	—	36	—	2
Motor blocks	([1])	—	—	—	([1])	—	—
Other iron scrap	32	—	70	—	95	7	12
Other mixed scrap	—	—	6	—	6	—	([1])
Total[2]	**1,727**	**7**	**664**	**([1])**	**2,343**	**13**	**193**
IRON FOUNDRIES AND MISCELLANEOUS USERS							
Carbon steel:							
Low-phosphorus plate and punchings	1,258	43	302	1	1,618	—	56
Cut structural and plate	1,180	65	174	([1])	1,492	([1])	82
No. 1 heavy melting steel	149	26	392	—	276	295	16
No. 2 heavy melting steel	307	([1])	42	—	358	—	5
No. 1 and electric-furnace bundles	313	127	63	—	514	—	6
No. 2 and all other bundles	124	—	—	—	121	—	25
Electric furnace, 1 foot and under (not bundles)	22	4	5	—	34	—	1
Railroad rails	227	([1])	3	—	225	3	36
Turnings and borings	361	1	27	—	370	4	36
Slag scrap (Fe content 70%)	55	—	—	—	54	—	2
Shredded or fragmentized	2,087	117	—	—	2,174	([1])	72
No. 1 busheling	492	49	22	—	557	2	11
All other carbon steel scrap	770	2	53	([1])	820	2	56
Stainless steel scrap	32	—	14	—	56	3	7
Alloy steel (except stainless)	45	([1])	11	([1])	57	([1])	12
Ingot mold and stool scrap	167	24	192	—	390	28	25
Machinery and cupola cast iron	1,329	75	463	29	1,860	5	142
Cast-iron borings	685	94	123	5	875	39	39
Motor blocks	526	56	1,063	([1])	1,653	15	39
Other iron scrap	667	142	2,668	—	3,503	14	118
Other mixed scrap	614	121	447	1	1,195	51	57
Total[2]	**11,411**	**947**	**6,064**	**36**	**18,202**	**461**	**844**

See footnotes at end of table.

TABLE 2—Continued

U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP AND PIG IRON IN 1988, BY GRADE

(Thousand short tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of both purchased and home scrap (includes recirculating scrap)	Shipments of scrap	Ending stocks, Dec. 31
	From brokers, dealers, other outside sources	From other own-company plants	Recirculating scrap resulting from current operations	Obsolete scrap (includes ingot molds, stools, scrap from old equipment, buildings, etc.)			
TOTAL—ALL TYPES OF MANUFACTURERS[2]							
Carbon steel:							
Low-phosphorus plate and punchings	2,195	49	445	28	2,728	5	111
Cut structural and plate	2,630	272	611	25	3,560	32	271
No. 1 heavy melting steel	10,054	224	7,154	260	16,849	617	914
No. 2 heavy melting steel	4,040	148	979	2	5,147	16	388
No. 1 and electric-furnace bundles	6,432	280	1,177	2	7,189	675	464
No. 2 and all other bundles	1,025	74	114	—	1,179	42	97
Electric furnace, 1 foot and under (not bundles)	155	107	30	(1)	278	15	15
Railroad rails	577	19	35	—	622	3	54
Turnings and borings	1,330	97	219	(1)	1,599	23	98
Slag scrap (Fe content 70%)	1,101	10	2,099	1	2,884	269	162
Shredded or fragmentized	5,753	1,907	71	—	7,682	(1)	435
No. 1 busheling	2,436	302	128	(1)	2,810	82	153
All other carbon steel scrap	2,825	973	6,248	38	9,533	524	325
Stainless steel scrap	788	21	571	—	1,361	19	53
Alloy steel (except stainless)	249	153	892	(1)	1,273	58	163
Ingot mold and stool scrap	638	108	597	313	1,387	291	199
Machinery and cupola cast iron	1,459	76	470	29	1,951	8	196
Cast-iron borings	842	112	138	5	1,038	52	44
Motor blocks	526	56	1,063	(1)	1,653	15	39
Other iron scrap	1,182	236	3,182	1	4,489	138	271
Other mixed scrap	822	280	515	1	1,607	68	101
Grand total[2]	**47,059**	**5,505**	**26,739**	**706**	**[3]76,822**	**2,951**	**4,554**

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

[3] Internal evaluation indicates that scrap consumption in electric furnaces operated by manufacturers of pig iron and raw steel and castings is understated by approximately 5.6 million short tons; that in open-hearth furnaces is understated by about 0.2 million tons.

TABLE 3

U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF PIG IRON AND DIRECT-REDUCED IRON IN 1988

(Thousand short tons)

	Receipts	Production	Consumption	Shipments	Stocks, Dec. 31
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS					
Pig iron	2,416	55,700	57,499	814	141
MANUFACTURERS OF STEEL CASTINGS					
Pig iron	20	—	12	—	4
IRON FOUNDRIES AND MISCELLANEOUS USERS					
Pig iron	1,553	—	1,535	19	62
TOTAL-ALL TYPES OF MANUFACTURERS					
Pig iron[1]	3,988	55,700	59,047	833	207
Direct-reduced or prereduced iron	856	—	843	W	21

W Withheld to avoid disclosing company proprietary data.
[1] Data may not add to totals shown because of independent rounding.

TABLE 4

CONSUMPTION OF IRON AND STEEL SCRAP AND PIG IRON IN THE UNITED STATES IN 1988, BY TYPE OF FURNACE OR OTHER USE

(Thousand short tons)

Type of furnace or other use	Manufacturers of pig iron and raw steel and castings		Manufacturers of steel castings		Iron foundries and miscellaneous users		Total, all types[1]	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
Blast furnace[2]	3,012	—	—	—	—	—	3,012	—
Basic oxygen process[3]	17,822	52,027	—	—	—	—	17,822	52,027
Open-hearth furnace[4]	978	3,858	—	—	—	—	978	3,858
Electric furnace	[5]34,208	248	2,215	12	6,990	488	43,413	748
Cupola furnace	—	1,029	115	—	11,131	370	11,246	1,399
Other (including air furnace)[6]	257	26	13	—	81	18	351	44
Direct castings[7]	—	310	—	—	—	659	—	969
Total[1]	**56,277**	**57,499**	**2,342**	**12**	**18,202**	**1,535**	**76,822**	**59,047**

[1] Data may not add to totals shown because of independent rounding.
[2] Includes consumption in blast furnaces producing pig iron.
[3] Includes scrap and pig iron processed in metallurgical blast cupolas and used in oxygen converters.
[4] Internal evaluation indicates that scrap consumption was understated by about 0.2 million tons and pig iron was understated by about 0.8 million tons.
[5] Internal evaluation indicates that scrap consumption in electric furnaces operated by manufacturers of pig iron and raw steel and castings is understated by approximately 5.6 million short tons.
[6] Includes vacuum melting furnaces and miscellaneous uses.
[7] Includes ingot molds and stools.

TABLE 5

PROPORTION OF IRON AND STEEL SCRAP AND PIG IRON USED IN FURNACES IN THE UNITED STATES IN 1988

(Percent)

Type of furnace	Scrap	Pig iron
Basic oxygen process	25.5	74.5
Open-hearth furnace	20.2	79.8
Electric furnace	98.3	1.7
Cupola furnace	88.9	11.1
Other (including air furnace)	88.9	11.1

TABLE 6

IRON AND STEEL SCRAP SUPPLY[1] AVAILABLE FOR CONSUMPTION IN 1988, BY REGION AND STATE

(Thousand short tons)

Region and State	Receipts of scrap		Production of home scrap		Total new supply[2]	Shipments of scrap[3]	New supply available for consumption[2]
	From brokers, dealers, other outside sources	From other own-company plants	Recirculating scrap resulting from current operations	Obsolete scrap (includes ingot molds, stools, scrap from old equipment, buildings, etc.)			
New England and Middle Atlantic:							
Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	1,238	73	303	3	1,619	19	1,599
Pennsylvania	6,701	566	4,930	88	12,285	658	11,627
Total[2]	**7,939**	**639**	**5,233**	**91**	**13,904**	**677**	**13,226**
North Central:							
Illinois	4,418	1,064	2,554	22	8,058	101	7,957
Indiana	4,626	589	5,052	3	10,270	817	9,453
Iowa, Kansas, Minnesota, Missouri, Nebraska, Wisconsin	4,104	247	1,825	—	6,176	1	6,175
Michigan	4,508	400	1,889	29	6,826	140	6,685
Ohio	7,483	800	4,694	443	13,419	773	12,647
Total[2]	**25,139**	**3,100**	**16,014**	**497**	**44,749**	**1,832**	**42,917**
South Atlantic:							
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	5,059	643	2,475	47	8,227	159	8,068
South Central:							
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	5,750	1,085	2,334	56	9,226	264	8,962
Mountain and Pacific:							
Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	3,170	39	682	13	3,903	19	3,885
Grand total[2]	**47,059**	**5,505**	**26,739**	**706**	**80,009**	**2,951**	**77,058**

[1] New supply available for consumption is a net figure computed by adding production to receipts and deducting scrap shipped during the year. The plus or minus difference in stock levels at the beginning and end of the year is not taken into consideration.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes scrap shipped, transferred, or otherwise disposed of during the year.

TABLE 7

U.S. CONSUMPTION OF IRON AND STEEL SCRAP AND PIG IRON[1] IN 1988, BY REGION AND STATE

(Thousand short tons)

Region and State	Pig iron and steel ingots and castings		Steel castings		Iron foundries and miscellaneous users		Total[2]	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	1,075	3	20	([3])	507	46	1,602	49
Pennsylvania	10,083	6,298	112	3	1,465	617	11,660	6,917
Total[2]	**11,158**	**6,301**	**132**	**3**	**1,972**	**663**	**13,262**	**6,966**
North Central:								
Illinois	6,167	3,511	100	—	1,717	76	7,984	3,588
Indiana	7,880	19,380	229	2	933	71	9,042	19,452
Iowa, Kansas, Minnesota, Missouri, Nebraska, Wisconsin	2,278	2	516	2	3,492	204	6,285	207
Michigan	4,276	5,109	1	([3])	2,465	232	6,742	5,341
Ohio	9,235	12,229	471	5	2,916	171	12,622	12,404
Total[2]	**29,836**	**40,231**	**1,317**	**9**	**11,523**	**754**	**42,675**	**40,993**
South Atlantic:								
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	6,186	6,826	8	—	1,855	69	8,052	6,895
South Central:								
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	6,701	3,225	323	([3])	1,864	38	8,888	3,264
Mountain and Pacific:								
Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	2,395	917	563	—	989	12	3,947	930
Grand total[2]	**56,277**	**57,499**	**2,343**	**12**	**18,202**	**1,535**	**76,822**	**59,047**

[1] Includes molten pig iron used for ingot molds and direct castings.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

TABLE 8

U.S. CONSUMER STOCKS OF IRON AND STEEL SCRAP AND PIG IRON, DECEMBER 31, 1988, BY REGION AND STATE

(Thousand short tons)

Region and State	Carbon steel (excludes rerolling rails)	Stainless steel	Alloy steel (excludes stainless)	Cast iron (includes borings)	Other grades of scrap	Total scrap stocks[1]	Pig iron stocks
New England and Middle Atlantic:							
Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	109	6	26	19	3	163	7
Pennsylvania	424	25	67	100	14	631	43
Total[1]	**532**	**31**	**93**	**120**	**17**	**793**	**49**
North Central:							
Illinois	394	—	12	44	8	458	12
Indiana	422	2	9	141	6	580	78
Iowa, Kansas, Minnesota, Missouri, Nebraska	184	2	3	13	16	219	14
Michigan	241	1	4	49	19	315	7
Ohio	474	9	20	75	1	578	13
Wisconsin	26	2	—	10	—	38	8
Total[1]	**1,742**	**15**	**48**	**331**	**51**	**2,187**	**131**
South Atlantic:							
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	351	8	2	124	10	493	22
South Central:							
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	683	([2])	7	141	17	848	4
Mountain and Pacific:							
Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	174	1	15	40	5	235	1
Grand total[1]	**3,483**	**53**	**163**	**753**	**101**	**4,554**	**207**

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

TABLE 9

U.S. AVERAGE MONTHLY PRICE AND COMPOSITE PRICE FOR NO. 1 HEAVY MELTING STEEL SCRAP IN 1988

(Per long ton)

Month	Chicago	Pittsburgh	Philadelphia	Composite price[1]
January	$100.80	$104.35	$94.00	$99.72
February	119.43	123.85	100.38	114.55
March	119.02	120.28	102.50	113.93
April	117.24	110.86	100.71	109.60
May	111.38	107.50	95.00	104.63
June	108.55	104.00	95.00	102.52
July	120.00	116.00	99.00	111.67
August	119.78	120.00	100.00	113.26
September	115.00	117.00	100.00	110.67
October	115.00	116.71	100.71	110.81
November	109.16	113.84	104.50	109.17
December	106.33	111.00	104.50	107.28
Average 1988	113.47	113.78	99.69	108.98
Average 1987	87.22	90.58	79.47	85.76

[1] American Metal Market, composite price, Chicago, Pittsburgh, and Philadelphia.

TABLE 10

U.S. EXPORTS[1] OF IRON AND STEEL SCRAP, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1984		1985		1986		1987		1988[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	779	59,521	446	38,445	365	31,436	331	30,516	628	62,367
China	227	21,190	387	32,793	340	28,506	249	23,423	31	5,010
Italy	306	27,038	307	30,250	286	26,177	175	15,675	89	12,926
Japan	2,680	264,857	2,110	199,135	1,725	170,015	986	123,051	649	148,362
Korea, Republic of	1,833	160,892	1,978	160,674	2,989	247,055	2,630	213,550	2,358	271,155
Mexico	484	47,663	597	57,535	318	29,981	501	48,278	916	101,785
Spain	608	55,228	910	72,312	673	51,771	417	42,503	404	108,067
Taiwan	405	54,515	414	45,163	667	74,387	426	46,629	669	89,021
Turkey	807	69,579	955	80,133	1,417	115,334	2,254	195,971	1,985	230,853
Venezuela	392	33,346	471	36,384	483	36,673	150	10,273	258	26,109
Other	977	124,151	1,373	165,360	2,441	242,514	2,247	217,149	2,112	296,298
Total[3]	**9,498**	**917,981**	**9,950**	**918,186**	**11,704**	**1,053,849**	**10,367**	**967,018**	**10,098**	**1,351,955**

[1] Excludes rerolling material and ships, boats, and other vessels for scrapping.
[2] U.S. exports were shipped to 55 countries.
[3] Data may not add to totals shown because of independent rounding.

TABLE 11

U.S. EXPORTS AND IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY CLASS

(Thousand short tons and thousand dollars)

Class	1984		1985		1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Export:										
No. 1 heavy melting scrap	2,512	215,482	2,766	218,593	2,922	230,519	2,446	200,980	2,400	255,370
No. 2 heavy melting scrap	879	70,906	767	58,537	797	58,879	579	45,994	691	68,102
No. 1 bundles	77	8,258	185	17,172	155	13,876	167	14,890	74	8,852
No. 2 bundles	286	18,836	306	21,160	301	21,095	366	23,623	371	31,567
Stainless steel scrap	164	96,426	180	104,898	165	90,066	172	94,025	243	239,807
Shredded steel scrap	2,775	251,976	2,559	220,320	3,495	293,040	3,314	298,259	2,910	343,188
Borings, shovelings, turnings	800	49,664	875	56,314	731	43,955	528	28,835	515	36,230
Other steel scrap[1]	1,416	155,685	1,646	162,484	2,048	209,094	2,033	195,197	2,042	277,281
Iron scrap	590	50,748	666	58,707	1,091	93,325	762	65,217	852	91,557
Total[2]	**9,498**	**917,981**	**9,950**	**918,186**	**11,704**	**1,053,849**	**10,367**	**967,018**	**10,098**	**1,351,955**
Ships, boats, other vessels (for scrapping)	283	9,503	131	6,627	212	16,475	246	20,264	330	43,548
Rerolling material	58	10,918	110	15,604	78	11,302	57	8,863	42	7,330
Total exports[2]	**9,840**	**938,402**	**10,191**	**940,416**	**11,994**	**1,081,626**	**10,670**	**996,145**	**10,470**	**1,402,833**
Imports for consumption:										
Iron and steel scrap	577	47,427	611	46,480	724	49,073	843	82,016	1,038	133,577

[1] Includes terneplate and tinplate.
[2] Data may not add to totals shown because of independent rounding.

TABLE 12

U.S. EXPORTS OF REROLLING MATERIAL (SCRAP), BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1984		1985		1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	([1])	2,550	([1])	41	([1])	44	1	170	1	134
China	—	—	19	2,497	—	—	—	—	—	—
Korea, Republic of	—	—	—	—	—	—	([1])	8	—	—
Mexico	57	8,248	90	12,511	77	11,186	45	7,346	40	6,794
Turkey	—	—	—	—	—	—	10	1,111	—	—
Other	([1])	120	1	[r]555	([1])	72	1	228	1	401
Total[2]	**58**	**10,918**	**110**	**15,604**	**78**	**11,302**	**57**	**8,863**	**42**	**7,330**

[r] Revised.
[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP,[1] BY COUNTRY

Country	1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	169	$350	18	$39
Belgium-Luxembourg	2	5	36,398	430
Canada	725,622	68,558	841,888	113,048
Germany, Federal Republic of	863	205	43,428	225
Japan	16,754	1,227	15,924	1,577
Mexico	18,757	3,783	48,068	11,176
Netherlands	10,997	964	28,368	3,474
Sweden	624	153	24	3
United Kingdom	50,157	5,961	11,429	1,297
Other	19,032	810	12,274	2,309
Total[2]	**[r]842,977**	**82,016**	**1,037,821**	**133,577**

[r] Revised.
[1] Includes tinplate and terneplate.
[2] Data may not add to totals shown because of independent rounding.

TABLE 14

IRON AND STEEL SCRAP CONSUMPTION IN SELECTED COUNTRIES[1]

(Thousand short tons)

Continent, country group, and country	1983	1984	1985	1986	1987
North America:					
Canada[2 3 4 5]	6,965	[e]7,000	7,905	7,804	7,875
United States[2 5 6]	61,782	65,702	70,493	65,856	68,303
Latin America:[7]					
Argentina	1,570	1,281	1,264	1,253	1,444
Brazil	6,137	6,971	7,714	7,934	8,068
Chile	209	237	241	152	241
Colombia	369	378	433	491	593
Ecuador	26	21	21	20	30
Mexico	2,383	3,181	3,413	3,253	2,844
Peru	186	343	257	292	343
Uruguay	56	53	51	41	40
Venezuela	457	1,292	1,195	996	1,284
Central America, not further detailed	74	126	192	456	430
Europe:					
European Community:[8]					
Belgium[2]	3,563	3,880	3,430	2,956	[e]2,810
Denmark[9]	644	718	656	776	714
France[3 4 5]	7,197	7,135	7,109	7,128	[10]7,160
Germany, Federal Republic of[5]	19,692	20,510	20,517	18,795	17,813
Greece[e]	275	300	300	1,220	1,120
Ireland[10]	174	208	254	256	271
Italy	15,861	17,380	17,133	16,144	16,407
Luxembourg	1,508	1,857	1,761	1,644	1,461
Netherlands	1,607	1,797	1,658	[3]1,436	1,442
Portugal	617	[e]600	[e]600	[r e]420	435
Spain	10,795	10,911	11,152	[10]9,641	[e]9,500
United Kingdom	10,569	10,578	7,712	7,341	7,782
European Free Trade Association:					
Austria[3]	1,797	1,851	1,681	1,615	[e]1,615
Finland[3]	786	831	838	837	815
Norway[3 4]	577	638	597	[e]600	697
Sweden[e 2 3 4]	3,395	3,500	3,500	3,500	3,500
Switzerland[e]	915	915	915	1,100	1,100
Council for Mutual Economic Assistance:					
Bulgaria[e]	820	850	850	850	950
Czechoslovakia[2 4 5]	8,665	8,354	8,471	8,422	[e]8,500
German Democratic Republic[2 3 4 5]	5,682	5,779	5,593	5,516	5,642
Hungary	2,445	2,705	2,754	2,912	2,723
Poland[3]	9,796	9,630	9,490	10,070	10,061
Romania[e]	4,270	4,300	4,280	4,300	4,500
U.S.S.R.[e]	63,400	64,500	[r]52,110	[r]54,115	55,115

See footnotes at end of table.

TABLE 14—Continued

IRON AND STEEL SCRAP CONSUMPTION IN SELECTED COUNTRIES[1]

(Thousand short tons)

Continent, country group, and country	1983	1984	1985	1986	1987
Other:					
Yugoslavia[3 4 5]	2,434	e2,500	e2,500	2,730	1,672
Africa:					
South Africa, Republic of[e 2]	2,600	3,000	3,300	3,500	3,500
Asia:					
China[e]	10,100	10,900	11,700	12,500	13,500
India[e]	4,050	4,060	4,300	4,400	4,400
Japan[5]	44,269	47,934	48,685	44,378	44,777
Korea, Republic of[e]	3,350	3,600	3,700	3,800	4,000
Taiwan[e 11]	1,700	1,700	1,700	1,800	2,000
Turkey[10]	1,736	1,863	2,127	e2,200	e2,500
Oceania:					
Australia[e]	1,820	2,050	2,100	2,000	2,000
New Zealand[e]	150	180	150	150	150
Total	**327,473**	**344,099**	**r336,802**	**r327,600**	**332,127**

[e] Estimated. [r] Revised.

[1] Unless otherwise noted, figures represent reported consumption of iron and steel scrap utilized in the production of pig iron, ferroalloys, crude steel, foundry products, and rerolled steel, as well as other unspecified uses in the steel industry and by other unspecified industries as reported by the United Nations Economic Commission for Europe in its Annual Bulletin of Steel Statistics for Europe 1987, v. 15, New York, 1988, 28 pp., which is the source of all reported data unless otherwise noted. All estimates are by the U.S. Bureau of Mines.

[2] Excludes scrap consumed by steel rerollers.

[3] Excludes scrap consumed in iron foundries.

[4] Excludes scrap consumed within the steel industry for purposes other than the manufacturer of pig iron, ferroalloys, crude steel, foundry products, and rerolled steel (details on use not available.)

[5] Excludes scrap consumed outside the steel industry.

[6] Source: U.S. Bureau of Mines.

[7] Reported data are from Instituto Latino Americano del Fierro y el Acero. Statistical Yearbook of Steel Making and Iron Ore Mining in Latin America, 1988. Santiago, 1989, 235 pp. Source does not provide details on what is included; presumably figures include total steel industry ferrous scrap consumption but exclude scrap used outside the steel industry.

[8] Portugal and Spain became members of the European Community on Jan. 1, 1986.

[9] Includes scrap used in production of steel castings in shipyards, but excludes scrap, if any, used in production of pig iron and that used in iron foundries.

[10] Source: Organization for Economic Cooperation and Development. The Iron and Steel Industry in 1984, Paris, 1986, 52 pp.; The Iron and Steel Industry in 1985, Paris, 1987, 52 pp.; The Iron and Steel Industry in 1986, Paris, 1987, 52 pp.; and The Iron and Steel Industry in 1987, Paris, 1988, 52 pp.

[11] Excludes a substantial tonnage derived from shipbreaking, possibly in the order of several million tons annually, for electric-furnace-equipped steel mills.

TABLE 15

IRON AND STEEL SCRAP EXPORTS, BY SELECTED COUNTRIES[1]

(Thousand short tons)

Continent, country group, and country	1983	1984	1985	1986	1987
North America:					
Canada	965	876	968	r[2]1,016	[2]1,198
United States[2 3]	7,554	9,556	10,060	11,782	10,424
Latin America:					
Cuba[4]	50	159	129	122	165
Mexico[2]	4	17	r24	24	25
Europe:					
European Community:[5]					
Belgium-Luxembourg	752	853	811	725	829
Denmark	193	258	298	202	246
France	3,557	4,525	4,366	3,484	3,558
Germany, Federal Republic of	3,282	3,602	3,756	3,768	4,650
Greece	1	1	1	1	[2]2
Ireland	23	47	55	45	29
Italy	20	21	11	8	17
Netherlands	1,678	1,851	2,023	2,192	2,474
Portugal	11	10	18	12	8
Spain	1	4	1	1	18
United Kingdom	4,182	4,758	4,982	4,230	[2]3,644
European Free Trade Association:					
Austria	14	23	35	24	101
Finland	(6)	11	11	—	—
Iceland	7	12	7	3	11
Norway	40	23	10	9	12
Sweden	23	24	24	32	e35
Switzerland	164	118	110	r[2]67	[2]96
Council for Mutual Economic Assistance:					
Bulgaria	42	53	42	4	39
Czechoslovakia[4]	137	205	155	112	e120
German Democratic Republic[4]	23	40	29	8	e10
Hungary	55	87	r30	r7	118
Poland[2]	161	194	88	81	e90
U.S.S.R.[2]	3,715	3,756	3,655	4,506	4,299
Other:					
Yugoslavia	78	157	191	174	405
Africa:					
Algeria[2]	61	91	93	164	166
Morocco[2]	75	101	89	57	69
South Africa, Republic of[4]	51	r53	r74	r161	78

See footnotes at end of table.

TABLE 15—Continued

IRON AND STEEL SCRAP EXPORTS, BY SELECTED COUNTRIES[1]

(Thousand short tons)

Continent, country group, and country	1983	1984	1985	1986	1987
Asia:					
Bahrain[2]	2	[e]10	[e]10	[e]10	[e]10
Brunei	10	12	9	[e]10	[e]10
China[4]	40	15	24	3	121
Cyprus	9	15	16	15	5
Hong Kong[2]	363	331	332	[r]304	353
India[e]	20	20	20	20	20
Indonesia[2]	1	1	1	[r]7	3
Japan	128	161	183	508	416
North Korea[4]	7	[e]10	2	28	20
Korea, Republic of[2]	314	149	82	79	46
Kuwait	77	136	[e]100	[e]100	[e]100
Malaysia[2]	14	22	24	51	49
Mongolia[4]	24	([7])	([7])	([7])	—
Philippines[2]	1	2	1	1	[e]1
Saudi Arabia[e]	35	35	35	35	50
Singapore[2]	132	120	184	100	172
Taiwan[2]	308	223	428	310	108
Thailand[2]	2	4	4	6	5
Turkey	([6])	3	[2]4	[r2]5	[2]6
United Arab Emirates[e]	10	10	10	10	10
Vietnam[4]	13	2	61	101	93
Oceania:					
Australia[2]	574	409	555	623	965
New Zealand[2]	3	4	[e]2	[r]4	3
Total	**29,011**	**[r]33,180**	**[r]34,233**	**[r]35,351**	**35,502**

[e]Estimated. [r]Revised.
[1]Unless otherwise noted, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1987, v. 15, New York, 1988, 38 pp.
[2]Source: Official trade returns of subject country.
[3]Includes rerolling material.
[4]Partial figure; compiled from import statistics of trading partner country.
[5]Portugal and Spain became members of the European Community on Jan. 1, 1986.
[6]Less than 1/2 unit.
[7]Revised to zero.

TABLE 16

IRON AND STEEL SCRAP IMPORTS, BY SELECTED COUNTRIES[1]

(Thousand short tons)

Continent, country group, and country	1983	1984	1985	1986	1987
North America:					
Canada	737	1,253	974	[2]827	[2]858
United States[2]	641	577	611	724	843
Latin America:					
Argentina[2]	8	2	1	1	1
Brazil[2]	([3])	34	35	541	161
Chile	[2]6	[e]10	[e]10	[2]19	[e]25
Colombia[2]	51	48	[e]50	[e]50	[e]50
Cuba[4]	107	106	109	98	[e]100
Mexico[2]	390	696	[r]926	475	[e]500
Peru[e]	20	20	20	20	20
Venezuela[2]	20	400	547	[e]550	[e]550
Europe:					
European Community:[5]					
Belgium-Luxembourg	1,158	1,843	1,642	1,347	1,746
Denmark	74	146	53	133	98
France	338	449	508	389	572
Germany, Federal Republic of	1,424	1,935	1,776	1,517	1,311
Greece	573	362	345	502	[2]720
Ireland	77	97	150	134	164
Italy	4,901	6,047	6,368	5,232	5,413
Netherlands	401	527	646	936	1,143
Portugal	119	132	116	114	131
Spain	5,227	5,531	6,776	4,784	4,702
United Kingdom	12	37	55	52	[2]80
European Free Trade Association:					
Austria	241	400	263	127	76
Finland	41	36	125	71	60
Norway	17	14	12	7	35
Sweden	496	925	976	769	870
Switzerland	162	301	265	[r] [2]357	[2]150
Council for Mutual Economic Assistance:					
Czechoslovakia[4]	173	172	[r]49	[r]47	[e]50
German Democratic Republic[4]	741	1,141	977	1,087	995
Hungary	31	22	15	9	15
Poland[2]	6	8	6	6	7
U.S.S.R.[6]	24	49	28	49	[e]50
Other: Yugoslavia	812	861	804	718	759

See footnotes at end of table.

TABLE 16—Continued

IRON AND STEEL SCRAP IMPORTS, BY SELECTED COUNTRIES[1]

(Thousand short tons)

Continent, country group, and country	1983	1984	1985	1986	1987
Africa:					
Egypt[2]	2	1	2	2	2
Morocco[2]	3	1	2	4	2
South Africa, Republic of[4]	8	61	8	[e]50	[e]25
Asia:					
Bahrain[2]	3	[e]3	[e]3	[e]3	[e]3
China[4]	2	74	547	[r]716	451
Hong Kong[2]	30	31	22	37	48
India[e]	500	500	800	800	1,000
Indonesia[2]	284	268	210	524	508
Japan	4,306	4,429	3,587	3,554	2,599
Korea, Republic of[2]	2,090	2,294	2,640	3,434	3,879
Malaysia[2]	55	53	37	5	244
Pakistan[2]	132	134	169	162	647
Philippines[2]	([3])	1	1	94	[e]100
Singapore[2]	104	87	72	230	140
Syria[2]	7	2	[e]15	[e]15	[e]15
Taiwan[2]	811	637	766	1,351	1,040
Thailand[2]	707	545	725	612	996
Turkey	1,184	1,144	[2]1,323	[r 2]1,983	[2]3,121
Oceania:					
Australia	—	13	1	1	[e]1
New Zealand[2]	3	3	3	6	[e]6
Total	**29,259**	**34,462**	**[r]36,171**	**[r]35,275**	**37,082**

[e]Estimated. [r]Revised.

[1]Unless otherwise noted, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1987, v. 15, New York, 1988, 38 pp.

[2]Source: Official trade returns of subject country.

[3]Less than 1/2 unit.

[4]Partial figure; compiled from import statistics of trading partner countries.

[5]Portugal and Spain became members of the European Community on Jan. 1, 1986.

[6]Partial figure; compiled from incomplete returns of subject country and export statistics of trading partner countries.

TABLE 17

SHREDDER PROCESSING CAPACITY IN SELECTED COUNTRIES[1]

Country	Shredder data						
	Reference year	Total power requirements, horsepower, during reference year	Total number of shredders in operation, including mills, during reference year	Total annual capacity/ output; thousand metric tons, during reference year	Average power requirements, horsepower, per shredder, during reference year	Average power requirements, horsepower, per metric ton of annual capacity/ output, during reference year	Number of new plants under construction in 1988
Belgium-Luxembourg	1987	15,700	9	324	1,740	0.048	NA
Brazil	1986	e2,400	2	84	e1,200	e0.029	NA
Canada	1988	60,000	21	1,500	2,860	0.040	1
Denmark	1988	6,400	5	100	1,280	0.064	NA
France	1987	45,790	34	933	1,350	0.049	NA
Germany, Federal Republic of	1988	52,220	38	1,400	1,370	0.037	3
Italy	1987	20,000	14	700	1,430	0.029	2
Japan	1988	114,500	136	3,446	840	0.033	3
Netherlands	1988	11,850	11	450	1,080	0.026	1
Spain	1987	14,450	11	e360	1,310	e0.040	1
Turkey	1988	—	—	—	—	—	1
United Kingdom	1987-88	82,000	54	1,700	1,520	0.048	6
United States	1980-84	e440,000	200	13,100	e2,200	e0.034	NA
Total	**—**	**865,310**	**535**	**24,097**	**—**	**—**	**18**
Average	—	72,109	45	2,008	1,617	0.036	—

e Estimated. NA Not available.

[1] Unless otherwise specified, source for figures developed by the Bureau of Mines is either the Institute of Scrap Recycling Industries Inc., or the Bureau International de la Recuperation (BIR).

KYANITE AND RELATED MATERIALS

By Michael J. Potter[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that have the same chemical formula, $Al_2O_3 \cdot SiO_2$. The related materials synthetic mullite, dumortierite, and topaz also are classified as aluminum silicates, although the last two additionally contain substantial proportions of boron and fluorine, respectively. All of these kyanite-group substances can serve as raw materials for manufacturing high-performance, high-alumina refractories.

Although published statistics were incomplete, France, India, the Republic of South Africa, and the United States appeared to be the leading world producers of kyanite-group minerals. The U.S.S.R. and perhaps a few other industrialized nations also were presumed to produce significant quantities of these materials.

U.S. kyanite production in 1988 was estimated to have increased compared with that of 1987 owing to the improved outlook and activity in such refractories-consuming industries as iron and steel and aluminum.

DOMESTIC DATA COVERAGE

Domestic production data for kyanite and synthetic mullite were developed by the Bureau of Mines by means of two separate, voluntary, domestic surveys. The only kyanite producer, who has two active mines, did not respond. The Bureau estimated total production by using the last reported production levels adjusted by the trend of the iron and steel and nonferrous metals industries.

In the synthetic mullite survey, both canvassed operations responded, providing 100% of the total production tonnage data represented in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1988, were 22% for domestic production and 14% for foreign operations.

DOMESTIC PRODUCTION

Kyanite was produced at two open pit mines by Kyanite Mining Corp: the Willis Mountain and East Ridge Mines in Buckingham County, VA.

An andalusite-pyrophyllite-quartz deposit, the Hillsborough Mine, was operated by Piedmont Minerals Div. of Resco Products Inc. in Orange County, NC. The ore was selectively mined, followed by tertiary crushing, screening, and blending. The final products were admixtures of all three minerals. Andalusite content of the products ranges from 30% to 50% with a total alumina content of approximately 35%. End uses were mostly in the domestic refractory and ceramic markets such as tile, foundry mould washes, and electrical porcelain. Piedmont Minerals was canvassed under the talc and pyrophyllite survey of the U.S. Bureau of Mines.[2]

There are three types of synthetic mullite. Fused synthetic mullite is made by melting Bayer process alumina and silica, or bauxite and kaolin in an electric furnace at about 3,450° F. High-temperature sintered synthetic mullite is prepared by sintering mixtures of alumina and kaolin, bauxite and kaolin, or alumina, kaolin, and kyanite above 3,180° F. Low-temperature sintered synthetic mullite is made by sintering siliceous bauxite or mixtures of bauxite and kaolin above 2,820° F.

High-temperature sintered mullite was produced by C-E Minerals Div. of Combustion Engineering Inc. at Americus, GA. Electric-furnace-fused mullite was produced by Electro Minerals U.S. Inc. at Niagara Falls, NY.

CONSUMPTION AND USES

Kyanite and related materials were consumed mostly in the manufacture of high-alumina or mullite-class refractories and in lesser quantities as ingredients in ceramic compositions. U.S. kyanite, already ground to minus 35 mesh as required by the flotation process used in its separation and recovery, was marketed either in this raw form, or after heat treatment, as mullite, sometimes further reduced in particle size before use. In the 35- to 48-mesh range, kyanite was used mostly in monolithic refractory applications such as high-temperature mortars or cements, ramming mixes, and castable refractories, or with clays and other ingredients in refractory compositions for making kiln furniture, insulating brick, firebrick, and a wide variety of other articles. More finely ground material, minus 200 mesh, was used in body mixes for sanitary porcelains, wall tile, investment-casting molds, and miscellaneous special-purpose ceramics.

TABLE 1

U.S. PRODUCTION OF SYNTHETIC MULLITE

Year	Quantity (short tons)	Value (thousands)
1984[e]	27,000	$5,300
1985[e]	27,000	5,450
1986	W	W
1987	W	W
1988	W	W

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

PRICES

Some prices at yearend 1988, in British pounds, from Industrial Minerals (London) were the same as those of 1987. The sharp increase in price for 60% alumina, South African andalusite was in part because of the weakness of the rand relative to the pound sterling.[3] The slight price decreases in table 2 reflect a corresponding decrease in the value of the British pound against the U.S. dollar.[4]

FOREIGN TRADE

Shipments of U.S. kyanite- and mullite-containing materials were believed to have been made to destinations in Europe and Asia. Based on data from a non-Government source, imports of andalusite in 1988 were estimated to be 9,800 short tons from the Republic of South Africa.

WORLD CAPACITY

The data in table 3 are rated capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Capacity data for Japan, the Republic of South Africa, and Sweden were obtained from literature sources. For other countries, recent peak production or estimated production were considered to be equal to rated capacity.

WORLD REVIEW

The Republic of South Africa is the world's largest producer of andalusite and is itself a major consumer of the mineral, with an estimated 100,000 tons annually in recent years. Europe is the other major world market with an estimated 100,000 tons to 150,000 tons

TABLE 2

PRICES OF KYANITE AND RELATED MATERIALS

(Dollars per short ton)

	1987	1988
Andalusite, Transvaal, 57% Al_2O_3, bulk, c.i.f. main European port	—	139–154
Andalusite, Transvaal, 60% Al_2O_3, c.i.f main European port	147	200
Sillimanite, South African, 70% Al_2O_3, bags, c.i.f. main European port	310	293
U.S. kyanite, 59% to 62% Al_2O_3, 35–325 Tyler mesh, raw and/or calcined, 18-ton lots, c.i.f main European port	147–253	139–239
U.S. kyanite, f.o.b. plant, carlots:		
Calcined	123–172	123–172
Raw	70–137	70–137

Source: Industrial Minerals (London). Dec. 1988, No. 255, p. 83.

TABLE 3

WORLD KYANITE AND RELATED MINERALS ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

	Rated capacity
North America:	
United States:	
Kyanite	W
Synthetic mullite	W
Total	**W**
South America: Brazil: Kyanite[e]	5
Europe:	
France: Andalusite	65
Federal Republic of Germany:	
Synthetic mullite[e]	10
Italy: Synthetic mullite[e]	5
Spain: Andalusite	5
Sweden: Kyanite	25
United Kingdom: Synthetic mullite	10
Other:	
Market economy countries[e]	20
Centrally planned economy countries[e]	200
Total	**345**
Africa:	
Republic of South Africa:	
Andalusite	300
Sillimanite[e]	3
Zimbabwe: Kyanite	2
Total	**305**
Asia:	
China: Unspecified	3
India:	
Kyanite	40
Sillimanite	17
Total	**57**
Japan: Synthetic mullite[e]	30
Total	**90**
Oceania:	
Australia:	
Kyanite[e]	1
Sillimanite[e]	1
Total	**2**
World total (rounded)[1]	**740**

[e] Estimated. W Withheld to avoid disclosing company proprietary data.
[1] Includes capacity at operating plants as well as at plants on standby basis.
[2] Excludes U.S. kyanite and synthetic mullite.

per year. Although there is a relative lack of indigenous refractory minerals in Europe, production of fine-granular andalusite does occur in France. Most of the material is exported, mainly to the United Kingdom, the Federal Republic of Germany, and Italy.

Japan is a relatively small consumer of kyanite-group minerals. Imports range from 20,000 to 30,000 tons per year, primarily andalusite from the Republic of South Africa and kyanite from the United States. The only large-volume refractory minerals mined in Japan are clays, roseki (a pyrophyllite material), and silica. The following factors are thought to limit potential growth in demand for andalusite in Japan: (1) a sharp decline in refractories consumption by the steel industry from 30 pounds per ton of steel in 1974 to less than 18 pounds per ton of steel; (2) strong competition from synthetic materials such as synthetic mullite; and (3) the Japanese policy of changing raw materials to avoid dependence on a particular mineral or supplier.[5]

Australia

Otter Exploration of Sydney planned to conduct laboratory comminution and flotation studies as a result of promising assay results from the Mount Cavana andalusite prospect near Bowen in central Queensland. Sixty outcrop samples taken over a 0.6 mile by 0.3 mile grid averaged 13.2% alumina, 1.8% iron oxide (principally as pyrite), and 0.36% titanium dioxide.[6]

Canada

A kyanite deposit was being evaluated by Société d'Exploration Minière Mazarin Inc. Known as the Lac Croche property, the deposit is 22 miles south-southeast of Fermont in Quebec. Preliminary exploration indicated a zone with 20% to 40% kyanite in large, bluish crystals, 0.4 inch to 0.8 inch in size. An early estimate of tonnage was 4.5 million tons to a depth of 100 feet.[7]

France

The sole producer of andalusite in Europe is Denain-Anzin Mineraux Refractaire Ceramique (Damrec), a subsidiary of Mineraux Industrielle de Refractaire et Ceramique. Based at Glomel in Brittany, the operation has been producing approximately 55,000 to 60,000 tons annually in recent years. The two grades of product sold by the company have been Kerphalite KA, with a minimum of 59% alumina, and KB, with a minimum of 53% alumina. Damrec planned to introduce a new grade of andalusite, KF, by the addition of a flotation unit to the flow scheme. KF would have a minimum of 60% alumina with a maximum of 0.6% to 0.7% iron oxide.[8]

TECHNOLOGY

The Council for Mineral Technology (Mintek) reviewed the development of the andalusite industry in the Republic of South Africa.[9] Topics discussed included early benefication methods and Mintek's role in the development of beneficiation techniques since 1962. Mintek not only had a significant role in improving both the recovery efficiency and product grade, but also was

TABLE 4

KYANITE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2] and commodity	1984	1985	1986	1987[p]	1988[e]
Australia:					
Kyanite	1,383	245	847	[r e]72	550
Sillimanite[3]	559	[r]472	147	[r e]11	80
Brazil: Kyanite	1,422	2,590	1,047	[e]1,650	1,650
China: Unspecified[e]	2,800	2,800	2,800	2,800	2,800
France: Andalusite	57,300	62,391	56,108	55,116	55,100
India:					
Andalusite	[e]3,000	556	807	531	550
Kyanite	40,812	33,590	35,708	41,207	38,600
Sillimanite	14,746	18,844	16,175	15,836	16,500
Kenya: Kyanite	1	1	[e]1	[e]1	1
Korea, Republic of: Andalusite	230	46	—	—	—
South Africa, Republic of:					
Andalusite	157,967	214,612	200,206	214,259	248,000
Sillimanite	1,445	1,474	1,466	1,370	900
Spain: Andalusite	3,307	3,087	2,696	[e]2,760	2,800
Sweden	—	2,425	[e]5,500	[r e]5,500	5,500
United States:					
Kyanite	W	W	W	W	W
Mullite, synthetic[e]	27,000	27,000	W	W	W
Zimbabwe: Kyanite	—	—	2,040	[e]2,040	2,040

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Owing to incomplete reporting, this table has not been totaled. Table includes data available through Apr. 5, 1989.
[2]In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.
[3]In addition, about 8,000 short tons of sillimanite clay (also called kaolinized sillimanite) is produced annually containing 40% to 48% Al_2O_3.

instrumental in introducing heavy-medium separation as a standard beneficiation operation. It developed standard procedures of sample evaluation, designed mill modifications, and improved flow sheets. The report also discusses treatment of both hard shales and andalusite fines. Cooperation over the years between Mintek and andalusite producers resulted in a large number of significant improvements in process development.

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Benbow, J. Pyrophyllite—Far East Steels the Market. Ind. Miner. (London), No. 249, June 1988, p. 44.

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LEAD

By William D. Woodbury[1]

Major events in lead during 1988 were the continuing rationalization of the industry in the Western World through multinational corporate acquisitions and mergers, record world demand exceeding 5.8 million metric tons for the first time, and near-record performance by secondary smelter-refineries in the United States, especially in the recycling of spent automotive batteries.

Domestic mine and refined metal production increased significantly compared with that of 1987 and net imports of lead in all forms were the lowest since 1980. On the consumer side, 1988 shipments and exports of starting-lighting-ignition (SLI) lead-acid storage batteries by the domestic industry exceeded 80 million for the first time. Significant advances were made in the United States toward the mass-marketing of electric vehicles in general private transportation. Total domestic consumption of lead in 1988 was at the same high level as 1987, the highest since the late 1970's.

Although the U.S. price and London Metal Exchange (LME) prices were generally higher than in 1987, the average spread between the U.S. and LME prices were lower, and which at no time reached the record-high levels of 1987. This was reflected by considerably less pig lead imports during 1988.

TABLE 1

SALIENT LEAD STATISTICS

(Metric tons unless otherwise specified)

		1984	1985	1986	1987	1988
United States:						
Production:						
Domestic ores, recoverable lead content		322,677	413,955	339,793	r311,381	384,983
Value	thousands	$181,745	$174,008	$165,150	r$246,720	$315,222
Primary lead (refined):						
From domestic ores and base bullion		323,989	422,650	348,217	336,471	371,348
From foreign ores and base bullion		65,409	71,353	22,071	37,139	20,739
Secondary lead (lead content)		633,374	615,695	624,769	r710,067	737,040
Exports (lead content):						
Lead ore and concentrates		11,858	9,987	4,380	8,764	20,902
Lead materials excluding scrap		16,563	37,322	19,778	13,586	29,077
Imports for consumption:						
Lead in ore and concentrates		29,888	2,649	4,604	873	20,606
Lead in base bullion		43	760	142	10,827	4,046
Lead in pigs, bars, reclaimed scrap		166,515	134,521	143,511	192,260	155,893
Stocks, Dec. 31:						
Primary lead[1]		45,126	84,502	20,400	21,608	15,398
At consumers and secondary smelters		97,077	93,130	83,824	88,586	89,828
Consumption of metal, primary and secondary		1,207,033	1,148,298	1,125,521	r1,230,373	1,230,732
Price: Metals Week average, delivered, cents per pound		25.55	19.07	22.05	35.94	37.14
World:						
Production:						
Mine	thousand metric tons	r3,268.7	r3,429.7	3,353.7	p3,429.2	e3,426.3
Refinery[2]	do.	r3,172.3	r3,368.4	3,206.0	p3,215.2	e3,254.3
Secondary refinery	do.	r2,296.3	r2,300.6	2,369.8	p2,511.6	e2,600.7
Price: London Metal Exchange, pure lead, cash average, cents per pound		20.12	17.84	18.43	26.99	29.73

e Estimated. p Preliminary. r Revised.

[1] Source: American Bureau of Metal Statistics, Inc. (ABMS).

[2] Primary metal production only. Includes secondary metal production where inseparably included in country total.

World mine production was estimated to have been about the same as that of 1987, and on a recoverable basis represented only 55% of demand as world secondary refinery production, led by the United States, achieved a record production level of 2.6 million tons. World demand increased for the sixth consecutive year.

DOMESTIC DATA COVERAGE

Domestic data for lead are developed by the Bureau of Mines from five voluntary surveys of U.S. operations. Typical of these are the combined secondary producer and consumer surveys, both monthly and annual. Of the 265 consuming plants to which a survey request was sent, 251 responded, representing 89% of the total U.S. lead consumption shown in tables 1, 12, 13, 14, and 15. Of the 54 smelter-refineries to which a survey request was sent, 48 responded, representing 91% of the total refinery production of secondary lead, exclusive of that from copper-base scrap, shown in tables 1, 9, 10, and 11. Production and consumption for the nonrespondents were estimated using prior year levels adjusted for general industry trends.

LEGISLATION AND GOVERNMENT PROGRAMS

In July, the U.S. Court of Appeals for the District of Columbia ruled that impounded primary lead smelter wastes were to be listed and treated as hazardous. The industry has until January 1991 to be in permitted compliance, and until March 1993 for full retrofitted operational compliance. In August, the Environmental Protection Agency (EPA) published a notice of proposed rulemaking to reduce by 90% the allowable level for lead in drinking water. If a final rule were promulgated, it could significantly increase costs for the U.S. lead and battery industries to treat process effluents and discharges and protect ground water to comply with an amended Resource Conservation and Recovery Act (RCRA) and the Clean Water Act.

At yearend, EPA was receiving comments on its October proposed ruling to continue the large-volume, low-hazard exemption of primary lead smelter slag from listing under RCRA subtitle C standards. EPA also was considering a stricter national ambient air quality standard for lead for the Clean Air Act reauthorization anticipated in 1989.

DOMESTIC PRODUCTION

Mine Production

The increase in domestic mine output was the result of a number of developments. ASARCO Incorporated finally met its planned production schedule for its West Fork Mine in Missouri and completed the first full year of production at its Sweetwater Mine. The Bunker Hill Mine in Idaho, closed since 1981, was reopened, and Hecla Mining Co. attained a full year of production at its Lucky Friday Mine in Idaho. West Fork, which had opened in the last quarter of 1985, reportedly had been having continual technical problems, and Lucky Friday had reopened in mid-1987 after a 14-month shutdown owing to unfavorable silver prices. Eight operating mines in Missouri, plus the next four shown on table 7, produced all but about 1,800 tons of the domestic recoverable mine output. The mines in Missouri accounted for 92% of the year's total. On the basis of lead in concentrates produced, the domestic mining industry as a whole performed at 60% of capacity owing to restricted smelter capacity.

The Doe Run Co. of St. Louis, MO, the Nation's largest lead producer, operated three mine-and-mill complexes involving five mines in southeastern Missouri on the Viburnum Trend. The Buick Mine, the largest single producing property, retained its position by a significant margin. Doe Run's Brushy Creek unit did not operate in 1988 as a lead producer. However, the mill was recommissioned early in the year to produce copper concentrates from various Missouri lead mines, and in June a copper flotation circuit was completed at the Buick mill. As a result of both projects, Doe Run produced almost 9,000 tons of copper in concentrates from its lead mines, according to the annual report published by Homestake Mining Co. This compares with 220,000 tons of lead in concentrates produced, according to the annual report by Fluor Corp. Fluor Corp. controlled 57.5% of Doe Run in 1988, and Homestake 42.5%, which was the production apportionment. The producing facilities, however, were jointly operated by the respective subsidiaries: St. Joe Minerals Division of Fluor Corp. and Homestake Lead Mining Co. of Missouri.

Asarco operated two mine and mill complexes in the Viburnum Trend, with the West Fork Mine attaining its originally planned operational capacity for the first time in August following completion of an additional ventilation shaft. Operation with the additional shaft resulted in a 70% increase in production over that of 1987. Asarco planned to further increase the capacity and production at West Fork in 1989. The Sweetwater Mine, potentially the Nation's largest lead mine, operated at less than one-quarter of its rated capacity but planned to increase the operating rate significantly in 1989. According to Asarco's annual report, these two mines plus the company's Leadville Unit in Colorado produced just over 70,000 tons of lead in concentrates in 1988, about one-third of Asarco's refinery production.

The Magmont Mine, the Nation's second largest producing unit, produced just under 70,000 tons of lead in concentrates from just over 1 million tons of ore hoisted, according to the annual report published by Cominco Ltd. of Canada. The mine was equally owned by Cominco American Incorporated and Dresser Industries Inc. Slightly less ore was hoisted than in 1987 owing to an increase in average grade. Ore reserves at the Magmont Mine continued to decline, standing at only 3.9 million tons at yearend, down 363,000 tons from yearend 1987.

The 54-mile road from Cominco Alaska Incorporated's Red Dog Mine site to its port northwest of Kotzebue, AK, was completed, and construction began on the 12-story-equivalent concentrate storage facility. Scheduled for completion in 1989, the storage facility will be the length of five football fields and accommodate 500,000 tons of concentrates for the short ice-free shipping season. Eleven mill modules were under construction in the Philippines and 300 accommodation modules were being assembled in Idaho. This equipment was to be barged to the port and hauled to the mine site. The mine was expected to come on-stream in the last quarter of 1989. Revised production estimates are for 70,000 tons of lead and 325,000 tons of zinc per year. At what would be the world's largest zinc mine in terms of proven reserves and annual production, total development costs were estimated to be $420 million.

Primary Smelter-Refinery Production

According to Homestake's annual report, Doe Run produced 214,000 tons of refined lead in 1988, all but 10,000 tons at the Herculaneum, MO, smelter-refinery, the Nation's largest. This was an 18% increase over that of 1987. Parts of the Boss (Buick), MO, smelter-refinery, which had been on standby since May 1986, began operating again in 1988 to provide additional sintering capacity for Herculaneum. Because of a strong surge in demand in October, the smelter and refinery returned briefly to metal production from stockpiled sinter, which allowed Herculaneum to produce at its full rated capacity of 204,000 tons for the year.

According to the Asarco annual report, the company produced 179,000 tons of refined lead in 1988, nearly two-thirds of that at its Glover, MO, smelter-refinery. The balance was produced at the Omaha, NE, refinery, which received bullion from the East Helena, MT, smelter. The Omaha plant also produced lead from purchased old and new scrap in 1988. Total production was down less than 2,000 tons from 1987. Operations were unexpectedly shut down for 7 days in July at East Helena after a fire destroyed the ore handling and storage facility. A modern, completely enclosed facility costing $16 million was scheduled for completion by late 1989.

Secondary Smelter-Refinery Production

Domestic secondary production increased for the third consecutive year, achieving the fourth-highest level ever as the industry performed at 87% of rated capacity, the highest rate ever. At yearend, this sector consisted of 43 companies, which operated 51 plants with refined metal capacities ranging from less than 1,000 to 100,000 tons per year (tpy). The ten largest of these companies, with 17 plants, produced 86% of the total. Several of the larger secondary plants added capacity, five of the smallest plants were closed, and ratings of some others were reduced. Total capacity dropped about 5,000 tons during the year. Twenty-three small producers operated 24 plants with annual capacities averaging 1,000 tons. These plants produced mainly specialty alloys for such uses as solders, brass or bronze ingots, and bearing metals. Total annual secondary rated capacity for refined lead and lead alloys at yearend was estimated by the Bureau of Mines to be 850,000 tons.

During the last quarter of 1988, several companies announced plans for changes that could profoundly affect the future structure and direction of the domestic secondary industry. In November, RSR Corp., the world's largest secondary lead producer, announced that over the next several years, starting in 1989, it would convert its three domestic conventional smelter-refineries to electrochemical/electrowinning plants. The process, which RSR had patented in the late 1970's and early 1980's, is virtually pollution free, and at the same time will allow the company to expand production at each facility by up to 50% at minimal capital expenditure. In December, the Doe Run Co. announced that it would be entering the secondary lead business by mid-1990, utilizing a hybrid, patented Italian process, the Tonolli-Engitec CX Battery Breaking System, at its Boss (Buick) plant in Missouri. In this process, agricultural-grade ammonium sulfate is recovered from spent battery sludges prior to smelting. This significantly reduces fluxing and slagging agents and the resulting slags and fumes, and it increases pyrometallurgical efficiency by up to 30%.

CONSUMPTION AND USES

Storage battery manufacturers consumed a record amount of lead as total SLI automotive battery shipments exceeded 80 million units for the first time and total consumption reached the highest level since 1979. However, lead in oxides for glass, paint, ceramics, and other chemicals, the second largest use sector, decreased for the fourth consecutive year. Lead in shot and bullets, the third largest end use, increased. Communications transmissions decreased in 1988, following 4 consecutive years of increases. The decline was apparently the result of a drop in the demand for replacing plastic sheathing in some underwater or saturated soil conditions.

Demand for lead in industrial and traction batteries, which includes uninterruptible power supply (UPS) for large computer systems at hospitals, banks, communications networks, etc., and standby power supply (SBS) for emergency lighting and some telephone systems, was estimated by the Bureau of Mines to be 155,200 tons. About one-third of that was for traction batteries, i.e., electric vehicles including in-plant fork lifts.

STOCKS

A nearly 30% decrease in refined metal stocks at domestic primary refineries was offset by increases in consumer stocks and raw material feedstocks at the primary plants. Therefore, in terms of metal equivalents, domestic stocks (excluding scrap) were about the same as at yearend 1987. This reflected the close supply-demand balance that generally existed worldwide in 1987 and 1988. The sensitive balance sustained the relatively high world price levels during the period. Stocks of lead and antimonial lead metal in the market economy countries reporting to the International Lead and Zinc Study Group (ILZSG) were approximately 417,000 tons at yearend, about 7% of 1988 total world demand, and only 5,000 tons higher than stocks at yearend 1987.[2] Stocks in LME warehouses increased considerably, however, to 62,000 tons at yearend, the highest since 1985. This paradoxical situation developed at midyear because Australian producers had been carrying relatively high stocks during the normally soft market in the Northern Hemisphere late winter and spring. Producers in Australia apparently had anticipated a higher second-half European market share than actually was available. Producers in some European countries reportedly also had relatively high stock levels as they entered the second-half consumer buying season.

PRICES

According to Metals Week, the North American primary producers U.S. list price of 42 cents per pound, which had first been established in July 1987, was finally lowered in the second week of January 1988 to 38 cents. The list price dropped to 37 cents in the first week of February, and to 34 cents in the second week. These actions clearly reflected the more-than-10,000,000-unit battery-stock buildup at the end of 1987. The 34-cent quotation held until the third week of May, when it rose to 36 cents, and then split to a range of 36 to 38 cents per pound in mid-June as the buying season of the battery manufacturers began. These quotes held through August but increased to 38 to 40 cents in early September, and to 40 to 42 cents in late October as demand mirrored the last quarter of 1987. In early December, the range narrowed to 42 to 42.5 cents to finish the year. The spread against the LME, however, never reached the record levels of the last quarter of 1987. The spread ranged from a low of 4.3 cents per pound in May to 10.8 cents in September. A sustained spread greater than 5 cents is generally necessary to attract high levels of imports, and these usually occur in the second half of the year.

On the LME, the average cash price, which had been 29.9 cents per pound for December 1987, fluctuated weekly over a range of 28.8 cents to 32.3 cents during the first half of 1988 but generally hovered around 30 cents plus or minus 1 cent per pound. From mid-July through September, there was a general drop to a weekly fluctuation in a narrow range from about 27 cents to 28 cents per pound. In the last quarter of the year, LME cash prices recovered almost weekly, reaching 33.6 cents per pound for the weeks ending December 9 and 16, the high points of the year, and averaging 33 cents for the month, also the year's high. The LME average cash price for 1988 exceeded that of 1987 by 2.7 cents per pound, whereas the North American primary producer mean-weighted list price exceeded that of 1987 by only 1.2 cents per pound. While domestic consumption was the same in both years, demand in the rest of the world reached a record level. There were occasional spot shortages of 99.99% lead late in the fourth quarter, mostly in the Far East, which commanded temporary premiums as high as 5 cents per pound (f.a.s. port) over the LME price.

The domestic prices for lead oxides were based on the selling price plus conversion charges for pig lead in a given period. Premium adjustments were also made by individual producers to reflect differences in manufacturing techniques, freight considerations, quality, and packaging requirements, or other factors. According to American Metal Market, the quoted premiums for litharge ranged from 4 cents to 9 cents per pound in 1988, averaging about 6 cents for bags or drums in truckload lots, and 10 to 13 cents, averaging about 11 cents per pound, for 97% red lead. The premiums for Bulk Battery (leady litharge) ranged from 1 cent to 4 cents, and averaged about 2 cents per pound.

FOREIGN TRADE

Owing to the significantly increased performances of the domestic lead mining and refining industries in the face of continuing high demand, net imports of lead in all forms during 1988, excluding chemicals, pigments and oxides, declined by 67,200 tons. The resulting net imports of 86,500 tons, compared with the revised figure of 153,700 tons for 1987, was the lowest since the net export year of 1980. Unwrought pig metal imports declined by 20%, while exports of that item nearly doubled. Imports and exports of lead in concentrates were in balance, but exports of drosses and scrap lead in 1988 increased significantly. The lead content of scrap exported was estimated to be 60%, almost all of which was thought to be spent lead-acid storage batteries. Brazil, Canada, Mexico, and Taiwan received over 60% of the scrap exported. Almost 90% of the contained lead imported was refined pig lead. Over 90% of the refined pig lead came from Canada and Mexico.

Imports of chemicals, which includes pigments and oxides and other lead compounds, also declined in 1988. Imports of chrome yellow, used for highway markings, and which represented 20% of this category, increased marginally. Imports of litharge, used primarily in TV tubes and video display terminals for computers, and which represented 60% of the category, declined by 20%. Mexico accounted for almost all of the U.S. imports of litharge, and Canada supplied almost one-half of the remainder of the whole chemicals category, including nearly three-quarters of the chrome yellow. Hungary and the Federal Republic of Germany (FRG) supplied nearly all of the balance of chrome yellow. The Netherlands, Peru, and Canada supplied all of the basic white lead carbonate, while Canada supplied all of the basic white lead sulfate. Mexico and the FRG supplied nearly all of the red lead, while the United Kingdom supplied all of the sublimed blue lead. China, Belgium, and Mexico supplied nearly all of the lead nitrate; Mexico and the FRG supplied all of the lead acetate; and Canada, the Netherlands, and the FRG supplied all of the other lead salts. The FRG, Canada, Norway, and the United Kingdom supplied nearly 90% of the nonspecific lead pigments, while the FRG, the Netherlands, and Canada supplied about two-thirds of all the remaining nonspecific lead compounds. Canada and Mexico accounted for over 80% of the total U.S. imports of all lead chemicals on a tonnage basis.

WORLD CAPACITY

The data in Table 3 are annual rated production capacities for mines, primary smelters, and primary refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time at a normally sustainable long-term operating rate, based on the physical equipment of the mine or plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Mine capacity for lead is based on typical practices and average grades of the individual properties of the producers in various countries who report through their governments to the ILZSG. For smelters and refineries, the data are maximum engineering estimates similarly derived and provided.

Estimates of smelter and refinery capacities for those centrally planned economy nations or others who do not report to the ILZSG are based on an average of the 5 most recent years production from Bureau of Mines records, or the highest production if there is a marked continuing increase or decrease over that period not otherwise explainable. For those nations having continuously declining mine production, however, the lowest of the values was used to indicate the probable capacity rating.

In the case of primary lead, which in most of the world is a coproduct with zinc and silver or byproduct of gold or copper mines, changes in capacity and/or utilization rates do not generally affect the market except in unusual situations. Secondary production can be altered to stabilize markets relatively easily. Year-to-year changes in primary lead smelter and refinery capacities are limited, most often involving replacements or environmental retrofitting. Examples of this are new plants which were under development during the year in Canada, the Federal Republic of Germany, and Mexico. Mine capacity changes on a year-to-year basis can be expected to be dramatic on occasion depending on the prognosis for zinc and/or silver, but on a world total basis there is usually a significant margin over production.

TABLE 2

U.S. IMPORT DUTIES FOR LEAD MATERIALS

(Lead content)

Item	TSUS No.	Most favored nation (MFN)	Least developed developing countries	Non-MFN
Ore	602.10	0.75 cent per pound	Free[1] or current MFN rate.	1.5 cents per pound.
Lead bullion	624.02	3.5% ad valorem	do.	10.5% ad valorem.
Other unwrought	624.03	3.5% ad valorem[2]	Current MFN rate only.	10.0% ad valorem.
Waste and scrap	624.04	2.3% ad valorem	Free[1] or current MFN rate.	11.5% ad valorem.

[1] Free if eligible under General System of Preferences.

[2] Established at 3.0% ad valorem (retroactive to July 1, 1983) but not to be less than 1.0625 cents per pound, on Oct. 30, 1984, by the Omnibus Trade Act.

TABLE 3

WORLD PRIMARY PRODUCTION CAPACITY, ANNUAL

(Thousand metric tons)

	1983[r]			1984[r]			1985			1986			1987			1988		
	Mine	Smelter	Refinery	Mine	Smelter	Refinery	Mine	Smelter	Refinery	Mine	Smelter	Refinery	Mine	Smelter	Refinery	Mine	Smelter	Refinery
North America:																		
Canada	390	205	205	390	205	205	383	205	205	418	205	205	358	205	205	455	205	230
Mexico	200	290	320	208	290	320	208	290	320	206	290	320	209	290	320	210	300	320
United States	595	715	715	512	595	595	559	515	595	559	515	595	655	515	595	655	515	595
Other	20	—	—	20	—	—	20	—	—	27	—	—	27	—	—	10	—	—
Total	**1,205**	**1,210**	**1,240**	**1,130**	**1,090**	**1,120**	**1,170**	**1,010**	**1,120**	**1,210**	**1,010**	**1,120**	**1,249**	**1,010**	**1,120**	**1,330**	**1,020**	**1,145**
South America:																		
Peru	200	90	90	205	90	90	220	90	90	220	100	100	200	100	100	205	115	110
Other	95	150	150	95	150	150	95	150	150	95	150	150	93	150	150	80	140	140
Total	**295**	**240**	**240**	**300**	**240**	**240**	**315**	**240**	**240**	**315**	**250**	**250**	**293**	**250**	**250**	**285**	**255**	**250**
Europe:																		
Belgium	—	90	125	—	90	125	—	90	125	—	90	125	—	90	125	—	90	125
Bulgaria[e]	125	130	120	125	130	120	125	130	120	125	130	120	125	130	120	100	130	120
France	—	190	150	2	190	150	2	190	150	2	190	150	2	190	150	2	190	150
Germany, Federal Republic of	30	195	260	30	195	260	30	195	260	30	195	260	25	195	260	7	190	250
Italy	15	30	80	15	30	80	15	30	80	15	30	80	15	115	80	13	115	80
Poland	50	90	90	50	90	90	50	90	90	50	90	90	50	90	90	50	90	90
Spain	90	110	110	90	110	110	100	110	110	97	80	80	97	80	80	92	85	85
U.S.S.R.[e]	600	585	700	605	585	700	605	585	700	605	635	675	605	635	675	550	635	675
United Kingdom	—	40	150	—	40	150	—	40	150	—	40	150	—	40	150	—	50	160
Yugoslavia	130	155	155	130	155	155	130	155	155	130	155	155	130	155	155	115	155	155
Other	305	160	125	255	160	125	255	160	125	253	160	125	266	135	130	220	145	110
Total	**1,345**	**1,775**	**2,065**	**1,302**	**1,775**	**2,065**	**1,312**	**1,775**	**2,065**	**1,307**	**1,795**	**2,010**	**1,315**	**1,855**	**2,015**	**1,149**	**1,875**	**2,000**
Africa:																		
Morocco	145	65	65	145	65	65	145	65	65	96	65	65	94	65	65	74	65	65
Namibia	40	75	75	40	75	75	40	75	75	42	75	75	42	75	75	40	75	75
South Africa, Republic of	85	—	—	95	—	—	100	—	—	106	—	—	106	—	—	102	—	—
Other	40	60	60	43	60	60	43	60	60	44	60	60	45	30	30	24	30	15
Total	**310**	**200**	**200**	**323**	**200**	**200**	**328**	**200**	**200**	**288**	**200**	**200**	**287**	**170**	**170**	**240**	**170**	**155**
Asia:																		
China[e]	160	190	185	180	190	185	200	190	185	230	190	185	250	200	190	250	200	190
Japan	40	320	295	50	320	295	50	320	295	48	320	295	38	270	285	30	270	285
North Korea[e]	100	110	120	100	110	120	100	110	120	100	110	120	100	110	120	85	90	70
Other	145	50	50	145	50	50	145	50	50	147	50	85	147	60	95	100	95	150
Total	**445**	**670**	**650**	**475**	**670**	**650**	**495**	**670**	**650**	**525**	**670**	**685**	**535**	**640**	**690**	**465**	**655**	**695**
Oceania:																		
Australia	515	460	250	515	460	250	530	460	250	545	460	250	556	460	250	516	445	235
World total	**4,115**	**4,555**	**4,645**	**4,045**	**4,435**	**4,525**	**4,150**	**4,355**	**4,525**	**4,190**	**4,385**	**4,515**	**4,235**	**4,385**	**4,495**	**3,985**	**4,420**	**4,480**

[e]Estimated. [r]Revised.

Sources: 1984 and 1988 International Lead and Zinc Study Group Directories, Bureau of Mines estimates, and other published data.

WORLD REVIEW

According to the ILZSG statistics, consumption of soft lead and antimonial lead in the market economy countries was a record 4.35 million tons in 1988, exceeding 1987's previous high by about 100,000 tons.[3] Estimated world consumption of lead in all forms during 1988 increased for the sixth consecutive year, reaching a record of 5.87 million tons, exceeding 1987's previous high by about 140,000 tons. The world demand growth since 1982 has averaged 2.0% per year, owing primarily to steadily increasing motor vehicle production and UPS and SBS battery systems. ILZSG has estimated that the proportion of the world's lead consumed by the centrally planned economy nations, principally the U.S.S.R. and China, rose from 21% in 1960 to 26% in 1987, the latest specific estimate available. The Federal Republic of Germany overtook the United Kingdom in 1967 as the third largest consumer, behind the United States and the U.S.S.R, and was itself superseded by Japan in 1978.[4] In the market economy nations, consumption of lead for batteries has steadily increased from a market share of 52% in 1982 to 61% in 1987.[5]

Estimated world total refinery production in 1988, including that from recycled scrap, increased by about 128,000 tons compared with that of 1987. Worldwide environmental awareness has led to the construction of new, and upgrading and/or expansion of old secondary facilities in many countries, especially emerging nations in Asia. Prior to 1984, secondary lead supplied 40% or less of the world's demand. Since then, that sector's share has increased to over 44% in 1988 and is expected to continue rising to over 50% by the end of the century.

Australia

Production of lead in concentrates was less than in 1987. The drop was the result of major shaft repair and rebuilding at ZC Mines' Broken Hill Mine in New South Wales, an operating subsidiary of Australia Mining and Smelting Ltd. (AM&S). Declining reserves of the Que River Mine, West Coast, Tasmania, owned by Aberfoyle Ltd. (46% of which is held by Cominco Ltd. of Canada), also contributed to the decline. The work at the ZC mine will reportedly result in an unspecified increase in hoisting capacity in 1989. A slight increase in lead production was recorded at the predominantly zinc Hellyer Mine (owned by Aberfoyle), on Tasmania. Expansion of the Hellyer Mine was expected to result in an additional 38,000 tons of capacity by 1990. A new open pit, known as the Cadjebut Mine and owned by BHP Minerals (58%) and Billiton Australia (42%), started production at West Kimberley, Western Australia. Cadjebut's capacity for lead, however, is only 7,500 tpy, compared with 41,000 tpy of zinc.

Lead bullion output declined slightly at both the Mount Isa, Queensland, and Cockle Creek, New South Wales, smelters, owned by Mount Isa Mines Ltd. and Sulphide Corp. Pty. Ltd., respectively. Production at Broken Hill Associated Smelters Ltd.'s (BHAS) plant at Port Pirie, South Australia, the nation's only primary lead refinery, declined significantly in the early part of the year following a fire in the sinter plant. Estimated production of refined lead from secondary sources remained at the same level as 1987 at Australian Refined Alloy Ltd.'s plants in Sydney and Melbourne.

Early in the year, North Broken Hill Holdings Ltd. (NBHH), a substantial mine producer, merged with Peko-Wallsend Ltd. in order to expand and diversify its resource base. The new entity, North Broken Hill Peko Ltd., then proposed a merger in midyear with Conzinc Rio Tinto of Australia Ltd. (CRA), the parent company of AM&S. The new company, Pasminco Ltd., would be one of the largest lead and zinc mining and smelting-refining groups in the world, and also would include all the principals' international marketing operations and foreign subsidiaries. The merger was approved by the Government of Australia late in the year. Pasminco represented over one-half of Australia's lead mine capacity, and planned to invest significantly in modernization of its production facilities, including BHAS and Sulphide Corp. plants. The trading arm will be known as Pacific Mining and Smelting Co.

The joint venture, Pancontinental Mining Ltd. (51%) and Outokumpu Oy (of Finland, 49%), announced at yearend that the Thalanga and Lady Loretta Mines in Queensland would be brought on-stream in 1990. The two mines would have a combined capacity to produce about 20,000 tpy of lead by 1991. Initially, high-grade ore from Lady Loretta was expected to be trucked to Thalanga for treatment at a recommissioned plant purchased and shipped during the year from the Teutonic Bore copper mine in Western Australia, which closed in 1986. Aberfoyle announced that in addition to its expansion project at the Hellyer Mine, it was also constructing a mill on-site to be commissioned in early 1989. During 1987 and 1988, ore production from the Hellyer Mine was shipped to a converted tin mill about 40 kilometers away.

MIM Holdings Ltd. (MIM) announced plans to increase production of its Hilton Mine, 20 kilometers north of Mount Isa. The mine operated on a trial basis in 1987 and 1988. MIM planned to install a new concentrator and underground crusher in 1989 and be fully operational in 1990 as production declines at the Mount Isa Mine. Proven reserves at the Hilton Mine were 11 million tons of ore grading 6.7% lead and 9.1% zinc according to MIM's June 1988 fiscal yearend report. Proven reserves of the open pit Mount Isa Mine were 46 million tons of ore grading 5.7% lead and 6.9% zinc. Probable reserves at both mines were estimated to be 38 million tons at 6.4% lead and 9.3% zinc, and 4 million tons at 5.8% lead and 5.5% zinc, respectively. An additional 23 million tons of probable reserves at 6.4% lead and 12.1% zinc has been estimated for the adjacent Hilton North property, where further exploration is in progress.

Both proven and probable reserves are considered to be technically recoverable in Australia, with proven reserves being fully blocked out. MIM properties represented over one-third of the nation's lead mine capacity at yearend. MIM also announced plans to construct a new 60,000 tpy lead smelter of its own advanced design, known as Isasmelt, to be operational in 1991. At the same time MIM plans to reduce output from its existing conventional pyrometallurgical plant, built in 1931, from 180,000 tpy to 140,000 tpy. Total bullion capacity would be 200,000 tpy for the company, matching its mine output.

Brazil

The underground Morro Agudo Mine in Minas Gerais, after several years of delay, reached capacity of 6,500 tpy of lead in concentrates. An additional 8,000 tpy of lead capacity was also brought on-stream from expansions of the underground Boquira and Plumbum mines in Bahia and Paraná, respectively. Cia. Brasileira de Cobre (CBC) announced plans to produce 22,000 tpy of lead by the early 1990's at Cacapava do Sul in Rio Grande. The National Development Bank, BNDES, was planning to privatize CBC in order to encourage investment in the project. Cia. Paraibuna de Metais, a 50% partner in the Morro Agudo Mine, announced that it was adding a lead circuit of 20,000 tpy capacity at its existing electrolytic zinc plant at Juiz de Fora to be fully operational in 1991.

Canada

Production of lead in concentrates decreased significantly in 1988 compared with 1987 owing primarily to the exhaustion of stockpiled ore at the Pine Point Mine, 50% owned by Cominco Ltd., in the Northwest Territories. The mine had closed in midyear 1987, and the mill processed the last of the stockpiled ore in April 1988. Shipments of the stockpiled concentrates were to continue into 1991 to a Cominco-owned smelter in Japan. At yearend, the company was in the process of dismantling the town and rehabilitating the mine site. Mining activities were suspended for about a month due to a strike at the large Faro open pit in the Yukon Territory. Owned by Curragh Resources, Corp., it is Canada's largest single producing lead mine. During the strike, nonunion staff maintained milling operations, at about one-half the normal level, from ore stocks.

New reserves in 1988 reportedly did not make up for all Canadian lead ores mined in 1988, owing primarily to the accelerated exhaustion of the Pine Point Mine. Combined with Cominco's decision to leave larger pillars at its Polaris Mine in the Northwest Territories, the world's most northerly base metals operation, this resulted in a slight lowering of the lead reserves for Canada in 1988. On a more positive note, work progressed on schedule on Cominco's QSL-process replacement smelter at Trail, British Columbia, which was anticipated to come on-stream in late 1989. During the year, Cominco sold a 45% interest in the Polaris Mine and exploration properties to Pine Point Mines Ltd.

The only new lead mine opened during the year was the open-pit Caribou Mine at Bathurst, New Brunswick, which will have a capacity of 14,000 tpy of lead in concentrates by 1989, according to East West Minerals N.L.

Noranda Minerals Inc. announced the only closing during the year, the Mattabi Mine at Ignace, Ontario, operated by Mattabi Mines Ltd. The open-pit-underground operation had been in production since 1972, and was depleted.

Federal Republic of Germany

After 7 years in the permitting process, Berzelius Metallhütten GmbH started construction of a new QSL bath smelter at Stolberg. When fully operational in 1992, the 100,000 tpy capacity plant will replace the company's existing conventional 80,000 tpy plant at Binsfeldhammer, which was originally built in 1846. During the year, one of the Federal Republic's two lead-zinc mines, the Rammelsberg Mine at Gaslar, was permanently closed after almost continuous operation since A.D. 968. A merger with profound international implications in lead and other minerals production was effected at yearend when Preussag AG and Peñarroya S.A. of France became operational as Metaleurop S.A. The new company is Europe's largest lead producer with a production capacity of 250,000 tpy of primary lead and 115,000 tpy of secondary lead.

India

At midyear, the government gave Hindustan Zinc Co. permission to proceed with the first phase of development of the proposed Rampura-Agucha Mine in Rajasthan and ISF smelter at Chanderiya. Phase 1 includes engineering, environmental impact assessment, and initial excavation and ore testing of the open pit. Pending a final investment decision in 1989, the projects would have capacities of 8,000 tpy of lead in concentrates and 35,000 tpy of lead bullion in the early 1990's.

Two other projects known to be under consideration at yearend, and scheduled for operation in the early 1990's, were underground mines at Ambamata in Gujrat, and at Deri in Rajasthan, with planned combined capacity of 8,500 tpy of lead.

Korea, Republic of

Korea Zinc Co. Ltd. announced plans to build a 60,000 tpy lead smelter at Onsan using QSL technology. Lurgi of the Federal Republic of Germany, the engineering subsidiary of Metallgesellschaft, has agreed to provide the license as patentholder, the engineering and design services, and some specialized equipment. The plant is expected to be completed by the end of 1990 and fully on-stream in 1991. Korea Zinc constructed an electrolytic lead refinery on the site in 1986. Young Poong Mining Co. was evaluating a property near Taebaek, 280 kilometers southeast of Seoul, for a possible new mine of up to 25,000 tpy of lead.

Morocco

The state-owned mining company, Bureau de Recherches et de Participations Minières, and the country's largest privately owned company, Omnium Nord Africain, agreed to develop the Douar Lahjar polymetallic deposit in the Guemassa area. The proposed underground mine reportedly has 16 million tons of proven reserves grading 2.8% lead, 9.5% zinc, 0.9% copper, and 74 grams per ton of gold. The mine is expected to come on-stream in 1990 with a capacity of 5,000 tpy of lead in concentrates.

Thailand

The country's first primary lead smelter-refinery, located at Kanchanaburi, was brought on-stream by Thai Lead Metal Co. Ltd. early in the year. Startup had been delayed about a year owing to environmental protests, and improved air filtering and water collection systems were installed. The present capacity is rated at 12,000 tpy, but reported expansion plans to 20,000 tpy may be shelved because of the economics of pollution control. A new underground mine nearby at Bon Gam was opened during the year by the company to produce 6,000 tpy of lead. Three other mines in the area have a total aggregate capacity of about 20,000 tpy of lead.

United Kingdom

Shaft sinking and other work was started at Parys Mountain, Anglesey, North Wales, to develop a new mine to be operational in the early 1990s. Estimated probable capacity would be 12,000 tpy of lead from 400,000 tpy of ore hoisted. Estimated "reserves" are reportedly 5.3 million tons of ore grading 3.03% lead, 6.04% zinc, 1.49% copper, and 62.8 grams per ton of silver. At Darley Dale, Derbyshire, Billiton (U.K.) Ltd. opened a new 60,000 tpy secondary lead plant to replace the one originally built in 1942.

TECHNOLOGY

During 1988, extensive final-stage, commercial-scale, prototype testing was performed by General Motors Corp. (GM) and Chrysler Corp. of electric vehicles (EV's) expected to be marketed in 1989 or 1990 in the United States. Over a 2-year period, GM and the Electric Power Research Institute (EPRI) monitored the reliability of 31 British-built Griffon full-size vans in use by 11 utility companies. Based on the success of the Griffon, the GM-Electric G-Van will be the first modern-day, fully warranted EV to be produced in the United States by a major automobile manufacturer. GM will build the basic van, and an independent contractor will install the mechanics. Chloride EV Systems, a British company, developed the lead-acid battery package and power train. Chrysler's successful Plymouth Voyager/Dodge Caravan minivan is the basic model for the automaker's new electric TE Van to be introduced in late 1989 or early 1990. With the use of advanced technologies such as microprocessor controls and a nickel-iron battery developed by Eagle-Picher Industries Inc., the TE Van is expected to have a top speed of 65 miles per hour and go about 110 miles between charges. On the basis of size and performance, the TE Van is targeted more for general purpose use and the G-Van for the commercial market. However, where there is crossover appeal there could be downstream implications for the competing power systems with respect to overall economics versus performance as energy costs become even more critical.[6]

A comprehensive coverage of lead-related investigations and an extensive review of current world literature on the extraction and uses of lead and its products including batteries, were published in quarterly issues of Leadscan, Lead Development Association, London, United Kingdom.

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] International Lead and Zinc Study Group (London). Lead and Zinc Statistics. ILZSG Mon. Bull., v. 29, No. 10, Oct. 1989, p 18.

[3] Page 31 of work cited in footnote 2.

[4] International Lead and Zinc Study Group (London). Trends in Consumption of Lead and Zinc. Spec. Publ., Apr. 1989, p. 13.

[5] Page 23 of work cited in footnote 4.

[6] Independent Battery Manufacturers Association (IBMA). The Battery Man, v. 30, No. 11, Nov. 1988, pp. 32–33.

TABLE 4

MINE PRODUCTION OF RECOVERABLE LEAD IN THE UNITED STATES, BY STATE

(Metric tons)

State	1984	1985	1986	1987	1988
Arizona	W	581	W	—	W
California	W	—	—	—	—
Colorado	W	W	W	W	W
Idaho	W	33,707	9,951	W	W
Illinois	W	W	W	W	W
Missouri	278,329	371,008	319,900	W	353,194
Montana	W	846	W	W	8,266
Nevada	W	([1])	—	—	W
New Mexico	—	W	10	W	W
New York	W	W	W	W	W
Tennessee	W	W	—	W	W
Utah	W	—	—	—	—
Total	**322,677**	**413,955**	**339,793**	**[r]311,381**	**384,983**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Less than 1/2 unit.

TABLE 5

MINE PRODUCTION OF RECOVERABLE LEAD IN THE UNITED STATES, BY MONTH

(Metric tons)

Month	1987[r]	1988
January	24,288	27,771
February	24,004	28,231
March	27,932	36,080
April	23,725	32,720
May	27,035	30,346
June	26,384	32,540
July	29,088	30,424
August	24,208	36,340
September	28,016	33,157
October	28,286	34,446
November	23,062	31,098
December	25,353	31,830
Total	**311,381**	**384,983**

[r] Revised.

TABLE 6

PRODUCTION OF LEAD AND ZINC, IN TERMS OF RECOVERABLE METAL, IN THE UNITED STATES IN 1988, BY STATE

(Metric tons)

State	Lead ore			Zinc ore			Lead-zinc ore		
	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc
Arizona	—	—	—	—	—	—	—	—	—
Colorado	—	—	—	—	—	—	W	W	W
Idaho	—	—	—	—	—	—	W	W	W
Illinois	—	—	—	—	—	—	—	—	—
Kentucky	—	—	—	—	—	—	—	—	—
Missouri	5,357,059	330,470	40,836	—	—	—	—	—	—
Montana	—	—	—	—	—	—	—	—	—
Nevada	—	—	—	—	—	—	—	—	—
New Mexico	—	—	—	—	—	—	—	—	—
New York	—	—	—	W	W	W	—	—	—
Tennessee	—	—	—	W	W	W	—	—	—
Total	**5,357,059**	**330,470**	**40,836**	**W**	**W**	**W**	**W**	**W**	**W**
Percent of total lead or zinc	XX	86	17	XX	W	W	XX	W	W

State	Copper-lead, copper-zinc, copper-lead-zinc ores			All other sources[1] [2]			Total		
	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc
Arizona	—	—	—	W	W	—	W	W	—
Colorado	—	—	—	223,402	4,464	5,156	W	W	W
Idaho	—	—	—	W	W	—	W	W	W
Illinois	—	—	—	—	W	W	—	W	W
Kentucky	—	—	—	W	—	W	W	—	W
Missouri	616,706	22,724	486	—	—	—	5,973,765	353,194	41,322
Montana	—	—	—	3,639,389	8,266	18,935	3,639,389	8,266	18,935
Nevada	—	—	—	W	W	—	W	W	—
New Mexico	—	—	—	W	W	—	W	W	—
New York	—	—	—	—	—	—	W	W	W
Tennessee	—	—	—	—	—	—	W	W	W
Total	**616,706**	**22,724**	**486**	**W**	**W**	**W**	**23,682,567**	**384,983**	**244,314**
Percent of total lead or zinc	XX	6	([3])	XX	W	W	XX	100	100

W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] Includes lead and zinc recovered from copper, gold, gold-silver, and silver ores, from fluorspar and from mill tailings.

[2] Excludes tonnages of fluorspar in Illinois from which lead and zinc were recovered as byproducts.

[3] Less than 1/2 unit.

TABLE 7

TWENTY-FIVE LEADING LEAD-PRODUCING MINES IN THE UNITED STATES IN 1988, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of lead
1	Buick	Iron, MO	The Doe Run Co.	Lead ore.
2	Magmont	do.	Cominco American Incorporated	Do.
3	Fletcher	Reynolds, MO	The Doe Run Co.	Do.
4	West Fork	do.	ASARCO Incorporated	Do.
5	Viburnum No. 29	Washington, MO	The Doe Run Co.	Do.
6	Casteel	Iron, MO	do.	Copper-lead ore.
7	Sweetwater	Reynolds, MO	ASARCO Incorporated	Lead ore.
8	Viburnum No. 28	Iron, MO	The Doe Run Co.	Do.
9	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Lead-zinc ore.
10	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Gold ore.
11	Leadville Unit	Lake, CO	ASARCO Incorporated	Lead-zinc ore.
12	Sunnyside	San Juan, CO	Alta Gold Co.	Gold ore.
13	Bunker Hill	Shoshone, ID	Bunker Hill Mining Co (U.S.) Inc.	Lead-zinc ore.
14	Balmat	St. Lawrence, NY	Zinc Corporation of America	Zinc ore.
15	Rosiclare	Hardin and Pope, IL	Ozark-Mahoning Co.	Fluorspar.
16	Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Zinc ore.
17	Sunshine	Shoshone, ID	Sunshine Mining Co.	Silver ore.
18	Coeur	do.	ASARCO Incorporated	Do.
19	Black Pine	Granite, MT	Black Pine Mining Co.	Do.
20	Elk Peak	Fergus, MT	Blue Range Mining Co.	Gold ore.
21	Camp Bird	Ouray, CO	Western Mining Corp.	Do.
22	New Market	Jefferson, TN	ASARCO Incorporated	Zinc ore.
23	Mission	Pima, AZ	do.	Copper ore.
24	St. Cloud	Sierra, NM	St. Cloud Mining Co.	Silver ore.
25	Equity Project	Mineral, CO	Homestake Mining Co.	Gold ore.

TABLE 8

REFINED LEAD PRODUCED AT PRIMARY REFINERIES IN THE UNITED STATES, BY SOURCE MATERIAL[1]

(Metric tons unless otherwise specified)

Source material	1984	1985	1986	1987	1988
Refined lead:					
From primary sources:					
Domestic ores and base bullion	323,989	422,650	348,217	336,471	371,348
Foreign ores and base bullion	65,409	71,353	22,071	37,139	20,739
Total	**389,398**	**494,003**	**370,288**	**373,610**	**392,087**
Calculated value of primary refined lead[2] thousands	$219,340	$207,689	$180,004	$296,026	$321,039

[1] Total refined lead: American Bureau of Metal Statistics, Inc. Domestic and foreign ores: Bureau of Mines calculations.
[2] Value based on average quoted price.

TABLE 9

STOCKS AND CONSUMPTION OF NEW AND OLD LEAD SCRAP IN THE UNITED STATES, BY TYPE OF SCRAP

(Metric tons, gross weight)

Type of scrap	Stocks, Jan. 1	Receipts	Consumption New scrap	Consumption Old scrap	Consumption Total	Stocks, Dec. 31
1987						
Smelters, refiners, others:						
Soft lead [1]	1,188	31,910	—	31,243	31,243	1,855
Hard lead	214	5,249	—	4,896	4,896	567
Cable lead	465	2,054	—	1,665	1,665	854
Battery-lead plates	21,502	799,442	—	792,360	792,360	28,584
Mixed common babbitt	133	1,593	—	1,631	1,631	95
Solder and tinny lead	2,395	21,908	—	22,527	22,527	1,776
Type metals	181	1,902	—	1,911	1,911	172
Drosses and residues	5,372	68,407	68,586	—	68,586	5,193
Other	—	2,134	—	2,095	2,095	39
Total [r]	**31,450**	**934,599**	**68,586**	**858,328**	**926,914**	**39,135**
1988						
Smelters, refiners, others:						
Soft lead [1]	1,855	28,548	—	28,721	28,721	1,682
Hard lead	567	5,717	—	6,093	6,093	191
Cable lead	854	3,699	—	3,668	3,668	885
Battery-lead plates	28,584	812,343	—	819,470	819,470	21,457
Mixed common babbitt	95	1,853	—	1,833	1,833	115
Solder and tinny lead	1,776	20,861	—	20,425	20,425	2,212
Type metals	172	1,808	—	1,877	1,877	103
Drosses and residues	5,193	58,225	59,428	—	59,428	3,990
Other	39	1,147	—	1,131	1,131	55
Total	**39,135**	**934,201**	**59,428**	**883,218**	**942,646**	**30,690**

[r] Revised.

[1] Includes remelt lead from cable sheathing plus other soft lead scrap processing.

TABLE 10

SECONDARY METAL RECOVERED[1] FROM LEAD AND TIN SCRAP IN THE UNITED STATES

(Metric tons)

	Lead	Tin	Antimony	Other	Total
1987					
Refined pig lead[2]	r345,073	—	—	—	r345,073
Refined pig tin[3]	—	r1,361	—	—	r1,361
Lead and tin alloys:					
Antimonial lead	r323,311	623	11,205	756	r335,895
Lead-base babbitt	1,132	77	129	2	1,340
Solder	23,152	3,765	171	(4)	27,088
Type metal	r908	66	130	4	r1,108
Other alloys including cable lead	2,229	30	19	—	2,278
Total	**r350,732**	**4,561**	**11,654**	**762**	**r367,709**
Tin content of chemical products	—	W	—	—	W
Grand total	**r695,805**	**r5,922**	**11,654**	**762**	**r714,143**
1988					
Refined pig lead[2]	367,055	—	—	—	367,055
Refined pig tin[3]	—	583	—	—	583
Lead and tin alloys:					
Antimonial lead	331,341	902	13,866	736	346,845
Lead-base babbitt	1,439	112	162	(4)	1,713
Solder	19,487	3,619	141	(4)	23,247
Type metal	973	70	139	(4)	1,182
Other alloys including cable lead	1,852	29	24	—	1,905
Total	**355,092**	**4,732**	**14,332**	**736**	**374,892**
Tin content of chemical products	—	W	—	—	W
Grand total	**722,147**	**5,315**	**14,332**	**736**	**742,530**

r Revised. W Withheld to avoid disclosing company proprietary data.
[1] Most of the figures herein represent actual reported recovery of metal from scrap.
[2] Includes remelt lead.
[3] Includes remelt tin.
[4] Included with "Antimony" to avoid disclosing company proprietary data.

TABLE 11

LEAD RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Metric tons)

	1987r	1988
KIND OF SCRAP		
New scrap:		
Lead-base	49,035	42,013
Copper-base	3,462	e3,600
Tin-base	38	5
Total	**52,535**	**45,618**
Old scrap:		
Battery-lead plates	588,694	623,033
All other lead-base	57,947	56,989
Copper-base	10,891	e11,400
Tin-base	—	—
Total	**657,532**	**691,422**
Grand total	**710,067**	**737,040**
FORM OF RECOVERY		
As soft lead	345,073	367,055
In antimonial lead	323,311	331,341
In other lead alloys	27,292	23,639
In copper-base alloys	14,353	e15,000
In tin-base alloys	38	5
Total	**710,067**	**737,040**
Value[1] thousands	$562,615	$603,485

e Estimated. r Revised.
[1] Value based on average quoted price of common lead.

TABLE 12

U.S. CONSUMPTION OF LEAD, BY PRODUCT

(Metric tons)

SIC Code	Product	1987	1988
	Metal products:		
3482	Ammunition: Shot and bullets	46,835	52,708
	Bearing metals:		
35	Machinery except electrical	393	425
36	Electrical and electronic equipment	173	(1)
371	Motor vehicles and equipment	4,362	5,152
37	Other transportation equipment	[r]332	457
	Total bearing metals	**[r]5,260**	**6,034**
3351	Brass and bronze: Billets and ingots	9,868	9,994
36	Cable covering: Power and communication	20,140	16,170
15	Calking lead: Building construction	1,893	1,618
	Casting metals:		
36	Electrical machinery and equipment	970	1,290
371	Motor vehicles and equipment	(2)	(2)
37	Other transportation equipment	14,299	13,474
3443	Nuclear radiation shielding	[r]4,640	1,065
	Total casting metals	**[r]19,909**	**15,829**
	Pipes, traps, other extruded products:		
15	Building construction	11,532	11,193
3443	Storage tanks, process vessels, etc.	(3)	(3)
	Total pipes, traps, other extruded products	**11,532**	**11,193**
	Sheet lead:		
15	Building construction	13,746	14,009
3443	Storage tanks, process vessels, etc.	(4)	(4)
3693	Medical radiation shielding	3,654	3,449
	Total sheet lead	**17,400**	**17,458**
	Solder:		
15	Building construction	3,946	3,985
341	Metal cans and shipping containers	1,027	848
367	Electronic components and accessories	4,654	4,824
36	Other electrical machinery and equipment	2,658	3,052
371	Motor vehicles and equipment	7,473	6,355
	Total solder	**19,758**	**19,064**
	Storage batteries:		
3691	Storage battery grids, post, etc.	529,362	506,758
3691	Storage battery oxides	424,236	448,505
	Total storage batteries	**953,598**	**955,263**
371	Terne metal: Motor vehicles and equipment	2,286	2,324
27	Type metal: Printing and allied industries	(5)	(5)
34	Other metal products[6]	[r]4,833	5,290
	Total metal products	**[r]1,113,312**	**1,112,945**

See footnotes at end of table.

TABLE 12—Continued

U.S. CONSUMPTION OF LEAD, BY PRODUCT

(Metric tons)

SIC Code	Product	1987	1988
	Other oxides:		
285	Paints	W	W
32	Glass and ceramics products	W	W
28	Other pigments and chemicals	W	W
	Total other oxides	**68,094**	**62,524**
2911	Gasoline additives	(7)	(7)
	Miscellaneous uses	r48,967	55,263
	Grand total	**r1,230,373**	**1,230,732**

r Revised. W Withheld to avoid disclosing company proprietary data; included in "Total other oxides."
[1] Included with "Other transportation equipment" to avoid disclosing company proprietary data.
[2] Included with "Other transportation equipment" to avoid disclosing company proprietary data.
[3] Included with "Building construction" to avoid disclosing company proprietary data.
[4] Included with "Building construction" to avoid disclosing company proprietary data.
[5] Included with "Other metal products" to avoid disclosing company proprietary data.
[6] Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, and fishing weights.
[7] Included with "Miscellaneous uses" to avoid disclosing company proprietary data.

TABLE 13

U.S. CONSUMPTION OF LEAD, BY MONTH[1]

(Metric tons)

Month	1987r	1988
January	96,518	99,785
February	91,068	101,399
March	103,011	116,000
April	100,967	99,328
May	101,367	103,957
June	103,459	103,625
July	97,363	92,114
August	103,164	102,456
September	108,513	103,009
October	119,086	110,617
November	105,798	103,385
December	100,059	95,057
Total[2]	**1,230,373**	**1,230,732**

r Revised.
[1] Monthly totals include monthly reported consumption plus the prorated monthly distribution for companies that report on an annual basis only.
[2] Includes lead that went directly from scrap to fabricated products.

TABLE 14

U.S. CONSUMPTION OF LEAD IN 1988, BY STATE[1]

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	49,649	37,747	9,794	—	97,190
Connecticut	2,327	4,762	—	—	7,089
Florida	9,682	7,108	1,165	—	17,955
Georgia	15,638	16,763	546	—	32,947
Illinois	27,104	43,648	2,474	942	74,168
Indiana	208,891	27,999	9,885	616	247,391
Kansas	17,521	9,101	8,260	—	34,882
Kentucky	11,584	13,324	3,425	—	28,333
Maryland	104	—	—	—	104
Massachusetts	237	96	73	49	455
Michigan	15,505	10,663	585	—	26,753
Missouri	11,087	16,040	—	—	27,127
New Jersey	45,356	93	2,066	256	47,771
New York	16,788	5,900	9,296	—	31,984
Ohio	14,951	16,225	4,331	255	35,762
Pennsylvania	97,061	33,779	30,290	1,568	162,698
Tennessee	4,231	9,911	2,533	—	16,675
Alabama and Mississippi	12,128	1,009	431	2,563	16,131
Arkansas and Oklahoma	1,709	322	135	—	2,166
Colorado and Nebraska	201	50	251	666	1,168
District of Columbia, Virginia, West Virginia	38	535	2,242	—	2,815
Hawaii and Oregon	5,487	7,432	1,021	—	13,940
Idaho, Montana, Washington	14,097	534	—	—	14,631
Iowa and Minnesota	22,691	20,027	15,285	—	58,003
Louisiana and Texas	96,249	20,725	4,545	—	121,519
New Hampshire, Maine, Vermont, Delaware	14,783	12,411	—	22	27,216
North Carolina and South Carolina	43,678	27,179	8,534	—	79,391
Rhode Island and Wisconsin	3,651	304	35	43	4,033
Utah, Nevada, Arizona	333	63	39	—	435
Total	**762,761**	**343,750**	**117,241**	**6,980**	**1,230,732**

[1] Includes lead that went directly from scrap to fabricated products.

TABLE 15

U.S. CONSUMPTION OF LEAD IN 1988, BY CLASS OF PRODUCT[1]

(Metric tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	63,934	62,503	24,265	6,980	157,682
Storage batteries	593,893	280,020	81,350	—	955,263
Other oxides	62,524	—	—	—	62,524
Gasoline additives	W	—	—	—	W
Miscellaneous	42,410	1,227	11,626	—	55,263
Total	**762,761**	**343,750**	**117,241**	**6,980**	**1,230,732**

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1] Includes lead that went directly from scrap to fabricated products.

TABLE 16

PRODUCTION AND SHIPMENTS OF LEAD PIGMENTS[1] AND OXIDES IN THE UNITED STATES

(Metric tons unless otherwise specified)

Product	1987				1988			
	Production		Shipments		Production		Shipments	
	Gross weight	Lead content	Quantity	Value[2]	Gross weight	Lead content	Quantity	Value[2]
White lead, dry	W	W	W	W	W	W	W	W
Litharge and red lead	79,252	73,414	80,568	$72,292,620	83,719	77,747	84,065	$91,828,401
Leady oxide	436,688	414,855	NA	NA	460,937	437,890	NA	NA
Total	**515,940**	**488,269**	**NA**	**NA**	**544,656**	**515,637**	**NA**	**NA**

NA Not available. W Withheld to avoid disclosing company proprietary data.
[1] Excludes basic lead sulfate; withheld to avoid disclosing company proprietary data.
[2] At plant, exclusive of container.

TABLE 17

U.S. IMPORTS FOR CONSUMPTION OF LEAD PIGMENTS AND COMPOUNDS, BY KIND

Kind	1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
White lead	644	$939	219	$297
Red lead	703	626	804	756
Litharge	14,263	10,290	11,494	8,325
Chrome yellow	3,354	5,573	3,999	7,720
Other lead pigments	445	1,286	1,202	2,830
Other lead compounds	1,804	2,431	1,724	2,363
Total	**21,213**	**21,145**	**19,442**	**22,291**

Source: Bureau of the Census.

TABLE 18

STOCKS OF LEAD AT CONSUMERS AND SECONDARY SMELTERS IN THE UNITED STATES, DECEMBER 31

(Metric tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1984	53,802	37,015	5,326	934	97,077
1985	50,475	36,374	5,770	511	93,130
1986	47,589	30,442	5,524	269	83,824
1987	55,278	27,959	5,185	164	88,586
1988	50,850	34,071	4,756	151	89,828

TABLE 19

AVERAGE MONTHLY AND ANNUAL QUOTED PRICES OF LEAD[1]

(Cents per pound)

Month	1987		1988	
	North American primary producer mean	London Metal Exchange	North American primary producer mean	London Metal Exchange
January	27.88	21.02	38.00	30.21
February	26.04	20.86	34.85	29.71
March	26.00	22.07	34.00	29.39
April	27.84	25.17	34.00	29.41
May	34.95	31.40	34.57	30.27
June	36.93	28.51	36.30	30.68
July	41.67	30.06	36.50	28.06
August	42.00	29.88	36.52	27.25
September	42.00	29.31	38.41	27.63
October	42.00	27.25	39.15	29.68
November	42.00	29.10	41.38	31.33
December	42.00	29.86	42.02	33.12
Average	35.94	26.99	37.14	29.73

[1] Metals Week. Quotations for the United States on a nationwide, delivered basis. LME cash average.

TABLE 20

U.S. EXPORTS OF LEAD, BY COUNTRY

Country	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Ore and concentrates (lead content):				
Australia	187	$100	23	$9
Belgium-Luxembourg [1]	36	16	1,035	445
Canada	793	240	5,735	2,308
Germany, Federal Republic of	—	—	332	100
India	8	5	99	41
Japan	1,800	958	6,609	4,694
Korea, Republic of	—	—	370	144
Mexico	5,326	1,597	72	21
Mozambique	90	83	—	—
Netherlands	—	—	711	287
Spain	—	—	1,224	577
Taiwan	466	291	3,557	1,523
United Kingdom	—	—	741	336
Venezuela	18	10	27	8
Other	40	33	367	185
Total	**8,764**	**3,333**	**20,902**	**10,678**
Drosses and residues including flue dust (lead content):				
Austria	40	46	16	41
Belgium-Luxembourg [1]	54	620	14,637	7,892
Canada	2,642	874	314	225
France	18	200	19	204
Germany, Federal Republic of	35	18	34	50
Hong Kong	—	—	20	23
Japan	—	—	17	20
Mexico	11	4	4	12
Thailand	151	54	—	—
United Kingdom	519	773	418	318
Other	—	—	4	23
Total	**3,470**	**2,589**	**15,483**	**8,808**
Unwrought lead and lead alloys (lead content):				
Australia	73	78	202	222
Belgium-Luxembourg [1]	55	207	5	10
Canada	526	706	2,365	2,286
Chile	76	98	132	165
Dominican Republic	111	122	88	89
Germany, Federal Republic of	2	4	64	345
Haiti	—	—	10	13
Honduras	20	19	22	26
Indonesia	17	17	—	—
Israel	15	12	478	377

See footnote at end of table.

TABLE 20—Continued

U.S. EXPORTS OF LEAD, BY COUNTRY

Country	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Italy	7	$13	61	$147
Japan	69	80	99	123
Korea, Republic of	1,267	1,166	1,043	850
Liberia	18	16	—	—
Malta	1	2	54	65
Mexico	347	694	1,103	1,743
Netherlands	—	—	14	12
Panama	17	39	1	2
Philippines	25	59	18	26
Saudi Arabia	—	—	22	76
Singapore	83	117	77	48
South Africa, Republic of	16	86	73	79
Sudan	—	—	608	549
Taiwan	959	737	886	600
Trinidad	451	363	5	20
United Kingdom	146	138	31	36
Venezuela	4	15	7	33
Other	r46	r134	78	147
Total	**4,351**	**4,922**	**7,546**	**8,089**
Wrought lead and lead alloys (lead content):				
Argentina	11	13	(2)	2
Australia	18	41	—	—
Brazil	2	17	—	—
Canada	4,374	3,413	2,734	2,178
Chile	—	—	10	45
Dominican Republic	34	46	30	38
France	62	115	77	179
Germany, Federal Republic of	4	64	4	14
Guatemala	(2)	2	7	7
Haiti	12	108	7	61
Honduras	6	18	3	8
Hong Kong	1	29	6	37
Ireland	6	8	(2)	2
Israel	16	73	8	11
Italy	6	7	8	11
Jamaica	77	98	49	59
Japan	48	49	174	260
Korea, Republic of	2	6	78	190
Mexico	1,005	2,643	2,533	3,899
Netherlands	18	19	71	116
Panama	8	14	(2)	2
Paraguay	—	—	23	35

See footnotes at end of table.

TABLE 20—Continued

U.S. EXPORTS OF LEAD, BY COUNTRY

Country	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Philippines	(2)	$2	121	$240
Singapore	3	25	7	41
Taiwan	8	36	1	15
United Kingdom	8	21	23	19
Venezuela	13	21	60	288
Other	r23	r135	14	73
Total	**5,765**	**7,023**	**6,048**	**7,830**
Grand total	**22,350**	**17,867**	**49,979**	**35,405**
Scrap (gross weight):				
Austria	183	40	—	—
Belgium-Luxembourg[1]	659	110	107	31
Brazil	7,289	2,183	16,112	4,171
Canada	9,337	2,903	12,480	3,900
China	—	—	398	89
Colombia	451	87	—	—
France	—	—	160	35
Germany, Federal Republic of	1,469	431	2,788	579
India	617	184	2,417	687
Ireland	—	—	266	154
Israel	—	—	820	614
Italy	41	9	28	6
Japan	82	196	120	290
Korea, Republic of	4,507	1,032	3,198	960
Mexico	5,667	1,360	11,112	2,221
Netherlands	125	56	391	108
Pakistan	263	69	—	—
Philippines	—	—	99	24
South Africa, Republic of	204	45	2,692	962
Spain	1,268	225	4,720	1,116
Taiwan	8,953	1,669	10,036	2,446
Thailand	—	—	65	8
United Arab Emirates	800	205	98	24
United Kingdom	5,618	3,832	6,731	2,719
Venezuela	5,260	1,025	6,972	2,034
Other	30	9	100	34
Total	**52,823**	**15,670**	**81,910**	**23,212**

r Revised.

[1] For 1987 Belgium and Luxembourg combined, data not available to separate: 1988 data for Belgium only.

[2] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 21

U.S. EXPORTS OF LEAD[1]

Year	Blocks, pigs, anodes, etc.				Wrought lead and lead alloys				Scrap (gross weight)		Drosses, etc.	
	Unwrought[2]		Unwrought alloys		Sheets, plates, rods, other forms		Foil, powder, flakes					
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	8,869	$6,036	2,321	$3,546	1,200	$4,183	211	$232	58,998	$14,921	7,177	$4,872
1987	3,367	3,181	984	1,741	5,686	6,910	79	113	52,823	15,670	3,470	2,589
1988	6,413	6,196	1,133	1,893	5,848	7,582	200	248	81,910	23,212	15,483	8,808

[1] Lead content, unless otherwise specified.
[2] Includes bullion.

Source: Bureau of the Census.

TABLE 22

U.S. IMPORTS[1] OF LEAD, BY COUNTRY

(Lead content)

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Ore and concentrate:[2]						
Australia	11,497	$2,246	1,724	$456	1,431	$631
Bolivia	—	—	—	—	377	191
Canada	62,900	7,325	201,165	50,683	221,785	72,976
Chile	3,106	914	3,231	985	3	1
China	—	—	3,568	2,203	—	—
Mexico	827	287	1,070	628	—	—
Peru	8,417	1,174	19,098	10,309	11,436	6,077
Total	**86,747**	**11,946**	**229,856**	**65,264**	**235,032**	**79,876**
Base bullion:						
Belgium-Luxembourg[3]	—	—	1,414	955	999	737
Canada	121	67	—	—	50	33
France	—	—	1,699	1,136	249	170
Germany, Federal Republic of	—	—	350	258	—	—
Italy	—	—	1,250	904	—	—
Japan	—	—	1,800	1,165	—	—
Korea, Republic of	—	—	17	10	76	49
Mexico	21	47	881	278	1,213	779
Morocco	—	—	—	—	376	267
Netherlands	—	—	1,749	1,276	—	—
Peru	—	—	—	—	501	354
Spain	—	—	1,200	886	—	—
Sweden	—	—	—	—	2,002	1,498
United Kingdom	—	—	401	284	999	660
Other	—	—	r66	r87	84	48
Total	**142**	**114**	**10,827**	**7,239**	**6,549**	**4,595**
Pigs and bars:						
Australia	—	—	63	37	6,719	3,981
Belgium-Luxembourg[3]	([4])	1	4,950	3,299	499	310
Canada	105,281	44,080	92,643	61,384	104,815	77,207
China	77	31	574	357	653	403
France	—	—	3,193	2,102	299	94
Germany, Federal Republic of	496	658	8,824	5,755	1,212	1,446
Italy	—	—	1,800	1,232	1,800	1,139
Japan	1	2	906	704	—	—
Macao	—	—	403	298	—	—
Mexico	29,532	11,617	42,635	28,457	30,937	21,580
Morocco	—	—	1,500	1,001	—	—
Mozambique	—	—	87	66	—	—
Netherlands	—	—	6,317	3,939	—	—

See footnotes at end of table.

TABLE 22—Continued

U.S. IMPORTS[1] OF LEAD, BY COUNTRY

(Lead content)

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Panama	47	$19	—	—	—	—
Peru	1,053	449	350	$189	—	—
Poland	—	—	2,500	1,535	—	—
Spain	—	—	5,999	3,887	—	—
Sweden	2,773	1,055	9,086	5,887	—	—
Switzerland	20	11	201	141	58	$40
U.S.S.R.	262	96	—	—	—	—
United Kingdom	679	1,153	4,039	3,180	88	161
Yugoslavia	—	—	1,020	634	—	—
Zambia	—	—	903	612	—	—
Other	—	—	83	146	44	68
Total	**140,221**	**59,172**	**188,076**	**124,842**	**147,124**	**106,429**
Reclaimed scrap, including drosses:[5]						
Canada	1,444	383	3,062	1,600	2,854	1,230
Costa Rica	—	—	2	1	52	28
Hong Kong	—	—	48	31	—	—
Japan	—	—	323	185	16	90
Malaysia	—	—	38	23	—	—
Mexico	1,831	1,060	3,034	1,230	4,202	1,845
Netherlands Antilles	—	—	—	—	22	3
Panama	—	—	44	23	92	53
Philippines	—	—	17	10	—	—
United Arab Emirates	—	—	—	—	25	78
Other	15	28	r19	r25	26	12
Total	**3,290**	**1,471**	**6,587**	**3,128**	**7,289**	**3,339**
Grand total	**230,400**	**72,703**	**435,346**	**200,473**	**395,994**	**194,239**

r Revised.
1 Data are "general imports;" that is, they include lead imported for immediate consumption plus material entering the country under bond.
2 Also includes other lead-bearing materials containing greater than 5 troy ounces of gold per short ton, or greater than 100 troy ounces of total precious metals per short ton.
3 For 1986 and 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
4 Less than 1/2 unit.
5 Also includes other lead-bearing materials containing greater than 10% by weight of copper, lead, or zinc (any one).

Source: Bureau of the Census.

TABLE 23

U.S. IMPORTS FOR CONSUMPTION OF LEAD, BY COUNTRY

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Ore and concentrates (lead content):[1]						
Australia	1,725	$380	—	—	6,656	$3,508
Canada	—	—	696	$231	8,171	3,995
Chile	2,052	677	—	—	—	—
Honduras	—	—	—	—	1,396	1,016
Mexico	827	287	177	77	—	—
Peru	—	—	—	—	4,383	2,705
Total	**4,604**	**1,344**	**873**	**308**	**20,606**	**11,224**
Base bullion (lead content):						
Belgium-Luxembourg[2]	—	—	1,414	955	999	737
Canada	121	67	—	—	50	33
France	—	—	1,699	1,136	249	170
Germany, Federal Republic of	—	—	350	258	—	—
Italy	—	—	1,250	904	—	—
Japan	—	—	1,800	1,165	—	—
Korea, Republic of	—	—	—	—	76	49
Mexico	21	47	881	278	1,213	779
Morocco	—	—	—	—	376	267
Netherlands	—	—	1,749	1,276	—	—
Spain	—	—	1,200	886	—	—
United Kingdom	—	—	401	284	999	660
Other	—	—	83	97	84	48
Total	**142**	**114**	**10,827**	**7,239**	**4,046**	**2,743**
Pigs and bars (lead content):						
Australia	—	—	63	37	6,719	3,981
Belgium-Luxembourg[2]	—	—	4,950	3,299	499	310
Canada	105,281	44,080	92,643	61,384	104,815	77,207
China	77	31	574	357	653	403
France	—	—	3,193	2,102	299	94
Germany, Federal Republic of	496	658	7,325	4,682	2,713	2,519
Italy	—	—	1,800	1,232	1,800	1,139
Japan	1	2	906	704	—	—
Macao	—	—	403	298	—	—
Mexico	29,532	11,617	42,635	28,457	30,916	21,562
Morocco	—	—	1,500	1,001	—	—
Mozambique	—	—	87	66	—	—
Netherlands	—	—	6,317	3,939	—	—
Peru	1,053	449	350	189	—	—
Poland	—	—	2,500	1,535	—	—
Spain	—	—	5,999	3,887	—	—
Sweden	2,773	1,055	9,086	5,887	—	—
Switzerland	21	11	201	141	58	40

See footnotes at end of table.

TABLE 23—Continued

U.S. IMPORTS FOR CONSUMPTION OF LEAD, BY COUNTRY

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
United Kingdom	679	$1,153	4,039	$3,180	88	$161
U.S.S.R.	262	96	—	—	—	—
Yugoslavia	—	—	1,020	634	—	—
Other	46	20	82	146	44	68
Total	**140,221**	**59,172**	**185,673**	**123,157**	**148,604**	**107,484**
Reclaimed scrap, etc. (lead content):[3]						
Canada	1,444	383	3,062	1,600	2,854	1,230
Costa Rica	—	—	2	1	52	28
Hong Kong	—	—	48	31	—	—
Japan	—	—	323	185	16	90
Malaysia	—	—	38	23	—	—
Mexico	1,831	1,060	3,034	1,230	4,202	1,845
Netherlands Antilles	—	—	—	—	22	3
Panama	—	—	44	23	92	53
Philippines	—	—	17	10	—	—
United Arab Emirates	—	—	—	—	25	78
Other	15	28	r19	r25	26	12
Total	**3,290**	**1,471**	**6,587**	**3,128**	**7,289**	**3,339**
Grand total	**148,257**	**62,101**	**203,960**	**133,832**	**180,545**	**124,790**
Sheets, pipe, shot, other forms (gross weight):						
Belgium-Luxembourg[2]	454	418	18	38	32	65
Canada	299	293	352	414	283	472
Germany, Federal Republic of	132	422	256	827	199	494
Italy	18	40	55	110	39	87
Japan	20	241	128	2,338	3	76
Mexico	43	22	180	121	2,285	1,280
Peru	100	45	622	360	40	28
Spain	13	11	118	140	45	101
United Kingdom	228	255	1,047	895	478	586
Other	r37	r78	17	58	41	91
Total	**1,344**	**1,825**	**2,793**	**5,301**	**3,445**	**3,280**

r Revised.
[1] Also includes other lead-bearing materials containing greater than 5 troy ounces of gold per short ton, or greater than 100 troy ounces of total precious metals per short ton.
[2] For 1986 and 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
[3] Also includes other lead-bearing materials containing greater than 10% by weight of copper, lead, or zinc (any one).

Source: Bureau of the Census.

TABLE 24

U.S. IMPORTS FOR CONSUMPTION OF LEAD[1]

Year	Blocks, pigs, anodes, etc.[2]				Wrought lead and lead alloys (gross weight)				Scrap		Drosses, etc.	
	Unwrought		Unwrought alloys		Sheets, plates, rods, other forms		Foil, powder, flakes					
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	124,061	$50,279	16,302	$9,007	1,165	$1,526	179	$299	2,269	$1,306	1,021	$165
1987	182,852	119,444	13,648	10,952	2,483	2,768	310	2,533	6,088	2,805	499	323
1988	137,598	97,565	15,052	12,662	3,331	3,101	114	179	6,938	3,094	351	245

[1] Lead content, unless otherwise specified.
[2] Includes bullion.

Source: Bureau of the Census.

TABLE 25

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS PRODUCTS CONTAINING LEAD[1]

Year	Gross weight (metric tons)	Lead content (metric tons)	Value (thousands)
1985	3,377	1,453	$22,124
1986	1,016	517	3,810
1987	970	515	4,185
1988	1,623	992	8,838

[1] Babbitt metal, solder, white metal, and other lead-containing combinations.

Source: Bureau of the Census.

TABLE 26

LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY[1]

(Thousand metric tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria[e]	4.0	3.8	3.6	3.6	3.6
Argentina	28.5	28.6	26.9	26.1	26.0
Australia	440.6	498.0	447.7	489.1	475.0
Austria	4.2	7.5	5.9	6.6	5.0
Bolivia	7.4	6.2	3.1	9.0	[3]12.5
Brazil	16.7	19.2	[e]19.5	[e]14.9	13.2
Bulgaria[e]	95.0	95.0	95.0	97.0	97.0
Burma	21.9	21.9	18.2	27.1	25.0
Canada	264.3	268.3	349.3	413.7	[3]368.4
Chile	4.3	2.5	1.5	.8	1.0
China	[e]180.0	[e]200.0	227.0	252.0	300.0
Colombia	.1	.1	.2	.2	—
Congo (Brazzaville)	1.7	1.5	[e]1.4	1.4	1.4
Czechoslovakia	3.1	2.7	2.9	[r e]2.8	2.8
Ecuador[e]	[3].2	.2	.2	.2	.2
Finland	2.5	2.4	2.0	[e]2.2	4.9
France	2.3	2.5	2.5	2.2	2.5
Germany, Federal Republic of	21.0	20.5	16.7	18.8	[3]14.3
Greece	22.2	19.8	20.9	20.6	20.0
Greenland	17.7	17.8	16.2	20.5	[3]23.1
Honduras	20.5	21.2	12.6	5.0	[3]11.2
Hungary[e]	.7	.7	([4])	([4])	—
India	24.8	27.1	37.6	36.7	[3]30.5
Iran[e]	[3]19.9	[3]21.6	21.6	21.6	21.6
Ireland	37.2	34.6	36.4	33.8	36.0
Italy	20.8	15.6	11.1	12.2	13.0
Japan	48.7	50.0	40.3	27.9	[3]22.7
Kenya[e]	2.0	2.0	2.0	2.0	2.0
Korea, North[e]	110.0	110.0	110.0	110.0	110.0
Korea, Republic of	10.8	9.7	11.9	14.0	[3]13.7
Mexico	202.6	197.5	195.4	177.2	[3]170.2
Morocco	100.7	106.8	76.2	75.7	[3]72.2
Namibia	33.3	34.6	37.5	33.0	37.2
Nigeria[e]	.3	.3	.1	[3].1	.1
Norway	4.0	3.6	3.4	[r e]3.1	3.1
Peru	193.7	201.5	194.4	204.0	[3]149.0
Poland	52.8	51.3	42.5	48.8	50.0
Romania[e]	30.0	28.0	28.0	28.0	26.0
South Africa, Republic of	94.8	98.4	97.8	93.6	[3]91.3
Spain	96.6	85.6	79.6	83.2	86.0
Sweden	82.8	80.6	[e]90.0	[e]90.0	91.0

See footnotes at end of table.

TABLE 26—Continued

LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY[1]

(Thousand metric tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Thailand	16.7	19.7	26.3	23.5	[3]29.5
Tunisia	4.1	2.5	1.9	3.5	3.5
Turkey[e]	[r]14.6	10.0	[r]10.4	10.0	12.0
U.S.S.R.[e]	440.0	440.0	440.0	440.0	440.0
United Kingdom	2.4	4.0	3.6	[e]3.6	.6
United States	334.5	424.4	353.1	318.7	[3]394.0
Yugoslavia	113.6	[e]115.1	114.6	106.7	100.0
Zambia	18.1	15.0	14.9	14.5	14.0
Total[5]	**[r]3,268.7**	**[r]3,429.7**	**3,353.7**	**3,429.2**	**3,426.3**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 19, 1989.
[2]In addition to the countries listed, Uganda may produce lead, but available information is inadequate to make reliable estimates of output levels.
[3]Reported figure.
[4]Revised to zero.
[5]Data may not add to totals shown because of independent rounding.

TABLE 27

LEAD: WORLD SMELTER PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina:					
Primary (refined)	16.3	15.1	15.7	16.2	16.0
Secondary (refined)	15.0	13.6	15.0	16.0	16.0
Total	**31.3**	**28.7**	**30.7**	**32.2**	**32.0**
Australia:					
Primary:					
Bullion for export	179.5	183.2	188.4	197.2	[2]191.2
Refined	198.8	200.1	156.2	201.7	[2]162.7
Secondary (refined)[e]	21.5	15.6	14.8	[r]15.0	15.0
Total[e 3]	**399.8**	**398.9**	**359.4**	**[r]413.8**	**368.9**
Austria:					
Primary	1.7	1.9	1.5	3.4	3.0
Secondary	16.5	15.6	15.0	15.7	16.0
Total	**18.2**	**17.5**	**16.5**	**19.1**	**19.0**
Belgium:					
Primary[e 4]	71.5	58.0	[r]48.1	[r]59.4	64.1
Secondary[5]	30.0	[r]30.0	26.0	18.5	15.0
Total	**101.5**	**[r]88.0**	**74.1**	**77.9**	**79.1**
Bolivia: Primary (refined)	.2	.2	.2	.2	.4
Brazil:					
Primary (refined)	26.0	29.8	32.7	29.8	30.0
Secondary (refined)	45.7	51.8	52.0	58.4	55.0
Total	**71.7**	**81.6**	**84.7**	**88.2**	**85.0**
Bulgaria:[e]					
Primary	112.0	112.0	110.0	110.0	105.0
Secondary[5]	4.0	4.0	5.0	5.0	5.0
Total	**116.0**	**116.0**	**115.0**	**115.0**	**110.0**
Burma: Primary (refined)	7.0	9.6	5.4	4.0	[2]4.4
Canada:					
Primary (refined)	173.0	173.2	169.9	139.5	[2]179.4
Secondary (refined)	79.0	68.4	87.7	91.2	[2]89.9
Total	**252.0**	**241.6**	**257.6**	**230.7**	**[2]269.3**
China:[e]					
Primary (refined)	165.0	170.0	200.0	200.0	200.0
Secondary (refined)	30.0	40.0	40.0	40.0	45.0
Total	**195.0**	**210.0**	**[2]240.0**	**240.0**	**245.0**
Colombia: Secondary (refined)[e]	3.0	3.0	4.0	4.0	4.0
Cyprus: Secondary (refined)[e]	2.5	2.0	2.0	2.0	2.0
Czechoslovakia: Secondary (refined)	21.1	21.4	23.6	26.0	24.0
Denmark: Secondary (refined)	13.0	4.5	.6	—	—
Finland: Secondary (refined)	4.5	4.4	1.2	[e]1.2	2.0
France:					
Primary (refined)	117.9	133.6	132.0	138.8	148.0
Secondary	13.5	12.2	[e]12.5	[e]12.3	15.0
Total	**131.4**	**145.8**	**[e]144.5**	**[r e]151.1**	**163.0**

See footnotes at end of table.

TABLE 27—Continued

LEAD: WORLD SMELTER PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
German Democratic Republic: Secondary[e]	22.0	20.0	20.0	18.0	20.0
Germany, Federal Republic of:					
Primary	102.3	109.7	111.1	113.6	[2]126.4
Secondary	254.9	246.6	255.5	226.8	218.3
Total	**357.2**	**356.3**	**366.6**	**340.4**	**[2]344.7**
Greece: Primary (refined)	—	[r]13.7	14.3	2.7	5.0
Guatemala: Secondary (refined)	.1	.1	.1	.1	[2].1
Hungary: Secondary (refined)[e]	.1	.1	.1	.1	.1
India:					
Primary (refined)	15.2	15.6	19.9	20.7	[2]18.8
Secondary (refined)	[e]10.0	[e]10.0	11.3	12.1	[2]14.0
Total	**[e]25.2**	**[e]25.6**	**31.2**	**32.8**	**[2]32.8**
Ireland: Secondary (refined)	9.1	9.0	10.2	9.6	10.0
Italy:					
Primary (refined)	37.6	29.5	29.3	[e]66.0	40.0
Secondary (refined)	102.9	96.7	101.7	[e]94.0	90.0
Total	**140.5**	**126.2**	**131.0**	**[e]160.0**	**130.0**
Jamaica: Secondary (refined)[e]	1.0	1.0	1.0	1.0	1.0
Japan:					
Primary	207.9	218.3	220.4	224.6	[2]223.3
Secondary (refined)	129.2	133.3	128.7	119.7	[2]122.3
Total[3]	**337.1**	**351.6**	**349.1**	**344.3**	**[2]345.5**
Kenya: Secondary (refined)	2.0	2.0	5.0	5.0	[2]5.0
Korea, North: Primary (refined)[e]	95.0	95.0	95.0	95.0	95.0
Korea, Republic of:[e]					
Primary (refined)	11.4	11.0	32.1	[r]52.5	50.1
Secondary (refined)	8.9	9.2	27.5	[r]30.0	30.0
Total	**20.3**	**20.2**	**59.6**	**[r]82.5**	**80.1**
Malaysia: Secondary (refined)	10.3	[r]11.4	13.8	10.3	11.0
Mexico:					
Primary	174.8	203.0	182.0	177.0	170.0
Secondary (refined)[e]	30.0	31.0	33.0	[2]35.0	35.0
Total[e]	**204.8**	**234.0**	**[r]215.0**	**[2]212.0**	**205.0**
Morocco:					
Primary (refined)	46.1	59.5	[e]60.0	[e]62.5	[2]68.4
Secondary (refined)[e]	2.0	2.0	2.0	2.0	2.0
Total[e]	**48.1**	**61.5**	**62.0**	**64.5**	**70.4**
Namibia: Primary (refined)	28.9	38.5	40.0	40.6	38.2
Netherlands: Secondary (refined)[e]	25.0	25.0	[r]33.0	[r]35.7	40.0
New Zealand: Secondary (refined)[e]	6.0	6.0	[r]4.0	[2]3.6	3.0
Nigeria: Secondary	.6	.8	1.0	.3	.5
Peru:					
Primary (refined)	70.2	[r]81.9	66.4	71.3	53.6
Secondary (refined)[e]	5.0	5.0	5.0	5.0	5.0
Total[e]	**75.2**	**[r]86.9**	**71.4**	**[r]76.3**	**58.6**

See footnotes at end of table.

TABLE 27—Continued

LEAD: WORLD SMELTER PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Philippines: Secondary (refined)	4.0	7.0	7.0	[e]7.0	7.0
Poland:					
Primary (refined)[e]	58.4	61.1	63.3	[r]64.5	60.0
Secondary (refined)[e 5]	25.0	26.2	25.0	25.0	25.0
Total	**83.4**	**87.3**	**88.3**	**[r e]89.5**	**85.0**
Portugal: Secondary (refined)	6.0	7.0	[e]6.5	[e]6.5	6.0
Romania:					
Primary (refined)[e]	35.9	38.6	36.0	[2]33.2	30.0
Secondary (refined)[e]	10.0	10.0	15.5	10.0	10.0
Total	**45.9**	**48.6**	**51.5**	**43.2**	**40.0**
South Africa, Republic of: Secondary (refined)	30.8	32.8	40.5	38.3	[2]37.4
Spain:					
Primary (refined)[4]	110.1	112.8	88.0	[e]77.0	80.0
Secondary (refined)	49.9	43.3	42.0	[e]40.0	40.0
Total	**160.0**	**156.1**	**130.0**	**[e]117.0**	**120.0**
Sweden:					
Primary	65.6	58.8	55.7	62.7	63.5
Secondary	27.7	25.9	27.8	30.2	32.0
Total	**93.3**	**84.7**	**83.5**	**92.9**	**95.5**
Switzerland: Secondary (refined)	2.0	2.0	2.0	2.0	2.0
Taiwan: Secondary (refined)[e]	44.3	44.4	53.5	54.0	68.0
Thailand: Secondary (refined)	6.2	7.5	9.1	11.4	[2]15.6
Trinidad and Tobago: Secondary (refined)[e]	2.0	2.0	2.0	1.8	1.8
Tunisia:					
Primary (refined)	8.4	2.0	2.2	[e]2.2	2.2
Secondary (refined)[e]	.5	.5	.5	.5	.5
Total[e]	**8.9**	**2.5**	**2.7**	**2.7**	**2.7**
Turkey: Secondary (refined)[e]	9.0	10.0	10.0	10.0	10.0
U.S.S.R.:[e]					
Primary (refined)	495.0	500.0	500.0	505.0	505.0
Secondary (refined)	260.0	265.0	270.0	275.0	280.0
Total	**755.0**	**765.0**	**770.0**	**780.0**	**785.0**
United Kingdom:					
Primary	36.1	36.0	37.8	34.4	34.9
Secondary (refined)[6]	191.3	179.1	172.5	200.7	201.6
Total	**227.4**	**215.1**	**210.3**	**235.1**	**236.5**
United States:					
Primary (refined)	389.4	494.0	370.3	373.6	[2]392.1
Secondary (refined)	633.4	615.7	624.8	710.2	737.0
Total	**1,022.8**	**1,109.7**	**995.1**	**1,083.8**	**1,129.1**

See footnotes at end of table.

TABLE 27—Continued

LEAD: WORLD SMELTER PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Venezuela: Secondary (refined)[e]	17.0	18.0	16.0	17.0	18.5
Yugoslavia:					
Primary	109.8	116.7	129.9	[r e]126.0	125.0
Secondary	11.5	15.0	25.0	20.0	20.0
Total	**121.3**	**131.7**	**154.9**	**[r e]146.0**	**145.0**
Zambia: Primary (refined)	8.8	8.9	6.6	8.0	7.0
Grand total[3]	**[r]5,424.8**	**[r]5,598.4**	**5,522.4**	**5,686.5**	**5,716.3**
Of which:					
Primary	[r]3,175.8	[r]3,391.3	3,220.4	3,313.3	3,292.7
Secondary	[r]2,249.0	[r]2,207.1	2,302.0	2,373.2	2,423.6

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 19, 1989. Figures presented represent, to the extent possible, production of unrefined lead, including bullion and impure lead derived from new and old scrap. The figures for secondary lead for a number of countries are undoubtedly high, but sufficient information is not available to separate reprocessed scrap lead from lead merely remelted. Countries for which this is the case have been footnoted (See footnote 5). For those countries from which unrefined lead production is not reported, but where available information suggests that there is little if any import or export of bullion for refining and refined lead output has been reported, it is so noted parenthetically because it is believed that the difference between smelter output and refined output is negligible.

[2] Reported figure.

[3] Data may not add to totals shown because of independent rounding.

[4] Data not reported, derived from reported primary refined lead output minus imports of lead bullion plus exports of lead bullion and checked against use of lead content of domestically produced ores plus lead content of imported ores (estimated) minus lead content of exported ores (estimated).

[5] Some part of the total entered may be merely remelt, and as such probably should not be included here, but a substantial part of the total presumably was reprocessed to qualify as a secondary smelter product. Available information is inadequate to permit differentiation, and the total has been included, although it is recognized that this produces a slightly inflated figure.

[6] Includes a small amount of primary lead from domestic concentrate.

TABLE 28

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina:					
Primary	16.3	15.1	15.7	16.2	19.0
Secondary	15.0	13.6	15.0	16.0	16.0
Total	**31.3**	**28.7**	**30.7**	**32.2**	**35.0**
Australia:					
Primary	198.8	200.1	156.2	201.7	[2]162.7
Secondary[e]	21.5	15.6	14.8	[r]15.0	15.0
Total[e]	**220.3**	**215.7**	**171.0**	**[r]216.7**	**177.7**
Austria:					
Primary	10.0	10.0	6.0	5.0	3.0
Secondary	16.2	15.5	19.0	15.0	14.0
Total	**26.2**	**25.5**	**25.0**	**20.0**	**17.0**
Belgium:					
Primary	89.6	[r]75.3	64.5	71.1	75.0
Secondary	38.1	[r]39.0	33.8	36.9	50.6
Total	**127.7**	**114.3**	**98.3**	**108.0**	**125.6**
Bolivia: Primary	.2	.2	.2	.2	.4
Brazil:					
Primary	26.0	29.8	32.7	29.8	30.0
Secondary	45.7	51.8	52.0	58.4	55.0
Total	**71.7**	**81.6**	**84.7**	**88.2**	**85.0**
Bulgaria:[e]					
Primary	98.6	98.0	97.0	98.0	98.0
Secondary	17.4	18.0	17.0	17.0	17.0
Total	**116.0**	**116.0**	**114.0**	**115.0**	**115.0**
Burma: Primary	7.0	9.6	5.4	4.0	[2]4.4
Canada:					
Primary	173.0	173.2	169.9	139.5	[2]179.5
Secondary	79.0	68.4	87.7	91.2	[2]89.9
Total	**252.0**	**241.6**	**257.6**	**230.7**	**269.4**
China:[e]					
Primary	165.0	170.0	200.0	200.0	200.0
Secondary	30.0	40.0	40.0	40.0	45.0
Total	**195.0**	**210.0**	**240.0**	**240.0**	**245.0**
Colombia: Secondary[e]	3.0	3.0	4.0	4.0	4.0
Cyprus: Secondary[e]	2.5	2.0	2.0	2.0	2.0
Czechoslovakia: Secondary	21.1	21.4	23.6	[r e]26.0	26.0
Denmark: Secondary	13.0	4.5	.6	—	—
Finland: Secondary	4.5	4.4	1.2	[e]1.2	2.0
France:					
Primary	117.9	133.6	132.0	138.8	148.0
Secondary	88.8	90.0	98.4	107.1	108.0
Total	**206.7**	**223.6**	**230.4**	**245.9**	**256.0**

See footnotes at end of table.

TABLE 28—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
German Democratic Republic: Secondary[e]	35.0	55.0	[r]36.4	[r]38.0	39.0
Germany, Federal Republic of:					
Primary	191.9	181.0	182.1	167.6	160.0
Secondary	165.3	175.3	184.5	172.8	185.0
Total	**357.2**	**356.3**	**366.6**	**340.4**	**345.0**
Greece: Primary	[r]11.6	[r]13.7	19.3	2.7	24.0
Guatemala: Primary	.1	.1	.1	.1	[2].1
Hungary: Secondary[e]	.1	.1	.1	.1	.1
India:					
Primary	15.2	15.6	19.9	20.7	[2]18.8
Secondary	[e]10.0	[e]10.0	11.3	12.1	[2]14.0
Total	**[e]25.2**	**[e]25.6**	**31.2**	**32.8**	**32.8**
Ireland: Secondary	9.1	9.0	10.2	[r][e]9.6	10.0
Italy:					
Primary	37.6	[r]38.3	28.4	56.9	54.0
Secondary	102.9	96.7	98.0	111.4	111.0
Total	**140.5**	**[r]135.0**	**126.4**	**168.3**	**165.0**
Jamaica: Secondary[e]	1.0	1.0	1.0	1.0	1.0
Japan:					
Primary	233.8	233.7	232.7	218.8	[2]217.7
Secondary	129.2	133.3	128.7	119.5	[2]122.3
Total	**363.0**	**367.0**	**361.4**	**338.3**	**[2]340.0**
Kenya: Secondary	2.0	2.0	5.0	5.0	5.0
Korea, North: Primary[e]	95.0	95.0	95.0	95.0	95.0
Korea, Republic of:[e]					
Primary	11.4	11.0	32.1	[r]52.5	50.1
Secondary	8.9	9.2	27.5	[r]30.0	30.0
Total	**20.3**	**20.2**	**59.6**	**[r]82.5**	**80.1**
Malaysia: Secondary	10.3	14.6	13.8	11.8	12.4
Mexico:					
Primary	163.2	193.5	178.9	173.8	165.0
Secondary[e]	30.0	31.0	33.0	[r]35.0	35.0
Total[e]	**193.2**	**224.5**	**211.9**	**208.8**	**200.0**
Morocco:					
Primary	46.1	59.5	60.0	62.5	62.5
Secondary[e]	2.0	2.0	2.0	2.0	2.0
Total[e]	**48.1**	**61.5**	**62.0**	**64.5**	**64.5**
Namibia: Primary	28.9	38.5	40.0	40.6	38.2
Netherlands: Secondary[e]	25.0	25.0	[r]33.0	[r]35.7	40.0
New Zealand: Secondary[e]	6.0	6.0	[r]4.0	[2]3.6	3.0
Nigeria: Secondary	.6	.8	1.0	.3	.5
Pakistan: Secondary[e]	1.0	1.0	1.0	[r]2.0	2.0
Peru:					
Primary	70.2	[r]81.9	66.4	71.3	[2]53.6
Secondary[e]	5.0	5.0	5.0	5.0	5.0
Total[e]	**75.2**	**[r]86.9**	**71.4**	**[r]76.3**	**58.6**

See footnotes at end of table.

TABLE 28—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Philippines: Secondary[e]	4.0	7.0	7.0	7.0	7.0
Poland:					
Primary[e]	58.4	61.1	63.3	[r]64.5	64.0
Secondary[e]	25.0	26.2	25.0	25.0	25.0
Total	**83.4**	**87.3**	**88.3**	**89.5**	**89.0**
Portugal: Secondary	6.0	7.0	6.0	6.5	6.5
Romania:[e]					
Primary	35.9	38.6	36.0	[r]33.0	30.0
Secondary	10.0	10.0	15.5	10.0	10.0
Total	**45.9**	**48.6**	**51.5**	**[r]43.0**	**40.0**
South Africa, Republic of: Secondary	30.8	32.8	40.5	38.3	[2]37.4
Spain:					
Primary	110.1	112.8	88.0	71.4	70.0
Secondary	49.9	43.3	42.0	51.3	50.0
Total	**160.0**	**156.1**	**130.0**	**122.7**	**120.0**
Sweden:					
Primary	49.8	43.2	50.0	61.2	60.0
Secondary	27.7	25.9	29.8	30.2	30.0
Total	**77.5**	**69.1**	**79.8**	**91.4**	**90.0**
Switzerland: Secondary	2.0	2.0	2.0	2.0	2.0
Taiwan: Secondary[e]	44.3	44.4	53.5	54.0	68.0
Thailand: Secondary	6.2	7.5	9.1	11.4	[2]15.6
Trinidad and Tobago: Secondary[e]	2.0	2.0	2.0	1.8	1.8
Tunisia:					
Primary	8.4	2.0	2.2	[e]2.2	2.2
Secondary	.5	.5	.5	.5	.5
Total[e]	**8.9**	**2.5**	**2.7**	**2.7**	**2.7**
Turkey: Secondary[e]	9.0	10.0	10.0	10.0	9.6
U.S.S.R.:[e]					
Primary	495.0	500.0	500.0	505.0	505.0
Secondary	260.0	265.0	270.0	275.0	280.0
Total	**755.0**	**765.0**	**770.0**	**780.0**	**785.0**
United Kingdom:					
Primary	147.1	148.1	156.1	137.5	173.0
Secondary	191.3	179.1	172.5	200.7	201.0
Total	**338.4**	**327.2**	**328.6**	**338.2**	**374.0**
United States:					
Primary	389.4	494.0	370.3	373.6	392.1
Secondary	633.4	615.7	624.8	710.2	737.0
Total	**1,022.8**	**1,109.7**	**995.1**	**1,083.8**	**1,129.1**

See footnotes at end of table.

TABLE 28—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Venezuela: Secondary[e]	17.0	18.0	16.0	17.0	18.5
Yugoslavia:					
Primary	[r]62.0	83.0	99.0	92.0	92.0
Secondary	[r]38.0	40.0	39.0	36.0	39.0
Total	**100.0**	**123.0**	**138.0**	**128.0**	**131.0**
Zambia: Primary	8.8	8.9	6.6	8.0	7.0
Grand total	**[r]5,468.6**	**[r]5,669.0**	**5,575.8**	**5,726.8**	**5,855.0**
Of which:					
Primary	[r]3,172.3	[r]3,368.4	3,206.0	3,215.2	3,254.3
Secondary	[r]2,296.3	[r]2,300.6	2,369.8	2,511.6	2,600.7

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 19, 1989. Data included represent the total output of refined lead by each country, whether derived from ores and concentrates (primary) or scrap (secondary), and include the lead content of antimonial lead, but exclude, to the extent possible, simple remelting of scrap.

[2] Reported figure.

LIME

By M. Michael Miller[1]

Total lime sold or used by domestic producers, including that from Puerto Rico, increased from 15.8 million short tons in 1987 to 17.3 million tons in 1988. These products, valued at over $832 million, include quicklime and hydrated lime for commercial or captive consumption.

Lime is consumed primarily in chemical and industrial applications. The iron and steel industry was once again the largest consumer of lime. Significant gains in raw steel production for 1988 fueled an increased demand for lime.

Consumption of lime increased in chemical, industrial, construction, and refractory industries. Consumption for agricultural uses decreased by 44%.

DOMESTIC DATA COVERAGE

Domestic production data for lime are developed by the Bureau of Mines from two separate voluntary surveys of U.S. operations. Typical of these surveys is the annual "Lime" survey. Of the 116 operations to which the annual survey request was sent, 113 responded, representing 97% of the total sold or used by producers shown in table 2. Production for the three nonrespondents was estimated using reported prior-year production figures.

DOMESTIC PRODUCTION

The term "lime," as used throughout this chapter, refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. They are (1) quicklime, calcium oxide (CaO); (2) hydrated lime, calcium hydroxide ($Ca(OH)_2$); (3) dolomitic quicklime ($CaO \cdot MgO$); (4) two types of dolomitic hydrate, type N ($Ca(OH)_2 \cdot MgO$) and type S ($Ca(OH)_2 \cdot Mg(OH)_2$); and (5) dead-burned dolomite. Nondolomitic quicklime and hydrated lime are also called high-calcium lime. Lime can also be produced from a variety of calcareous materials such as aragonite, chalk, coral, marble, and shell. Lime was regenerated, i.e., produced as a byproduct, by paper mills, carbide plants, and water treatment plants; however, regenerated lime is beyond the scope of this report.

Total U.S. lime production from limestone, including that of Puerto Rico, increased 10%. Commercial lime, sold by producers, increased 14%, and captive lime, used by producers, decreased 12%.

Seventy-three companies produced lime in 1988. Leading producing companies, in descending order, were Dravo Lime Co. with two plants in Kentucky and one plant each in Alabama and Texas; Mississippi Lime Co. in Missouri; Marblehead Lime Co. with two plants in Illinois and one each in Indiana and Michigan; Chemstar Inc. with two plants each in California and Nevada and one each in Arizona and Utah; Martin Marietta Corp. in Ohio; Allied Products Co. with two plants in Alabama; Continental Lime Inc. with one plant each in Montana, Utah, and Washington; APG Lime Co. with one plant each in Texas and Virginia; Broyhill and Associates Inc. with two plants in Pennsylvania; and LTV Steel Co. in Ohio. These 10 companies operated 26 plants and accounted for 55% of total lime production.

A number of industry changes took place during the year. Marblehead Lime sold its lime facilities in central

TABLE 1

SALIENT LIME STATISTICS

(Thousand short tons unless otherwise specified)

	1984	1985	1986	1987	1988
United States:[1]					
Number of plants	129	115	116	116	115
Sold or used by producers:					
Quicklime	13,134	12,997	11,850	12,979	14,027
Hydrated lime	2,302	2,314	2,199	2,468	2,518
Dead-burned dolomite	487	378	424	285	748
Total[2]	**15,922**	**15,690**	**14,474**	**15,733**	**17,293**
Value[3] thousands	$811,183	$809,000	$757,867	$786,125	$828,007
Average value per ton	$50.95	$51.56	$52.36	$49.96	$47.88
Lime sold	13,064	13,409	12,097	13,105	14,976
Lime used	2,858	2,281	2,377	2,628	2,317
Exports[4]	25	19	16	13	15
Imports for consumption[4]	247	194	201	178	210
Consumption, apparent[5]	16,144	15,865	14,658	15,898	17,489
World: Production	[r]129,024	[r]127,922	125,481	[p]124,776	[e]131,212

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Excludes regenerated lime. Excludes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.
[3]Selling value, f.o.b. plant, excluding cost of containers.
[4]Bureau of the Census.
[5]Calculated by sold or used plus imports minus exports.

TABLE 2

LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	1987					1988				
	Plants	Hydrated (thousand short tons)	Quicklime (thousand short tons)	Total[2] (thousand short tons)	Value (thousands)	Plants	Hydrated (thousand short tons)	Quicklime (thousand short tons)	Total[2] (thousand short tons)	Value (thousands)
Alabama	5	100	1,132	1,232	$52,200	5	159	1,291	1,450	$66,576
Arizona	3	W	W	546	21,932	3	66	607	674	29,637
Arkansas, Louisiana, Oklahoma	4	108	240	348	22,989	4	59	201	259	14,325
California	11	W	W	465	25,745	11	W	W	699	30,356
Colorado, Nevada, Wyoming	7	W	W	227	15,999	8	W	W	290	21,152
Hawaii, Oregon, Washington	5	W	W	389	25,650	5	W	W	409	26,431
Idaho	3	—	97	97	5,149	3	—	W	W	W
Illinois, Indiana, Missouri	8	392	2,826	3,218	150,136	8	412	3,190	3,602	163,051
Iowa, Nebraska, South Dakota	4	W	W	W	W	4	W	W	W	W
Kentucky, Tennessee, West Virginia	5	124	1,500	1,622	76,306	5	110	1,668	1,777	84,334
Maryland	1	3	6	9	486	1	3	3	6	329
Massachusetts	2	16	W	W	W	2	16	W	W	W
Michigan	8	W	W	569	30,320	8	75	639	714	36,088
Minnesota and Montana	7	—	W	W	13,142	7	—	W	W	W
North Dakota	3	W	W	127	11,912	3	86	22	108	7,094
Ohio	9	W	W	1,926	93,108	9	W	W	2,065	87,431
Pennsylvania	10	325	1,249	1,574	93,430	10	298	1,343	1,641	91,214
Puerto Rico	1	25	—	25	3,558	1	25	—	25	3,802
Texas	7	527	613	1,140	59,027	7	484	708	1,192	55,935
Utah	4	W	W	562	17,894	4	W	W	365	17,252
Virginia	5	123	576	699	29,435	5	143	598	741	33,875
Wisconsin	5	116	277	393	21,733	3	122	329	452	23,986
Other[3]	([4])	635	4,748	590	19,535	([4])	484	4,177	848	38,938
Total[2]	**117**	**2,493**	**13,264**	**15,758**	**789,683**	**116**	**2,542**	**14,776**	**17,318**	**831,809**

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes data indicated by the symbol W.
[4] Included with data for each individual State.

Pennsylvania to Glenn O. Hawbaker Inc. of State College, PA. S. W. Barrick and Sons Inc. of Maryland was acquired by Kingdon Gould, Jr., of Washington, DC, and ceased lime production. The firm had been in the lime business for 114 years. USG Corp. completed the transfer of its Texas and Virginia lime operations to its spun-off subsidiary A. P. Green Industries. The two plants are now producing under the name APG Lime Corp. USG Corp. also announced plans to sell its lime plant in Genoa, OH, as part of a plan to emphasize the growth of its core businesses.

The J. E. Baker Co. entered into a joint-venture agreement with Servicios Industrias Peñoles SA de CV to manufacture refractory bricks for cement and steel applications in Mexico, other North American countries, and South America. An existing 20,000-ton-per-year plant at Monterrey, Mexico, was purchased and refurbished during the year. It will be supplied with refractory dolomite from J. E. Baker and magnesia from Industria Peñoles.

CONSUMPTION AND USES

Lime was consumed in every State. Lime sold or used by producers was for chemical and industrial uses, 87%; construction, 8%; refractories, 4%; and a small amount for agriculture. Captive lime was used mainly in sugar refining and in the production of steel in basic oxygen furnaces.

In steel refining, quicklime was used as a flux to remove impurities such as phosphorus, silica, and sulfur. Dolomitic lime was often substituted for a fraction of the high-calcium lime to extend refractory life. Dead-burned dolomite, also called refractory lime, was used to line the bottom of open-hearth steel furnaces to extend the life of the brick lining. Dead-burned dolomite was a component in tar-bonded refractory bricks used in basic oxygen furnaces. Lime consumption for raw steel production increased 7% to 5.3 million tons and accounted for 31% of all lime consumed in the United States.

In nonferrous metallurgy, lime was used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and maintain the proper pH in the flotation process. It was used to process alumina and magnesia, to extract uranium from gold slimes, to control pH and reduce cyanide loss in gold and silver leaching operations, and in the recovery of nickel by precipitation.

Lime was used in the softening and clarification of municipal potable water. In sewage treatment, lime was used to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aided clarification and killing of bacteria. Lime was used to neutralize acid mine and industrial discharges. In flue gas desulfurization systems serving utility and industrial plants, lime was used to react with sulfur oxides in the flue gas. Lime was used to stabilize sludges from sewage and desulfurization plants before disposal.

The paper industry used lime as a causticizing agent and for bleaching paper pulp to the desired degree of whiteness. Lime was also used in the clarification and color removal of paper mill wastes and to make precipitated calcium carbonate, a specialty pigment used in premium-quality coated and uncoated papers.

The chemical industry used lime in the manufacture of alkalies. Quicklime was combined with coke to produce calcium carbide, which was used to make acetylene and calcium cyanide. Lime was used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk of lime, a suspension of hydrated lime in water, was used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself is then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide is a byproduct of calcium carbonate.

Dolomitic quicklime was used as a flux in the manufacture of glass. Quicklime was used to make calcium silicate building products, e.g., sand-lime brick, and hydrated lime was used to produce silica refractory brick.

In construction, lime was used for soil stabilization to upgrade clay soils into satisfactory base and subbase materials. Common applications included the construction of roads, airfields, building foundations, earthen dams, and parking areas. Hydrated lime was used with fly ash to make a base material, in asphalt mixes to act as an antistripping agent, and to improve durability in plaster, stucco, and mortar. Other applications of lime included agricultural uses, leather tanning, plastics manufacture, and pigments.

PRICES

The average value of lime sold or used by producers, as reported to the Bureau of Mines on an f.o.b. plant basis, decreased to $48.03 per short ton. Average values were $46.34 per ton for chemical and industrial lime, $60.50 for refractory dolomite, $58.83 for construction lime, and $59.12 for lime used in agriculture.

The average value of quicklime sold decreased slightly to $46.36 per ton. Average values per ton were $45.31 for chemical lime, $44.35 for lime used in agriculture, $46.02 for construction lime, and $60.47 for refractory dead-burned dolomite.

The average value of hydrated lime sold decreased by almost 9% to $57.74 per ton. Average values were $50.92 for chemical lime, $67.40 for lime used in agriculture, and $65.47 for construction lime.

TABLE 3

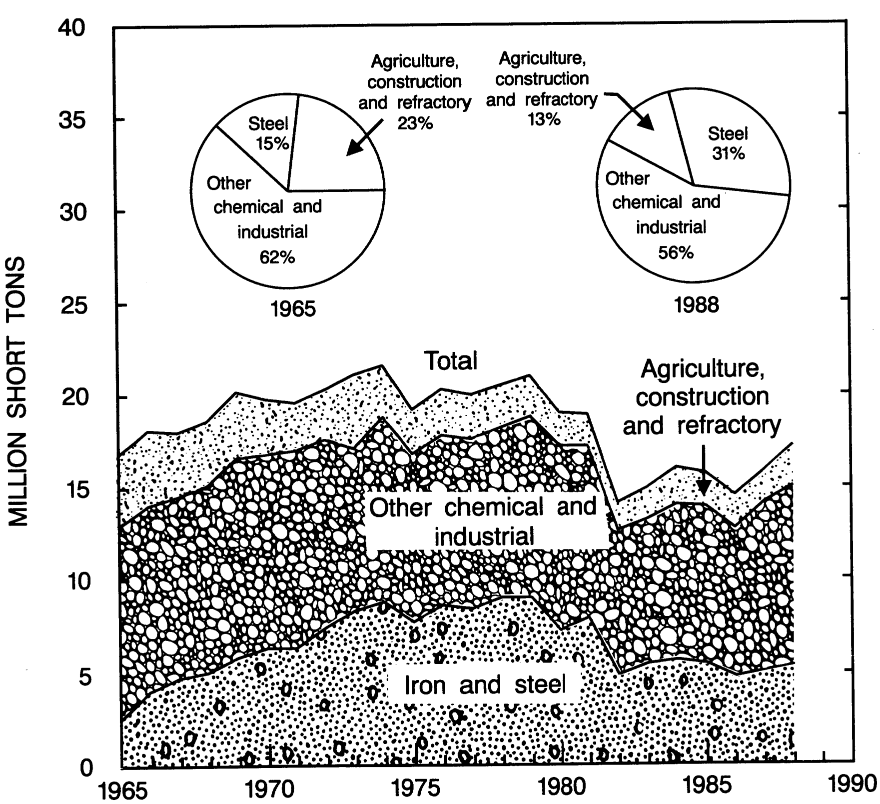
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES,[1] BY SIZE OF PLANT

Size of plant	1987 Plants	1987 Quantity (thousand short tons)	1987 Percent of total	1988 Plants	1988 Quantity (thousand short tons)	1988 Percent of total
Less than 10,000 tons	9	49	(2)	14	89	1
10,000 to 25,000 tons	22	372	2	20	338	2
25,000 to 50,000 tons	16	576	4	13	512	3
50,000 to 100,000 tons	24	1,761	11	16	1,150	7
100,000 to 200,000 tons	18	2,639	17	22	3,099	18
200,000 to 400,000 tons	22	5,797	37	22	5,830	33
More than 400,000 tons	6	4,564	29	9	6,299	36
Total	**117**	**15,758**	**100**	**116**	**[3]17,318**	**100**

[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.

FIGURE 1

TRENDS IN MAJOR USES OF LIME



FOREIGN TRADE

Exports and imports of lime increased to 14,908 tons and 209,916 tons respectively, insignificant quantities when compared to total domestic consumption of 17.3 million tons.

In September 1984, the U.S. Department of Commerce established a countervailing duty on imports of Mexican lime of 55.89% for one firm, Sonocal SA de CV, and 1.21% for all others affected by the order. At the time of the determination, State-owned Sonocal benefited from bounties and grants from the Government of Mexico. On July 21, 1988, the Government of Mexico requested a review of Commerce's countervailing duty order. Mexican officials requested that Commerce examine the purchase of Sonocal by Sociedad Cooperativa E.E.R.R. Bomintzha, S.C.L., to determine whether the transaction was at arm's length, and that Bomintzha was not benefiting from bounties and grants previously received by Sonocal.[2] A preliminary determination by Commerce found no benefits and also determined that the countervailing duty rate for Bomintzha is the "all other" rate of 1.21%.[3] A report by the U.S. International Trade Commission on the probable economic effects of the proposed change on the domestic lime industry was to be sent to the President by July 10, 1989.[4]

WORLD CAPACITY

The data in table 9 are rated capacity for lime plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

Domestic lime plant capacity is based on 365 days minus the average number of days for maintenance, times the average 24-hour capacity of quicklime production, including quicklime converted to hydrated lime, and reported in short tons per year. Where specific plant capacity data were unavailable, capacity was estimated based on 1988 reported production and on a weighted average for capacity utilization; the latter was derived from annual production and capacity figures as reported to the Bureau of Mines in the annual survey of lime producers. It is estimated that the domestic lime industry operated at nearly 78% of capacity in 1988.

WORLD REVIEW

Most major lime producing countries reported increases in production. As in the United States, these increases were driven primarily by increased steel production, but also by solid demand for use in metals processing, pulp and paper manufacturing, flue gas desulfurization, and water purification.

Belgium

Lime production in 1988 was dominated by three producers—the Lhoist Group, Carrières et Fours à Chaux de la Meuse SA, and the captive producer Solvay & Cie. SA. Total annual production was about 1.9 million tons. Most of Belgium's production was consumed in Belgium, Luxembourg, and the Netherlands.

The steel industry is the major market for Belgium's lime production and consumes over 60%. Environmental uses account for an additional signifi-

TABLE 4

DESTINATION OF SHIPMENTS OF LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

(Thousand short tons)

State	1987			1988		
	Quicklime	Hydrated lime	Total[2]	Quicklime	Hydrated lime	Total[2]
Alabama	460	49	508	479	45	524
Alaska	([3])	1	1	1	1	2
Arizona	227	87	313	591	79	670
Arkansas	202	19	220	98	21	119
California	476	107	583	579	110	689
Colorado	65	11	76	98	8	107
Connecticut	5	9	14	15	5	20
Delaware	12	5	17	14	7	21
District of Columbia	23	14	38	16	28	44
Florida	307	30	337	413	22	435
Georgia	240	52	292	264	80	344
Hawaii	([3])	3	3	([3])	3	3
Idaho	103	2	105	118	3	120
Illinois	507	99	606	538	110	648
Indiana	1,562	31	1,593	1,562	26	1,588
Iowa	87	16	104	113	16	129
Kansas	60	23	83	70	18	88
Kentucky	448	22	470	472	20	493
Louisiana	235	104	339	252	111	363
Maine	([3])	1	1	([3])	1	1
Maryland	279	15	294	354	22	376
Massachusetts	2	15	17	134	11	144
Michigan	954	29	984	1,071	83	1,153
Minnesota	236	18	254	175	149	324
Mississippi	144	8	152	180	8	188
Missouri	140	51	191	182	63	245
Montana	44	10	54	121	17	139
Nebraska	57	5	61	57	5	61
Nevada	44	14	59	133	25	158
New Hampshire	1	([3])	1	1	1	2
New Jersey	100	48	148	112	26	138
New Mexico	177	35	212	101	15	116
New York	25	29	54	88	37	125
North Carolina	237	43	281	239	31	270
North Dakota	135	47	181	127	90	217
Ohio	1,372	154	1,526	1,666	152	1,818
Oklahoma	96	16	112	124	8	132
Oregon	117	20	136	123	25	148
Pennsylvania	1,620	239	1,859	1,759	160	1,919

See footnotes at end of table.

TABLE 4—Continued

DESTINATION OF SHIPMENTS OF LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

(Thousand short tons)

State	1987 Quicklime	1987 Hydrated lime	1987 Total[2]	1988 Quicklime	1988 Hydrated lime	1988 Total[2]
Rhode Island	([3])	1	2	([3])	1	1
South Carolina	125	21	146	154	16	170
South Dakota	15	2	16	19	1	21
Tennessee	197	64	262	177	57	235
Texas	644	506	1,150	709	501	1,210
Utah	405	183	588	233	18	251
Vermont	([3])	1	1	([3])	1	1
Virginia	133	84	217	133	87	220
Washington	244	12	257	250	18	268
West Virginia	471	39	510	438	35	473
Wisconsin	137	43	180	115	50	165
Wyoming	55	17	72	71	20	90
Total[2]	**13,225**	**2,454**	**15,680**	**14,739**	**2,447**	**17,186**
Exports:						
Canada	26	8	34	31	6	36
Other countries	13	28	41	70	26	96
Total	**39**	**36**	**75**	**101**	**32**	**132**
Grand total[2]	**13,264**	**2,490**	**15,758**	**14,840**	**2,479**	**17,318**

[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

cant market share in such areas as wastewater treatment, removal of chlorine and sulfur from plastics during municipal waste incineration, and desulfurization for powerplants. The latter has the potential to be a major use.[5,6]

France

Much of the French lime industry continues to be controlled by the Lhoist Group of Belgium. Its five subsidiaries include four lime producers operating five plants in Dugny, Rety, Boran, Sorcy, and Vendeuil. Although some of the traditional lime markets such as water treatment, nonferrous metallurgy, and minerals treatment have declined in recent years, market growth is expected in road construction, the manufacture of building products, and possibly in new environmental applications.[7]

Germany, Federal Republic of

After several years of steadily decreasing production, the West German lime industry rebounded with its best-year since 1981. Production was up by almost 18% in response to demand created by the increased production of steel.

Spain

A significant portion of the Spanish lime industry derived its raw material from the high-purity dolomites in the Cantabria-Asturias area. Much of this output was in the form of dead-burned dolomite for use by the refractory industry. Major producers were Dolomitas del Norte—with production of 132,000 tons per year of dead-burned dolomite and dolomitic lime, Productos Dolomiticos SA—with production of 243,000 tons per year of various dead-burned dolomite refractories, and Cales de la Plana—with production of an estimated 38,000 tons per year of quicklime and dolomitic lime.[8]

TECHNOLOGY

Dravo Lime Co. and the U.S. Department of Energy's Argonne National Laboratory are cooperating in a program to demonstrate and commercialize the Argonne Laboratory's patented nitrogen oxide (NO_x) removal technology for use in wet flue gas desulfurization systems (FGD).

The process, termed Argonox, involves the use of one of three metal-chelate additives to remove NO_x from flue gas emissions. Laboratory work indicates that NO_x removal efficiencies in excess of 70% are possible. In lime/limestone FGD chemistry, the best NO_x removal observed has been 50%. In all cases the SO_2 removal has either been unaffected or has been improved.

Research and development is continuing, concentrating on such areas as the performance of the additives in various wet-scrubbing processes, an examination of additive breakdown and consumption rates, and changes in scrubber sludge properties caused by NO_x reaction products. Further testing of the overall concept will be accomplished as part of a pilot-plant testing program.

If successful, the process will provide an effective NO_x removal system that can be retrofitted into existing lime FGD systems with only simple modifications. This could expand the market

TABLE 5

LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

(Thousand short tons and thousand dollars)

Use	1987 Sold	1987 Used	1987 Total[2]	1987 Value	1988 Sold	1988 Used	1988 Total[2]	1988 Value
Agriculture	89	—	89	6,877	50	—	50	2,956
Chemical and industrial:								
Acid water, mine or plant	W	W	342	16,294	398	—	398	18,788
Alkalies	W	W	118	7,790	W	W	101	5,370
Aluminum and bauxite	W	—	W	W	171	—	171	7,617
Brick, sand-lime and slag	6	—	6	368	(3)	—	(3)	(3)
Copper ore concentration	W	W	677	20,340	W	W	682	28,988
Fertilizer	6	—	6	415	(3)	—	(3)	(3)
Food products, animal or human	17	—	17	914	25	—	25	1,222
Glass	129	—	129	6,221	131	—	131	6,420
Magnesia from seawater or brine	W	W	W	20,083	W	W	482	22,190
Metallurgy	5	—	5	208	W	—	W	316
Oil well drilling	W	—	W	W	W	—	W	445
Ore concentration, other	141	—	141	6,906	364	—	364	17,377
Oil and grease[4]	W	—	W	W	24	—	24	1,122
Paint	3	—	3	185	—	W	W	W
Paper and pulp	1,071	—	1,071	49,385	W	W	1,260	59,781
Petroleum refining	W	—	W	W	—	—	—	—
Sewage treatment	W	W	496	25,501	424	1	424	21,965
Steel, BOF	W	W	4,084	189,733	W	W	4,239	182,911
Steel, electric	W	W	760	35,242	954	—	954	44,397
Steel, open hearth	W	W	145	6,733	132	—	132	6,286
Sugar refining	25	639	664	41,399	37	649	686	31,254
Sulfur removal from stack gases	W	W	1,441	68,052	1,388	—	1,388	67,046
Tanning	20	—	20	1,218	W	W	32	1,764
Water purification	W	W	1,190	59,583	1,199	46	1,245	59,043
Wire drawing	17	—	17	863	(3)	—	(3)	(3)
Other[5]	10,161	1,861	2,769	125,009	7,688	1,442	2,336	114,228
Total[2]	**11,599**	**2,501**	**14,101**	**682,442**	**12,935**	**2,138**	**15,074**	**698,530**
Construction:								
Road stabilization	394	—	394	21,981	(6)	—	(6)	(6)
Soil Stabilization	355	—	355	15,584	831	—	831	40,265
Finishing lime	203	—	203	20,121	183	—	183	17,479
Mason's lime	W	W	194	13,874	W	W	239	16,842
Other[7]	136	—	136	7,037	194	—	194	10,480
Total[2]	**W**	**W**	**1,282**	**78,598**	**W**	**W**	**1,446**	**85,066**
Refractory dolomite	W	W	285	21,766	W	W	748	45,256
Grand total[2]	**13,129**	**2,628**	**15,758**	**789,683**	**15,001**	**2,317**	**17,318**	**831,809**

W Withheld to avoid disclosing company proprietary data.
[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] No comparable data for 1988 due to changes in use categories.
[4] Includes petroleum refining for 1988.
[5] Includes briquetting, brokers, calcium carbide, chrome, citric acid, commercial hydrators, desiccants, environmental uses, explosives, ferroalloys, fiberglass, glue, insecticides, ladle desulfurizing, magnesium metal, manganese, pelletizing, pharmaceuticals, petrochemicals, percipitated calcium carbonate, rubber, silica brick, soap, and uses indicated by symbol W in "Chemical and Industrial" lime only.
[6] Included in soil stabilization for 1988.
[7] Includes asphalt antistripping.

for lime FGD systems by providing an affordable alternative to systems that employ a separate catalytic NO_x reduction system.[9]

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Federal Register. International Trade Administration/Import Administration (Dep. Commerce). Lime From Mexico. V. 53, No. 148, Aug. 2, 1988, p. 29076.

[3] ———. International Trade Administration/Import Administration. Lime From Mexico; Preliminary Results of Changed Circumstances Countervailing Duty Administrative Review. V. 54, No. 10, Jan. 17, 1989, pp. 1753-1756.

[4] ———. United States International Trade Commission. Lime From Mexico; Investigation and Hearing. V. 54, No. 49, Mar. 15, 1989, pp. 10742-10743.

[5] Benbow, J. Belgium, An Industry Profile. Industrial Minerals (London). No. 260, May 1989, pp. 23-27.

[6] O'Driscoll, M. Burnt Lime/Dolime, Seeking Markets Green. Industrial Minerals (London). No. 248, May 1988, pp. 46-47.

[7] Russell, A. Industrial Minerals of France, Current Production and Developments. Industrial Minerals (London). No. 249, June 1988, p. 28.

[8] O'Driscoll, M. Dolomite, More Than Crushed Stone. Industrial Minerals (London). No. 252, Sept. 1988, pp. 56-59.

[9] Industrial Minerals (London). Dravo in FGD/NO_x Removal Process. No. 252, Sept. 1988, p. 28.

TABLE 6

U.S. EXPORTS OF LIME

	Quantity (short tons)	Value[1] (thousands)
1985	19,383	$5,155
1986	16,448	4,500
1987	12,644	2,971
1988	14,908	3,113

[1] Customs value.

Source: Bureau of the Census.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF LIME

	Hydrated lime		Other lime		Total	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
1985	48,827	$3,407	145,230	$8,810	194,057	$12,217
1986	57,842	4,108	142,865	8,129	200,707	12,237
1987	39,734	3,021	138,171	7,558	177,905	10,579
1988	54,419	4,031	155,497	8,541	209,916	12,572

[1] Customs value.

Source: Bureau of the Census.

TABLE 8

WORLD LIME ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

	Rated capacity[1]
North America:	
Canada	3,700
Cuba	260
Jamaica	170
Mexico	8,800
United States	22,300
Other[2]	250
Total[3]	**35,500**
Other:	
Africa	5,300
Asia	17,900
Europe	104,000
Oceania	2,000
South America	11,200
World total[3]	**176,000**

[1] Includes capacity at operating plants as well as at plants on standby basis.

[2] Includes Costa Rica, Dominican Republic, Guatemala, Martinique, and Nicaragua.

[3] Data do not add to total shown because of independent rounding.

TABLE 9

QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria[e]	45	45	45	45	45
Australia[e 3]	1,210	[r]1,330	1,210	1,210	1,100
Austria	1,391	1,434	1,405	1,519	1,540
Belgium	2,392	1,997	1,971	1,944	1,910
Brazil	5,053	5,255	5,411	5,842	6,060
Bulgaria	1,682	1,467	1,799	1,409	1,430
Burundi	([4])	1	([4])	([4])	([4])
Canada	2,498	2,438	2,472	2,458	[5]2,794
Chile	858	882	[e]880	[e]830	830
China[e]	2,430	2,620	2,890	3,130	3,290
Colombia[e]	1,430	1,430	1,430	1,430	1,430
Costa Rica[e]	11	11	11	11	11
Cuba	166	187	[e]200	[e]180	180
Cyprus	8	9	8	8	8
Czechoslovakia	3,436	3,557	3,670	3,569	3,640
Denmark (sales)	141	142	147	132	130
Dominican Republic[e]	44	37	37	40	40
Egypt[e]	107	107	105	105	105
Fiji Islands	[e]3	4	3	[e]2	—
Finland	266	278	288	[r e]300	290
France	3,450	3,417	3,200	[e]3,300	3,300
German Democratic Republic	3,965	3,932	3,908	3,724	3,860
Germany, Federal Republic of	7,651	7,545	7,139	6,736	7,940
Guatemala	56	68	41	88	[5]79
Hungary	907	883	916	916	[5]938
India[e]	550	550	660	770	770
Iran[e]	700	700	700	700	700
Ireland	75	93	97	85	88
Israel[e]	55	55	55	55	55
Italy	2,648	2,509	2,310	2,572	2,650
Jamaica	127	95	[e]100	[e]100	[5]88
Japan (quicklime only)	8,547	8,217	7,404	7,435	8,270
Jordan	247	[e]250	5	4	4
Kenya	23	31	14	29	28
Korea, Republic of[e]	220	220	220	220	250
Kuwait	17	58	63	69	72
Lebanon[e]	11	11	11	11	11
Libya[e]	290	290	290	290	290
Malawi	2	2	3	3	3
Malta[e]	6	6	6	6	6
Martinique[e]	6	6	6	[r]6	6

See footnotes at end of table.

TABLE 9—Continued

QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Mauritius[e]	8	8	8	8	8
Mexico	5,614	6,112	6,662	4,850	6,610
Mongolia[e]	105	105	105	105	110
Mozambique[e]	11	11	11	11	11
Nepal	8	[6]8	1	1	[5]23
New Zealand[e]	165	175	175	175	165
Nicaragua[e]	3	[5]4	4	4	4
Norway[e]	145	110	110	110	110
Paraguay	94	88	97	102	95
Peru[e]	40	40	40	40	40
Philippines	56	52	42	[e]50	45
Poland	4,686	4,546	4,576	4,697	4,520
Portugal[e]	230	220	220	220	220
Romania	4,242	4,097	[e]4,100	[e]4,000	3,900
Saudi Arabia[e]	[5]13	13	13	13	13
South Africa, Republic of (sales)	2,325	2,220	2,143	1,744	1,800
Spain[e]	[5]1,199	1,200	1,300	1,300	1,300
Sweden	714	715	[e]720	[e]720	720
Switzerland	45	41	39	44	46
Taiwan	130	116	[e]120	116	[5]117
Tanzania[e]	3	[4]3	3	3	3
Tunisia[e]	660	660	720	720	720
Turkey[e]	1,100	1,100	1,200	1,200	1,600
Uganda[e]	1	1	1	1	1
U.S.S.R.	32,520	32,190	[r e]32,000	[r e]32,000	32,000
United Arab Emirates[e]	50	50	50	50	50
United Kingdom[e]	2,750	2,750	2,750	3,100	3,100
United States including Puerto Rico (sold or used by producers)	15,956	15,713	14,498	15,758	[5]17,318
Uruguay	9	10	11	14	11
Venezuela[e]	2	2	2	2	2
Yugoslavia	3,039	2,984	2,212	1,967	[5]1,939
Zaire	121	127	150	109	110
Zambia	256	282	268	259	260
Total	**[r]129,024**	**[r]127,922**	**125,481**	**124,776**	**131,212**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 21, 1989.
[2]Lime is produced in many other countries besides those listed. Argentina, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available.
[3]Data are for years ending June 30 of that stated.
[4]Less than 1/2 unit.
[5]Reported figure.
[6]Data for year ending mid-July of that stated.

LITHIUM

By Joyce A. Ober[1]

The United States remained the worldwide leader in lithium minerals and compound production and consumption with a slight increase in domestic production. The growth of imports of lithium compounds continued, and, for the first time in 3 years, exports increased significantly. Estimated consumption increased slightly, and world production also grew. Expanded production, prices, and exports indicated improved economic health for the domestic lithium industry.

DOMESTIC DATA COVERAGE

Domestic production data for lithium were developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the two companies to which a survey request was sent, both responded, representing 100% of total production. However, production and stock data were withheld from publication to avoid disclosing company proprietary data.

LEGISLATION AND GOVERNMENT PROGRAMS

The General Services Administration (GSA) reported sales of 24,000 pounds of lithium hydroxide monohydrate valued at $19,560 with about 80 million pounds remaining in U.S. Department of Energy (DOE) excess stocks. GSA had been responsible for sales of lithium hydroxide from the National Defense Stockpile and DOE stocks, but when the responsibility for the maintenance and disposal of Stockpile material was transferred to the U.S. Department of Defense (DOD) on July 3, 1988, the disposal responsibility for the remaining lithium hydroxide returned to DOE. Disposal of DOD stocks of lithium hydroxide were/ completed in 1986. The remaining DOE stocks are excess from a weapons program that used the lithium to make tritium, an isotope of hydrogen necessary for nuclear fission reactions. The Stockpile originally contained 46,000 short tons of material, about 75% of which was depleted of the lithium 6 isotope and possibly contained 8 to 9 parts per million of mercury.

DOMESTIC PRODUCTION

Two companies produced lithium in the United States in 1988, and one of those changed ownership. Early in the year Cyprus Minerals Co. completed its purchase of Foote Mineral Co.; 87.5% of the stock was from Newmont Mining Corp. and the remainder from private shareholders. Cyprus merged the lithium operations with its Cyprus Specialty Metals Div., but later renamed these operations Cyprus Foote Mineral Co. to take advantage of the reputation Foote maintained as a leader in the lithium industry. Cyprus Foote operated processing facilities for downstream lithium products and metal in Frazer, PA, Sunbright, VA, and New Johnsonville, TN, and owned a spodumene mine and chemical plant in Kings Mountain, NC. The facilities in North Carolina remained inactive in 1988, with only small amounts of ore concentrates produced.

Lithium Corp. of America (Lithco), a subsidiary of FMC Corp., continued to mine spodumene, a lithium ore, from pegmatite dikes near Bessemer City, NC. The company produced lithium carbonate and downstream compounds, including lithium metal and some organic lithium compounds, at a chemical plant near the mine.

CONSUMPTION AND USES

The aluminum, ceramics and glass, lubricating grease, and synthetic rub-

TABLE 1

SALIENT LITHIUM STATISTICS

(Short tons of contained lithium)

	1984	1985	1986	1987	1988
United States:					
Production[1]	W	W	W	W	W
Producers' stock changes[1]	W	W	W	W	W
Imports[2]	90	410	700	900	1,100
Shipments of Government stockpile surplus[3]	1	1	2	4	2
Supply[1 4]	6,600	5,500	4,100	4,000	4,400
Supply[e 5]	6,100	5,000	3,500	3,200	3,700
Exports[e 6]	2,900	2,500	2,000	2,000	2,500
Consumption:					
Apparent	W	W	W	W	W
Estimated	3,200	2,500	2,600	2,700	3,000
Rest of world: Production[e 1]	[r]2,900	[r]3,700	[r]4,000	[r]4,000	4,600

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Mineral concentrate and carbonate.
[2]Compounds, concentrate, ores, and metal.
[3]Lithium hydroxide monohydrate.
[4]Production minus inventory increase.
[5]Based primarily on monitoring at the carbonate stage and assuming a 15% lithium loss during conversion of concentrate to chemicals.
[6]Compounds.

ber industries were the major consumers of lithium minerals and chemicals. These markets were primarily related to transportation, i.e., the aircraft and automotive industries. Ceramics and glass were also used in industrial and consumer applications. Estimated domestic consumption and U.S. production increased in 1988. Imported lithium ores continued to replace lithium carbonate in some ceramics and glass applications, but to a lesser degree than in 1987. An increasingly healthy aluminum industry remained the leading end use for lithium in the United States, with the ceramics and glass industry consuming nearly as much. Lithium carbonate is added to the cryolite bath in aluminum potlines where it is converted to lithium fluoride. The lithium fluoride lowers the melting point of the bath, allowing a lower operating temperature for the potline and increasing the electrical conductivity of the bath. Operators use these factors to increase production, reduce power consumption, or increase current efficiency.

Lithium additions in ceramics and glass manufacturing processes, in the form of carbonate and mineral concentrates, lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic chemicals. The manufacture of thermal-shock-resistant cookware, or pyroceramics, consumed the majority of lithium used in the ceramics and glass industry. Low-iron petalite and spodumene, two lithium ores, were a source of lithium used to improve the physical properties of container and bottle glass, as well as a source of alumina (Al_2O_3), another important component of the glass. Lithium is being used increasingly in container and bottle glass, enabling glass manufacturers to produce lighter weight, thinner walled products.

The third largest end use for lithium in 1988 was in the multipurpose grease industry. Lithium-based greases are favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases continued to be utilized in military, industrial, automotive, aircraft, and marine applications.

Nearly all major battery manufacturers marketed lithium batteries in some configuration, and research and development continued for further substitution in applications that implement more conventional alkaline batteries. Although they represent a small percentage of total lithium consumption, sales of these batteries remained the most favorable growth area for lithium consumption. Lithium batteries offer improved performance over alkaline batteries, although at a slightly higher cost. Lithium batteries have been used in watches, microcomputers, and cameras, and more recently in small appliances, electronic games, and toys. Large and small lithium batteries were purchased for a variety of military applications.

Aircraft manufacturers in several countries tested aluminum-lithium alloys for wing and fuselage skin and structural members of new aircraft. At least one U.S. company used these alloys in their new planes, both military and commercial. Use of aluminum-lithium alloys can reduce the weight of the aircraft by more than 10%, allowing significant fuel savings over the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, are of interest to the aircraft and aerospace industry because of their reduced density and superior corrosion resistance compared with that of conventional aluminum alloys. These alloys face direct competition, however, from composite materials consisting of boron, graphite, or aramid fibers imbedded in polymers.

Small quantities of other lithium compounds were important to many industries. Butyllithium was used as a catalyst in synthetic rubber production. Lithium chloride and lithium bromide were used in industrial air-conditioning systems, commercial dehumidification systems, and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contained lithium hypochlorite, as did dry bleach for commercial laundries. Patients diagnosed as suffering from manic-depressive mental disorder were prescribed medication containing a pharmaceutical grade of lithium carbonate. Lithium metal was used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride was used in fluxes for hard-to-weld metals such as steel alloys and aluminum.

STOCKS

Neither U.S. lithium producer reported beginning or ending stocks for 1988.

PRICES

For the second consecutive year, both domestic companies announced 5% price increases for nearly all lithium products. The close balance between supply and demand worldwide was instrumental in improving the price situation. Although installed production capacity remained in excess of demand, the chemical plant at Kings Mountain, NC, remained inactive, and supply and demand were balanced sufficiently to maintain strong prices.

FOREIGN TRADE

Exports of all lithium compounds increased 25% in 1988, the first such increase since 1984. The largest importers of lithium compounds from the United States were the Federal Republic of Germany, Japan, and the United Kingdom.

TABLE 2

DOMESTIC YEAREND PRODUCERS' AVERAGE PRICES OF LITHIUM AND LITHIUM COMPOUNDS

(Dollars per pound)

	1987	1988
Lithium bromide, 54% brine: Truckload lots, delivered in drums	4.33	4.55
Lithium carbonate, technical: Truckload lots, delivered	1.55	1.63
Lithium chloride, anhydrous, technical: Truckload lots, delivered	3.66	3.42
Lithium fluoride	5.38	5.65
Lithium hydroxide monohydrate: Truckload lots, delivered	1.97	2.07
Lithium metal ingot, battery-grade: 1,000-pound lots, f.o.b.	37.68	38.50
Lithium metal ingot, standard-grade: 1,000-pound lots, f.o.b.	25.45	26.70
Lithium sulfate, anhydrous	3.51	3.69
N-butyllithium in n-hexane (15%): Truckload lots, delivered	[r]15.10	15.85

[r]Revised.
Source: U.S. lithium producers.

U.S. imports for consumption of lithium ore concentrates decreased 13% from the figures reported in 1987 to about 16,000 tons, with 50% of the concentrates coming from Canada, 32% from Zimbabwe, and 14% from Australia. Imports of lithium compounds increased 56%, with 99% of these imports from Cyprus Foote's joint venture with the Government of Chile at the Salar de Atacama. Lithium metal imports decreased 45%. Imports of lithium salts were also down slightly, but the volume of these imports is negligible compared with total imports of lithium compounds.

WORLD CAPACITY

The data in table 5 are annual rated capacity for mines and chemical processing plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgement of the author, can be brought into production within a short period of time with minimum capital expenditure.

Lithium products varied from less than 4% lithium in high-grade ore concentrates to nearly 20% lithium in lithium carbonate. Lithium carbonate is the primary compound produced at lithium chemical plants and the compound from which all other lithium chemicals were produced in 1988. To compare production capacities of ore concentration operations to those of carbonate plants, capacity information obtained from various published reports was compiled based on the lithium contained in the products.

WORLD REVIEW

Markets for high-grade spodumene concentrates continued to expand worldwide. These products have successfully replaced lithium carbonate in television picture tube glass and pyroceramics production. Bulk glass producers in Australia, Austria, the Federal Republic of Germany, Italy, and Switzerland began routine use of glass-grade spodumene from Australia, and customers in Canada and the United States were testing the material.

Australia

Lithium Australia Ltd. (LAL) aggressively pursued new markets for its spodumene concentrates, sales of which have expanded nearly 60% per year for the past 5 years. LAL sponsored research to develop a process for recovering lithium oxide directly from spodumene to provide a less costly method for lithium metal production. The company also sought commitments from lithium compound producers to purchase the full production from a proposed lithium chemical plant under consideration.[2]

Bolivia

Industria Minera Tierra Ltda., a Government-owned company in Bolivia, requested permission to begin a feasibility study for lithium production from the Salar de Uyuni. The company planned to install a pilot plant to produce 44 tons per year of lithium carbonate near the location containing the highest lithium concentration in the Salar. Planned production capabilities could be expanded to eight times that amount if demand warranted. A Government agency, Complejo Industrial de los Recursos Evaporíticos del Salar de Uyuni, organized to coordinate development of salt deposits, sought international funds to finance the feasibility study.[3]

Chile

Cyprus Foote increased its share of the Chilean lithium brine operation, Sociedad Chilena de Litio Ltda. (SCL), which it operates as a joint venture with Corporación de Fomento de la Producción (CORFO), a Chilean Government agency. Cyprus Foote purchased an additional 25% of SCL from CORFO, bringing the total Cyprus Foote share to 80%.[4] SCL increased production capacity to 18 million pounds of lithium carbonate per year, and initiated production of byproduct potassium compounds and a low-boron lithium carbonate product. Minera Salar de Atacama Ltda., the consortium formed by AMAX Exploration Inc. (United States), CORFO, and Molibdenos y Metales S.A. (Chile), completed a feasibility study of developing another lithium operation on the Salar. The results were evaluated, and a decision from AMAX to pursue the project was expected in early 1989.[5]

Japan

Two separate companies announced plans to begin production of lithium metal in Japan. Yahagi Iron Co. Ltd. planned to produce 5 tons per year of lithium at its Nagoya plant by a vacuum process that reduces sodium contamination problems and consumes less energy than the more common electrolytic process. The metal is expected to contain 99.9% lithium with less than 100 parts per million sodium. The low sodium will make this lithium especially attractive to battery manufacturers.[6] Asia Lithium Corp., a joint venture of Lithco and Honjo Chemical Corp. of Osaka, began construction of a 110-ton-per-year lithium metal plant at Naoshima-cho, Kagaway, Shikoku. Asia Lithium has been importing about 70 tons per year of lithium metal from the United States. Company plans included eventual export of lithium metal, particularly to the Republic of Korea.[7]

Zimbabwe

The installation of a dense media separator at the Bikita Minerals Ltd. lithium operation near Masvingo has extended the anticipated mine life by over 30 years. Although the ore reserves were becoming depleted, the new separation device made it possible to recover lithium in the form of petalite with an average 4.4% lithium oxide content from a stockpile of previously rejected material. Hand sorting since

TABLE 3

U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY

Compound and country	1987 Gross weight (pounds)	1987 Value	1988 Gross weight (pounds)	1988 Value
Lithium carbonate:				
Australia	144,000	$201,240	186,920	$280,588
Brazil	6,600	10,416	63,800	91,448
Canada	908,506	1,264,924	1,041,500	1,597,289
China	—	—	84,656	84,656
Germany, Federal Republic of	5,239,635	6,377,717	5,013,548	6,237,532
Hong Kong	1,067	1,600	—	—
India	14,722	23,589	195,516	259,180
Japan	2,703,248	3,644,631	3,601,854	4,985,716
Korea, Republic of	196,433	281,507	1,014,887	1,477,147
Mexico	186,114	283,317	81,209	124,211
Netherlands	476,551	653,764	377,296	502,432
New Zealand	4,409	8,780	2,860	14,195
Singapore	23,491	35,236	—	—
South Africa, Republic of	39,600	64,740	28,689	47,326
Taiwan	431,403	615,576	590,788	845,816
United Kingdom	2,344,063	3,237,207	3,334,267	4,500,385
Venezuela	20,009	30,812	8,800	13,200
Zimbabwe	9,700	15,833	—	—
Total	**12,749,551**	**16,750,889**	**15,626,590**	**21,061,121**
Lithium hydroxide:				
Argentina	262,732	436,559	192,643	352,973
Australia	167,000	278,238	—	—
Austria	—	—	150,800	263,730
Brazil	649,345	1,125,288	1,091,633	1,858,444
Canada	136,000	257,980	227,998	414,976
Chile	34,394	65,200	95,237	172,951
Colombia	47,550	82,786	41,960	77,386
Ecuador	39,688	72,468	21,805	36,619
Egypt	—	—	44,000	77,000
France	44,000	66,002	—	—
Germany, Federal Republic of	1,079,765	1,755,831	1,055,689	1,695,173
Greece	3,307	7,335	—	—
Honduras	4,400	8,395	—	—
India	420,336	762,876	938,099	1,721,493
Indonesia	76,000	152,065	—	—
Israel	48,492	87,025	63,434	105,871
Japan	1,335,087	2,043,074	1,924,972	3,588,531
Kenya	44,000	81,445	—	—
Korea, Republic of	240,393	389,534	370,085	674,637
Malaysia	8,818	15,432	4,409	8,159
Mexico	104,781	209,400	185,254	669,011
Netherlands	315,429	510,567	380,044	690,843
New Zealand	6,614	12,864	11,023	22,400
Pakistan	58,367	103,590	33,730	64,460
Peru	25,543	42,605	—	—
Philippines	50,325	91,460	56,000	100,240
Saudi Arabia	68,343	121,575	57,320	106,600
Singapore	70,437	121,662	114,400	192,400
South Africa, Republic of	178,105	303,944	200,278	348,062

TABLE 3—Continued

U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY

Compound and country	1987 Gross weight (pounds)	1987 Value	1988 Gross weight (pounds)	1988 Value
Sweden	44,000	$ 64,626	—	—
Taiwan	41,002	141,995	19,800	$ 36,570
Thailand	36,000	63,665	41,200	74,367
United Arab Emirates	372,239	65,313	17,600	31,504
United Kingdom	795,825	1,196,244	921,991	1,515,839
Uruguay	—	—	2,205	4,938
Venezuela	87,291	168,018	88,184	164,000
Yugoslavia	15,000	32,326	—	—
Zimbabwe	26,400	47,366	—	—
Total	**6,430,174**	**11,032,905**	**8,351,793**	**15,069,177**
Other:				
Argentina	12,202	587,602	7,943	15,904
Australia	64,956	155,299	85,406	217,572
Belgium	12,720	12,466	50,517	63,231
Brazil	34,259	144,542	123,302	206,387
Canada	840,024	1,336,830	1,357,388	2,132,539
China	11,000	20,624	—	—
Colombia	1,615	12,840	3,115	6,074
Denmark	14	1,596	—	—
Ecuador	—	—	11,000	20,500
France	48,624	128,216	94,520	91,761
Germany, Federal Republic of	175,230	240,100	210,198	399,073
India	40	1,600	3,000	5,505
Iraq	—	—	1,789	3,181
Ireland	—	—	440	2,260
Israel	1,548	8,451	353	12,091
Italy	10,062	24,523	30	1,980
Jamaica	—	—	9,830	25,409
Japan	159,759	746,502	87,109	830,872
Jordan	1,074	1,879	—	—
Korea, Republic of	157,164	209,610	1,533	17,343
Mexico	534,796	1,463,046	400,179	927,616
Netherlands	66,000	97,662	189,739	369,826
Nigeria	73	4,440	—	—
Pakistan	12,042	31,835	29,608	55,756
Philippines	21,580	258,232	20,000	14,910
Saudi Arabia	—	—	12,641	22,531
Singapore	3,309	19,969	36,125	75,358
South Africa, Republic of	298	3,986	50,603	94,060
Sweden	1,561	155,365	—	—
Switzerland	—	—	7,714	13,500
Taiwan	31,487	97,666	92,189	311,104
Trinidad	—	—	62,200	141,791
Turkey	—	—	110	16,390
United Arab Emirates	6,613	11,905	32,000	15,500
United Kingdom	474,780	1,157,173	379,088	953,413
Venezuela	4,758	23,038	44,398	135,062
Yugoslavia	486	105,080	284	92,359
Total	**2,688,074**	**7,062,077**	**3,404,351**	**7,290,858**

Source: Bureau of the Census.

the mining began in 1916 amassed a stockpile of more than 1 million tons that could be recovered with a significant savings in mining costs. Hand sorting continued to be used only for special small orders of minerals other than petalite.[8]

TECHNOLOGY

Eveready Battery Co. became the second major U.S. battery producer to market a lithium battery that could directly substitute for one of the most popular sizes of consumer alkaline batteries.[9] Gould Electronics, a division of Gould Inc., introduced a new flat type of battery available in 3, 6, and 9 volts, all of which are less than ¼-inch thick and measure 3 by 3.7 inches. These flat batteries may be especially attractive for use in devices in which the use of more conventional batteries present serious constraints to size and shape. Devices that could be designed to take advantage of the special characteristics of flat batteries are laptop computers; other portable electronic devices, including those with medical applications; and "smart" credit cards that are programmed to emit electronic signals.[10]

A Japanese Government research group improved an extraction technique for lithium from seawater, which could reduce Japan's dependence on imported lithium. Japan imported its entire annual lithium requirements from several sources, including Australia, Chile, China, and the United States. The researchers believed commercialization of the modified adsorption process could produce nearly one-half of the country's lithium requirements, although improvements on the cost of the process were required. Lithium adsorption technology was available before this development, but the material used for the adsorption was dissolved and lost during the extraction of the lithium, making the

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF LITHIUM-BEARING MATERIALS, BY COMMODITY AND COUNTRY

Commodity and country	1987			1988		
	Gross weight (Pounds)	Value (Thousands)		Gross weight (Pounds)	Value (Thousands)	
		Customs	C.i.f.		Customs	C.i.f.
Lithium ores:						
Australia	4,977,337	$491	$687	4,425,085	$413	$577
Brazil	30	1	2	—	—	—
Canada[1]	13,958,632	1,414	1,414	15,975,570	1,667	1,667
Japan	22	2	2	—	—	—
Namibia	—	—	—	905,962	24	24
United Kingdom	496,000	57	57	—	—	—
Zaire	—	—	—	79,808	2	2
Zimbabwe	16,914,565	1,627	1,825	10,273,839	943	1,220
Total[2]	**36,346,586**	**3,592**	**3,987**	**31,660,264**	**3,048**	**3,489**
Lithium compounds:						
Belgium	132	4	4	—	—	—
Canada	55	1	1	231	10	10
Chile	4,347,930	4,845	5,121	7,102,102	6,259	6,759
China	4,409	6	8	39,683	83	84
France	6,013	593	598	5,078	125	127
Germany, Federal Republic of	34,014	249	257	30,336	388	397
Hong Kong	37,478	53	56	—	—	—
Japan	455	67	70	3,739	122	128
Luxembourg	—	—	—	65	1	2
Mexico	—	—	—	218	23	23
Switzerland	144,002	173	183	—	—	—
Taiwan	37,478	53	56	—	—	—
United Kingdom	6,129	130	131	9,075	97	99
Total[2]	**4,618,095**	**6,174**	**6,485**	**7,190,527**	**7,108**	**7,629**
Lithium salts:						
France	10,723	9	10	13,200	9	10
Germany, Federal Republic of	—	—	—	—	—	—
Japan	3,288	27	29	55	2	3
United Kingdom	—	—	—	252	3	3
Total	**14,011**	**36**	**39**	**13,507**	**14**	**16**
Lithium metal:						
France	3,340	7	8	8,571	17	18
Germany, Federal Republic of	10,482	21	23	—	—	—
Japan	50	2	3	—	—	—
United Kingdom	13,935	201	201	6,687	14	15
Total[2]	**27,807**	**231**	**238**	**15,258**	**31**	**33**

[1] Spodumene concentrate.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

technique impractical. The modification added an ammonia compound to the adsorbent to reduce its solubility during the extraction process.[11]

Interest in fusion reactors intensified, prompting the formation of an agreement between the United States, the European Community, Japan, and the U.S.S.R. to jointly sponsor a project to develop a design concept for a thermonuclear fusion reactor by December 1990. If current theories for

TABLE 5

WORLD LITHIUM ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988 RATED CAPACITY[1]

(Short tons of c ontained lithium)

Country	Capacity
North America:	
United States	6,200
Canada	550
Total	**6,750**
South America:	
Argentina[e]	10
Brazil[e]	320
Chile	1,700
Total[e]	**2,030**
Europe:[e]	
Portugal	20
U.S.S.R.[2]	1,200
Total	**1,220**
Africa:	
Namibia[e]	30
Zimbabwe	800
Total	**830**
Asia: China[e 2]	800
Oceania: Australia	1,400
World total[e]	**[3]13,000**

[e] Estimated.
[1] Includes capacity at operating plants as well as plants on standby basis.
[2] These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available. Output from China and the U.S.S.R. has never been reported.
[3] Data do not add to total shown because of independent rounding.

TABLE 6

LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina (minerals not specified)	[r]28	39	203	[r,e]110	110
Australia, spodumene	[r]10,973	[r]13,046	14,003	[e]13,000	13,000
Brazil:					
Amblygonite	54	[r]175	54	[r,e]55	55
Lepidolite	[r]9	[r]29	33	[r,e]33	33
Petalite	526	1,458	1,779	[r,e]1,750	1,750
Spodumene	317	118	403	[r,e]440	440
Canada, spodumene	[r]1,400	[r]5,100	8,300	[r,e]12,700	15,400
Chile, carbonate from subsurface brine	2,326	4,969	4,914	6,767	8,400
China (minerals not specified)[e 3]	16,500	16,500	16,500	16,500	16,500
Namibia:					
Amblygonite	[r]64	[r]54	57	117	120
Lepidolite	[r]20	[r]78	[e]57	67	60
Petalite	[r]914	[r]1,932	828	826	850
Portugal, lepidolite	[r]33	[r]4	[e]30	—	—
U.S.S.R. (minerals not specified)[e 3]	60,600	60,600	60,600	60,600	60,600
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe (minerals not specified)	24,855	30,765	36,112	16,489	28,000

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through Apr. 19, 1989.
[2]In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported and no valid basis is available for estimating production levels.
[3]These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available. Output by China and the U.S.S.R. has never been reported.

reactor designs prove to be correct, thermonuclear fusion could create a high-growth market for lithium in the next century. Research has indicated that each reactor would contain a lithium "blanket" of perhaps as much as 60 tons of lithium metal enriched in the lithium 6 isotope. Fusion research began in the early 1950's, but had not been enthusiastically pursued in recent years. Concerns for the environment have prompted the search for cleaner energy sources. Thermonuclear fusion could offer an excellent source for electrical energy without the serious environmental problems inherent in power production from nuclear fission and the burning of fossil fuels.[12]

Aluminum-lithium alloy properties were improved, as were processing and forming techniques. New aircraft, including military and civilian, fixed-wing models and helicopters, were designed to take advantage of the improved properties of the alloys in the form of sheet, extrusions, and forgings. Powder metallurgy techniques have made it possible to produce alloys with higher and more homogeneous lithium content,[13] and superplastic forming techniques have made possible the formation of very thin sheet products.[14] Most major aluminum companies produced the aluminum-lithium alloys. Although the alloys had not been used in a large number of aircraft, the companies were poised to supply an expected enlarged demand.

[1]Physical scientist, Branch of Industrial Minerals.
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[12]O'Sullivan, D. A. International Effort to Design Nuclear Fusion Reactor Launched. Chem. & Eng. News, v. 66, No. 21, 1988, pp. 18–21.
[13]Metal Bulletin Monthly (London). Aluminum-Based Components Are on The Way. Nov. 1988, p. 27.
[14]Materials Engineering. Superplastic Forming of Exotic Alloys. V. 105, No. 8, 1988, p. 9.

MAGNESIUM

By Deborah A. Kramer[1]

Continued strong demand for magnesium throughout the world led U.S. primary producers to increase plant operating capacities to nearly 100% of their rated capacities by yearend. Even with the increase in magnesium production, yearend U.S. producers' stocks dropped to the lowest level since 1983. Magnesium production in Europe declined because of plant closures owing to renovations and tightened environmental regulations. Tightness in world supply should be eased somewhat by yearend 1989 when two newly constructed plants in Canada were scheduled to begin primary magnesium production.

Aluminum alloying remained the dominant end use for most primary magnesium, but developments in casting technology could increase the use of magnesium in computer housings as a substitute for plastic. Research and development continued on high-purity alloys and metal-matrix composites to increase the use of magnesium components in the automotive industry.

DOMESTIC DATA COVERAGE

Domestic consumption data for magnesium metal are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 119 operations to which a survey request was sent, 85% responded, representing 62% of the primary magnesium consumption shown in tables 1 and 3. Consumption for the 18 nonrespondents was estimated using reported prior year consumption levels and other factors.

LEGISLATION AND GOVERNMENT PROGRAMS

In December, the Environmental Protection Agency (EPA) proposed a list of processing wastes to be exempted from regulation under the Resource Conservation and Recovery Act. Wastewater from the anhydrous process for primary magnesium production was included among the proposed list of exemptions. EPA sent this list to the Office of Management and Budget for review; the final list was due in February 1989.[2]

DOMESTIC PRODUCTION

Primary magnesium production increased substantially from that in 1987 as producers operated at 91% of the industry's rated capacity. Magnesium was produced by three companies in the United States: AMAX Magnesium Corp., Rowley, UT, that recovered magnesium from brines by an electrolytic process; Dow Chemical Co., Freeport, TX, that recovered magnesium from seawater by an electrolytic process; and Northwest Alloys Inc., a subsidiary of Aluminum Co. of America, Addy, WA, that recovered magnesium from dolomite by a silicothermic process.

Because of tight magnesium supplies and rapidly declining inventories, Dow announced several increases in production rates during the year. In mid-May, the company increased the annual operating capacity at the Freeport plant from 83,000 short tons to 88,000 tons by bringing additional electrolytic cells on-line. By late June, Dow brought the remaining idled cells on-stream to increase the operating capacity to 100% of its rated annual capacity of 96,000 tons. In December, Dow announced that new electrolytic cells would come on-stream in April 1989 to bring the company's rated capacity to about 105,000 tons per year.

On April 2, 1988, United Steelworkers of America union employees walked out at AMAX's primary magnesium plant, whose labor contract expired on March 19. Management continued to operate the plant until April 8, when the walkout ended. The company announced that it had reached an agreement with the union employees on the terms of a 3-year wage pact, which involved a 5% reduction in wages and implementation of a program to give workers a share of future cost savings. At the end of March, AMAX was receiving brine from its new solar evaporation ponds in Knolls, UT, and planned to increase output at the Rowley plant to its annual capacity of 38,000 tons.

In September, AMAX announced that it was seeking a buyer for its

TABLE 1

SALIENT MAGNESIUM STATISTICS

(Short tons unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Production:					
Primary magnesium	159,207	149,614	138,493	137,123	156,509
Secondary magnesium	48,357	45,523	46,084	49,786	55,344
Exports	48,337	40,322	43,992	r48,702	54,897
Imports for consumption	9,381	9,271	9,210	11,961	15,881
Consumption, primary	89,887	83,502	77,119	r93,279	111,105
Price per pound	$1.43–$1.48	$1.48–$1.53	$1.53	$1.53	$1.58–$1.63
World: Primary production	r361,617	r362,420	353,560	p361,217	e372,418

eEstimated. pPreliminary. rRevised.

primary magnesium plant. The sale of the magnesium operations was part of the company's corporate restructuring to concentrate on a few major business lines. At yearend, no buyer had been found for the plant.

CONSUMPTION AND USES

U.S. magnesium consumption increased significantly, particularly in the aluminum alloying sector. Magnesium consumption for iron and steel desulfurization was estimated to be 12,000 tons.

A die-cast magnesium alloy cube was selected as the housing for the new NeXT computer system rather than a molded plastic housing. Magnesium was selected because of its built-in shielding against electromagnetic interference, high strength-to-weight ratio, ability to maintain precision tolerances, and more effective heat dissipation. The magnesium hot-chamber diecasting for the new system is to be supplied by Chicago White Metal Casting Inc., which recently installed the world's largest hot-chamber diecasting machine at the company's Bensenville, IL, facility. The nearly 650-ton-capacity machine made possible the high-speed casting of magnesium shapes up to 24 inches by 24 inches and weighing up to 7 pounds. Before introduction of the new caster, housings greater than 20 inches by 20 inches could be produced only by cold-chamber diecasting. This meant that many large housings were designed as plastic components. Chicago White Metal Casting also produced computer parts for large corporations including IBM Corp. and NEC Corp.[3]

Prototype magnesium castings for a super-heavy-duty (SHD) Quad 4 engine block and sump were delivered to Oldsmobile by Dow. The engine castings were machined and shipped to Feuling Engineering Corp. for assembly and dynamometer testing. The original aluminum version of the SHD Quad 4 engine achieved very high volumetric, fuel, and thermal efficiencies with the highest specific output of any engine in history. By testing magnesium components, which are one-third lighter than aluminum, engineers and the engine designers hope to increase the Quad 4's performance even further.

In January, Pechiney of France and Norsk Hydro A/S of Norway began a collaborative research project to develop new magnesium alloys with improved corrosion resistance and with mechanical strength competitive with that of aluminum alloys. The project, which is expected to extend for 3 years at a cost of about $2 million, planned to develop the new alloys by rapid solidification processes. The project also would involve two national research institutes, one in France and one in Norway.

Dow announced the sale of its magnesium photoengraving plate operation in Findlay, OH, to Spectrulite Consortium Inc. (SCI) in February. SCI planned to continue the operation at Dow's facility until midyear when the operation and most of the workers move to another location in Findlay. Dow, which estimated that it supplies about 1.9 million pounds of magnesium to the photoengraving market annually, was expected to continue supplying magnesium ingot to Spectrulite.

An article highlighting magnesium diecasting presented a partial list of die-cast components currently in use. This list covers components used in automobiles, communications equipment, computers, machinery, and sports equipment.[4]

TABLE 2

MAGNESIUM RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Short tons)

	1984	1985	1986	1987	1988
KIND OF SCRAP					
New scrap:					
Magnesium-base	3,192	1,664	1,092	932	2,911
Aluminum-base	18,402	17,915	19,645	23,002	21,965
Total	**21,594**	**19,579**	**20,737**	**23,934**	**24,876**
Old scrap:					
Magnesium-base	5,232	5,104	4,363	4,252	4,279
Aluminum-base	21,531	20,840	20,984	21,600	26,189
Total	**26,763**	**25,944**	**25,347**	**25,852**	**30,468**
Grand total	**48,357**	**45,523**	**46,084**	**49,786**	**55,344**
FORM OF RECOVERY					
Magnesium alloy ingot[1]	4,229	4,231	4,327	4,410	4,332
Magnesium alloy castings	980	483	607	493	483
Magnesium alloy shapes	—	—	34	—	1,174
Aluminum alloys	41,072	39,459	41,108	44,876	48,311
Zinc and other alloys	12	9	3	W	W
Chemical and other dissipative uses	9	3	W	W	1,039
Cathodic protection	2,055	1,338	W	—	W
Total	**48,357**	**45,523**	**46,084**	**49,786**	**55,344**

W Withheld to avoid disclosing company proprietary data; included in "FORM OF RECOVERY: Total."
[1] Includes secondary magnesium content of both secondary and primary alloy ingot.

TABLE 3

U.S. CONSUMPTION OF PRIMARY MAGNESIUM, BY USE

(Short tons)

Use	1984	1985	1986	1987	1988
For structural products:					
Castings:					
Die	595	2,457	4,019	4,090	4,831
Permanent mold	1,666	909	825	[r]1,236	1,040
Sand	1,932	1,634	1,513	1,603	1,921
Wrought products:					
Extrusions	5,828	7,756	6,928	7,500	7,613
Other[1]	4,418	4,193	4,341	4,281	6,304
Total	**14,439**	**16,949**	**17,626**	**[r]18,710**	**21,709**
For distributive or sacrificial purposes:					
Alloys:					
Aluminum	48,673	40,850	40,569	54,878	56,420
Other	8	8	6	9	8
Cathodic protection (anodes)	4,777	4,748	6,991	6,104	6,872
Chemicals	5,501	3,824	1,597	1,154	860
Nodular iron	2,408	1,698	1,788	1,996	2,245
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	6,689	8,126	5,771	5,827	9,333
Other[2]	7,392	7,299	2,771	4,601	13,658
Total	**75,448**	**66,553**	**59,493**	**74,569**	**89,396**
Grand total	**89,887**	**83,502**	**77,119**	**[r]93,279**	**111,105**

[r] Revised.
[1] Includes sheet and plate and forgings.
[2] Includes scavenger, deoxidizer, and powder.

TABLE 4

U.S. STOCKS AND CONSUMPTION OF NEW AND OLD MAGNESIUM SCRAP[1]

(Short tons)

	Stocks, Jan. 1	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
1987	1,092	4,452	234	4,252	4,486	1,058
1988	1,058	6,184	2,095	4,279	6,374	868

[1] Cast scrap, solid wrought scrap, borings, turnings, and drosses.

STOCKS

Consumers' stocks of primary magnesium increased to 7,564 tons at yearend 1988 from 6,185 tons at yearend 1987. Magnesium alloy ingot stocks increased to 924 tons at yearend 1988 from 676 tons at yearend 1987.

Producers' primary magnesium stocks dropped substantially to 18,835 tons at yearend 1988 from 24,516 tons at yearend 1987. Yearend 1988 inventories were at their lowest level since 1983.

PRICES

Through the first half of 1988, AMAX's and Dow's price quotes remained at $1.53 per pound for primary ingot magnesium, the same as at yearend 1987. Amax's price quote for diecasting alloy was $1.29 per pound, and Dow's price was $1.33 per pound. On June 1, Dow raised its primary ingot price to $1.58 per pound. Late in June, AMAX matched Dow's price increase, and AMAX raised its diecasting alloy price quote to $1.33 per pound. Late in the year, Dow announced price increases of 5 cents per pound for both primary magnesium and diecasting alloy, to be effective December 2 for spot sales and as terms permit for contract customers. AMAX matched Dow's price increases, to be effective January 1, 1989. At yearend 1988, the primary magnesium price was quoted at $1.58 to $1.63 per pound, and diecasting alloy price was quoted at $1.38 to $1.43 per pound.

FOREIGN TRADE

Imports and exports of magnesium increased significantly in quantity from those in 1987, reflecting an increase in world demand for magnesium. Canada and Norway remained the principal sources of U.S. imports for consumption, accounting for 79% of the total in 1988.

WORLD CAPACITY

The data in table 7 are rated estimated annual capacity for primary magnesium plants as of December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

WORLD REVIEW

Increased production levels in North America reflected an overall increase in world demand for magnesium. European production declined owing to plant renovations and plant closures in response to tightened environmental regulations. World inventory drawdown helped meet part of the increase in demand as inventories fell to 31,800 tons, according to the International Magnesium Association. Yearend 1988 stock levels dropped 11,000 tons from those at yearend 1987 and represented only 1.4 months of the average monthly demand during 1988.

Brazil

Because of insufficient hydroelectric power supplies, Cia. Brasileira do Magnesio S.A. (Brasmag) again delayed its expansion plans to double rated annual capacity at its primary magnesium plant in Minas Gerais. The expansion, to raise capacity to 13,200 tons, was originally scheduled to be completed in 1987. Brasmag postponed the expansion indefinitely.

Canada

In April, Magnesium Co. of Canada Ltd. (MagCan) began construction of the first phase of its 69,000-ton-per-year primary magnesium facility near High River, Alberta. The first phase, with an annual capacity of 13,800 tons and an estimated cost of $100 million, would begin producing metal and alloy by the fall of 1989 and become fully operational by 1990. Additional capacity expansions would be determined by market conditions. MagCan announced that it would purchase magnesite feed material for the new plant from Baymag, Canada's sole magnesite producer. Production from the first phase is to be targeted to the aluminum alloying market.

TABLE 5

U.S. EXPORTS AND IMPORTS FOR CONSUMPTION OF MAGNESIUM

Year	EXPORTS					
	Waste and scrap		Metals and alloys in crude form		Semifabricated forms, n.e.c.	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1986	852	$1,990	41,012	$106,896	2,128	$13,492
1987	1,417	3,623	[r]44,340	[r]110,956	2,945	16,151
1988	1,305	3,429	51,207	127,800	2,385	14,083

Year	IMPORTS FOR CONSUMPTION							
	Waste and scrap		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (magnesium content)	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1986	2,099	$3,895	3,093	$8,115	1,808	$7,008	2,210	$5,556
1987	2,873	5,391	3,959	10,832	2,921	8,624	2,208	6,117
1988	4,727	8,447	3,986	10,883	4,638	12,702	2,530	7,225

[r] Revised.

Source: Bureau of the Census.

TABLE 6

U. S. EXPORTS OF MAGNESIUM, BY COUNTRY

Country	Waste and scrap		Primary metals, alloys		Semifabricated forms, n.e.c., including powder	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1987:						
Argentina	—	—	540	$1,262	71	$379
Australia	—	—	1,918	4,470	150	679
Austria	—	—	1	9	6	91
Bahrain	—	—	459	1,160	—	—
Belgium-Luxembourg[1]	4	$8	69	145	479	1,729
Brazil	11	27	764	1,902	2	10
Canada	505	1,170	[r]5,195	[r]12,134	185	1,549
China	—	—	2,275	5,368	289	722
Colombia	—	—	31	75	18	74
France	—	—	1	2	38	450
Germany, Federal Republic of	633	1,895	1,717	4,606	260	988
Ghana	—	—	930	2,315	—	—
Hong Kong	—	—	22	54	—	—
India	5	15	314	904	12	93
Ireland	—	—	97	232	—	—
Italy	—	—	23	51	139	1,214
Japan	163	299	9,671	23,620	176	1,314
Korea, Republic of	3	6	637	2,188	77	243
Mexico	64	132	656	1,495	193	667
Netherlands	6	12	16,214	41,737	307	1,221
New Zealand	—	—	36	78	4	57
Norway	—	—	55	163	2	32
Peru	—	—	43	122	2	12
Singapore	—	—	45	89	15	137
South Africa, Republic of	—	—	20	55	69	356
Spain	—	—	2,103	5,360	30	487
Sweden	—	—	42	97	15	249
Taiwan	21	51	255	670	44	187
Turkey	—	—	118	298	—	—
United Kingdom	—	—	14	44	151	1,781
Venezuela	2	8	—	—	41	157
Other	—	—	[r]75	[r]251	[r]170	[r]1,273
Total	**1,417**	**3,623**	**[r]44,340**	**[r]110,956**	**2,945**	**16,151**
1988:						
Argentina	20	69	916	2,392	60	307
Australia	—	—	2,702	6,824	187	1,000
Austria	—	—	—	—	2	32
Bahrain	—	—	671	1,701	—	—
Belgium[1]	4	26	175	534	193	749
Brazil	233	684	1,464	3,782	6	34
Canada	59	130	9,963	24,057	149	1,120

See footnotes at end of table.

TABLE 6—Continued

U. S. EXPORTS OF MAGNESIUM, BY COUNTRY

Country	Waste and scrap		Primary metals, alloys		Semifabricated forms, n.e.c., including powder	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
China	—	—	759	$1,947	—	—
Colombia	—	—	42	118	34	$158
France	—	—	20	21	24	411
Germany, Federal Republic of	243	$691	1,392	3,523	601	2,364
Ghana	—	—	449	1,115	—	—
Hong Kong	—	—	116	306	(2)	2
India	—	—	421	1,161	22	161
Ireland	—	—	97	202	—	—
Italy	9	25	72	158	113	1,162
Japan	36	343	10,001	25,699	113	1,056
Korea, Republic of	6	10	1,371	4,189	176	763
Mexico	587	1,241	905	2,323	123	437
Netherlands	77	159	16,111	38,666	174	650
New Zealand	—	—	33	79	2	30
Norway	—	—	699	1,764	2	30
Peru	—	—	63	179	(2)	2
Singapore	—	—	2	7	20	24
South Africa, Republic of	—	—	—	—	50	295
Spain	3	6	1,676	4,182	25	420
Sweden	—	—	—	—	16	239
Taiwan	—	—	558	1,413	39	101
Turkey	—	—	43	85	—	—
United Kingdom	22	33	108	249	123	1,639
Venezuela	—	—	209	638	11	34
Other	6	12	169	486	120	863
Total	**1,305**	**3,429**	**51,207**	**127,800**	**2,385**	**14,083**

[r] Revised.

[1] For 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

[2] Less than 1/2 unit.

Source: Bureau of the Census.

Noranda Inc. and Lavalin Industries Inc. formed a joint-venture firm, Magnola, to conduct a feasibility study for the construction of a plant to recover magnesium from asbestos tailings. The results of a prefeasibility study prompted a $7 million, 2-year feasibility study on the construction of a 55,000-ton-per-year plant to be built near East Broughton, Quebec. The feasibility study, which includes pilot-plant testing of a new recovery process developed by Noranda, is to be 50% funded by the Quebec Provincial and Canadian Federal Governments.

Italy

Operating capacity at Sta. Italiana per il Magnesio e Leghe di Magnesio's primary magnesium plant in Bolzano decreased to less than one-half of its annual capacity of 10,000 tons because of a plant retrofit and modernization that began in December 1987. The plant modernization, which was expected to take at least 1 year, involved automating the production of dolomite and replacing the magnesium furnaces. A group of banks that owned the plant sold the plant to a group of local business executives in 1987, who immediately began the renovations. Two-thirds of the workforce was temporarily laid off, but management planned to return production to previous levels after the modernization is completed.

TABLE 7

WORLD ANNUAL PRIMARY MAGNESIUM PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Short tons)

	Rated capacity
North America:	
Canada	10,000
United States	172,000
Total	**182,000**
South America: Brazil	6,000
Europe:	
France	15,000
Italy	10,000
Norway	53,000
U.S.S.R.	100,000
Yugoslavia	5,000
Total	**183,000**
Asia:	
China	10,000
Japan	16,600
Total	**26,600**
World total	**397,600**

[1] Includes capacity at operating plants as well as at plants on standby basis.

Japan

Japan Metals & Chemicals Co. (JMC) completed construction of a 3,300-ton-per-year primary magnesium plant in April. The plant in Takaoku, Toyama, began full-scale production in June, and JMC planned to increase its annual capacity to 5,500 tons within 2 years. JMC planned to use a modified version of Pechiney's Magnetherm process at its plant. The company would use imported dolomite from the Republic of Korea as feed material because it was less expensive than domestically produced dolomite. In May, JMC entered into a joint-venture agreement with Kanematsu Ltd. The new firm, Nichiju A.M., will be owned 70% by JMC and 30% by Kanamatsu.

Furakawa Magnesium Co. Ltd. planned to close its 5,300-ton-per-year primary magnesium facility in Oyama City, Tochigi, by the end of March 1989.

Norway

Norsk Hydro closed 13,200 tons of annual capacity—6,600 tons in March and 6,600 tons in May—at its Porsgrunn magnesium complex. The closure was in response to the Norway State Pollution Board's plans to impose $237,000 per month in fines, beginning September 1, for failure to meet tightened environmental regulations concerning the emission of chlorinated hydrocarbons, particularly dioxin, into a nearby fjord. In a report to the State Board in September, Norsk Hydro stated that it planned to spend $20 million over the next 3 years to construct a treatment plant to remove about 95% of the contaminants from its wastewater. In addition, the company would continue research to reduce emissions further from the chlorination process and improve brine processing.[5] The State Board rejected this plan and ruled for an emission reduction of 99% to 100% by January 1, 1995. Company officials stated that it was possible to meet this reduction through the methods outlined in their original report. Under the new ruling, hydrocarbon emissions must be reduced 50% by the end of 1989, 95% by July 1990, 97% by April 1993, and 98.5% by April 1994, before they are virtually eliminated by 1995.[6]

TECHNOLOGY

Dow developed a proprietary process to produce magnesium-alloy-ceramic-particle composites using molten magnesium. Research efforts focused on a wide variety of magnesium alloys reinforced with either silicon carbide or aluminum oxide. The composite parts could be fabricated by conventional techniques such as diecasting, sand casting, and extrusion. Tests on the silicon carbide-reinforced magnesium alloy composites demonstrated that although mechanical properties varied depending upon the alloy type and the volume percentage of silicon carbide used, the composite parts generally had higher yield strengths and elastic modulus than did nonreinforced parts. Prototype aluminum oxide-reinforced magnesium alloy parts were shown to have increased wear resistance.

TABLE 8

MAGNESIUM: WORLD PRIMARY PRODUCTION, BY COUNTRY[1]

(Short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Brazil	[r]1,317	[r]2,883	4,802	6,049	[2]6,465
Canada[e]	[r]9,200	[r]7,900	[r]5,600	[r]9,700	8,400
China[e]	7,700	7,700	7,700	7,700	7,700
France	14,299	[r]15,034	14,728	14,993	15,400
Italy	[r]9,021	8,667	7,986	9,706	5,000
Japan	7,830	9,321	8,946	9,017	[2]11,044
Norway	54,343	60,301	62,305	62,729	57,000
U.S.S.R.[e]	94,000	96,000	98,000	99,200	100,300
United States	159,207	149,614	138,493	137,123	[2]156,509
Yugoslavia[e]	4,700	5,000	5,000	5,000	4,600
Total	**[r]361,617**	**[r]362,420**	**353,560**	**361,217**	**372,418**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through June 27, 1989.
[2] Reported figure.

Research personnel at Dow developed a fluxless method to handle and melt die-cast magnesium scrap. By eliminating the flux, nonmetallic inclusions could be reduced and the quality of the resulting ingot could be improved. After scrap is compacted and degreased, it is preheated to at least 150° C and fed to an electrically heated furnace. Instead of a protective flux, a sulfur hexafluoride-carbon dioxide-air atmosphere was used in the furnace, which is maintained at 680° C to 720° C. After melting is completed, the molten metal was pumped through a filter to remove nonmetallic inclusions and cast into molds. Testing results indicated that the quality of the secondary ingot, with respect to nonmetallic inclusions, was comparable to that of a virgin ingot, and that mechanical properties of the secondary ingot were comparable to those of a virgin ingot.[7]

[1] Physical scientist, Branch of Nonferrous Metals.

[2] Metals Week. V. 59, No. 52, Dec. 26, 1988, p. 8.

[3] Fusaro, D. New Casting Idea Helps Chicago White Metal Beat Plastics. Am. Met. Mark., v. 96, No. 237, Dec. 7, 1988, p. 4.

[4] Robbins, J. Magnesium. Heavier Marketing for a Lighter Metal. Mater. Edge, No. 5, June 1988, pp. 33-35.

[5] Metals Week. V. 59, No. 23, June 6, 1988, p. 9.

[6] ———. V. 59, No. 41, Oct. 17, 1988, p. 2.

[7] Petrovich, V. W., and J. S. Waltrip. Fluxless Refining of Magnesium Scrap. Magnesium. A Strategic Material. Proceedings of 45th Annual World Magnesium Conference. Int. Magnesium Assoc., 1988, pp. 11-18.

TABLE 9

MAGNESIUM: WORLD SECONDARY PRODUCTION, BY COUNTRY[1]

(Short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Brazil	—	2,211	1,948	1,517	1,650
Japan	17,258	23,032	15,890	11,336	[2]11,045
U.S.S.R.[e]	9,000	9,000	9,000	9,000	9,000
United Kingdom	1,102	992	[e]1,100	[e]1,000	1,100
United States	48,357	45,523	46,084	49,786	[2]55,344
Total	**75,717**	**[r]80,758**	**74,022**	**72,639**	**78,139**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through June 27, 1989.
[2] Reported figure.

MAGNESIUM COMPOUNDS

By Deborah A. Kramer[1]

Fueled by strong demand for use in refractories in nonferrous metals production, domestic shipments of dead-burned magnesia increased significantly in 1988. Imports of dead-burned magnesia also increased as they have each year since 1982 and supplied a significant share of U.S. demand. Domestic shipments of caustic-calcined magnesia rose in 1988 and continued to be used primarily for animal feed supplements and in the chemical industry.

Seawater and brines were the principal raw material sources for most of the magnesium compounds produced in the United States, with magnesite, dolomite, and olivine as secondary sources. In 1988, two of the five olivine mines in the United States were closed. Two magnesium compound plants, one using seawater and one using brines, were scheduled to be closed in 1989. However, world production capacity for magnesium compounds was expected to increase as expansions were planned in Canada, North Korea, Mexico, and Pakistan.

DOMESTIC DATA COVERAGE

Domestic data for magnesium compounds shipped and used are developed by the Bureau of Mines from a voluntary survey of U.S. operations entitled "Magnesium Compounds." Of the 21 operations to which a survey request was sent, 81% responded, representing 68% of the magnesium compounds shipped and used shown in table 3. Data for the four nonrespondents were estimated based on prior year consumption levels and other factors.

LEGISLATION AND GOVERNMENT PROGRAMS

The Occupational Safety and Health Administration (OSHA) proposed regulations to amend its existing air contaminant standards for more than 100 substances. Magnesite dust and magnesium oxide fumes were considered to be nuisance dusts for which OSHA proposed a permissible exposure limit of 10 micrograms per cubic meter of ambient air, measured as total dust. Existing exposure limits for both these materials were 15 micrograms per cubic meter of ambient air. At yearend, final rules had not been determined.[2]

DOMESTIC PRODUCTION

Production of dead-burned and caustic-calcined magnesias continued to increase from record low 1986 levels. Seawater and brines remained the dominant source for U.S. magnesium compounds production, with the remainder supplied by dolomite, magnesite, and olivine.

PQ Corp., which purchased The Dow Chemical Co.'s epsom salt technology and assets in 1987, planned to increase its share of the U.S. epsom salt market by increasing plant capacity. PQ increased annual capacity at its plant in Berkeley, CA, by about 30%, bringing the total capacity to about 10,000 short tons. The company also was constructing a new facility in Utica, IL, with an annual capacity of 25,000 tons. The $6 million plant was scheduled for startup in February 1989. Although PQ has increased its production capacity, total U.S. epsom salt capacity was not expected to increase significantly be-

TABLE 1

SALIENT MAGNESIUM COMPOUND STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Caustic-calcined and specified magnesias:[1]					
Shipped by producers:[2]					
Quantity	142	100	95	113	137
Value	$42,257	$33,772	$33,969	$27,565	$36,500
Exports: Value[3]	$14,026	$9,773	$13,295	$14,167	$13,322
Imports for consumption: Value[3]	$9,594	$10,407	$11,493	$4,575	$2,371
Refractory magnesia:					
Shipped by producers:[2]					
Quantity	374	290	274	326	409
Value	$87,945	$81,149	$73,172	$80,760	$103,400
Exports: Value	$3,641	$5,529	$5,488	$3,240	$9,262
Imports for consumption: Value	$23,715	$29,767	$36,718	$41,333	$42,885
Dead-burned dolomite:					
Sold and used by producers:					
Quantity	487	376	424	285	p748
Value	$29,391	$24,454	$27,789	$21,766	p$45,256
World: Production (magnesite)	r13,024	r13,411	13,626	p13,370	e13,358

e Estimated. p Preliminary. r Revised.
[1] Excludes caustic-calcined magnesia used in the production of refractory magnesia.
[2] Includes magnesia used by producers.
[3] Caustic-calcined magnesia only.

cause Dow's 75,000-ton-per-year plant in Midland, MI, was scheduled to close when PQ was in full production.[3]

Olivine production decreased by 3%, but the average value increased by about 6%. Two olivine mines were closed in 1988. In August, Applied Industrial Materials Corp. (AIMCOR) closed one of its mines in North Carolina because of depletion of reserves. AIMCOR also closed its mine in Washington and reached an agreement with Olivine Corp., the other domestic olivine producer, to use raw material from Olivine's mine for processing at the AIMCOR plant in Washington. At yearend, Olivine operated one mine and processing plant in Washington, and AIMCOR operated two mines and one plant in North Carolina and one processing plant in Washington.[4]

AIMCOR also was constructing a plant in Aurora, IN, to process between 44,000 to 55,000 tons of olivine annually. Olivine for the new plant, scheduled to come on-stream in March 1989, would be supplied from Norway. Grades to be produced at this plant include those for steelmaking, foundry sand, and refractories.

TABLE 2

MAGNESIUM COMPOUND PRODUCERS, BY RAW MATERIAL SOURCE, LOCATION, AND PRODUCTION CAPACITY IN 1988

Raw material source and producing company	Location	Capacity (short tons of MgO equivalent)
Magnesite: Basic Inc.	Gabbs, NV	110,000
Lake brines:		
Great Salt Lake Minerals & Chemicals Corp.	Ogden, UT	100,000
Reilly Industries Inc.	Wendover, UT	50,000
Well brines:		
The Dow Chemical Co.	Ludington, MI	220,000
Do.	Midland, MI	75,000
Martin Marietta Chemicals	Manistee, MI	330,000
Morton Chemical Co.	do.	10,000
Seawater:		
Barcroft Co.	Lewes, DE	5,000
Basic Magnesia Inc.	Port St. Joe, FL	55,000
The Dow Chemical Co.	Freeport, TX	75,000
Genentech Inc.	South San Francisco, CA	15,000
National Refractories & Minerals Corp.	Moss Landing, CA	150,000
Total		**1,195,000**

TABLE 3

U.S. MAGNESIUM COMPOUNDS SHIPPED AND USED

	1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Caustic-calcined[1] and specified (USP and technical) magnesias	113,460	$27,565	136,582	$36,500
Magnesium hydroxide (100% $Mg(OH)_2$)[1]	263,187	52,578	432,925	76,031
Magnesium sulfate (anhydrous and hydrous)	61,294	19,447	67,798	19,185
Precipitated magnesium carbonate[1]	2,828	660	3,171	655
Refractory magnesia	325,634	80,760	409,284	103,400

[1] Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

CONSUMPTION AND USES

Consumption for both dead-burned and caustic-calcined magnesias continued to increase from that of 1987. Dead-burned magnesia was primarily used as a refractory material for furnaces used in iron and steel and nonferrous metals production. Greater production of many nonferrous metals was the main reason for the upturn in dead-burned magnesia demand.

Caustic-calcined magnesia continued to be used in the agricultural, chemical, and construction industries. Animal feed supplements accounted for 27% of domestic shipments of caustic-calcined magnesia. Chemicals, the second largest end-use sector, represented 21% of domestic shipments. Refractories, petroleum additives, and rayon, in declining order, accounted for 20% of U.S. shipments. The following uses, in declining order, accounted for the remaining 32% of caustic-calcined magnesia shipments: stack-gas scrubbing, rubber, fertilizer, water treatment, insulation and wallboard, oxychloride and oxysulfate cements, medicinals and pharmaceuticals, electrical heating rods, ceramics, sugar, pulp and paper, uranium processing, candy, foundry, and winemaking.

Magnesium carbonate was mainly used in the chemical and pharmaceutical industries, although small quantities were used for ceramics, cosmetics, fertilizer, and rubber. Magnesium hydroxide was principally used in the pulp and paper industry. Other applications for magnesium hydroxide were ceramics, chemicals, pharmaceuticals, and water treatment. Pharmaceuticals and chemicals were the principal end-use industries for magnesium sulfate.

The principal end use for olivine was as foundry sands, which accounted for 78% of olivine shipments. Refractories represented 18% of olivine shipments, and the remainder was used for slag control and soil conditioners.

PRICES

Prices of magnesium compounds at yearend 1988, published in the Chemical Marketing Reporter, remained the same as those at yearend 1987.

Magnesia, natural, technical, heavy, 85%, f.o.b. Nevada	per short ton	$232
Magnesia, natural, technical, heavy, 90%, f.o.b. Nevada	do.	265
Magnesium chloride, hydrous, 99%, flake	do.	290
Magnesium carbonate, light, technical (freight equalized)	per pound	$0.73-.78
Magnesium hydroxide, National Formulary, powder (freight equalized)	do.	.78
Magnesium sulfate, technical	do.	.14

FOREIGN TRADE

Magnesia exports in all categories increased from those of 1987. Canada was the destination for more than one-half of U.S. exports of dead-burned magnesia, and Canada and Mexico combined accounted for over 70% of domestic exports of caustic-calcined magnesia.

Imports for consumption of caustic-calcined magnesia decreased substantially in 1988, but this decrease was more than offset by an increase in imports of magnesium oxide (table 6). Dead-burned magnesia imports for consumption continued to increase as they have each year since 1982.

Olivine imports and exports were not

TABLE 4

U.S. EXPORTS OF MAGNESITE AND MAGNESIA, BY COUNTRY

Country	Magnesite and magnesia, dead-burned				Magnesite, n.e.c., including crude caustic-calcined, lump or ground			
	1987		1988		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	—	—	135	$66	72	$74	58	$37
Australia	—	—	—	—	191	214	107	89
Belgium-Luxembourg[1]	—	—	—	—	403	377	191	255
Brazil	—	—	—	—	397	624	446	724
Canada	4,337	$972	21,455	4,871	16,354	9,238	8,538	4,205
Chile	3,967	992	790	272	3	3	7	5
Colombia	1,774	290	27	7	72	105	191	168
Czechoslovakia	—	—	—	—	122	161	11	24
Dominican Republic	514	96	—	—	—	—	—	—
France	—	—	138	29	175	134	288	177
Germany, Federal Republic of	—	—	—	—	808	629	1,416	906
Guatemala	—	—	—	—	555	208	3	2
India	—	—	2,205	680	25	38	8	7
Italy	—	—	—	—	420	415	471	393
Japan	136	31	—	—	98	61	3	2
Korea, Republic of	50	11	117	32	37	22	15	11
Mexico	508	105	2,497	490	412	305	8,025	3,788
Netherlands	—	—	—	—	390	299	961	573
New Zealand	—	—	—	—	65	71	85	69
Peru	2,755	730	—	—	13	14	39	33
Romania	—	—	—	—	24	56	244	342
Saudi Arabia	—	—	—	—	11	12	—	—
Spain	—	—	2,204	634	229	202	596	493
Sweden	—	—	—	—	318	216	411	277
Taiwan	90	13	—	—	51	31	190	169
Thailand	—	—	5,845	1,635	8	5	—	—
Trinidad and Tobago	—	—	5,064	537	—	—	—	—
United Kingdom	—	—	—	—	157	214	79	35
Venezuela	—	—	—	—	741	237	595	331
Yugoslavia	—	—	—	—	149	73	64	44
Other	—	—	39	9	r96	r129	161	163
Total	**14,131**	**3,240**	**40,516**	**9,262**	**22,396**	**14,167**	**23,203**	**13,322**

r Revised.
[1]For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
Source: Bureau of the Census.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY

Country	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Lump or ground caustic-calcined magnesia:[1]				
Canada	10,366	$1,547	92	$12
China	9,677	685	4,384	335
Czechoslovakia	8,777	653	3,870	274
Greece	9,758	1,041	9,492	1,058
Mexico	502	64	2,227	260
Spain	432	104	20	3
Turkey	2,401	464	2,670	377
Other	98	17	95	52
Total	**42,011**	**4,575**	**22,850**	**2,371**
Dead-burned and grain magnesia and periclase:				
Not containing lime or not over 4% lime:				
Brazil	55	10	40	6
Canada	2,328	902	8,080	2,857
China	47,651	6,410	93,760	8,151
Czechoslovakia	—	—	4,647	299
Greece	50,190	7,787	52,944	8,008
Iceland	3,378	958	—	—
Ireland	24,431	6,730	34,766	9,644
Israel	9,211	3,638	7	30
Italy	591	139	—	—
Japan	25,081	5,202	11,528	2,532
Mexico	16,367	4,339	18,318	5,582
Netherlands	8,864	2,330	9,897	2,639
South Africa, Republic of	1,102	490	—	—
United Kingdom	15,669	2,334	15,949	3,081
Other	149	64	51	56
Total	**205,067**	**41,333**	**249,987**	**42,885**
Containing over 4% lime:				
Australia	—	—	1,122	357
Austria	1,078	394	560	53
Canada	15,600	1,683	21,404	2,469
France	9	7	—	—
Germany, Federal Republic of	—	—	490	162
Greece	—	—	2,435	598
Mexico	1,801	122	1,969	124
Other	—	—	41	19
Total	**18,488**	**2,206**	**28,021**	**3,782**
Total dead-burned and grain magnesia and periclase	**223,555**	**43,539**	**278,008**	**46,667**

[1] In addition, crude magnesite was imported as follows, in short tons and thousand dollars: 1987—Canada, 29 ($6); Italy, 3,176 ($695); Japan, 4 ($2); and the Netherlands, 109 ($30). 1988—Austria, 2,940 ($897); Greece, 2,910 ($131); Italy, 3,136 ($692); and the United Kingdom, 20 ($8).

Source: Bureau of the Census.

separately identified by the Bureau of the Census. Through the Journal of Commerce Port Import/Export Reporting Service (PIERS), imports and exports of olivine, transported by ship, were identified. A total of 155,109 tons of olivine was imported from Norway, and 2,381 tons of olivine was exported. Export destinations were Chile, 34%; Australia, 22%; Peru, 18%; the Republic of Korea, 17%; Italy, 4%; Taiwan, 4%; and Japan, 1%.

WORLD CAPACITY

The data in table 7 are rated annual capacity for plants producing magnesium compounds as of December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

Data in table 7 are presented as magnesium oxide equivalent, although not all facilities produce magnesium oxide. Two plants in the United States were scheduled to close in the beginning of 1989, which would reduce the total capacity for seawater and brine plants by 90,000 tons.

WORLD REVIEW

Canada

Baymag announced that it expanded the caustic-calcined magnesia production capacity at its plant in Exshaw, Alberta, from 66,000 to 79,000 tons per year in August. This expansion was the second in the past 2 years. In 1987,

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM COMPOUNDS

Year	Oxide or calcined magnesia		Magnesium carbonate[1] (precipitated)		Magnesium chloride (anhydrous)		Magnesium chloride (other)		Magnesium sulfate (epsom salts and kieserite)		Magnesium salts and compounds, n.s.p.f.[2]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1986	5,702	$5,804	217	$346	15	$5	3,633	$381	27,174	$1,711	3,066	$2,791
1987	34,875	13,768	554	713	475	102	7,125	935	24,408	1,581	3,309	3,494
1988	60,889	19,293	425	592	145	47	6,772	1,028	33,521	1,865	3,030	3,056

[1] In addition, magnesium carbonate, not precipitated, was imported as follows, in short tons and thousand dollars: 1986—23 ($48); 1987—71 ($105); and 1988—125 ($145).
[2] Includes magnesium silicofluoride or fluosilicate and calcined magnesia.

Source: Bureau of the Census.

Baymag increased its annual production capacities for fused magnesia from 3,900 tons to 7,700 tons. Raw magnesite for the plant was supplied from the company's mine at Radium Hot Springs, British Columbia.

Korea, North

A planned expansion of the Taehung magnesite mine and construction of an ore-dressing plant at the Ryongyang Mine was expected to increase production capacity for magnesia clinker. The new ore-dressing plant would have the capability to process 1.38 million tons of magnesite ore per year, and the magnesia clinker produced there would be supplied to the Tanchon processing plant for production of dead-burned magnesia.

Mexico

Quimíca del Rey S.A. de C.V. increased its annual production capacity for dead-burned magnesia from 83,000 tons to 110,000 tons by installing a third vertical-shaft kiln at its seawater plant in Ciudad Madero. The company also was undertaking improvements in its product handling and quality in three separate projects. One project was designed to improve the conveying and mixing of caustic-calcined magnesia prior to briquetting. A second involved improving the combustion in the shaft kiln by the addition of oxygen. The third was to add magnesium chloride to the briquetting sand to improve its properties, allowing for the removal of chrome, which was required to produce high-density magnesia products.

Improvements also were underway at the Química del Mar S.A. de C.V. 77,000-ton-per-year seawater magnesia plant at Ciudad Madero to bring the plant operating rate to full capacity by yearend.[5]

Pakistan

A Pacific Energy & Mining Co. subsidiary, Pakistan Chrome Mines, installed a vertical-shaft kiln at its plant in Muslim Bagh with a capacity of about 72 tons per day to produce dead-burned magnesia. The product, averaging 93% magnesium oxide, was to be used locally for refractory brick manufacturing. Pakistan Chrome also planned to install a 330-ton-per-day rotary kiln for production of magnesia for export. The kiln was to be operational by yearend 1989. Pakistan relied on imports, principally from China, to supply its magnesia needs. Since Pacific Energy & Mining acquired control of Pakistan Chrome Mines in 1985, the company had explored for magnesite and found proven reserves of more than 7.7 million tons.[6]

TECHNOLOGY

A group of scientists at Texas A&M University announced the development of a commercial-scale process to convert methane to ethylene, the basic raw material for polyethylene used for many plastic containers. The proposed process uses a lithium-magnesium oxide catalyst to accomplish the conversion. Ethylene, which is normally produced from petroleum, has been in short supply recently because of high export demand, and the price more than doubled within a year. Production of ethylene from methane, a component of natural gas, could reduce the dependence on petroleum reserves.

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Federal Register. Occupational Safety and Health Administration (Dep. Labor). Air Contaminants. V. 53, No. 109, June 7, 1988, pp. 20960-21393.

[3] Chemical Marketing Reporter. PQ Presiding at Change of Guard in Epsom Salt Market. V. 234, No. 10, Sept. 5, 1988, pp. 7, 28.

[4] Griffiths, J. Olivine—Volume the Key to Success. Ind. Miner. (London), No. 256, Jan. 1989, pp. 25-35.

[5] ———. Mexico's Industrial Minerals. Meeting Mañana's Challenge. Ind. Miner. (London), No. 250, July 1988, pp. 19-41.

[6] Industrial Minerals (London). PEMC Magnesia and Chrome Developments. No. 252, Sept. 1988, pp. 22, 25.

TABLE 7

WORLD MAGNESIUM COMPOUNDS ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons, MgO equivalent)

Country	Raw Material: Magnesite	Raw Material: Seawater or brines
North America:		
United States	110	1,085
Canada	110	—
Mexico	—	187
Total	**220**	**1,272**
South America: Brazil	347	—
Europe:		
Austria	618	—
Czechoslovakia	772	—
France	—	33
Greece	734	—
Ireland	—	110
Italy	—	204
Netherlands	—	110
Norway	—	28
Spain	215	—
Turkey	385	—
U.S.S.R.	2,315	110
Yugoslavia	265	—
Total	**5,304**	**595**
Africa:		
Kenya	187	—
South Africa, Republic of	110	—
Zimbabwe	2	—
Total	**299**	**—**
Asia:		
China	1,100	—
India	214	—
Israel	—	62
Japan	—	568
Korea, North	1,323	—
Korea, Republic of	—	55
Total	**2,637**	**685**
Oceania: Australia	28	—
Grand total	**8,835**	**2,552**

[1] Includes capacity at operating plants as well as at plants on standby basis.

TABLE 8

MAGNESITE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Australia	73,900	63,421	45,681	[e]55,100	55,100
Austria	1,304,484	1,383,446	1,195,301	1,043,825	1,040,000
Brazil[2]	259,043	[r]287,703	387,386	422,185	440,000
Canada[e 3]	76,000	150,000	160,000	165,000	165,000
China[e]	2,200,000	2,200,000	2,200,000	2,200,000	2,200,000
Colombia[e]	1,800	1,800	[4]16,464	16,500	16,500
Czechoslovakia[e]	[4]727,525	739,000	750,000	770,000	770,000
Greece	1,173,111	932,431	974,853	[e]990,000	990,000
India	456,388	460,117	465,175	462,896	470,000
Iran[e 5]	[r]5,500	[r]5,500	[r]5,500	[r]5,500	5,500
Kenya[e]	[4]343,098	330,000	330,000	330,000	330,000
Korea, North[e]	2,095,000	2,095,000	2,095,000	2,095,000	2,095,000
Mexico	33,537	21,274	8,300	8,103	8,300
Nepal	16,097	21,882	69,655	42,316	44,100
Pakistan	4,578	2,329	1,937	4,123	4,400
Philippines	689	745	[e]715	[e]715	715
Poland	22,046	21,164	23,038	24,582	24,300
South Africa, Republic of	36,441	31,855	67,446	82,630	[4]88,436
Spain	762,294	763,015	[e]770,000	[e]780,000	780,000
Turkey	849,415	1,244,465	1,448,174	1,307,234	1,320,000
U.S.S.R.[e]	[r]2,200,000	[r]2,175,000	[r]2,120,000	[r]2,095,000	2,040,000
United States	W	W	W	W	W
Yugoslavia	359,462	459,663	466,277	444,231	445,000
Zimbabwe	23,856	21,368	24,966	[e]25,400	25,400
Total	**[r]13,024,264**	**[r]13,411,178**	**13,625,868**	**13,370,340**	**13,357,751**

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1] Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria produced magnesite, but output is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels. Table includes data available through May 9, 1989.

[2] Series reflects output of marketable concentrates. Production of crude ore was as follows, in short tons: 1984—864,520 (revised); 1985—687,103; 1986—720,000 (estimated); 1987—970,000 (revised, estimated); and 1988—1,010,000 (estimated).

[3] Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.

[4] Reported figure.

[5] Year beginning Mar. 21 of that stated.

MANGANESE

By Thomas S. Jones[1]

World production of manganese ore advanced slightly, according to preliminary data. Among major market economy producers, the combined production gain for Australia, Mexico, and the Republic of South Africa more than offset the decline for Brazil plus Gabon. Manganese production in the United States again consisted of only a small quantity of low-grade manganiferous material for brick coloring.

The price trend for manganese ore emphatically reversed its downward course of the last few years. The price of ore delivered to Japanese consumers under annual contracts was up 36%, and of that purchased by U.S. consumers was the highest ever. The only higher ore prices on record were those paid in past Government programs. Prices of manganese ferroalloys continued their strong trend upward that began in 1987. During 1988, U.S. prices rose nearly 60% for imported high-carbon ferromanganese, to a historic high. Prices rose over 50% for imported silicomanganese. Price increases stemmed from weakness of the U.S. dollar and, on a world scale, higher-than-expected steel production in the face of lowered ferroalloy production capacity.

Unit consumption of ferromanganese and silicomanganese in steelmaking was nearly the same as in 1986-87. Along with a 12% rise in U.S. raw steel production, domestic consumption of manganese ferroalloys also increased.

U.S. imports increased for all principal forms of manganese. The overall quantity of manganese imported was up 40% to the highest level since 1981. Record quantities of medium-carbon ferromanganese and silicomanganese were imported.

Governmental activities relating to national security concerns involving manganese included extension of the stockpile upgrading program through 1989 and an investigation of the economic consequences if manganese supplies from the Republic of South Africa were embargoed.

DOMESTIC DATA COVERAGE

Domestic production data for manganese are developed by the Bureau of Mines from three separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Manganese and Manganiferous Ores" survey. All three operations to which a survey request was sent responded, representing 100% of production.

LEGISLATION AND GOVERNMENT PROGRAMS

At midyear, the General Services Administration (GSA) exercised the option under its existing contract with Elkem Metals Co. to extend upgrading of stockpiled metallurgical manganese ore into high-carbon ferromanganese through 1989. This option called for converting 103,000 tons[2] of ore into 58,600 tons of high-carbon ferromanganese in 1989. Effective July 3, authority for stockpile administration was transferred from GSA to the Defense Logistics Agency (DLA) in the U.S. Department of Defense.

No excess stockpile manganese materials were sold in 1988. In January, GSA accepted into inventory 52,246 tons of high-carbon ferromanganese produced under the stockpile upgrading program. This, plus a small inventory adjustment for high-carbon ferromanganese, is included among 1988 net changes in stockpile inventories of manganese materials shown in the following table.

TABLE 1

SALIENT MANGANESE STATISTICS

(Thousand short tons, gross weight)

	1984	1985	1986	1987	1988
United States:					
Manganese ore (35% or more Mn):					
Exports	238	56	42	63	68
Imports for consumption	338	387	463	r341	512
Consumption	615	e545	e500	re533	e554
Stocks, Dec. 31:					
Consumers	582	e589	e455	re456	e458
Manganiferous ore (5% to 35% Mn):					
Production (shipments)	88	20	14	W	W
Ferromanganese:					
Exports	7	7	4	3	3
Imports for consumption	409	367	396	368	531
Consumption	492	466	376	409	468
Stocks, Dec. 31:					
Consumers and producers	159	100	93	48	91
World:					
Production of manganese ore	r27,613	r27,990	27,585	p26,160	e26,303

e Estimated. p Preliminary. r Revised. W Withheld to avoid disclosing company proprietary data.

Material	Short tons, gross weight		
	Sales		Change in yearend inventory
	Stockpile grade	Nonstockpile grade	
Natural battery ore	—	—	-1,992
High-carbon ferromanganese	—	—	+52,171
Metallurgical ore	—	—	-76,001

Studies related to formulation of Government policy concerning imports of strategic and critical minerals (SCM) from the Republic of South Africa led to reports published by the Bureau of Mines and the U.S. General Accounting Office (GAO). The Bureau's analysis, conducted at the request of the U.S. Department of State, put annual direct economic cost to the United States of an embargo of imports of South African SCM at about $2 billion, of which about 94% was for two platinum-group metals, platinum and rhodium. The annual direct economic cost of an embargo of imports of all forms of manganese was estimated at $31 million. The Bureau concluded that manganese was one of a number of SCM for which sufficient world sources alternative to the Republic of South Africa were available to meet U.S. industrial demand in event of an embargo.[3]

In interim and final reports on SCM and the Republic of South Africa, GAO reiterated the essentials of the Bureau's assessment. From discussion of the Bureau's report with industrial users of these minerals, GAO obtained their impression that the Bureau had understated the economic costs of an embargo and overstated the ability of other SCM-producing countries to replace such South African exports to the United States.[4]

The U.S. Environmental Protection Agency (EPA) imposed reporting requirements on those involved with certain manganese materials possibly affecting the environment (53 FR 4500). Owners or operators of facilities such as those classed in either the primary metal industries or chemicals and allied products were subject to reporting annual releases of manganese metal and manganese chemical compounds to the environment. This requirement applied to those whose manufacturing, processing, or use exceeded a threshold, which for 1987 was 75,000 pounds manufactured or processed and 10,000 pounds otherwise used. The first such annual report was due July 1, 1988.

EPA also required manufacturers and importers of high-carbon ferromanganese, manganese dioxide, and manganese sulfate to make a one-time report of annual production volume, end use, and exposure data (53 FR 10387). Purpose of this request was to assist EPA's Office of Air Quality Planning and Standards in making a preliminary ranking and screening of substances identified as potential air pollutants.

The Minerals Management Service of the U.S. Department of the Interior issued final regulations governing prelease activities for marine mining on the U.S. Outer Continental Shelf for all minerals other than oil, gas, and sulfur (53 FR 25242).

TABLE 2

U.S. GOVERNMENT STOCKPILE GOALS AND YEAREND INVENTORIES FOR MANGANESE MATERIALS IN 1988

(Short tons, gross weight)

Material	Stockpile goals	Physical inventory, Dec. 31				
		Uncommitted			Sold, pending shipment	Grand total
		Stockpile grade	Nonstockpile grade	Total		
Natural battery ore	62,000	169,093	33,561	202,654	1,017	203,671
Synthetic manganese dioxide	25,000	3,011	—	3,011	—	3,011
Chemical ore	170,000	171,717	89	171,806	417	172,223
Metallurgical ore	2,700,000	2,004,163	919,204	2,923,367	20,246	[1]2,943,612
High-carbon ferromanganese	439,000	757,123	—	757,123	—	757,123
Medium-carbon ferromanganese	—	29,057	—	29,057	—	29,057
Silicomanganese	—	23,574	—	23,574	—	23,574
Electrolytic metal	—	14,172	—	14,172	—	14,172

[1] Data do not add to total shown because of independent rounding.

DOMESTIC PRODUCTION

Ore and Concentrate

The only production and shipment of material containing 5% or more manganese was that mined in Cherokee County, SC, by brick manufacturers or contractors for use in coloring brick. This material consisted of manganiferous material associated with the Battleground Schist of the Kings Mountain area. This material has a natural manganese content ranging from 5% to 15%. Shipments declined moderately in 1988, for which the estimated manganese content was somewhat greater than 1,000 tons. Publication of shipments data was precluded to avoid disclosing proprietary data.

Ferroalloys and Metal

Publication of statistics was precluded to avoid disclosing proprietary data. Elkem Metals was the only producer of manganese ferroalloys, and only Elkem Metals and Kerr-McGee Chemical Corp. produced manganese metal.

Developments relating to operations at the Marietta, OH, plant of Elkem Metals included installation of a $3 million briquetting facility, the setting up of an adjacent air separation plant, and sale of a majority interest in the Marietta plant's coal-fired power generating station. The briquetting facility began operating at midyear and replaced a previous arrangement whereby materials such as manganese-aluminum powder mixtures were briquetted at Niagara Falls, NY, on a toll basis. The air separation plant for oxygen, nitrogen, and hydrogen was built by the Linde Div. of Union Carbide Corp. and was to furnish Elkem Metals with gases by pipeline instead of as formerly supplied by truck. Sale of a 70% interest in the Marietta plant's power station to American Municipal Power—Ohio was completed in the latter part of the year. Elkem Metals retained a 30% interest in the power station, whose generating capacity of 250 megawatts of electricity and process steam had been utilized only partly by Elkem Metals for some time.

Chemetals Inc. sold its Kingwood, WV, plant to local interests in mid-1988. This plant had been used to produce ferromanganese until disabled by a flood in 1985.

CONSUMPTION, USES, AND STOCKS

Ironmaking and Steelmaking

The average rate at which manganese was consumed as manganese ore in making pig iron or equivalent hot metal advanced to 1.2 pound per ton of raw steel. This rate was calculated from an estimated consumption of 138,000 tons of manganese ore, all containing at least 35% manganese and of foreign origin, in the production of 99.9 million tons of raw steel as ingots, continuous- or pressure-cast blooms, billets, slabs, etc. The corresponding average rate for 1987 was revised to 1.1 pound per ton of raw steel. As in 1987, no manganese ore containing 35% or more manganese was indicated to have been used directly in steelmaking.

Unit manganese consumption in steelmaking as ferroalloys and metal was little changed. For reported consumption in the production of 100.9 million tons of raw steel and steel castings in 1988, the pounds of manganese consumed per ton of raw steel was 7.0 as ferromanganese, 1.5 as silicomanganese, and 0.1 for metal, for a total of 8.6. For 1987 with revisions, the corresponding unit consumption in production of 90.0 million tons of raw steel and steel castings totaled 8.6, of which ferromanganese accounted for 6.9; silicomanganese, 1.6; and metal, 0.1.

Compared to a 12% increase in domestic raw steel production, the percentage increase in consumption of

TABLE 3

DOMESTIC PRODUCERS OF MANGANESE PRODUCTS IN 1988

Company	Plant location	Products[1] FeMn	SiMn	Mn	MnO_2	Type of process
Chemetals Inc.	Baltimore, MD	—	—	—	X	Chemical.
Do.	New Johnsonville, TN	—	—	—	X	Electrolytic.
Elkem Metals Co.	Marietta, OH	X	X	X	—	Electric furnace and electrolytic.
Kerr-McGee Chemical Corp.	Hamilton, MS	—	—	X	—	Electrolytic.
Do.	Henderson, NV	—	—	—	X	Do.
Ralston Purina Co.:						
Eveready Battery Co.	Marietta, OH	—	—	—	X	Do.
RAYOVAC Corp.:						
Materials Div.	Covington, TN	—	—	—	X	Do.

[1] FeMn, ferromanganese; SiMn, silicomanganese; Mn, electrolytic manganese metal; MnO_2, synthetic manganese dioxide.

manganese ferroalloys in steelmaking was slightly greater for ferromanganese and about one-half as great for silicomanganese, according to reported consumption data. However, silicomanganese consumption rose significantly in the production of high-strength, low-alloy and stainless and heat-resisting grades of steel. The apparent large decrease in consumption of manganese metal in steelmaking, especially for carbon steel, was a statistical rather than a melt shop development. Consumption formerly reported as having been of metal was determined to have been of medium-carbon ferromanganese.

Battery and Miscellaneous Industries

In dry-cell batteries, natural manganese dioxide continued as the basis of carbon-zinc cells and synthetic dioxide as the basis of alkaline-manganese dioxide cells. Developments in Japan in the highly competitive international battery industry involving cells with a manganese dioxide component included a rechargeable lithium-manganese dioxide battery as an alternative to nickel-cadmium batteries and a titanium-nickel alloy-manganese dioxide cell for memory back-up applications. In the United States, a wholly alkaline battery was introduced as a replacement for lithium-containing batteries being used as an energy source for personal computer clocks.

Duracell Inc., a manufacturer of alkaline batteries, became a private company toward the end of June. The Duracell business was purchased from Kraft Inc. by Duracell Holdings Corp., an affiliate of Kohlberg Kravis Roberts & Co. and partly owned by Duracell management.

In August, Eagle-Picher Industries Inc. sold its Fairbury, NE, sulfate plant to American MicroTrace Corp. of Virginia Beach, VA. Zinc sulfate and manganese sulfate are the products of the plant. Total plant capacity is 16,000 tons per year.

TABLE 4

U.S. CONSUMPTION AND INDUSTRY STOCKS OF MANGANESE ORE,[1] BY USE

(Short tons, gross weight)

Use	Consumption		Stocks, Dec. 31	
	1987	1988	1987	1988
Manganese alloys and metal	W	W	189,444	127,205
Pig iron and steel[e]	[r]115,000	138,000	[r]70,000	130,000
Dry cells, chemicals, miscellaneous[2]	W	W	196,548	201,252
Total[e]	**533,000**	**554,000**	**455,992**	**458,457**

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Containing 35% or more manganese (natural).
[2]Natural ore, including that consumed in making synthetic manganese dioxide.

TABLE 5

U.S. CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF MANGANESE FERROALLOYS AND METAL IN 1988

(Short tons, gross weight)

End use	Ferromanganese			Silico-manganese	Manganese metal
	High carbon	Medium and low carbon	Total		
Steel:					
Carbon	267,968	85,175	353,143	85,585	1,121
Stainless and heat-resisting	16,102	862	16,964	5,306	1,910
Full alloy	32,903	10,097	43,000	16,806	872
High-strength, low-alloy	31,124	5,264	36,388	7,220	([1])
Electric	([1])	([1])	([1])	([1])	([1])
Tool	318	([1])	318	([1])	84
Unspecified	678	112	790	429	187
Total steel[2]	**349,093**	**101,510**	**450,603**	**115,346**	**4,174**
Cast irons	11,037	1,105	12,142	1,642	—
Superalloys	W	—	W	W	158
Alloys (excluding alloy steels and superalloys)	373	W	373	W	[3]19,105
Miscellaneous and unspecified	4,511	68	4,579	1,917	549
Total consumption	**365,014**	**102,683**	**467,697**	**[4]118,905**	**23,986**
Total manganese content[5]	**285,000**	**82,000**	**367,000**	**78,000**	**24,000**
Stocks, Dec. 31:					
Consumers and producers	76,745	14,065	90,810	18,558	3,007

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."
[2]Includes estimates.
[3]Approximately 90% of this subtotal was for consumption in aluminum alloys.
[4]Internal evaluation indicates that silicomanganese consumption is considerably understated.
[5]Estimated based on typical percent manganese content (rounded).

PRICES

Manganese Ore

Prices depend primarily on manganese content but are also influenced by other factors, including other chemical constituents, physical character, quantity, delivery terms, ocean freight rates, insurance, inclusion or exclusion of duties if applicable, buyers' needs, and availability of ores having the specifications desired. Trade journal quotations reflect the editors' evaluation of the market.

The price of metallurgical manganese ore rebounded sharply from its trough of the mid-1980's. Extended negotiations in Japan did not result in agreement on annual contracts until the latter part of June. In the negotiations, Japanese consumers were led by an integrated steel producer using ore directly in steelmaking, rather than by a ferroalloy producer as usual. A price 36% higher than that in fiscal year 1987 was agreed to, which turned out to be about the extent to which prices eventually increased in Western Europe and the United States. Quarterly as well as annual contracts were made in Western Europe, so that prices there were rising rapidly while negotiations were still being carried out in Japan. For 1988 as a whole, the average price, c.i.f. U.S. ports, for metallurgical ore containing 48% manganese was $1.78 per long ton unit, compared with $1.29 in 1987; on a metric ton basis, these prices were $1.75 and $1.27, respectively. These prices convert to 7.9 and 5.8 cents per pound of manganese in ore, respectively.

The 1988 U.S. ore price surpassed the record $1.72 per long ton unit price of 1981 as the highest ever, exclusive of prices paid many years ago in Government programs. Strongly rising trends in manganese ferroalloy prices, weakness of the U.S. dollar, and increases in ocean freight rates helped drive the ore price upward.

Manganese Ferroalloys

Prices of major ferroalloys rose almost uninterruptedly to significantly higher levels. For high-carbon ferromanganese containing 78% manganese, the price of imported material, f.o.b. Pittsburgh or Chicago warehouse, went from January's level of $380 to $390 per long ton of alloy to December's final price of $600 to $615. This price increase of nearly 60% during 1988 to a historic high gave a price average for 1988 almost 50% greater than that in 1987. At midyear, Elkem Metals reestablished a published domestic producer price for the first time in years. Beginning at $565, f.o.b. Marietta, OH; Pittsburgh, PA; or Chicago, IL; this price was raised twice, to $615 finally as of the end of September. For imported silicomanganese containing 2% carbon, the price rises were only slightly less than for high-carbon ferromanganese: 53% for price increase in 1988 and 39% for increase over 1987 price average. Per pound of alloy, f.o.b. Pittsburgh or Chicago warehouse, the price of imported silicomanganese advanced from 22.5 to 24 cents in January to a late-December final price of 35 to 36.25 cents, with a dip only in September. Elkem Metals progressively raised its price, similar basis, from 25.5 cents in January to a final 36.5 cents in mid-December.

Among reasons cited for increased manganese ferroalloy prices were higher costs for ore and transportation, weakness of the U.S. dollar, lower world ferroalloy production capacity, and stronger-than-expected demand from U.S. and European steel producers.

Manganese Metal

The price of 86 cents per pound for bulk shipments, f.o.b. shipping point, that carried over from 1987 was maintained until July 1, when a new price of 91 cents became effective. Chemetals and Elkem Metals subsequently raised their price to 96 cents effective December 1. Compared with trends in ferroalloy prices, increases in metal price were relatively modest, about 10% both for average price increase in 1988 and increase over 1987 price average.

FOREIGN TRADE

All but about 500 tons of reported ore exports and all ore reexports were presumed to have been metallurgical ore, and apparently consisted of both stocks from industry and material from excess Government stocks. Of 2,294 tons of reexports, 1,508 tons went to Mexico and 786 tons went to Canada. Exports of nonmetallurgical ore, which apparently were imported manganese dioxide ore, possibly ground, blended, or otherwise classified in the United States, all went to Canada except for small quantities to Western Europe. Exports of ferromanganese were the second lowest of the 1980's, whereas those of silicomanganese rose dramatically to the highest total since data specific to silicomanganese exports became available beginning in 1978. The quantity of metal exported was greater than in any prior year except 1980.

Imports were increased for all categories of the principal forms of manganese. Overall quantity of manganese contained in the principal forms imported increased 40%. Import totals for overall quantity, ore, and ferromanganese were the greatest since 1981. Average grade of imported ore was 48.6%, the least since 1983. No imports of manganiferous ore (less than 35% manganese) were reported.

Average manganese content of all ferromanganese imports declined to 78.3% from 78.7%. Imports of medium-carbon ferromanganese, which among manganese materials increased by the greatest percentage, and of silicomanganese advanced to record quantities. Receipt from China of 4,778 tons of high-carbon ferromanganese was the first import of manganese material for metallurgical use reported from China since 5 tons of refined ferromanganese was imported in 1981. Reported imports of spiegeleisen were 147 tons, all from the Federal Republic of Germany, at a relatively high unit value.

Imports of manganese dioxide increased for the first time since 1985 because of rising imports from Japan for the second consecutive year. All but 37 tons from Morocco was apparently synthetic dioxide for battery or chemical applications. The imports from Morocco had an average unit value only about 10% lower than that for all dioxide imports.

Tariffs

The International Trade Administration (ITA) of the U.S. Department of Commerce completed its administrative review of the January 1984 antidumping duty order on potassium permanganate from Spain. The ITA's final determination (53 FR 21504) was that a less-than-fair-value (LTFV) margin of 16.16% existed for imports of potassium permanganate from Spain (Asturquimica S.A.) for the period January 1, 1986, through December 31, 1986. The Customs Service was instructed to assess antidumping duties in accordance with this margin for appropriate entries during that period. Also, a cash deposit of estimated antidumping duties of 16.16% was required on Spanish potassium permanganate imported for consumption on or after June 8, 1988.

On May 31, Chemetals and Kerr-McGee Chemical Corp. alleged in a petition to the U.S. International Trade Commission (ITC) that an industry in the United States was being injured by LTFV imports of electrolytic manganese dioxide (EMD) from Greece, Ireland, and Japan. On July 11, the ITC made a preliminary decision under section 733(a) of the Tariff Act of 1930 that there was a reasonable indication the allegation was correct. As a result, the ITA proceeded with an antidumping duty investigation, and on November 14 announced its preliminary determination of LTFV sales of EMD from Greece and Japan, but not Ireland, during the period of investigation, December 1, 1987, through May 31, 1988. Estimated margins by which foreign market values exceeded the U.S. price were 34.03% for EMD from Greece and 72.02% to 78.62% for EMD from Japan. Because of a preliminary determination of "critical circumstances," the ITA also directed the Customs Service to suspend liquidation of entries of imports for consumption of EMD from Greece and Japan beginning 90 days prior to November 14 and thereafter. The ITA and the ITC then proceeded toward making their respective final determinations in the matter.

WORLD MINE CAPACITY

The data in table 9 are rated capacity for mines as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operat-

TABLE 6

U.S. EXPORTS OF MANGANESE ORE, FERROALLOYS, AND METAL, BY COUNTRY

(Gross weight)

Country	1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ore and concentrates containing 5% or more manganese:				
Canada	7,496	$630	15,608	$1,349
Mexico	54,884	3,353	50,618	4,017
Other	[1] 890	[1] 242	1,765	129
Total [2]	**63,270**	**4,225**	**67,991**	**5,496**
Ferromanganese:				
Belgium-Luxembourg	269	217	428	368
Canada	1,877	1,351	2,182	1,854
Germany, Federal Republic of	428	347	295	250
Other	[1] 277	[1] 230	537	477
Total [2]	**2,851**	**2,144**	**3,442**	**2,950**
Silicomanganese:				
Canada	249	160	4,178	2,829
Trinidad and Tobago	4	2	2,755	1,543
Other	[1] 444	[1] 330	534	603
Total [2]	**697**	**493**	**7,467**	**4,975**
Metal including alloys and waste and scrap:				
Belgium-Luxembourg	701	1,053	836	1,264
Canada	1,208	2,028	1,741	3,107
Japan	1,492	2,606	1,822	2,933
Netherlands	706	1,320	2,419	4,096
Other	1,668	2,742	3,041	4,841
Total [2]	**5,775**	**9,748**	**9,859**	**16,242**

[1] Unspecified group of countries differs from the 1987 Minerals Yearbook.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census; adjusted by the Bureau of Mines.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY

Country	1987			1988		
	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)
ORE AND CONCENTRATES						
35% or more manganese:						
Australia	93,205	48,747	$3,819	[1]75,717	[1]39,324	[1]$3,440
Brazil	62,903	29,673	2,196	57,528	27,004	2,700
Gabon	175,695	88,413	8,282	[1]290,548	[1]146,654	16,972
Mexico	8,678	3,712	769	87,730	35,490	5,920
Morocco	58	[2]30	14	172	[2]94	42
Total [3]	**340,539**	**170,576**	**15,079**	**511,695**	**248,566**	**29,074**
Of which, more than 35% but less than 47% manganese:						
Brazil	10,758	4,626	357	22,652	10,263	879
Mexico	5,911	2,395	292	79,778	31,742	4,757
Total [3]	**16,669**	**7,021**	**649**	**102,430**	**42,005**	**5,636**
FERROMANGANESE						
All grades:						
Australia	8,185	6,072	1,885	14,897	10,777	3,011
Belgium-Luxembourg	2,474	2,150	1,490	3,733	3,074	2,869
Brazil	5,512	4,189	1,400	26,333	20,119	9,634
Canada	24,022	18,861	6,290	32,221	24,752	11,024
China	—	—	—	4,778	3,658	1,916
France	121,817	95,629	38,426	143,808	113,874	56,361
Germany, Federal Republic of	12,775	10,674	5,947	12,620	10,122	9,646
Italy	412	367	338	2,256	2,014	2,481
Japan	8,331	6,607	2,682	3,713	2,920	2,370
Mexico	17,910	14,562	7,463	37,012	29,361	19,685
Netherlands [4]	—	—	—	2,757	2,261	1,323
Norway	21,830	18,167	12,530	39,718	32,388	24,238
South Africa, Republic of	144,407	112,101	35,180	195,729	151,867	63,171
Spain	—	—	—	830	634	349
United Kingdom	—	—	—	3,600	2,556	622
Yugoslavia	—	—	—	7,275	5,479	3,520
Total [3]	**367,675**	**289,379**	**113,630**	**531,281**	**415,858**	**212,221**
Of which, 1% or less carbon:						
Belgium-Luxembourg	823	746	761	113	101	128
Canada	—	—	—	60	48	23
France	9,553	8,677	8,965	14,631	13,196	15,580
Italy	412	367	338	2,256	2,014	2,481
Japan	20	18	18	351	318	403
Norway	9,323	8,044	7,122	[1]3,488	[1]3,018	[1]4,060
South Africa, Republic of	—	—	—	36	33	29
Total [3]	**20,132**	**17,852**	**17,203**	**20,935**	**18,729**	**22,704**

See footnotes at end of table.

TABLE 7—Continued

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY

Country	1987 Gross weight (short tons)	1987 Manganese content (short tons)	1987 Value (thousands)	1988 Gross weight (short tons)	1988 Manganese content (short tons)	1988 Value (thousands)
More than 1% to 4% or less carbon:						
Belgium-Luxembourg	1,651	1,404	$729	3,620	2,973	$2,741
Brazil	—	—	—	941	718	594
Canada	—	—	—	405	321	249
France	6,151	4,997	2,944	4,707	3,863	2,230
Germany, Federal Republic of	12,775	10,674	5,947	12,104	9,856	9,481
Japan	2,800	2,240	1,262	3,362	2,602	1,967
Mexico	15,761	12,864	6,811	27,421	21,668	14,453
Netherlands[4]	—	—	—	2,757	2,261	1,323
Norway	10,743	8,729	5,000	[1]28,996	[1]23,771	[1]17,830
South Africa, Republic of	559	452	259	2,599	2,090	1,802
Total[3]	**50,440**	**41,359**	**22,951**	**86,913**	**70,123**	**52,670**
SILICOMANGANESE						
Australia	17,142	11,180	4,527	33,158	21,549	10,033
Belgium	—	—	—	415	263	306
Brazil	7,334	4,676	2,541	22,102	14,551	8,776
Canada	6,446	4,171	1,969	82	49	25
France	—	—	—	446	294	346
Italy	1,105	696	683	669	432	478
Mexico	39,704	24,866	11,072	34,459	22,590	13,806
Netherlands[4]	413	250	251	—	—	—
Norway	26,136	17,159	8,877	4,108	2,595	2,863
South Africa, Republic of	66,105	43,736	19,625	101,705	67,717	40,147
Spain	1,663	1,056	1,031	1,303	835	962
Venezuela	—	—	—	1,161	760	770
Yugoslavia	25,369	16,525	7,884	32,606	21,247	13,415
Total[3]	**191,418**	**124,315**	**58,461**	**232,214**	**152,884**	**91,928**
METAL						
Unwrought:						
South Africa, Republic of	8,925	XX	9,600	11,730	XX	14,946
Total	**8,925**	**XX**	**9,600**	**11,730**	**XX**	**14,946**
Waste and scrap:						
Canada	60	XX	8	82	XX	4
United Kingdom	6	XX	6	—	XX	—
MANGANESE DIOXIDE						
Belgium-Luxembourg	1,252	XX	1,508	1,293	XX	1,613
Brazil	884	XX	970	1,393	XX	1,500
Greece	62	XX	71	139	XX	168
Ireland	358	XX	401	—	XX	—
Japan	13,279	XX	14,719	18,895	XX	19,559
South Africa, Republic of	830	XX	889	597	XX	486
Other	180	XX	134	250	XX	405
Total[3]	**16,845**	**XX**	**18,692**	**22,567**	**XX**	**23,731**

See footnotes at end of table.

TABLE 7—Continued

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY

Country	1987 Gross weight (short tons)	1987 Manganese content (short tons)	1987 Value (thousands)	1988 Gross weight (short tons)	1988 Manganese content (short tons)	1988 Value (thousands)
MANGANESE SULFATE						
Australia	1,565	XX	$289	707	XX	$126
Belgium-Luxembourg	127	XX	32	3,085	XX	788
China	555	XX	95	44	XX	10
Mexico	2	XX	4	4,825	XX	1,552
Other	[5]68	XX	[5]208	67	XX	148
Total [3]	**2,317**	**XX**	**629**	**8,729**	**XX**	**2,624**
POTASSIUM PERMANGANATE						
China	803	XX	791	551	XX	568
German Democratic Republic	176	XX	206	220	XX	249
Spain	918	XX	1,587	677	XX	1,157
Other	101	XX	290	139	XX	491
Total [3]	**1,998**	**XX**	**2,874**	**1,587**	**XX**	**2,465**

XX Not applicable.
[1] Includes Bureau of Mines revision of part of reported data.
[2] Includes Bureau of Mines conversion of part of reported data (from apparent MnO_2 content to Mn content).
[3] Data may not add to totals shown because of independent rounding.
[4] Country of transshipment rather than original source.
[5] Unspecified group of countries differs from the 1987 Minerals Yearbook.

Source: Bureau of the Census, adjusted by the Bureau of Mines.

TABLE 8

U.S. IMPORT DUTIES ON MANGANESE MATERIALS[1]

Item	TSUS No.	Rate of duty effective Jan. 1, 1988: Most favored nation (MFN)	Rate of duty effective Jan. 1, 1988: Non-MFN
Manganese dioxide	419.4420	4.7% ad valorem[2]	25% ad valorem.
Ore and concentrate	601.27	Free	1 cent per pound Mn.
Ferromanganese:			
Low-carbon	606.26	2.3% ad valorem[2]	22% ad valorem.
Medium-carbon	606.28	1.4% ad valorem[2 3]	6.5% ad valorem.
High-carbon	606.30	1.5% ad valorem[4 5]	10.5% ad valorem.
Silicomanganese	606.44	3.9% ad valorem[2 6]	23% ad valorem.
Metal	632.30	14% ad valorem[5 7]	20% ad valorem.

[1] Rates of duty unchanged from those effective Jan. 1, 1987. Subject (1) to 0.17% ad valorem user fee except for products from beneficiary countries under the Caribbean Basin Economy Recovery Act (CBERA) and least-developed developing countries, and (2) to 0.04% ad valorem harbor-maintenance fee for cargo unloaded from waterborne vessels at U.S. ports open to public navigation.
[2] Free from certain countries under Generalized System of Preferences, including Israel.
[3] Not duty-free for Mexico.
[4] Free for products of Israel.
[5] Free from beneficiary countries under the CBERA.
[6] Not duty-free for Brazil.
[7] 5.6% ad valorem for products of Israel.

ing rate, based on the physical equipment of the plant and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

The mine capacity data in the table are for the manganese contents of ore and/or concentrates capable of being utilized, as in feed to a smelter. All of them involve some element of subjectivity and tempering on the basis of production levels attained in recent years.

TABLE 9

WORLD ANNUAL MANGANESE MINE PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons of manganese content)

	Rated capacity
North America:	
Mexico	250
United States	—
Total	**250**
South America:	
Brazil	1,400
Chile	20
Total	**1,420**
Europe:	
Bulgaria	15
Hungary	30
U.S.S.R.	3,500
Other	40
Total	**3,585**
Africa:	
Gabon	1,300
Ghana	150
Morocco	30
South Africa, Republic of	2,300
Total	**3,780**
Asia:	
China	550
India	600
Other	15
Total	**1,165**
Oceania:	
Australia	1,300
World total (rounded)	**11,500**

WORLD REVIEW

Australia

Preliminary data of the Australian Bureau of Mineral Resources indicated manganese ore production by Groote Eylandt Mining Co. Pty. Ltd. rose moderately. At times, mine output was at the maximum rate. Exports were up nearly one-fifth to the highest level so far during the 1980's, with shipments to Western and Eastern Europe increasing over 50%. Exports of about 1,710,000 tons plus domestic shipments of about 420,000 tons raised total shipments to almost 2,140,000 tons.[5]

Manganese deposits at Skull Springs in the Pilbara, Western Australia, were being explored by Imdex N.L. to evaluate the possibility of locating several million tons of high-grade ore.

Brazil

Overall shipments of manganese ore from the Serra do Navio, Amapá Territory, operations of Indústria e Comércio de Minérios S.A., all via Porto de Santana on the Amazon River, were 1,050,000 tons. A 30% increase in total shipments and 40% increase in exports were mostly because of larger volumes to destinations in Europe and South America. In tons, shipments were 582,000 to Europe; 130,000 to North America; 118,000 to South America; and in coastal vessels to Brazilian consumers, 220,000.[6]

Manganese ore production by Cia. Vale do Rio Doce (CVRD) rose to a record total of 733,000 tons, of which nearly 310,000 tons was exported, for an increase in exports of more than 80%.[7] For 1987, CVRD had reported ore production of just under 500,000 tons from its Azul Mine in the Carajás region of northern Brazil and about 100,000 tons from operations of its Urucum Mineração S.A. subsidiary in the southern Brazilian State of Mato Grosso do Sul.

Production of manganese ferroalloys increased for the fifth consecutive year, exceeding 400,000 tons for the first time. In reaching a total of slightly more than 412,000 tons, output of high-carbon ferromanganese rose nearly one-fifth. Changes in quantities produced otherwise were slight, for medium- and low-carbon ferromanganese a decline and for silicomanganese an increase.

The first of two major developments affecting current and future alignment of manganese ferroalloy producers occurred in April. Cia. Paulista de Ferro-Ligas (Paulista) acquired a controlling interest in Eletrosiderúrgica Brasileira S.A. (Sibra) by purchasing the 58% of voting capital and 18% of total capital of Sibra that had been released to private bidders by the National Bank for Economic and Social Development. Paulista subsequently acquired an additional small interest in Sibra that had been held by Industrias Siderúrgicas Grassi S.A. of Argentina. A remaining interest of about one-third continued to be divided between NKK Corp. and Marubeni Corp. of Japan. Combining the capabilities of the former Sibra plant in Bahia State with those of Paulista's various plants transformed Paulista into one of the world's largest manganese ferroalloy producers. The combination of plants has provided about four-fifths of Brazilian production in recent years.

Shortly thereafter, the seemingly firm three-party arrangement, called Provale, between Prometal Produtos Metalúrgicos S.A. (Prometal), CVRD, and the Soviet Union for manganese ferroalloys production in the Carajás region began dissolving. Prometal, the leader in Provale, withdrew in May, and by July, CVRD and the Soviet Union had abandoned the project. In withdrawing, Prometal proposed instead to set up a plant of its own in the Carajás on a scale comparable to that planned for Provale. Prometal proposed a six-furnace plant at Marabá, Pará State, with annual capacities of about 70,000 tons each for high-carbon ferromanganese and silicomanganese and about 25,000 tons combined for medium- and low-carbon ferromanganese. Production was projected for late 1990.

Canada

At the electric-furnace plant of Elkem Metal Canada Inc. at Beauharnois, Quebec, production of manganese ferroalloys was reduced by mishaps. Output of silicomanganese was affected by an electrical failure in July and of high-carbon ferromanganese by a burn-through in October. The plant of the Chromasco Div. of Timminco Ltd., also at Beauharnois, was put up for sale. Chromasco had been Canada's other producer of manganese ferroalloys. In mid-1987, it stopped making ferromanganese and silicomanganese but continued making ferrosilicon.

China

The practice since 1984 of importing high-grade ore to supplement generally lower-grade domestic production continued. The quantity of combined imports from Australia and Gabon was again reported to be in the 200,000- to 300,000-ton range. To expand usability of domestic resources, processing technology was developed whereby crude ore containing 20.5% manganese could be upgraded to a concentrate with 30% to 31% manganese. A combination of autogenous disintegrating washing, shear washing, and ultrasonic dispersion high-gradient magnetic separation was tested on soft, refractory ore that is plentiful and whose beneficiation by other methods has not been practical.[8]

Data for 1984–86 production of manganese ore given in a recent edition of the annual publication, Statistics of the Iron and Steel Industry of China, have been incorporated into the table of world production of manganese ore. Data for prior years in the 1980's were as follows, in rounded millions of tons: 1980, 2.6; 1981, 1.7; 1982, 1.9; and 1983, 2.7. Only quantity was reported, presumed to refer to crude ore for which an average manganese content of 20% was assumed.

According to a review of the geology of China's manganese ore deposits, 71% of total reserves was classed as sedimentary, an additional 13% as formed by sedimentary processes, and almost all of the remaining 16% as supergene.[9]

Capabilities for manganese ferroalloy production were being augmented in Hunan Province. At midyear, a blast furnace with a ferromanganese capacity of 60,000 tons per year was started at the Xiangtan Metal Materials Corp. Late in the year, a 30 megavolt-ampere furnace for silicomanganese was ordered from the Federal Republic of Germany by the Hunan Ferro-Alloys Factory in Xiangxiang, with startup projected for 1990. Manganese ferroalloys were among ferroalloys on which the Government imposed export taxes late in the year, presumably as a means of improving supply of these materials to domestic users.

France

Pechiney Électrométallurgie converted production at its Dunkirk plant in Normandy from ferrosilicon to silicomanganese. The change was effective with the spring startup after shutdown in the winter because of high seasonal electricity cost.

Gabon

A coastal mineral port at Owendo was inaugurated on December 30. This symbolized realization of a transportation system wholly in Gabon for exporting manganese ore produced by Compagnie Minière de l'Ogooué S.A. (COMILOG) at its Moanda Mine. An initial ore shipment to Owendo via the Trans-Gabon Railroad was made earlier in December. The new system made it feasible for COMILOG to increase ore shipments and production significantly. Henceforth, ore could be shipped either by this Gabonese route or the previously existing international route involving an aerial tramway in Gabon, railroads in neighboring Congo, and the Congolese port of Pointe-Noire.

In 1987, the contribution of manganese ore to Gabon's total export earnings was about 10%, a decline from over 13% in 1986.

Ghana

Ore exports by Ghana National Manganese Corp. increased by one-fifth to 325,000 tons, after having been in the 270,000- to 290,000-ton range during the preceding 4 years. Shipments through the Port of Takoradi went to Ireland, Norway, and Spain in Western Europe, to Romania in Eastern Europe, and to Japan in the Far East.[10]

Japan

Production increased about 14% for silicomanganese and ferromanganese overall, and over 30% for low-carbon ferromanganese. These advances brought output totals to 118,000 tons for silicomanganese and 417,000 tons for ferromanganese.

Ferromanganese exports of about 14,200 tons were one-third less than in 1987. Silicomanganese exports of 1,100 tons, all to Malaysia, though small were much greater than in recent years. Imports of ferromanganese remained at the 30,200-ton level. Silicomanganese imports increased about 5% to 175,000 tons, with China displacing the Republic of South Africa as leading source.

In electrolytic materials, production of synthetic manganese dioxide rose slightly to a new record total of 74,000 tons; according to preliminary data, exports decreased nearly one-tenth to 44,000 tons. Production of electrolytic manganese metal increased 7% to 4,340 tons from 4,050 tons in 1987. Imports of unwrought manganese metal, including scrap, were 10,900 tons.

Mexico

For operations of Cía. Minera Autlán S.A. in the Molango District, Hidalgo State, production of carbonate ore, oxide nodules (from calcined carbonate ore), and battery ore all decreased in 1987 from outputs in 1986. Respective 1987 and 1986 production quantities were 641,000 tons and 708,000 tons for carbonate ore and 370,000 tons and 435,000 tons for nodules. Production of battery ore at the Nonoalco Mine declined by a lesser extent, to 32,700 tons from 34,400 tons.

South Africa, Republic of

Ore production increased by about one-fifth to approach the totals reached in 1985–86. Production of the various categories of ore was as follows:

	Quantity (thousand short tons, gross weight)
METALLURGICAL ORE	
30% to 40% Mn	1,311
Over 40% to 45% Mn	557
Over 45% to 48% Mn	630
Over 48% Mn	1,170
Total [1]	**3,667**
CHEMICAL ORE	
35% MnO_2 and less	1
Over 35% to 65% MnO_2	123
Over 65% to 75% MnO_2	1
Total	**125**

[1] Data do not add to total shown because of independent rounding.

Manganese ore shipments by The Associated Manganese Mines of South Africa Ltd. (AMMOSAL) were the greatest since 1980, having increased over 70% to 1,674,000 tons from 968,000 tons in 1987. AMMOSAL's production was predominantly from the underground Gloria and Nchwaning Mines in the Kalahari Field in northern Cape Province. Samancor Ltd., the other major ore producer, obtained its output from the Hotazel, Mamatwan, and Wessels Mines in the same region. In the second half of the year, the South African Government eased constraints on shipping routes by approving use of the port at Saldanha Bay in addition to that at Port Elizabeth for handling manganese ore exports. Shipments through Saldanha Bay were limited to 330,000 tons per year, to the four lowest ore grades, and to coshipments with iron ore.

Samancor inaugurated a $30 million ore sintering plant at its Mamatwan Mine in September, the world's largest such plant and the first at a mine. Initial sinter plant capacity was 550,000 tons per year, of which about four-fifths was intended for use in making manganese ferroalloys at Samancor's Meyerton plant and the balance for export. The sinter plant made it possible to upgrade fine ore containing 38% manganese into a coarser product containing 44% manganese. A high-grade sinter containing 51% manganese was also scheduled to be produced beginning in late 1989 after a heavy-medium ore-beneficiating plant has been installed.

Use of the new sinter improved smelting efficiency about 5% at the Meyerton plant. Samancor also improved operations at the South Plant of this facility upon commissioning of a $5.7 million bag-house filter plant. This unit replaced an obsolete dust scrubbing plant and completed an environmental control program at Meyerton.

Manganese Metal Co. (Pty.) Ltd. (MMC) began construction in August of a plant for producing manganese oxide (Mn_3O_4) to be exported for use in making ferrites. The 2,200-ton-per-year plant was at Nelspruit, Transvaal Province, where MMC already produced electrolytic manganese metal and was expected to be operating within 1 year.

U.S.S.R.

Concentrate production from the Chiatura Basin in Georgia declined over 10% to 2.0 million tons, but was regarded as having exceeded the planned target. The decline in output from Chiatura, the prime source of high-grade concentrates, exacerbated problems in supply of raw materials for ferroalloy smelting. To help alleviate this situation, smelting technology was investigated for utilizing concentrate production being developed at the low-phosphorus Ushkatyn-III deposit in Kazakhstan and the Bol'shoy Tokmak deposit in the Ukraine.

An arrangement for the Soviet Union to have been one of three participants in a sizable ferromanganese project in Brazil was dissolved. (See Brazil section of this chapter.)

Ore exports of 787,000 tons in 1987 were 35% less than those in 1986. This sharp decline from the general level of exports in the 1980's gave the lowest export total since 1954. Principal destinations for 1987 exports, accounting for 92% of the total, were, in tons: Poland, 377,000; Czechoslovakia, 180,000; German Democratic Republic, 89,000; and Bulgaria, 75,000. Quantities to Poland, Czechoslovakia, and other countries were 41% less in 1987 than in 1986.

TECHNOLOGY

The Bureau of Mines conducted tests simulating in situ and heap leaching of domestic manganese ores. Samples from deposits in Arizona, Arkansas, California, Colorado, Maine, Minnesota, Nevada, and South Dakota were column-leached using 5-weight-percent-sulfur dioxide solutions. Manganese extractions in the 80% to 95% range were obtained for ½-inch to 1-inch samples that contained primarily pyrolusite, romanechite (psilomelane), and/or wad.[11]

The U.S. Geological Survey elaborated a model for large-scale manganese deposition as shallow-marine chemical sedimentation from the mixing of deep oxygen-poor manganese-

TABLE 10

MANGANESE ORE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons unless otherwise specified)

Country[2]	Range percent Mn[e 3]	Gross weight					Metal content				
		1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987[p]	1988[e]
Australia[4]	37–53	2,038	2,208	1,818	2,043	[5]2,189	969	1,056	867	971	1,042
Brazil[6 7]	30–50	2,969	2,781	2,973	[r][e]2,282	2,094	1,187	997	1,277	913	838
Bulgaria	29	50	42	41	42	44	14	12	12	12	13
China[6 8]	20–30	3,200	2,900	3,000	3,000	3,000	640	580	600	600	600
Gabon[6 9]	50–53	2,336	2,579	2,767	2,649	[5]2,480	1,078	1,191	1,277	1,223	1,145
Ghana[6]	30–50	296	[r]394	375	325	278	118	157	150	130	111
Hungary[6 10]	30–33	74	69	69	86	83	22	21	21	28	26
India[6 9 11]	10–54	1,246	1,367	1,337	1,436	[5]1,459	464	509	498	535	544
Iran[6]	25–35	73	61	61	61	61	22	18	18	18	18
Japan	26–27	68	23	7	—	—	18	6	2	—	—
Mexico	27–50	[e]525	[e]437	[e]506	[e]425	484	199	166	192	161	184
Morocco[6]	50–53	65	48	44	47	[5]33	35	26	24	25	[5]18
Romania[6 10]	30	73	[r]75	74	[e]72	72	22	22	22	21	21
South Africa, Republic of[6 9]	30–48 +	3,361	3,969	4,100	3,188	[5]3,792	1,341	1,587	1,663	1,337	[5]1,568
Thailand[6]	46–50	10	5	5	10	[5]8	5	2	3	5	[5]4
Turkey[6]	27–46	47	12	8	[e]8	8	17	4	3	3	3
U.S.S.R.	29–30	11,100	10,900	10,300	10,400	10,100	3,300	3,200	3,100	[e]3,100	3,000
Yugoslavia	25–45	23	[e]28	46	46	45	7	[e]10	16	16	15
Other[e 12]	XX	[r]60	92	[r]55	[r]42	72	23	[r]37	[r]21	[r]14	26
Total[13]	**XX**	**[r]27,613**	**[r]27,990**	**27,585**	**26,160**	**26,303**	**[r]9,482**	**[r]9,603**	**9,765**	**9,112**	**9,175**

[e]Estimated. [p]Preliminary. [r]Revised. XX Not applicable.
[1]Table includes data available through June 9, 1989.
[2]In addition to the countries listed, Colombia, Cuba, Panama, Peru, and Sudan may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels. Low-grade ore not included in this table has been reported as follows, in thousand short tons, gross weight: Argentina (19% to 30% Mn), 1984—7; 1985—8; 1986—11; 1987—11; and 1988—11 (estimated); and Czechoslovakia (about 17% Mn), an estimated 1 in each year.
[3]May be for average content of each year's production rather than for content of typical products.
[4]Metallurgical ore.
[5]Reported figure.
[6]Gross weight reported; metal content estimated. Estimated metal content figures have been revised as necessary.
[7]Reported gross-weight figures are the sum of (1) sales of direct-shipping manganese ore and (2) production of beneficiated ore, both as reported in Anuário Mineral Brasiliero.
[8]Includes manganiferous ore.
[9]Calculated metal content includes allowance for assumed moisture content.
[10]Concentrate.
[11]Much of India's production grades below 35% Mn; average content was reported as 38% Mn in 1984-85.
[12]Category represents the combined totals of Chile, Greece, Indonesia, Italy (from wastes), the Republic of Korea, Pakistan, and the Philippines.
[13]Data may not add to totals shown because of independent rounding.

bearing water with shallower oxygen-bearing water of low manganese solubility. The model was considered to apply to a number of significant deposits currently being exploited, such as the principal deposits in Australia, Gabon, Mexico, Morocco, and the Soviet Union, as well as the Batesville, AK, and Chamberlain, SD, resources of the United States. Analogous present-day marine environments were described, including those of the Baltic and Black Seas.[12]

The Survey also modified descriptive and grade-tonnage models of volcanogenic manganese deposits formed on the seafloor from those published in 1986. Separate grade and tonnage models were developed for each of four types of volcanogenic deposits into which 913 deposits were classified.[13]

In iron ore, too high a manganese content can be a detriment. To lower the 1.9% Mn content in iron concentrates from the Wabash Mine in Quebec Province, Canada, pilot-plant tests were conducted on a process analogous to that used on Three Kids ore in Nevada in the 1940's. Manganese removal was accomplished by the sequence of sulfur dioxide leaching the concentrates in an aqueous media, crystallization of manganese sulfate monohydrate from the leach solution, and two-step calcining of the sulfate, first by reduction with coal to manganese sulfide and second by air oxidation of the sulfide to Mn_3O_4. The tests demonstrated feasibility of operating the process continuously. Manganese content of the iron concentrates was lowered about one-half to 0.94%. The manganese oxide byproduct has potential use in steelmaking.[14]

Elkem Metals and the U.S. Defense National Stockpile Center of DLA jointly investigated the cause for decrepitation of high-carbon ferromanganese stored outdoors for long periods. The Government has been stockpiling high-carbon ferromanganese outdoors since about 1950, and in early 1960, degradation was found in localized zones of the piles. According to this recent study, probable cause of lumps breaking down into powder was that acidic rain water preferentially leached manganese from oxide inclusions in the ferromanganese.[15]

Technical feasibility of plasma processing for production and refining of medium-carbon ferromanganese into a low-silicon grade was investigated on a small scale in the Republic of South Africa. Using a transferred-arc plasma furnace, metal with 79% Mn, 1.6% C, and 1.3% Si was produced from Mamatwan ore fines containing 38% Mn, burnt lime, clays, and a low-grade silicomanganese, for which specific energy consumption was 1,900 kilowatt-hour per ton. Also by means of this furnace, the silicon content of medium-carbon ferromanganese could be reduced to the 0.1% to 0.2% level using various manganese ores as refining agent. The technology was yet to be optimized, including integrating into a single process the successive steps of producing medium-carbon ferromanganese and then lowering its silicon content to the level desired.[16]

Widespread interest in the direct alloying of manganese into steel by a smelting-reduction process was exemplified in laboratory work involving cooperation between China and Sweden. Test conditions in a study of manganese distribution between slag and metal were intended to resemble those in a converter. The results indicated that for direct alloying of manganese the carbon content of the steel should exceed 0.2% and the iron oxide content of the slag should be less than 10%.[17]

A symposium on austenitic steels high in manganese was presented at Cincinnati, OH, in October 1987. Almost all of the steels discussed have relatively high nitrogen content as a consequence of their manganese content and most contain enough chromium to be classed as stainless steel. The steels described included some having potential for use in superconducting magnets because of their cryogenic properties, various others for certain specific applications, and stainless steels in which manganese is used to replace nickel.[18]

The California Air Resources Board determined that addition of a manganese-containing antiknock compound to leaded gasoline was the probable cause of comparatively high levels of airborne manganese in southern California. The study indicated that legal addition of the compound, beginning about 1985, produced manganese concentrations averaging nearly as large as those attributable to the Earth's crust. These were mostly in fine particles. Elsewhere in California, the main source of airborne manganese was the Earth's crust.[19]

Relatively recent developments in world markets for metallurgical manganese included use of combined blowing processes that improve manganese yield in steelmaking, addition of manganese as ore directly into the converter by Japanese steelmakers, and a significant increase in imports of high-grade manganese ore by China and East European countries, principally the Soviet Union among the latter. Looking ahead toward 1995, the trend in manganese demand was foreseen to follow closely that for steel production in industrialized countries but to lag behind the expected increase in steel production in developing countries.[20]

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[1] Physical scientist, Branch of Ferrous Metals.

[2] Unless otherwise specified, the unit of weight in this report is the short ton of 2,000 pounds.

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MERCURY

By Robert G. Reese, Jr.[1]

Although mercury production was withheld by the Bureau of Mines to avoid disclosing company proprietary data, mercury production increased from that of the prior year, owing to the reopening of the McDermitt Mine. Mercury production as a byproduct of gold mining was reported to the Bureau by nine operations, an increase of one from the number of the previous year. Excluding domestic mine production, mercury supplies to the U.S. market declined in 1988, owing to a 48% drop in imports for consumption. Total sales of excess mercury from Government stocks remained essentially the same as in the year before, although most of the material sold in 1988 consisted of secondary mercury. In 1987, Government sales were almost evenly divided between secondary and prime virgin material.

The average New York dealer price was about $40 per flask higher than in 1987, marking the second consecutive year that the average price has increased.[2] During the first 7 months in 1988, the mercury price increased from $335 to $385 per flask, while for the remainder of the year, the price declined to a low of $275 per flask at yearend.

DOMESTIC DATA COVERAGE

Domestic data for mercury are developed by the Bureau of Mines from three separate, voluntary surveys of U.S. operations. Typical of these surveys is "Mercury," a survey of mercury consumption. Of the 329 firms to which this survey form was sent, 94% responded, representing an estimated 99% of the reported U.S. consumption shown in tables 1 and 4. Consumption for the nonrespondents was estimated using prior years consumption levels.

LEGISLATION AND GOVERNMENT PROGRAMS

On February 25, the President signed Executive Order 12626 consolidating management of the National Defense Stockpile (NDS) within the U.S. Department of Defense. Prior to issue of the Executive Order, responsibility for the NDS was divided among the General Services Administration, the Federal Emergency Management Agency, and Defense.

On September 29, the President signed Public Law 100-456, the National Defense Authorization Act Fiscal Year 1989. Title 15 of Public Law 100-456 authorized disposal of 7,500 flasks of mercury from the NDS during fiscal year 1989. Mercury disposals made under this law were restricted in that the total amount received, or to be received from the disposal, could not exceed the amount expended from the National Defense Stockpile Transaction Fund during the fiscal year.

DOMESTIC PRODUCTION

Mine production, which includes byproduct mercury production from gold mines, was withheld by the Bureau of Mines to avoid disclosing company proprietary data. Nevada remained the principal mercury-producing State in 1988. Ten mines, eight in Nevada and one each in California and Utah, reported mercury production to the Bureau.

In March, Placer Dome U.S. Inc. resumed mining operations at the McDermitt mercury mine in Nevada. Despite the fact that in prior years McDermitt had been the major source of domestically produced mercury, the 13-month closure of the mine apparently had little impact on the mercury market. During the time mining operations were suspended, Placer reportedly continued to sell mercury from stocks, which were estimated to be equivalent to 1 year of production when the mine was closed. Placer Dome Inc., the Ca-

TABLE 1

SALIENT MERCURY STATISTICS

		1984	1985	1986	1987	1988
United States:						
Producing mines		5	6	8	9	10
Mine production	flasks	19,048	16,530	W	W	W
Value	thousands	W	W	W	W	W
Secondary production:						
Industrial	flasks	5,673	5,358	6,362	7,692	8,071
Government[1]	do.	—	585	3,078	3,404	6,196
Industry stocks, yearend[2]	do.	27,255	27,985	W	W	W
Shipments from the National Defense Stockpile[3]	do.	4,092	4,534	463	3,700	1,500
Imports for consumption	do.	25,327	18,890	20,187	18,451	9,558
Consumption	do.	54,669	49,846	46,060	r41,942	46,196
Price: New York, average per flask		$314.38	$310.96	$232.79	$295.50	$335.52
Employment, mine and mill, average		41	35	22	9	12
World: Mine production	flasks	r195,380	r198,340	174,890	p172,090	e166,520

e Estimated. p Preliminary. r Revised. W Withheld to avoid disclosing company proprietary data.
[1] Secondary mercury released from U.S. Department of Energy stocks.
[2] Stocks at mines, consumers, and dealers.
[3] Primary mercury.

nadian parent company of Placer Dome U.S. Inc., reported that the McDermitt Mine produced approximately 11,000 flasks of mercury in 1988.[3]

According to the Alaska Division of Geological and Geophysical Surveys, the Mountain Top mercury mine southwest of Sleetmute, AK, was in production in 1987, the latest year for which information was available.[4] However, no details concerning the quantity of mercury produced were reported.

Total secondary production from industry and Government materials was equivalent to 31% of the reported mercury consumption. Secondary mercury was recovered from obsolete items and waste products such as amalgams, batteries, and industrial and control instruments, by the following companies: Adrow Chemical Co., Wanque, NJ; Bethlehem Apparatus Co. Inc., Hellertown, PA; D. F. Goldsmith Chemical and Metals Corp., Evanston, IL; and Mercury Refining Co. Inc., Albany, NY. It was also retrieved from operating chlorine and caustic soda plants and from the U.S. Department of Energy (DOE) shipments of mercury.

CONSUMPTION AND USES

Consumption of mercury was reported by about 200 plants. Prime virgin mercury accounted for 66% of the total reported consumption, followed by secondary mercury, 27%, and redistilled mercury, 7%.[5]

Total reported domestic mercury consumption increased 10% compared with that of 1987, and was essentially equivalent to the consumption reported in 1986. Increased mercury usage in the manufacture of chlorine and caustic soda, and in the manufacture of wiring devices and switches, accounted for most of the higher mercury consumption in 1988. The largest drop in mercury consumption was that reported for batteries, which declined for the fourth consecutive year.

STOCKS

Reports of stocks of mercury held by mine producers were withheld to avoid disclosing company proprietary data. Consumer and dealer-broker stocks continued to rise despite lower imports and increased domestic consumption. The stock increase was probably due in part to the reopening of the McDermitt Mine and increased industrial production of secondary mercury combined with Government sales of a portion of its excess mercury stocks.

At yearend 1987, the NDS contained 165,526 flasks of mercury, of which 155,026 flasks were determined to be excess to Government needs. Disposal of 7,500 flasks of this excess mercury was authorized by Public Law 100–456, the National Defense Authorization Act, Fiscal Year 1989. Government auctions of the excess mercury began in the fourth quarter of 1988 with 750 flasks offered each month. By yearend, 1,500 flasks had been shipped to the purchasers, and the NDS contained 164,026 flasks of mercury.

The secondary mercury stocks managed by the DOE in Oak Ridge, TN, consisted of 28,238 flasks at yearend 1987, all of which was considered excess to Government needs. As authorized by existing legislation, the Government continued sales of this material, offering a maximum of 1,500 flasks per month, from January through October, and a maximum of 750 flasks per month during November and December. Total disposals of DOE mercury in 1988 was 6,196 flasks, a significant increase from the previous year. At yearend 1988, the DOE stocks of secondary mercury contained 22,042 flasks.

PRICES

The range of the New York dealer price for primary mercury as reported in Metals Week, was $335 to $345 per flask for the week ending January 2. The range increased through January before retreating slightly during February. From March through May the range remained stable at $345 to $355 per flask. The peak for the range was $385 and occurred in early July. From midJuly, the price range declined, with the price range low of $275 occurring during the week ending December 10. The range remained at $275 to $290 through yearend.

Analysts attributed the rising and/or stable mercury price during the first half of the year to efforts by certain producing nations to restrict the supply of mercury. The declining price in the second half was attributed to an oversupply of mercury combined with a lack of demand caused in part by expectations of lower prices in the future.

FOREIGN TRADE

Imports for consumption of mercury and mercury-bearing waste and scrap decreased 48%. These included imports for immediate consumption plus material withdrawn from bonded warehouses. The primary reason was a cutback in shipments from China.

WORLD CAPACITY

The data in table 8 were rated capacity for mines as of December 31, 1988. Rated capacity was defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

WORLD REVIEW

Minas de Almadén y Arrayanes S.A. (MAYASA), a Spanish company and the largest world mercury producer, reached an agreement near midyear with Barex World Trade Corp. The agreement permitted Barex to sell MAYASA mercury in the United States. MAYASA reportedly believed that the agreement would help increase its share of the U.S. mercury market.

The MAYASA 15,000-flask-per-year mercury recycling plant at Almaden continued to have startup problems in early 1988. Only one of the four 6-ton-per-day furnaces of the plant was fully operational by midyear. The plant was built in 1987 to recover mercury from zinc-processing plant residues, battery scrap, and mercury-cell chloralkali plants.

TECHNOLOGY

The Bureau of Mines issued a report on selective electrowinning as a method for removing the small quantity of mercury contained in many of the gold ores being mined in the Western United States.[6] Cyanide leach liquors obtained from processing these ores may contain mercury in addition to the precious and base metals. Processing the leach liquors can result in the presence of mercury vapor in the refinery, creating potential pollution and health hazards. Bureau researchers found that selective electrowinning was a technique that could be used to remove mercury from gold-containing cyanide solutions, and that selection of the cathode material was critical in the electrowinning process.

[1] Physical scientist, Branch of Nonferrous Metals

[2] Flask, as used throughout this chapter, refers to the 76-pound flask.

[3] Placer Dome Inc. 1988 Annual Report. 80 pp.

[4] Bundtzen, T. K., C. B. Green, R. J. Peterson, and A. F. Seward. Alaska's Mineral Industry, 1987. Spec. Rep. No. 41, Fairbanks, AK, 1988, 69 pp.

[5] Redistilled mercury is primary mercury further processed or refined to a higher grade and is sometimes referred to as triple distilled mercury.

[6] Sheya, S. A. N., J. H. Maysilles, and R. G. Sandberg. Selective Electrowinning of Mercury From Gold Cyanide Solutions. BuMines RI 9191, 1988, 13 pp.

TABLE 2

BYPRODUCT MERCURY-PRODUCING MINES IN THE UNITED STATES IN 1988

Mine	County and State	Operator
Alligator Ridge	White Pine, NV	Amselco Minerals Inc.
Borealis Project	Mineral, NV	Echo Bay Minerals Co.
Carlin Mines Complex	Eureka, NV	Newmont Gold Co.
Hog Ranch	Washoe, NV	Western Goldfields Co.
Jerritt Canyon (Enfield Bell)	Elko, NV	Freeport-McMoran Gold Co.
McLaughlin	Napa, CA	Homestake Mining Co.
Mercur	Tooele, UT	Barrick Mercur Gold Mines Inc.
Paradise Peak	Nye, NV	FMC Gold Co.
Pinson and Prebble	Humboldt, NV	Pinson Mining Co.

TABLE 3

PRODUCTION OF SECONDARY MERCURY IN THE UNITED STATES

(Flasks)

Year	Industrial production	GSA releases	Total
1984	5,673	—	5,673
1985	5,358	585	5,943
1986	6,362	3,078	9,440
1987	7,692	3,404	11,096
1988	8,071	6,196	14,267

TABLE 4

MERCURY CONSUMED IN THE UNITED STATES, BY USE

(Flasks)

SIC code	Use	1984	1985	1986	1987	1988
28	Chemical and allied products:					
2812	Chlorine and caustic soda manufacture	7,347	6,804	7,499	9,014	12,894
2816	Pigments	W	W	W	W	W
2819	Catalysts, miscellaneous	359	488	515	402	321
2821	Catalysts for plastics	W	W	W	W	W
2819	Laboratory uses	269	413	571	589	740
283	Pharmaceuticals	—	—	W	W	W
2851	Paint	4,651	4,892	5,179	5,755	5,722
—	Other chemicals and allied products	W	478	W	W	W
36	Electrical and electronic uses:					
3641	Electric lighting	1,487	1,147	1,197	[r]1,301	891
3643	Wiring devices and switches	2,730	2,762	2,981	3,811	5,102
3692	Batteries	29,700	27,622	21,764	15,462	12,987
—	Other electrical and electronic uses	W	W	215	W	W
38	Instruments and related products:					
382	Measuring and control instruments	2,856	2,300	1,820	[r]1,718	2,233
3843	Dental equipment and supplies	1,432	1,444	1,507	1,613	1,532
—	Other instruments and related products	W	W	W	W	W
—	Other	1,404	267	349	420	749
	Total	**54,669**	**49,846**	**46,060**	**[r]41,942**	**46,196**

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

TABLE 5

STOCKS OF MERCURY IN THE UNITED STATES, DECEMBER 31

(Flasks)

Year	Producer (mine)	Consumer and dealer	Total
1984	19,964	7,291	27,255
1985	19,398	8,587	27,985
1986	W	6,792	W
1987	W	9,287	W
1988	W	9,803	W

W Withheld to avoid disclosing company proprietary data.

TABLE 6

AVERAGE PRICE OF MERCURY AT NEW YORK

(Per flask)

Period	Price
1984	$314.38
1985	310.96
1986	232.79
1987	295.50
1988:	
January	351.05
February	353.00
March	345.87
April	345.00
May	345.00
June	360.91
July	370.00
August	364.35
September	333.57
October	297.00
November	284.50
December	275.95
Average	**335.52**

Source: Metals Week.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF MERCURY AND MERCURY-BEARING WASTE AND SCRAP, BY COUNTRY

Country	1986 Flasks	1986 Value (thousands)	1987 Flasks	1987 Value (thousands)	1988 Flasks	1988 Value (thousands)
Algeria	1,251	$208	—	—	901	$253
Australia	39	7	—	—	—	—
Canada	10	53	156	$59	161	72
China	4,741	863	11,771	2,235	3,791	1,053
France	1,003	255	7	29	8	36
Germany, Federal Republic of	—	—	2	1	23	14
Hong Kong	—	—	500	62	—	—
Japan	2,202	318	1,000	238	—	—
Mexico	655	150	10	3	—	—
Netherlands	—	—	1	3	—	—
Spain	5,824	1,310	5,002	1,230	4,264	1,263
Turkey	4,328	975	—	—	100	30
United Kingdom	2	2	—	—	310	77
Venezuela	132	35	—	—	—	—
Total[1]	**20,187**	**4,176**	**18,451**	**3,860**	**9,558**	**2,798**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 8

WORLD ANNUAL MERCURY PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand 76-pound flasks)

	Rated capacity[1]
North America:	
United States	35
Mexico	12
Total	**47**
Europe:	
Spain	75
U.S.S.R.	80
Other	23
Total	**178**
Africa: Algeria	35
Asia:	
China	20
Turkey	8
Total	**28**
World total	**288**

[1] Includes capacity at operating plants as well as at plants on standby basis.

TABLE 9

MERCURY: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Flasks)

Country	1984	1985	1986	1987[p]	1988[e]
Algeria[e]	[2]23,000	23,000	22,000	22,000	20,000
China[e]	20,000	20,000	20,000	20,000	20,000
Czechoslovakia	4,409	4,583	4,873	[e]4,700	4,700
Dominican Republic	[r] [e]40	[r]20	13	2	[2]6
Finland	2,292	3,630	4,235	[e]4,000	4,000
Mexico	11,140	11,430	5,366	3,597	3,000
Spain	44,090	45,042	42,653	[e]43,000	43,000
Turkey	5,272	6,552	7,574	5,847	[2]2,814
U.S.S.R.[e]	64,000	65,000	66,000	67,000	67,000
United States	19,048	16,530	W	W	W
Yugoslavia	2,089	2,553	2,176	1,944	2,000
Total	**[r]195,380**	**[r]198,340**	**174,890**	**172,090**	**166,520**

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1] Table includes data available through May 2, 1989.
[2] Reported figure.

MICA

By Lawrence L. Davis[1]

In 1988, about 143,000 short tons of scrap and flake mica was produced in the United States, a decrease of 11% from 1987 production.

Nearly all sheet mica supply continued to be imported. Consumption of muscovite mica block decreased 47% to 30,400 pounds. Consumption of mica splittings increased 15% to 2.4 million pounds. The value of sheet mica exports increased 30% to $6.4 million. Imports for consumption of sheet mica increased 26% to 5.2 million pounds.

DOMESTIC DATA COVERAGE

Domestic production and consumption data for mica are developed by the Bureau of Mines by means of three separate, voluntary surveys and one mandatory survey. Of the 18 operations to which the crude scrap and flake mica production form was sent, 17 operations, or 94%, responded, representing 92% of the production shown in table 1. Of the 17 operations to which the ground mica form was sent, 16 operations or 94% responded, representing 98% of the production in table 1. Of the eight canvassed operations to which the mica block and film consumption form was sent, all responded, representing 100% of the consumption shown in table 1. Of the 10 canvassed operations to which the mica splittings consumption form was sent, 7 operations, or 78%, responded, representing 79% of the splittings consumption shown in table 1. Consumption for the nonrespondents was estimated using prior year production data.

LEGISLATION AND GOVERNMENT PROGRAMS

The Government inventory of stockpile-grade mica was reduced slightly to 22.1 million pounds. The General Services Administration sold 121,000 pounds of muscovite splittings.

DOMESTIC PRODUCTION

Scrap and Flake Mica

North Carolina remained the major producing State with 61% of the total production. The remainder was produced in Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota. Most mica was recovered from mica schist, high-quality sericite schist, and as a byproduct of kaolin, feldspar, and lithium beneficiation.[2] The five largest producers were, in alphabetical order, The Feldspar Corp., Spruce Pine, NC; KMG Minerals Inc., Kings Mountain, NC; Lithium Corp. of America, Gastonia, NC; Pacer Corp., Custer, SD; and Unimin Corp., New Canaan, CT. These five companies produced 67% of the national total.

TABLE 1

SALIENT MICA STATISTICS

		1984	1985	1986	1987	1988
United States:						
Production (sold or used by producers):						
Scrap and flake mica	thousand short tons	161	138	148	161	143
Value	thousands	$7,139	$6,330	$7,108	$8,201	$6,793
Ground mica	thousand short tons	146	136	123	124	120
Value	thousands	$21,334	$21,256	$21,872	$22,376	$23,687
Consumption:						
Block, muscovite	thousand pounds	62	51	50	58	30
Value	thousands	$842	$751	$755	$982	$628
Film	thousand pounds	W	W	W	W	W
Value	thousands	W	W	W	W	W
Splittings	thousand pounds	2,366	2,361	2,226	2,116	2,435
Value	thousands	$1,679	$1,610	$1,252	$1,417	$1,544
Exports	thousand short tons	9	10	8	6	8
Imports, for consumption	do.	13	11	13	13	16
World: Production	thousand pounds	r609,081	r561,416	637,405	p637,984	e595,960

e Estimated. p Preliminary. r Revised.
W Withheld to avoid disclosing company proprietary data.

TABLE 2

STOCKPILE GOALS AND GOVERNMENT INVENTORIES FOR MICA, DECEMBER 31, 1988

(Thousand pounds)

Material	Goal	Inventory: Stockpile grade	Inventory: Non-stockpile grade	Inventory: Available for disposal	Inventory: 1988 sales
Block:					
Muscovite, stained and better	6,200	5,008	207	—	—
Phlogopite	210	17	114	—	—
Film: Muscovite, 1st and 2d qualities	90	1,176	1	1,032	—
Splittings:					
Muscovite	12,630	14,392	—	750	121
Phlogopite	930	1,519	—	589	—

CONSUMPTION AND USES

Sheet Mica

Consumption of muscovite block (ruby and nonruby) totaled 30,400 pounds, a 47% decrease from that of 1987. Of the total muscovite block fabricated, 82% went into electronic uses. Consumption of stained and lower-than-stained quality decreased 48%, but remained in greatest demand, accounting for 91% of consumption. Roughly two-thirds of the muscovite consumed was grade No. 5 or smaller. The large decrease in consumption was the result of two companies ceasing their fabrication operations. Six companies continued to consume muscovite block and film in six plants in five States: two in North Carolina and one each in Massachusetts, New Jersey, Ohio, and Virginia.

Consumption of mica splittings increased 15% to 2.4 million pounds. Muscovite splittings from India accounted for 97% of the consumption. The remainder was phlogopite splittings from Madagascar. The splittings were fabricated into various built-up mica products by nine companies operating nine plants in seven States.

Ground Mica

Thirteen companies operated 17 grinding plants. Twelve plants produced dry-ground, and five produced wet-ground mica. The five largest producers accounted for 74% of the total. They were, in alphabetical order, KMG Minerals, Kings Mountain, NC; Mineral Mining Corp., Kershaw, SC; Pacer, Custer, SD; Unimin, New Canaan, CT; and USG Corp., Chicago, IL.

J.M. Huber Corp. began operation of its new mine and plant at Kings Mountain, NC. Crude mica was concentrated and dry-ground at the new plant. Some concentrate was shipped to Huber's plant at Spruce Pine, NC, for wet-grinding.

Production of low-quality sericite, used primarily in brick manufacturing, was 32,000 tons valued at $96,000. Approximately 37,000 tons of ground sericite valued at $292,000 was sold or used. Low-quality sericite is excluded from tabulated data contained in this report.

TABLE 3

SCRAP AND FLAKE MICA[1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

	Quantity	Value
1984	161	7,139
1985	138	6,330
1986	148	7,108
1987	161	8,201
1988:		
North Carolina	87	4,512
Other States[2]	56	2,281
1988 total	**143**	**6,793**

[1] Includes finely divided mica recovered from mica schist and high-quality sericite schist and mica that is a byproduct of feldspar, kaolin, and lithium beneficiation.
[2] Includes Connnecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota.

TABLE 4

GROUND MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY METHOD OF GRINDING[1]

(Thousand short tons and thousand dollars)

Year	Dry-ground: Quantity	Dry-ground: Value	Wet-ground: Quantity	Wet-ground: Value	Total: Quantity	Total: Value
1984	133	16,269	13	5,065	146	21,334
1985	123	15,993	13	5,263	136	21,256
1986	109	14,682	14	7,190	123	21,872
1987	111	15,140	13	7,237	124	[2]22,376
1988	104	14,570	16	9,117	120	23,687

[1] Domestic and some imported scrap. Low-quality sericite is not included.
[2] Data do not add to total shown because of independent rounding.

Built-Up Mica

The primary use of this mica-base product, made by mechanical or hand setting of overlapping splittings and alternate layers of binders and splittings, was as electrical insulation material. Total production, sold or used, of built-up mica increased 6% from that of 1987. Molding plates and segment plates were the major end products, each accounting for 33% of the total. Other end products included flexible plates, heater plates, and tapes.

Reconstituted Mica (Mica Paper)

Four companies consumed 3.3 million pounds of scrap mica to produce 2.1 million pounds of mica paper. The principal source of this scrap mica was India. Primary end uses for mica paper were the same as those for built-up mica. Manufacturing companies were Corona Films Inc., West Townsend, MA; General Electric Co., Coshocton, OH; Kirkwood-Acim Corp., Hempstead, NY; and US Samica Corp., Rutland, VT.

Ground Mica

The major end uses were joint cement, 55%; paint, 16%; and well-drilling muds, 6%. Other end uses included agricultural products, molded electrical insulation, plastics, roofing, rubber, and welding rods.

STOCKS

Reported yearend consumer stocks of sheet mica increased slightly to 1.1 million pounds; of this, mica splittings represented 93%, and mica block represented 7%.

PRICES

Average reported values of consumed muscovite sheet mica changed as follows: Block increased 84% to $20.63

TABLE 5

FABRICATION OF MUSCOVITE BLOCK MICA IN THE UNITED STATES IN 1988, BY QUALITY AND END-PRODUCT USE

(Pounds)

Quality	Electronic Uses	Nonelectronic Uses	Total
Good stained or better	1,000	1,600	2,600
Stained or lower[1]	24,000	3,900	[2]27,800
Total	**25,000**	**[2]5,400**	**30,400**

[1] Includes punch mica.
[2] Data do not add to total shown because of independent rounding.

TABLE 6

CONSUMPTION AND STOCKS OF MICA SPLITTINGS IN THE UNITED STATES, BY SOURCE

(Thousand pounds and thousand dollars)

	India		Madagascar		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
Consumption:						
1984	2,323	1,537	42	141	2,366	1,679
1985	2,327	1,485	34	125	2,361	1,610
1986	2,197	1,136	29	116	2,226	1,252
1987	2,050	1,231	67	185	2,116	1,417
1988	2,358	1,338	77	206	2,435	1,544
Stocks, Dec. 31:						
1984	877	NA	77	NA	954	NA
1985	1,085	NA	41	NA	1,126	NA
1986	1,249	NA	95	NA	1,344	NA
1987	899	NA	9	NA	908	NA
1988	968	NA	10	NA	978	NA

NA Not available.
[1] Data may not add to totals shown because of independent rounding.

TABLE 7

BUILT-UP MICA[1] SOLD OR USED IN THE UNITED STATES, BY PRODUCT

(Thousand pounds and thousand dollars)

Product	1987		1988	
	Quantity	Value	Quantity	Value
Flexible (cold)	177	626	188	499
Heater plate	51	88	47	76
Molding plate	680	2,397	723	1,898
Segment plate	571	2,211	717	2,241
Tape	161	1,197	81	305
Other	429	1,758	431	1,810
Total	**2,069**	**8,277**	**2,187**	**6,829**

[1] Consists of alternating layers of binder and irregularly arranged and partly overlapped splittings.

TABLE 8

GROUND MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY END USE

(Thousand short tons and thousand dollars)

End use	1987 Quantity	1987 Value	1988 Quantity	1988 Value
Joint cement	71	11,352	66	10,936
Paint	15	3,012	19	3,536
Plastics	2	338	1	366
Well-drilling mud	7	797	7	741
Other[1]	28	6,877	27	8,108
Total	**[2]124**	**22,376**	**120**	**23,687**

[1] Includes mica used for agricultural products, molding electrical insulation, plastics, rubber, textile and decorative coatings, and welding rods.
[2] Data do not add to total shown because of independent rounding.

TABLE 9

AVERAGE REPORTED PRICE FOR DRY- AND WET-GROUND MICA SOLD OR USED BY U.S. PRODUCERS IN 1988

(Dollars per short ton)

Kind	Price
Wet-ground	576
Dry-ground	140
End uses:	
Joint cement	166
Paint	186
Plastics	264
Well-drilling mud	106
Other[1]	299

[1] Includes mica used for agricultural products, molded electrical insulation, roofing, rubber, textile and decorative coatings, welding rods, and miscellaneous.

per pound; film increased slightly to \$13.96 per pound; and splittings increased 3% to \$0.62 per pound. The average value of phlogopite block increased 37% to \$8.33 per pound, while the value of phlogopite splittings decreased 27% to \$2.03 per pound. The large changes in average value are more a reflection of the quality of mica consumed during the year than actual changes in price. The average value of crude scrap (flake) mica, including high-quality sericite, was \$47 per ton. The average value per ton for North Carolina scrap (flake) mica, predominantly a flotation product, was \$52.

FOREIGN TRADE

The United States continued to rely on imports, mostly from India, for nearly all of its unmanufactured sheet mica and paper-quality scrap mica. Imports for consumption of unmanufactured block, film, and splittings increased 44% to 3.5 million pounds. The increase was a reflection of lower than average sales of mica from the Government stockpile and the decrease in domestic fabrication of mica parts. About 9,000 tons of ground mica was imported, mostly from Canada, while about 6,000 tons was exported to 35 countries. The combined value of all mica imports increased 30% to \$13.3 million, while the combined value of all mica exports increased 30% to 8.4 million.

WORLD CAPACITY

The data in tables 15 and 16 are rated capacity for mines and plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Domestic capacity was estimated by assuming that the highest production in the last 5 years was equivalent to 95% of current capacity. Foreign capacities were estimated by assuming that each country's highest production in the last 5 years is that country's current capacity. For countries where sheet mica production was not separately identified, it was assumed that all production was scrap and flake mica except for known sheet mica producers, Brazil, Madagascar, and the U.S.S.R., where it was estimated that 10% of production was sheet mica and 90% was scrap and flake mica.

WORLD REVIEW

World production of mica decreased 7% to 596 million pounds. The United States continued to lead in the production of scrap (flake) mica. India continued to lead in the production of sheet mica.

India

The Mica Trading Corp. of India Ltd. (MITCO) was adding at least two new mica paper units with combined annual capacity of 660 tons and a wet-ground mica plant with an anticipated annual capacity of 1,300 tons. For several years, MITCO has been trying to increase India's production of value-added mica, such as ground mica and mica paper. To further that effort, MITCO was establishing a $1.9 million[3] research and development center that will focus on the development of new mica products and applications.[4]

[1] Physical scientist, Branch of Industrial Minerals.

[2] Production of high-quality sericite is included in the totals; however, figures for low-quality sericite, used principally for brick manufacturing, are not included.

[3] Value has been converted from Indian rupees (Rs) to U.S. dollars (US$) at the exchange rate of Rs.15.90= US$1.00 as of May 15, 1989.

[4] U.S. Embassy, New Delhi, India. State Dep. Telegram 13625, May 27, 1988.

TABLE 10

U.S. EXPORTS OF MICA AND MANUFACTURES OF MICA IN 1988, BY COUNTRY

(Thousand pounds and thousand dollars)

Country	Scrap and flake mica				Sheet mica		
	Ground or pulverized		Waste and scrap[1]		Unmanufactured block, film, and splittings		Manufactured, cut or stamped, built-up
	Quantity	Value	Quantity	Value	Quantity	Value	Value
Argentina	46	5	—	—	—	—	33
Australia	78	13	40	12	—	—	195
Austria	—	—	—	—	—	—	68
Brazil	66	14	—	—	—	—	1,074
Canada	2,134	248	432	73	—	—	2,443
France	284	25	—	—	—	—	14
Germany, Federal Republic of	684	80	80	11	2	3	66
Hong Kong	44	6	20	3	2	3	140
India	—	—	146	21	6	19	33
Italy	62	6	108	15	—	—	384
Japan	1,108	112	324	51	10	35	180
Korea, Republic of	1,088	242	348	53	6	24	32
Mexico	2,492	319	370	53	44	48	583
Netherlands	934	128	—	—	—	—	109
Peru	80	11	—	—	—	—	42
Saudi Arabia	170	26	—	—	—	—	13
Spain	188	99	214	30	66	95	111
Taiwan	140	17	42	6	—	—	332
United Kingdom	302	55	38	5	—	—	37
Venezuela	464	70	78	11	—	—	113
Other[2]	1,106	146	160	22	2	2	147
Total[3]	**11,470**	**1,623**	**2,400**	**367**	**138**	**228**	**6,148**

[1] Some shipments of ground mica are included in this category.

[2] Includes the Bahamas, Barbados, Belgium, Bermuda, Bolivia, Chile, Columbia, the Dominican Republic, Ecuador, El Salvador, Guatemala, Indonesia, Ireland, Israel, Jamaica, Kuwait, Malaysia, the Netherlands Antilles, Pakistan, Philippines, Portugal, Singapore, the Republic of South Africa, Sweden, Switzerland, and Thailand.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF SCRAP AND FLAKE MICA, BY COUNTRY

(Thousand pounds and thousand dollars)

	Waste and scrap		Ground or pulverized	
	Quantity	Value	Quantity	Value
1986	9,945	1,225	12,017	2,324
1987	8,635	1,243	12,507	2,685
1988:				
Canada	88	5	16,841	3,267
France	—	—	76	41
Germany, Federal Republic of	—	—	15	3
India	9,493	1,333	40	14
Japan	—	—	149	886
Norway	—	—	30	11
Total	**9,581**	**[1]1,339**	**17,151**	**4,222**

[1] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF UNMANUFACTURED SHEET MICA, BY COUNTRY

(Thousand pounds and thousand dollars)

	Block		Splittings		Not cut or stamped, not over 0.006 inch in thickness[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
1986	11	61	1,824	580	32	13
1987	95	235	2,364	991	1	4
1988:						
India	140	100	2,921	1,229	54	73
Italy	—	—	106	52	—	—
Madagascar	115	220	104	213	—	—
Switzerland	—	—	36	14	—	—
United Kingdom	([2])	1	33	59	—	—
Other[3]	8	82	2	20	17	20
Total[4]	**264**	**403**	**3,201**	**1,587**	**71**	**93**

[1] Includes film.
[2] Less than 1/2 unit.
[3] Includes China, France, Japan, Mexico, the Netherlands, and Tanzania.
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of Census.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF MANUFACTURED SHEET MICA, BY COUNTRY

(Thousand pounds and thousand dollars)

	Cut or stamped				Plates and built-up		Articles not especially provided for	
	Not over 0.006 inch in thickness		Over 0.006 inch in thickness					
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1986	32	348	66	291	1,677	3,329	331	891
1987	42	407	62	392	1,159	2,807	382	1,519
1988:								
Belgium	—	—	—	—	1,293	3,321	4	43
France	—	—	—	—	53	108	9	22
India	30	496	48	294	1	12	8	338
Japan	—	—	108	408	13	61	8	41
Switzerland	—	—	—	—	—	—	25	247
Other[1]	—	—	5	17	21	46	29	226
Total[2]	**30**	**496**	**162**	**719**	**1,381**	**3,549**	**84**	**916**

[1] Includes Brazil, Canada, China, the Federal Republic of Germany, Indonesia, Italy, the Netherlands, Spain, Taiwan, Tanzania, and the United Kingdom.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 14

SUMMATION OF U.S. MICA TRADE DATA

(Thousand pounds and thousand dollars)

	Scrap and flake mica				Sheet mica			
	Ground or pulverized		Waste and scrap[1]		Unmanufactured block, film, and splittings		Manufactured, cut or stamped, built-up	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Exports:								
1984	11,500	1,506	3,806	532	348	549	NA	4,519
1985	14,460	1,962	2,918	408	82	159	NA	5,103
1986	11,686	1,758	3,206	472	98	196	NA	4,502
1987	9,338	1,275	1,816	259	170	145	NA	4,748
1988	11,470	1,623	2,400	367	138	228	NA	6,148
Imports for consumption:								
1984	12,814	2,266	10,384	985	1,480	644	856	2,836
1985	12,097	2,202	7,960	718	1,683	1,080	978	3,154
1986	12,017	2,324	9,945	1,225	1,866	653	2,105	4,859
1987	12,507	2,685	8,635	1,243	2,460	1,230	1,645	5,125
1988	17,151	4,222	9,581	1,339	3,535	2,083	1,657	5,679

NA Not available.
[1] Some shipments of ground mica are included in this category.

Source: Bureau of the Census.

TABLE 15

WORLD SHEET MICA ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand pounds)

	Rated capacity[e] [1]
South America:	
Argentina	700
Brazil	900
Total	**1,600**
Africa:	
Madagascar	350
Other	180
Total	**530**
Asia:	
China	7,700
India	15,000
U.S.S.R.	11,000
Total	**33,700**
World total	**35,830**

[e] Estimated.
[1] Includes capacities of operating plants as well as plants on standby basis.

TABLE 16

WORLD SCRAP AND FLAKE MICA ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand pounds)

	Rated capacity[e] [1]
North America:	
United States	169
Other	15
Total	**184**
South America	5
Europe	15
Africa	10
Asia:	
China	16
Korea	46
India	17
U.S.S.R	49
Other	1
Total	**129**
World total	**343**

[e] Estimated
[1] Includes capacities of operating plants as well as plants on standby basis.

TABLE 17

MICA: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand pounds)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina:					
Sheet	26	[r]765	516	[re]750	750
Waste, scrap, etc.	613	[r]825	712	[re]1,000	1,000
Brazil	8,834	6,352	4,817	[e]5,500	5,500
Canada[e]	23,000	25,000	26,000	[r]29,800	26,500
France	23,929	22,231	23,885	[e]24,000	24,000
India[e]:					
Exports:					
Block	2,400	2,600	2,600	[r]2,200	2,200
Film and disk	440	550	550	[r]440	440
Splittings	7,000	8,800	8,800	[r]6,600	6,600
Scrap	15,500	24,200	24,200	[r]22,000	22,000
Powder	9,000	10,400	10,400	[r]8,400	8,400
Manufactured	1,100	2,200	2,200	[r]4,400	4,400
Domestic consumption, all forms	6,600	7,700	7,700	8,800	8,800
Total	**42,040**	**56,450**	**56,450**	**[r]52,840**	**52,840**
Iran[e] [3]	[4]1,246	[4]1,808	1,800	1,800	1,800
Korea, Republic of (all grades)	53,872	44,189	92,587	70,411	66,000
Madagascar (phlogopite)	1,587	1,299	3,514	886	880
Mexico (all grades)	3,695	3,188	3,854	7,538	6,600
Morocco[e]	[4]2,646	[4]3,175	3,300	3,300	3,300
Mozambique[e]	660	660	[r]660	[r]660	660
Namibia	[r]192	—	—	—	—
Peru[e]	1,200	1,200	1,200	1,200	1,200
South Africa, Republic of:					
Sheet	—	179	—	—	—
Scrap	9,872	4,568	5,531	2,138	[4]3,558
Spain	2,183	1,603	717	[e]550	660
Sri Lanka (scrap)[e]	440	440	440	440	440
Sudan (all grades)[e]	[4]22	22	22	22	22
Taiwan	670	[e]250	1,706	1,735	1,500
Tanzania (sheet)	([5])	([5])	([5])	([5])	([5])
U.S.S.R. (all grades)[e]	108,000	110,000	110,000	110,000	110,000
United States (scrap and flake)[6]	322,000	275,100	296,300	321,100	[4]286,400
Yugoslavia[e]	[4]346	[4]829	[r]440	[r]550	550
Zimbabwe	2,008	1,283	2,954	1,764	1,800
Grand total	**[r]609,081**	**[r]561,416**	**637,405**	**637,984**	**595,960**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through May 10, 1989.
[2] In addition to the countries listed, China, Norway, Pakistan, Romania, and Sweden are known to produce mica, but available information is inadequate to make reliable estimates of output levels.
[3] Data are for year beginning Mar. 21 of that stated.
[4] Reported figure.
[5] Less than 1/2 unit.
[6] Excludes U.S. production of low-quality sericite and sheet mica, if any.

MOLYBDENUM

By John W. Blossom[1]

Domestic and foreign molybdenum markets expanded in 1988 and demand among market economy countries exceeded mine production. Domestic producer and consumer stocks decreased. U.S. mine output of molybdenum increased and represented 45% of the world production. Reported end-use consumption of molybdenum in raw materials and apparent domestic demand both increased. Exports of all forms of molybdenum from the United States increased. Domestic producer stocks of molybdenum products decreased to about 8 months of annual consumption.

DOMESTIC DATA COVERAGE

Domestic production data for molybdenum are developed by the Bureau of Mines by means of three separate, voluntary surveys. These surveys are "Molybdenum Ore and Concentrate," "Molybdenum Concentrate and Molybdenum Products," and "Molybdenum Concentrates." Out of 12 operations to which surveys were sent, all responded, representing 100% of the total production shown in table 1.

DOMESTIC PRODUCTION

Domestic mine production of molybdenum concentrate increased to a total of 95 million pounds of contained molybdenum, compared with 75 million pounds in 1987. The country's two largest suppliers, AMAX Inc. and Cyprus Minerals Co., produced sufficient material during 1988 to keep supply and demand in balance.

CONSUMPTION AND USES

Consumption data for 1988 are not available for publication. Domestic mine production of molybdenum concentrate was either roasted, exported for conversion, or purified to lubrication-grade molybdenum disulfide. The quantity of concentrate roasted domestically to produce technical-grade molybdic oxide increased over that of 1987. Oxide is the chief form of molybdenum utilized by industry, particularly steel, cast iron, and superalloy producers. However, some of the material is also converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder.

Apparent consumption (defined as U.S. primary plus secondary production plus imports minus exports plus adjustments for Government and industry stock changes) increased to 56 million pounds of molybdenum. The total reported end-use consumption of molybdenum products increased about 18% over that of 1987. Molybdenum consumed in oxide form (technical-grade, purified, and briquets) accounted for about 56% of total reported end-use consumption; in ferromolybdenum, 16%; and in other forms, 28%.

Molybdenum reported as consumed in the production of steel accounted for 57% of total consumption. Approximately 27% of consumption was attributed to other metallurgical uses, such as cast irons, superalloys, and as a refractory metal. Catalyst, lubricant, pigment, and other nonmetallurgical applications composed the final 16% of total consumption.

STOCKS

Total industry stocks, which include those of producers and consumers, decreased to 32 million pounds of contained molybdenum. Inventories of molybdenum in concentrate at mine locations decreased from 15 million to 10 million pounds. Producer stocks of molybdenum in consumer products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, decreased to 16 million pounds. Compared with apparent consumption, yearend

TABLE 1

SALIENT MOLYBDENUM STATISTICS

(Thousand pounds of contained molybdenum and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Concentrate:					
Production	103,664	108,409	93,976	75,117	94,911
Shipments	102,405	111,936	95,006	69,868	99,738
Value	$326,780	$347,812	$240,484	$179,286	$266,899
Reported consumption	54,843	W	53,061	37,442	78,684
Imports for consumption[r]	28	112	1,120	1,264	169
Stocks, Dec. 31: Mine and plant	12,450	9,322	8,715	15,082	10,061
Primary products:					
Production	79,689	87,436	41,490	34,659	56,540
Shipments	65,527	73,861	57,855	40,668	45,273
Stocks, Dec. 31: Producer's	22,155	21,014	20,699	22,168	15,688
Reported consumption	34,792	33,451	31,898	32,629	38,408
World: Mine production	[r]215,375	[r]216,959	204,588	[p]196,537	[e]208,880

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

TABLE 2

PRODUCTION, SHIPMENTS, AND STOCKS OF MOLYBDENUM PRODUCTS IN THE UNITED STATES

(Thousand pounds of contained molybdenum)

	1987	1988	1987	1988	1987	1988
	Molybdic oxides[1]		Metal powder		Ammonium molybdate	
Received from other producers	22,801	7,258	W	W	1,621	1,549
Gross production during year	W	W	5,925	6,214	W	W
Used to make other products listed here	18,706	21,214	1,744	1,836	1,771	1,772
Net production	W	W	4,181	4,378	W	W
Shipments	W	W	4,333	3,731	W	W
Producer stocks, Dec. 31	W	10,617	457	300	W	W
	Sodium molybdate		Other[2]		Total	
Received from other products	W	W	218	1,771	24,640	10,578
Gross production during year	W	W	28,734	50,326	34,659	56,540
Used to make other products listed here	W	W	1,181	1,937	23,402	26,759
Net production	W	W	7,076	25,404	11,257	29,782
Shipments	W	W	36,335	41,542	40,668	45,273
Producer stocks, Dec. 31	W	W	21,711	4,771	22,168	15,688

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes technical and purified molybdic oxide and briquets.

[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, molybdenum hexacarbonyl, and data indicated by symbol W.

producer stocks of these materials represented about an 8-month supply. Domestic consumers held inventories of about 6 million pounds, the same amount as in 1987, representing approximately a 2-month supply as measured by average monthly reported consumption.

PRICES

The "Metals Week Dealer" (MWD) price of molybdic oxide (per pound of contained molybdenum) increased from $2.85 in January to $3.49 at the end of December 1988. The average MWD price of oxide was $3.47, or $0.46 more than the average MWD price in 1987.

The posted producer price for molybdic oxide was $3.25 on January 1 and increased to $3.40 by the end of January. During March it increased to $3.65 and remained at that level through December 1988.

FOREIGN TRADE

Exports

Exports of molybdenum in concentrate and oxide increased compared with that of 1987. Molybdenum concentrate exports was about 55% of domestic mine production. Approximately 97% of reported concentrate and oxides was shipped to Belgium-Luxembourg, the Federal Republic of Germany, Japan, the Netherlands, Sweden and the United Kingdom. The calculated molybdenum content of all exports was about 59 million pounds in 1988. Total value of exports increased from $140 million in 1987 to $205 million in 1988.

Imports

Approximately 9 million pounds of molybdenum in various forms was imported into the United States, 4.5 million pounds less than in 1987. Total value of all forms of molybdenum imported decreased from $48 million in 1987 to $37 million in 1988. In terms of both value and quantity, the major forms imported were as ferromolybdenum and molybdenum compounds. The principal originating countries for these imports were Chile and China.

The duty-free treatment afforded under the Generalized System of Preferences (GSP) to imports of molybdenum ore, TSUS-601.33, and materials in chief value of molybdenum, TSUS-603.40, was withdrawn from all countries on or after December 31, 1987. In addition, Proclamation 5758 issued on December 24, 1987, with an effective date of February 29, 1988, proclaimed general headnote 3 (e)(v)(A) to the TSUS is modified by striking out "Chile" from the enumeration of independent countries whose products are eligible for benefits under GSP; and that no article that is the product of Chile and imported into the United States after the effective date of this Proclamation shall be eligible for pref-

TABLE 3

U.S. REPORTED CONSUMPTION OF MOLYBDENUM, BY END USE

(Thousand pounds of contained molybdenum)

End use	Molybdic oxides	Ferromo-lybdenum[1]	Ammonium and sodium molybdate	Other molybdenum materials[2]	Total[3]
1987					
Steel:					
Carbon	926	263	—	(4)	1,189
Stainless and heat resisting	5,604	504	—	148	6,257
Full alloy	6,454	1,198	—	59	7,712
High-strength, low-alloy	726	762	—	4	1,492
Tool	1,568	W	—	49	1,617
Cast irons	W	1,275	—	20	1,295
Superalloys	1,113	99	—	1,664	2,876
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	—	216	—	12	228
Other alloys[5]	217	120	—	120	456
Mill products made from metal powder	—	—	—	3,752	3,752
Chemicals and ceramics:					
Pigments	W	—	W	—	W
Catalysts	1,794	—	W	365	2,159
Other	8	—	1	729	737
Miscellaneous and unspecified	536	621	1,621	81	2,859
Total[3]	**18,945**	**5,059**	**1,622**	**7,003**	**32,629**
1988					
Steel:					
Carbon	1,199	217	—	30	1,446
Stainless and heat resisting	7,054	442	—	162	7,657
Full alloy	6,743	2,220	—	86	9,050
High-strength, low-alloy	1,089	898	—	2	1,989
Tool	1,810	W	—	33	1,843
Cast irons	178	1,372	—	20	1,570
Superalloys	964	102	—	1,671	2,737
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	—	130	—	15	144
Other alloys[5]	285	103	—	181	568
Mill products made from metal powder	—	—	—	5,259	5,259
Chemicals and ceramics:					
Pigments	—	—	240	—	240
Catalysts	1,579	—	W	406	1,985
Other	8	—	1	908	917
Miscellaneous and unspecified	696	752	1,492	64	3,004
Total[3]	**21,604**	**6,235**	**1,733**	**8,836**	**38,408**

W Withheld to avoid disclosing company proprietary data.

[1] Includes calcium molybdate.

[2] Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

[3] Data may not add to totals shown because of independent rounding.

[4] Less than 1/2 unit.

[5] Includes magnetic and nonferrous alloys.

TABLE 4

INDUSTRY STOCKS OF MOLYBDENUM MATERIALS, DECEMBER 31

(Thousand pounds of contained molybdenum)

Material	1984	1985	1986	1987	1988
Concentrate: Mine and plant	12,450	9,322	8,715	15,082	10,061
Producers:					
Molybdic oxides[1]	17,295	16,281	16,459	W	10,617
Metal powder	594	W	W	457	300
Ammonium molybdate	684	W	W	W	W
Sodium molybdate	W	W	W	W	W
Other[2]	3,582	4,733	4,240	21,711	4,771
Total	**22,155**	**21,014**	**20,699**	**22,168**	**15,688**
Consumers:					
Molybdic oxides[1]	1,552	2,020	2,168	3,653	3,486
Ferromolybdenum[3]	721	597	618	554	573
Ammonium and sodium molybdate	80	47	129	76	55
Other[4]	1,540	1,778	1,654	1,643	1,658
Total[5]	**3,893**	**4,441**	**4,569**	**5,925**	**5,772**
Grand total[5]	**38,498**	**34,777**	**33,983**	**43,175**	**31,521**

W Withheld to avoid disclosing company proprietary data.

[1] Includes technical and purified molybdic oxide and briquets.

[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

[3] Includes calcium molybdate.

[4] Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

[5] Data may not add to totals shown because of independent rounding.

TABLE 5

DOMESTIC PRICE LISTINGS FOR MOLYBDENUM

(Per pound of contained metal)

	1987	1988
Merchant quotes:[1]		
Concentrate (byproducts)	$2.59	$2.68
Ferromolybdenum-export	3.58	4.27
Oxide	3.01	3.47
Producer quotes:		
Oxide	$3.45– 3.25	$3.25– 3.65

[1] Average.

Source: Metals Week.

erential treatment under the GSP. This action was effective in reducing imports to the United States.

WORLD CAPACITY

The data in table 10 are rated capacity for mines and mills as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Mine capacity for molybdenum was based on published reports, production statistics, and estimates.

WORLD REVIEW

World mine production of molybdenum was 209 million pounds, an increase of 12 million pounds from that in 1987. Canada, Chile, the U.S.S.R., and the United States accounted for more than 89% of the molybdenum produced worldwide.

[1] Physical scientist, Branch of Ferrous Metals.

TABLE 6

U.S. EXPORTS OF MOLYBDENUM ORE AND CONCENTRATES (INCLUDING ROASTED CONCENTRATES), BY COUNTRY

(Thousand pounds of contained molybdenum and thousand dollars)

Country	1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value
Austria	—	—	4,369	11,576	26	71
Belgium-Luxembourg	3,088	8,782	5,337	12,526	8,560	25,557
Brazil	222	761	114	381	192	733
Canada	3,662	8,149	1,507	2,348	82	355
Chile	93	130	44	109	136	52
France	—	—	228	644	—	—
Germany, Federal Republic of	2,028	4,299	5,966	13,564	5,803	13,961
Japan	5,818	16,555	2,852	8,071	7,179	18,730
Mexico	22	137	3	18	45	51
Netherlands	24,997	75,802	12,443	31,557	16,984	51,703
Sweden	2,792	6,047	1,275	3,062	2,510	6,522
United Kingdom	6,243	14,499	5,765	12,911	9,034	26,763
Other	188	845	611	1,615	1,256	3,742
Total[1]	**49,153**	**136,006**	**40,514**	**98,381**	**51,807**	**148,237**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 7

U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1987		1988	
	Quantity	Value	Quantity	Value
Ferromolybdenum:[1]				
Canada	45	171	31	122
Japan	74	314	49	146
Malaysia	4	15	—	—
Mexico	27	74	24	80
Other	11	31	9	35
Total[2]	**161**	**605**	**113**	**382**
Metal and alloys in crude form and scrap:				
Belgium	1	4	68	472
Canada	22	184	21	140
France	8	36	5	49
Germany, Federal Republic of	70	418	36	283
India	1	6	2	13
Japan	227	1,406	503	3,101
Mexico	12	128	8	93
Netherlands	78	323	140	762
United Kingdom	16	154	21	158
Other	78	845	190	1,616
Total[2]	**513**	**3,504**	**995**	**6,686**
Wire:				
Argentina	2	41	5	95
Belgium-Luxembourg	20	257	18	162
Brazil	47	803	64	1,091
Canada	31	530	31	543
France	23	403	65	1,126
Germany, Federal Republic of	202	2,506	219	2,857
India	([3])	6	5	115
Italy	67	975	87	1,266
Japan	67	1,260	101	1,911
Mexico	9	252	9	271
Netherlands	4	32	1	14
Singapore	2	53	1	73
South Africa, Republic of	2	28	5	90
Spain	19	257	18	298
Sweden	25	382	26	429
United Kingdom	15	349	81	714
Other	39	907	105	1,929
Total[2]	**573**	**9,043**	**839**	**12,984**
Powder:				
Belgium-Luxembourg	974	2,363	529	1,934
Canada	289	2,576	79	185
France	92	589	25	167
Germany, Federal Republic of	77	379	22	291
Italy	2	31	1	30
Japan	7	88	238	807
Mexico	6	44	2	8

See footnotes at end of table.

TABLE 7—Continued

U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1987 Quantity	1987 Value	1988 Quantity	1988 Value
Netherlands	26	181	24	157
Sweden	13	92	—	—
Taiwan	133	944	123	1,003
United Kingdom	497	1,156	223	797
Other	28	423	75	510
Total[2]	**2,145**	**8,866**	**1,340**	**5,889**
Semifabricated forms, n.e.c.:				
Australia	8	149	2	34
Austria	—	—	28	292
Brazil	19	343	12	209
Canada	13	324	52	1,104
France	34	1,146	10	435
Germany, Federal Republic of	29	655	38	805
Japan	29	704	89	1,002
Korea	—	—	91	1,469
Mexico	3	76	4	67
Netherlands	63	2,547	60	2,355
Philippines	([3])	2	—	—
Singapore	([3])	5	—	—
South Africa, Republic of	7	291	1	79
Sweden	—	—	3	59
United Kingdom	47	1,287	50	1,120
Other	30	638	10	334
Total[2]	**282**	**8,167**	**451**	**9,362**
Molybdenum compounds:				
Argentina	([3])	2	([3])	2
Australia	8	16	55	159
Belgium-Luxembourg	68	342	244	867
Brazil	5	21	1	4
Canada	274	1,160	235	856
Chile	—	—	1,300	3,325
Germany, Federal Republic of	3	31	([3])	2
Japan	3,152	7,240	5,261	12,722
Korea	—	—	9	30
Mexico	86	220	4	18
Netherlands	159	335	755	2,524
Taiwan	—	—	5	16
Venezuela	—	—	342	834
United Kingdom	150	373	123	341
Other	791	1,407	16	128
Total[2]	**4,696**	**11,146**	**8,350**	**21,828**

[1] Ferromolybdenum contains about 60% to 65% molybdenum.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF MOLYBDENUM

(Thousand pounds and thousand dollars)

Item	TSUS No.	1987 Gross weight	1987 Contained molybdenum	1987 Value	1988 Gross weight	1988 Contained molybdenum	1988 Value
Ore and concentrate	601.33	2,195	1,264	3,109	310	169	349
Material in chief value molybdenum	603.40	8,664	5,248	15,497	1,591	965	2,863
Ferromolybdenum	606.31	3,815	2,283	8,042	3,704	2,369	8,504
Waste and scrap	628.72	NA	646	2,545	NA	678	3,276
Unwrought	628.72	NA	174	2,308	NA	296	3,752
Wrought	628.74	158	NA	2,801	119	NA	3,457
Ammonium molybdate	417.28	1,355	786	2,870	1,346	804	3,262
Molybdenum componds	419.60	2,702	1,822	7,594	2,192	1,575	7,137
Sodium molybdate	421.10	150	64	262	82	56	140
Mixtures of inorganic compounds, chief value molybdenum	423.88	66	46	220	1,247	906	1,348
Molybdenum orange	473.18	2,438	NA	2,461	2,494	NA	3,128
Total [1]		**21,543**	**12,333**	**47,711**	**13,085**	**7,818**	**37,216**

NA Not available.
[1] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 9

U.S. IMPORT DUTIES ON MOLYBDENUM

Item	TSUS No.	Most Favored Nation (MFN) Jan. 1, 1988	Non-MFN Jan. 1, 1988
Molybdenum ore and concentrate	601.33	9 cents per pound	35 cents per pound.
Material in chief value molybdenum	603.40	6 cents per pound plus 1.9% ad valorem	50 cents per pound plus 15% ad valorem.
Ferromolybdenum	606.31	4.5% ad valorem	31.5% ad valorem.
Molybdenum:			
Waste and scrap	628.70	6% ad valorem	50% ad valorum.
Unwrought	628.72	6.3 cents per pound	50 cents per pound
Wrought	628.74	6.6% ad valorem	60% ad valorem.
Molybdenum chemicals:			
Ammonium molybdate	417.28	4.3% ad valorem	29% ad valorem.
Calcium molybdate	418.26	Free	24.5% ad valorem.
Molybdenum compounds	419.60	3.2% ad valorem	20.5% ad valorem.
Potassium molybdate	420.22	3% ad valorem	23% ad valorem.
Sodium molybdate	421.10	3.7% ad valorem	25.5% ad valorem.
Mixtures of inorganic compounds, chief value molybdenum	423.88	2.8% ad valorem	18% ad valorem.
Molybdenum orange	473.18	3.9% ad valorem	25% ad valorem.

TABLE 10

WORLD MOLYBDENUM ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Million pounds of contained molybdenum)

Country	Rated capacity[1]
Bulgaria	2
Canada	35
Chile	45
China	10
Iran	4
Korea, Republic of	2
Mexico	15
Mongolia	5
Niger	([2])
Peru	10
U.S.S.R.	35
United States	165
Total	**328**

[1] Includes capacity at operating plants as well as at plants on standby basis.
[2] Less than 1/2 unit.

TABLE 11

MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Thousand pounds of contained molybdenum)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Bulgaria[e]	420	420	[r]420	[r]440	440
Canada (shipments)	25,479	17,311	24,804	32,564	[3]27,311
Chile	37,172	40,541	36,555	37,349	37,500
China[e]	4,400	4,400	4,400	4,400	4,400
Iran[e]	1,100	1,100	1,100	1,100	1,100
Japan[e]	324	215	—	—	[3]—
Korea, Republic of	348	734	697	717	660
Mexico	8,938	8,292	7,386	9,700	9,500
Mongolia[e]	2,200	2,200	2,425	2,425	2,425
Niger[e]	73	44	44	33	33
Peru	6,557	[r]8,393	7,681	7,392	5,300
U.S.S.R.[e]	24,700	24,900	25,100	25,300	25,300
United States	103,664	108,409	93,976	75,117	[3]94,911
Total	**[r]215,375**	**[r]216,959**	**204,588**	**196,537**	**208,880**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through June 14, 1989.
[2] In addition to the countries listed, North Korea, Romania, Turkey, and Yugoslavia are believed to produce molybdenum, but output is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.
[3] Reported figure.

NICKEL

By William S. Kirk[1]

The nickel market was beset by high demand, tight supply, and volatile prices. Although production of stainless steel, the largest end use for nickel, was at record-high levels, domestic reported consumption of nickel was slightly lower than that of 1987. This was partially due to substitution and increased imports of stainless steel. Nevertheless, nickel prices remained high.

DOMESTIC DATA COVERAGE

Domestic consumption data for nickel are developed by the Bureau of Mines from a voluntary survey of U.S. plants. Of the 300 plants to which a survey request was sent, 289 responded, representing 86% of the apparent primary nickel consumption shown in table 4. Apparent consumption of primary nickel was derived by using imports minus exports plus adjustments for Government and industry stock changes.

LEGISLATION AND GOVERNMENT PROGRAMS

Falconbridge Ltd., a Canadian nickel producer, sought a U.S. Government determination of the legality of shipping nickel to the United States that had been refined, in part, from Soviet matte. The question of legality arose because the U.S. Department of the Treasury, acting under the Cuban embargo, imposed a ban in 1983 on the importation of unfabricated nickel-bearing material originating in the U.S.S.R. This followed the confirmation that large quantities of Cuban nickel concentrate were being imported into the U.S.S.R. for refining. After examination of the documentation submitted by Falconbridge indicated that the particular Soviet matte was not

TABLE 1

SALIENT NICKEL STATISTICS

(Short tons of contained nickel unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Mine production:					
Nickel ore (gross weight)	1,674,600	868,100	603,400	—	—
Shipments	14,540	6,127	1,175	—	—
Plant production:					
Smelter, from domestic ores (includes byproduct nickel)	9,604	5,214	1,651	—	—
Refinery, from imported matte	35,329	31,168	—	—	—
Secondary recovery from purchased scrap:[e]					
From ferrous scrap	35,760	36,690	35,320	38,265	59,609
From nonferrous scrap	19,407	16,955	8,406	8,392	3,700
Exports:					
Primary (nickel content)	31,638	21,745	2,812	2,413	1,213
Secondary (nickel content)	12,266	13,500	12,405	12,920	18,251
Imports for consumption:					
Primary (nickel content)	176,715	157,690	129,094	148,273	154,366
Primary (gross weight)	249,929	220,349	159,298	[r]178,143	180,600
Total (gross weight)	264,778	236,001	172,683	191,154	195,198
Consumption:					
Reported:					
Primary	136,861	119,907	107,062	130,504	125,520
Secondary (purchased scrap)[e]	49,649	42,295	[r]31,824	34,316	43,715
Apparent:					
Primary	155,395	157,795	137,582	155,500	[1]132,449
Secondary (purchased scrap)[e]	55,167	53,645	43,724	46,657	63,309
Stocks, Dec. 31:					
Government	32,209	37,222	37,215	37,215	37,214
Producer	37,300	17,400	10,300	6,824	7,672
Consumer:					
Primary	20,934	19,106	16,557	10,393	11,999
Secondary	6,520	6,302	4,669	4,375	5,090
Employment, Dec. 31:					
Mine	130	130	—	—	—
Smelter	170	170	—	—	—
Refinery	420	—	—	—	—
Price (cathode):[2]					
New York dealer, per pound	$2.22	$2.26	$1.86	$2.28	$6.09
World: Mine production	[r]851,736	[r]886,698	850,261	[p]895,738	[e]920,016

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1] Includes secondary exports.
[2] Weighted average calculated by Metals Week.

derived from nickel of Cuban origin, Treasury authorized imports through December 31, 1988. Comparable imports subsequent to that date were to require renewed authorization by the U.S. Department of the Treasury Office of Foreign Assets Control.

The United States-Canada Free Trade Agreement, which was ratified during the year, specified that the tariff on nickel powders and flakes (containing less than 60% nickel) would be reduced 20% per year for 5 years. The Canadian duties on imports of U.S. ferronickel were immediately removed.

The Bureau of the Mint, U.S. Department of the Treasury, purchased 3,287 short tons of nickel under seven solicitations at a total price of $33,625,099.

DOMESTIC PRODUCTION

Although there was no domestic primary production, the production of domestic secondary nickel in the form of scrap was a major part of the supply of nickel for consumption. Since the Bureau of Mines documented only the recovery of nickel in scrap that was consumed, recovery and consumption were essentially the same. The nickel recovered from stainless steel scrap was calculated from the gross weight of the scrap and an estimated nickel content of 7.5%, which was the weighted-average nickel content of all grades of stainless steel scrap consumed.

CONSUMPTION

Apparent consumption at 195,758 tons was lower than that of 1987 at 202,507 tons. There was a decline in consumption in 1988, but part of the difference between the 1987 and 1988 figures was a result of having included stainless steel scrap exports in the apparent consumption formula for the first time. The comparable apparent consumption figure for 1987 would have been 189,235 tons.

TABLE 2

NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY[e]

(Short tons of contained nickel)

	1986	1987	1988[p]
KIND OF SCRAP			
Aluminum-base	107	188	233
Copper-base	2,031	2,097	722
Ferrous-base	35,320	38,265	59,609
Nickel-base	6,266	6,107	2,745
Total	**43,724**	**46,657**	**63,309**
FORM OF RECOVERY			
Aluminum-base alloys	118	229	561
Chemical compounds	W	—	—
Copper-base alloys	6,364	6,594	1,768
Ferrous alloys	35,367	38,297	59,664
Nickel-base alloys	1,875	1,537	1,316
Total	**43,724**	**46,657**	**63,309**

[e] Estimated. [p] Preliminary. W Withheld to avoid diclosing company proprietary data; included with "Copper-base alloys."

Although production of stainless steel, the largest end use for nickel, was at record-high levels, reported primary nickel consumption, as a whole, and consumption for use in stainless steel, declined in 1988. Two factors caused the decline. The first factor, caused by the sustained period of high nickel prices, was substitution. The ferritic and duplex grades of stainless steel were substituted for the austenitic grades, which had a higher nickel content and were, therefore, more costly. This was a reversal of a longstanding trend. The austenitic grades' share of Western World stainless steel production increased steadily from about 65% in 1960 to about 75% in 1987. In the United States, the austenitic share of stainless steel production fell from 76.3% in the first quarter of 1988 to 69.6% in the fourth quarter. Also, within the austenitic grades, stainless steels from the 200 series were substituted for the higher nickel content 300 series. The other trend caused by high prices was an increase in the ratio of stainless steel scrap to primary nickel used in producing stainless steel. Had the proportions of austenitic stainless produced and primary nickel consumed been the same as in 1987, U.S. primary nickel consumption would have been considerably higher in 1988.

The second factor was the increase in stainless steel imports, which had an impact on domestic nickel consumption. Although exports only rose from 84,000 tons in 1987 to 85,000 tons in 1988, imports jumped from 294,000 tons in 1987 to 316,000 tons in 1988. Apparent consumption for stainless steel, defined as shipments plus imports minus exports, rose from 1,628,000 tons in 1987 to 1,817,000 tons in 1988.

STOCKS

The combined stocks of primary nickel maintained in the United States by foreign producers with U.S. sales offices, and metal-trading companies with U.S. sales offices, increased 16% during the year. At yearend, these stocks represented 14 days of domestic consumption. The drop was a reflection of very strong demand. Nickel stocks on the London Metal Exchange (LME) fell 45%. The yearend inventory was 2,804 tons. Consumer stocks increased by 10% during the year. Stocks of nickel in ferrous scrap held by iron and steel producers were down 15% from those of 1987.

Nickel contained in the National Defense Stockpile decreased from 37,215 tons to 37,214 tons as a result of an inventory adjustment.

FIGURE 1

U.S. NICKEL CONSUMPTION IN 1988, BY FORM AND USE

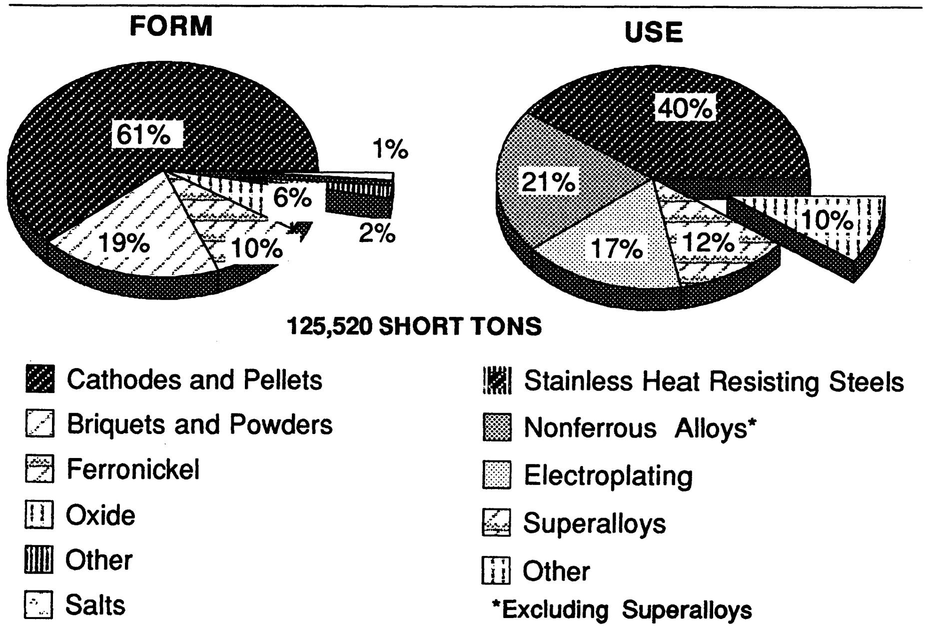


TABLE 3

REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM

(Short tons of contained nickel)

Form	1984	1985	1986	1987	1988
Primary:					
Ferronickel	18,419	17,993	13,256	17,418	12,936
Metal	104,958	90,379	82,884	98,673	99,398
Oxide and oxide sinter	7,087	6,297	7,357	9,926	7,790
Salts[1]	2,962	2,770	2,416	2,435	2,657
Other	3,435	2,468	1,149	2,052	2,739
Total primary	**136,861**	**119,907**	**107,062**	**130,504**	**125,520**
Secondary (scrap)[2]	49,649	42,295	31,824	34,316	43,715
Grand total	**186,510**	**162,202**	**138,886**	**164,820**	**169,235**

[1]Metallic nickel salts consumed by plating industry are estimated.
[2]Based on gross weight of purchased scrap consumed and estimated average nickel content.

PRICES

Nickel prices remained volatile, rising to record levels and reflecting a very tight supply-demand balance. The 1988 LME nickel price, in 1987 constant dollars, was $6.05 per pound. Since 1928, based on producer and LME listings, the highest previous price had been $4.11. The LME price remained the leading price indicator. For 1988, this price averaged $6.25 per pound, up 185% from that of 1987.

The LME nickel price began the year near $4 per pound and dropped slightly. Then came a rapid increase in prices, which ended in March at record-high levels. The increase was caused by a tightening supply situation that was a result of record-high demand for nickel in stainless steel. This situation was compounded by a dispute between the Government of the Dominican Republic and Falconbridge Dominicana C. por A., the world's second largest ferronickel producer (see World Review). The dispute caused Falconbridge to drastically limit its shipments of ferronickel. Moreover, many nickel consumers were concerned that the upcoming negotiations between Inco, the Western World's largest nickel producer, and the union representing its mineworkers might lead to a strike, further reducing the already tight supply of nickel. These concerns led nickel consumers to increase their inventories, when possible, thereby increasing upward pressure on prices.

When these problems were resolved in late May and early June and LME stock levels had rebounded, the tight supply seemed to have been somewhat relieved and prices began to decline. The decline continued, in a gradual manner, until late August. At that point, nickel consumers' nickel stocks were at their highest level in 16 months. Because the price was dropping, the producers decided to work off their inventories of high-priced materials. After stock levels were lowered, consumers began to reorder, causing

TABLE 4

U.S. CONSUMPTION OF NICKEL, BY USE

(Short tons of contained nickel)

Use	Commercially pure nickel	Ferronickel	Nickel oxide	Nickel salts	Other primary forms	Total primary	Secondary[e] (scrap)	1988 Grand total	1987 Grand total
Cast irons	572	290	57	—	306	1,225	1,375	2,600	1,754
Chemicals and chemical uses	1,603	—	76	127	196	2,002	—	2,002	1,945
Electric, magnet, expansion alloys	218	—	—	—	W	218	55	273	238
Electroplating (sales to platers)[1]	19,059	W	W	2,425	33	21,517	—	21,517	22,650
Nickel-copper and copper-nickel alloys	5,772	W	2	12	41	5,827	1,768	7,595	11,209
Other nickel and nickel alloys	19,297	331	53	W	90	19,771	1,223	20,994	19,155
Steel:									
Stainless and heat-resistant	30,233	11,988	6,715	—	1,283	50,219	38,082	88,301	79,141
Alloys (excludes stainless)	7,264	253	W	W	5	7,522	558	8,080	8,972
Superalloys	14,055	55	55	W	664	14,829	93	14,922	18,304
Other[2]	1,325	19	832	93	121	2,390	561	2,951	1,452
Total reported by companies canvassed	**99,398**	**12,936**	**7,790**	**2,657**	**2,739**	**125,520**	**43,715**	**169,235**	**164,820**
Total all companies, apparent	**XX**	**XX**	**XX**	**XX**	**XX**	**[3]132,449**	**63,309**	**196,539**	**202,157**

[e] Estimated. [p] Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
[1] Based on monthly estimates.
[2] Includes batteries, ceramics, and other alloys containing nickel.
[3] U.S. production plus imports minus exports minus stock increases.

tighter supplies and higher prices. Then, in December, P.T. International Nickel Indonesia's (P.T. Inco) nickel facility in Indonesia experienced production problems, further compounding the situation.

In the United States, the New York dealer price for electrolytic nickel best indicated the prices paid by U.S. consumers. At a weighted average of $6.09 per pound for 1988, as calculated by Metals Week, the New York dealer price rose slightly less from its 1987 level than the LME price. A major North American producer reported that its average realized price for the year rose 121% to $4.81 per pound.

The price of stainless steel scrap, the largest source of secondary nickel for consumption, followed the price of primary nickel. According to the American Metal Market, the price of 18-8 stainless steel scrap in Pittsburgh rose from a range of $740 to $760 per ton at the beginning of the year to a range of $1,350 to $1,400 by yearend.

A number of stainless steel and superalloy producers added raw materials surcharges during the year as a result of the sustained period of high prices for nickel and other metals. This enabled producers to retain their basic prices at constant levels and to change the surcharge to reflect changes in the LME price.

FOREIGN TRADE

The net import reliance fell to 68% as a result of improved statistical coverage of scrap. There was no domestic primary production and virtually all primary nickel consumed in the United States was imported. As usual, Canada supplied most of the imported nickel, including most of the nickel imported from Norway, which had been mined and smelted in Canada before being refined in Norway.

The high level of demand for primary nickel also meant high demand for nickel-bearing scrap, both domestically and abroad. As a result, U.S. stainless steel scrap exports increased considerably in 1988. Assuming a nickel content of 7.5%, 18,251 tons of nickel contained in stainless steel scrap was exported in 1988 compared with 12,920 tons in 1987 and an average of less than 12,000 tons per year for the 5

TABLE 5

NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM

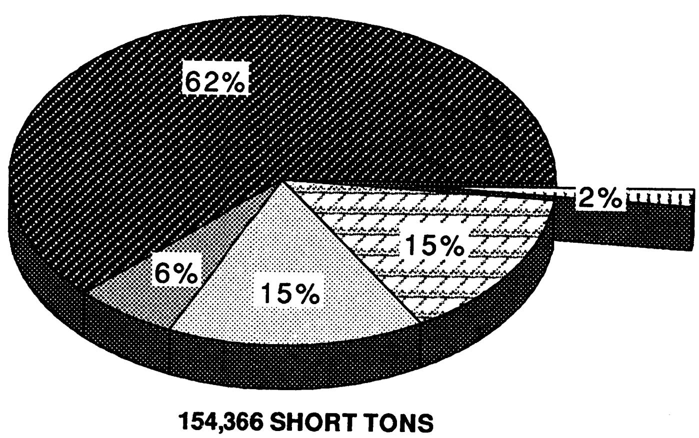
(Short tons of contained nickel)

Form	1984	1985	1986	1987	1988
Primary:					
Ferronickel	692	1,930	1,028	776	1,532
Metal	17,479	13,754	11,829	8,218	8,009
Oxide and oxide sinter	2,259	3,059	3,281	995	1,980
Salts	229	184	175	196	210
Other	275	179	244	208	268
Total primary	**20,934**	**19,106**	**16,557**	**10,393**	**11,999**
Secondary (scrap)	6,520	6,302	4,669	4,375	[p]5,090
Grand total	**27,454**	**25,408**	**21,226**	**14,768**	**17,089**

[p] Preliminary.

FIGURE 2

MAJOR SOURCES OF U.S. PRIMARY NICKEL IMPORTS, BY CLASS



years preceding 1988. Japan was the leading recipient of scrap in 1988, taking 5,461 tons. Spain followed closely with 5,055 tons, while Canada took 2,059 tons.

WORLD CAPACITY

The data in table 9 are rated capacity for mines, smelters, and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operation rate, based on the physical equipment of the plant, and given acceptable operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Mine capacity for nickel is based on about 255 working days per year, 1 shift per day, as calculated from available data on ore throughput, ore grade, and physical characteristics of the plant. Refinery capacity is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines.

WORLD REVIEW

Lower crude oil prices in 1988 contributed to generally lower production costs, particularly among those companies that produced nickel from laterite deposits, from which the extraction of nickel is more energy intensive than that of sulfide deposits. However, in the Dominican Republic, lower energy costs were offset by lower ore grades at Falconbridge Dominicana nickel smelter. Higher nickel production costs in Australia resulted from lower mill feed grades at Western Mining Corp. Ltd. (WMC) operations. Because nickel

TABLE 6

U.S. EXPORTS OF NICKEL AND NICKEL ALLOY PRODUCTS, BY CLASS

(Gross weight unless otherwise specified)

Class	1985		1986		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Primary:								
Cathodes, pellets, briquets, and shot (unwrought)	17,761	$86,596	1,936	$12,542	1,547	$10,581	1,940	$19,344
Electroplating anodes	132	965	108	961	213	1,864	206	1,618
Ferronickel	5,355	NA	455	NA	165	NA	—	—
Powder and flakes	1,106	8,942	584	5,913	582	6720	575	8,184
Total	**24,354**	**96,503**	**3,083**	**19,416**	**2,507**	**19,165**	**2,721**	**29,146**
Nickel content[1]	21,745	XX	2,812	XX	2,413	XX	1,213	XX
Secondary:								
Stainless steel scrap	180,000	104,898	165,402	90,066	172,273	94,025	243,344	239,807
Nickel content, secondary[2]	13,500	XX	12,405	XX	12,920	XX	18,251	XX
Total nickel content	**35,245**	**XX**	**15,217**	**XX**	**15,333**	**XX**	**19,464**	**XX**
Wrought:								
Bars, rods, angles, shapes, sections	4,253	45,060	2,239	29,735	2,780	31,595	2,796	40,191
Plates, sheets, strip	2,645	28,726	3,676	25,151	5,597	37,188	7,518	60,680
Tubes, pipes, blanks, fittings, hollow bar	303	6,356	684	6,430	294	6,916	673	14,419
Wire	954	9,147	844	8,520	1,216	11,896	1,754	20,270
Nickel-compound catalysts	3,523	22,811	2,243	10,631	3,984	16,940	4,812	21,745
Nickel waste and scrap	15,397	26,705	10,500	15,012	11,541	17,273	12,782	36,079
Grand total	**231,429**	**340,206**	**188,671**	**204,961**	**200,192**	**234,998**	**276,400**	**462,337**

NA Not available. XX Not applicable.
[1] Based on estimated nickel content and gross weight of primary nickel products.
[2] Nickel content of stainless steel scrap is considered to be 7.5%.

Source: Bureau of the Census.

reserves at the Greenvale Mine in Western Australia were nearly depleted, the ore grades were lower, and the ore was more difficult to mine. The Yabulu processing facility, which treated ore from the Greenvale Mine, was importing ore, primarily from New Caledonia. The associated transportation costs caused production costs to rise. There were also technical problems caused by the imported ore's chemistry. Canadian production costs increased significantly in 1988 because of a rise in labor costs. However, these higher costs were more than offset by record-high profits resulting from record high nickel prices and the sale of byproducts. Net production costs at Colombia's ferronickel operation decreased slightly because of improved smelter efficiency. In Japan, higher costs for treating imported Indonesian laterites, resulting from increased labor costs, were offset by lower costs for domestic matte production. The lower production cost were due to increased smelter productivity and efficient utilization of hydroelectric power.

Brazil's new constitution contains an article restricting mineral prospecting and mining to companies whose stock control and decisionmaking power were in the hands of Brazilian residents. A strike by nickel production workers from mid-November to late December slowed production and led to increased nickel imports. The Hellenic Mining & Metallurgical Co. of Larymna S.A. (Larco), the Greek ferronickel producer, was sold to the state-owned Organization for the Rehabilitation of Enterprises (ORE). The company had been owned 75% by two state-controlled banks; the balance had been in private hands. The Yugoslav Government was considering reopening

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS

(Gross weight unless otherwise specified)

Class	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Primary:						
Smelter products:						
Ferronickel	37,901	$53,672	45,398	$57,481	44,576	$116,990
Salts and other (including slurry)	9,170	19,281	5,241	24,754	9,067	51,512
Refined nickel:						
Cathodes, pellets, briquets, and shot (unwrought)	99,017	407,210	113,249	455,126	112,576	1,024,106
Flakes	600	2,420	937	3,622	730	6,274
Oxide and oxide sinter	2,868	4,372	2,278	4,277	3,397	26,009
Powder	9,742	48,631	11,040	56,784	10,254	94,469
Total	**159,298**	**535,586**	**178,143**	**602,044**	**180,600**	**1,319,360**
Nickel content[1]	129,094	XX	148,273	XX	154,366	XX
Wrought:						
Bars, plates, sheets, anodes	2,310	17,048	1,518	12,901	1,587	16,191
Pipes, tubes, fittings	1,487	16,616	1,539	24,633	1,187	20,454
Rods and wire	2,640	19,228	2,235	16,527	2,492	24,916
Shapes, sections, angles	153	1,002	152	800	71	860
Nickel waste and scrap	6,795	19,581	7,567	25,133	9,261	58,037
Grand total	**172,683**	**609,061**	**191,154**	**682,038**	**195,198**	**1,439,818**

XX Not applicable.

[1] Based on estimated nickel content and gross weight of primary nickel products.

Sources: Bureau of the Census and Journal of Commerce.

the Kavadarci ferronickel smelter, which closed in 1984 after 2 years of production. The plant, located in the Province of Macedonia, had a capacity of 132 million pounds per year of contained nickel. In Zambia the exploration of Munali Hills, southwest of Lusaka, in the 1970's revealed extensive high-grade nickel ore. Mining was not economically feasible at the time because nickel prices were depressed and the nearest nickel-refining facilities, in Zimbabwe, were unavailable. In 1988, Apollo Mining Ltd., which held a license for the site, reportedly was seeking a contractor to conduct a prefeasibility study to update the previous research.

Australia

WMC bought 60% of the Agnew nickel mine in Western Australia from British Petroleum Ltd. The mine, opened in 1979, had been on care-and-maintenance status since 1986. It closed as a result of a sustained period of low nickel prices. Later in 1988, WMC purchased the remaining 40% from Mount Isa Mines Ltd. and announced that the mine, renamed Leinster, would be reopened. Production was expected to begin by the third quarter of 1989.

Australian Consolidated Minerals (ACM) acquired 50% of the Mount Keith nickel-gold project in Western Australia by buying 30% from BP Australia Ltd. and 20% from MIM Holdings Ltd. The other 50% was held by the ACM associate Armada Resources. ACM and Armada were planning to begin exploration centered on the nickel sulfide potential and to conduct new development studies.

Dallhold Investments Pty. Ltd. was seeking new sources of feedstock for its Yabulu refinery, situated near Townsville, Queensland. The refinery's source of ore, the Greenvale Mine, also in Queensland, was expected to be depleted in a few years. To this end, Dallhold was considering forming a joint venture with the French Bureau de Recherches Géologiques et Minieres to develop a new nickel mine in New Caledonia. Lateritic ore from the mine was to be shipped to the Yabulu refinery. The refinery was 87.5% owned by Metals Exploration Queensland Nickel Ltd. (MEQ), a wholly owned subsidiary of Dallhold, and 12.5% owned by Nickel Resources North Queensland Ltd., a state-owned enterprise. Additionally, MEQ announced that it was considering developing its Digger Rocks nickel deposit as a possible source of nickel ore. Metallgesellschaft AG (MG) of the Federal Republic of Germany agreed to take 40% of the nickel production of MEQ for 15 years beginning in 1991, or about 17,000 tons annually. MG was also negotiating with the state of Queensland to acquire a portion of Queensland's 12.5% holding in the joint venture.

Botswana

Bamangwato Concessions Ltd. (BCL) was planning to develop a new nickel mine at the Selebi-Phikwe complex in eastern Botswana. Work on the new mine was scheduled to begin early in 1989, with full production being reached in mid-1990. BCL's main mine at Phikwe was approaching depletion. The new mine, Selebi North, was to be the company's third.

Canada

Inco Ltd. announced plans to improve

TABLE 8

U.S. NICKEL IMPORTS FOR CONSUMPTION OF NEW NICKEL PRODUCTS IN 1988, BY COUNTRY

(Short tons of contained nickel)

Country	Cathodes, pellets, briquets, shot (unwrought)	Powder and flakes	Oxide and oxide sinter	Ferronickel	Salts[e] and other	Total 1988	Total 1987
Australia	5,589	1,035	2,258	375	2	9,259	12,444
Botswana	60	40	—	—	—	99	218
Canada	72,857	8,576	596	109	8,105	90,242	75,240
Colombia	—	—	—	2,490	—	2,490	3,270
Dominican Republic	—	—	([1])	9,048	—	9,048	14,421
Finland	2,192	46	84	—	165	2,487	5,046
France	2,575	34	—	—	867	3,476	3,011
Germany, Federal Republic of	632	121	—	([1])	557	1,311	483
Japan	111	10	4	523	80	728	317
New Caledonia		—	—	3,458	136	3,595	1,254
Norway	21,879	—	—	—	31	21,910	21,694
South Africa, Republic of	1,511	606	—	52	9	2,179	3,081
United Kingdom	512	134	([1])	—	427	1,073	1,744
Zimbabwe	3,443	201	—	—	—	3,644	2,756
Other	1,216	181	—	10	1,418	2,826	3,294
Total[2]	**112,576**	**10,984**	**2,942**	**16,066**	**11,798**	**154,366**	**148,273**

[e] Estimated.
[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and Journal of Commerce.

TABLE 9

WORLD NICKEL ANNUAL MINE AND PLANT PRODUCTION CAPACITY DECEMBER 31, 1988

(Thousand short tons contained nickel)

Country	Mine capacity	Refinery and smelter[1] capacity
North America:		
Canada	220	170
United States[2]	—	55
Total	**220**	**225**
South America:		
Brazil	26	21
Colombia	24	25
Total	**50**	**46**
Caribbean:		
Cuba	60	33
Dominican Republic	35	35
Total	**95**	**68**
Europe:		
Albania	11	—
Finland	12	21
France	—	13
Greece	25	30
Norway	—	59
U.S.S.R.	210	225
United Kingdom	—	50
Other[3]	30	17
Total	**288**	**415**
Africa:		
Botswana	22	—
South Africa, Republic of	50	30
Zimbabwe	20	20
Total	**92**	**50**
Asia:		
China	40	25
Indonesia	65	6
Japan	—	124
Philippines[2]	45	35
Taiwan	—	9
Total	**150**	**199**
Oceania:		
Australia	83	59
New Caledonia	100	50
Total	**183**	**109**
World total	**1,078**	**1,112**

[1] Because matte is an intermediate product that must be refined before the nickel it contains can be used in making alloys or other products; smelter capacity for matte is not listed to avoid double counting.
[2] Standby or partially standby capacity.
[3] Includes Austria, Czechoslovakia, the Federal Republic of Germany, the German Democratic Republic, Poland, and Yugoslavia.

its Sudbury, Ontario, facilities. The $57 million program called for the consolidation of milling and concentrating activities that were being performed at three locations: the Frood-Stobie mill, the Copper Cliff mill, and the Clarabelle mill. These operations were to be located at the Clarabelle mill. The Frood-Stobie mill was to be closed permanently. The expansion of the Clarabelle facility was to feature a 32-foot-diameter semi-autogenous grinding mill and high-volume flotation cells. Only dewatering of concentrates for smelting was to be carried out at the Copper Cliff mill. An additional $16 million was to be spent to enlarge the tailings impoundment area of the mill. These actions were expected to result in lower costs and higher metal recoveries. The plans also called for the improved rejection of sulfur-bearing minerals, which would decrease the emissions of sulfur dioxide into the atmosphere.

Other Inco plans at Sudbury involved the Lower Coleman deposit. A project, valued at $42 million, called for the deepening of the existing shaft from 2,280 to 3,450 feet. When brought to full production in 1990, the mine was to be Inco's second all-electric mine.

Inco planned two major improvements at its Thompson, Manitoba facility, which were projected to cost $81 million. The Birchtree Mine, on standby since 1977, was to be redeveloped using oped using new equipment and techniques that would enable the company to double the former productivity of the mine. The Birchtree was scheduled to resume production in 1989. The other project involved developing a new open pit mine, to be called Thompson Open Pit South. The mine was slated to open in 1990, when the existing Thompson Open Pit North Mine was expected to be depleted.

Falconbridge Ltd. announced plans to sink an exploration shaft at its Lindsley property, where surface drilling had shown evidence of high-grade mineralization. Extensive diamond drilling had outlined four potentially minable ore zones. Falconbridge expected, over a 3-year period, to sink the 16-foot-diameter shaft to a depth of 4,550 feet below surface, to be followed by a drifting and drilling program on the 4,300-foot level.

Falconbridge signed an agreement with two Yugoslav companies to take delivery of nickel-copper matte from the Soviet nickel complex at Norilsk. (See Legislation and Government Programs.)

Sherritt Gordon Mines Ltd. changed its name to Sherritt Gordon Ltd. Inco announced that it would not renew its 10-year feedstock contract with Sherritt. The contract, which was due to expire at the end of 1989, provided the Sherritt refinery with just over one-half of its raw materials. Inco elected to refine the material at its own facilities. The Sherritt 1988 annual report announced the company objective of expanding production capacity at its nickel refinery from 55 million pounds per year to 75 million pounds provided that sufficient feedstock could be found.

The Namew Lake Mine, 40% owned by Outokumpu Mines Ltd., Toronto, a subsidiary of Outokumpu Oy, Finland, and 60% owned by Hudson Bay Mining and Smelting Co. Ltd., Toronto, began operations late in the year. Because the mine, located in northern Manitoba, had no on-site refinery, Hudson Bay agreed to sell its 60% share of the matte to be produced to Sherritt Gordon Mines Ltd. and Outokumpu Mines sold its share to Inco. Sherritt and Inco had refineries nearby. The mine was expected to produce about 8,000 tons per year of nickel contained in concentrates. Sherritt's share of the concentrates would not be enough to make up for its loss of feedstock from Inco.

China

Nickel production at the Gansu refinery in southern China reportedly was drastically reduced for a time as the result of an earthquake warning. As a precaution, the water level in the area reservoirs was drastically lowered, thereby reducing the hydroelectric power available to the refinery. The refinery operated at 30% of its normal output for a few months while the reservoirs were refilled. The production loss came at a time when nickel was in great demand for domestic stainless steel mills. At one point, one-half of China's stainless steel plants were idle

TABLE 10

NICKEL: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Short tons of nickel content)

Country	1984	1985	1986	1987[p]	1988[e]
Albania (content of ore)[e]	10,100	10,600	10,700	[r]9,900	9,900
Australia (content of concentrate)	84,793	94,531	84,590	82,182	[2]68,738
Botswana (content of ore milled)	[r]24,126	[r]25,373	24,604	21,447	29,200
Brazil (content of ore)	25,940	22,377	23,413	24,137	24,200
Burma (content of speiss)[e]	22	22	22	22	22
Canada[3]	[r]191,499	187,361	180,381	208,431	[2]219,316
China[e]	15,400	27,600	27,600	27,600	29,800
Colombia (content of ferroalloys)	24,124	17,013	20,975	21,301	[2]18,300
Cuba (content of oxide, sinter, sulfide)	35,087	35,458	[e]36,000	[r e]39,500	48,500
Dominican Republic	26,371	[r]27,992	24,116	35,848	32,300
Finland (content of concentrate)	7,626	9,421	13,102	11,637	11,000
German Democratic Republic[e]	2,200	2,200	2,200	2,200	2,200
Greece (recoverable content of ore)[e]	18,400	20,600	1,600	13,200	14,300
Indonesia (content of ore)[4]	52,474	44,463	59,171	63,674	58,400
New Caledonia (recoverable content of ore)[e]	[2]64,293	79,800	68,100	[r]62,700	74,600
Norway (content of concentrate)	358	468	483	[e]440	440
Philippines	14,993	31,039	14,099	8,619	11,900
Poland (content of ore)[e]	2,300	2,200	2,200	2,200	2,000
South Africa, Republic of[e]	27,600	27,600	35,100	37,800	38,400
U.S.S.R. (content of ore)[e]	192,000	198,000	205,000	205,000	209,000
United States (content of ore shipped)	14,540	6,127	1,175	—	—
Yugoslavia (content of ore)[e]	[r]4,100	[r]4,200	[r]4,200	[r]4,300	4,300
Zimbabwe (content of concentrate)[e]	13,390	12,253	11,430	[r]13,600	13,200
Total	**[r]851,736**	**[r]886,698**	**850,261**	**895,738**	**920,016**

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output, and this is noted parenthetically or by a footnote following the country name. Table includes data available through May 4, 1989.

[2]Reported figure.

[3]Refined nickel and nickel content of oxides and salts produced, plus recoverable nickel in exported matte and speiss.

[4]Includes a small amount of cobalt not reported or recovered separately.

TABLE 11

NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY[1]

(Short tons of nickel content)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Australia[3]	42,615	44,982	46,404	49,085	46,300
Brazil	[r]14,017	[r]14,513	14,843	15,280	15,450
Canada[3]	[r]123,008	[r]119,095	122,664	144,950	[4]166,800
China[e]	15,400	24,800	24,800	24,800	27,600
Colombia[5]	18,810	13,007	20,975	21,301	18,300
Cuba[6]	19,278	17,534	18,364	[r e]19,000	27,600
Czechoslovakia[e]	5,000	5,000	5,000	4,400	4,700
Dominican Republic[5]	26,698	28,450	24,239	32,023	32,300
Finland	16,846	17,258	19,611	16,967	17,600
France	5,751	7,738	10,119	9,458	9,400
German Democratic Republic[e]	3,300	3,300	3,500	[r]3,800	3,800
Germany, Federal Republic of[e 7]	1,100	800	—	—	—
Greece	17,448	17,584	11,380	10,141	14,900
Indonesia[5]	5,320	5,293	4,980	1,855	5,400
Japan[8]	98,489	102,175	102,239	104,472	101,400
New Caledonia[9]	32,141	39,797	36,377	32,552	[4]41,173
Norway	39,185	41,351	42,118	49,124	49,600
Philippines	3,889	18,732	2,288	—	—
Poland[e]	2,300	[r]2,200	[r]2,100	2,100	1,800
South Africa, Republic of	[4]22,597	22,000	28,000	30,200	30,700
U.S.S.R.[e]	[r]210,000	[r]216,000	222,000	222,000	227,000
United Kingdom	24,582	19,621	34,130	32,518	33,000
United States	44,933	36,382	1,651	—	—
Yugoslavia[e 5]	[r]2,200	[r]2,650	[r]2,750	[r]2,750	2,750
Zimbabwe[3]	11,300	10,340	10,725	11,457	11,000
Total	**[r]806,207**	**[r]830,602**	**811,257**	**840,233**	**888,573**

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Refined nickel plus nickel content of ferronickel produced from ore and/or concentrates unless otherwise specified. Table includes data available through May 12, 1989.

[2] In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate to make reliable estimates of output levels. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded in order to avoid double counting. Countries producing matte include the following, with output indicated in short tons of contained nickel: Australia, 1984—56,330 (estimated), 1985—56,858, 1986—54,078, 1987—52,728, and 1988—50,000 (estimated), Botswana: 1984—20,507, 1985—21,567, 1986—20,913, 1987—18,230, and 1988—24,845, Indonesia: 1984—27,854 (revised), 1985—34,567 (revised), 1986—30,837, 1987—29,213, and 1988—31,000 (estimated), and New Caledonia: 1984—6,021, 1985—9,816, 1986—10,097, 1987—9,130, and 1988—11,541.

[3] Refined nickel plus the nickel content of oxide.

[4] Reported figure.

[5] Nickel content of ferronickel only; no refined nickel was produced.

[6] Revised to include nickel content of granular nickel oxide, nickel oxide powder, and nickel oxide sinter. Cuba also produces nickel sulfide, but it has been excluded in order to avoid double counting. Output of processed sulfide was as follows, in short tons: 1984—15,971, 1985—17,835, 1986—18,588 (revised), 1987—19,500 (estimated, revised), and 1988—19,850 (estimated).

[7] Includes nickel content of nickel alloys.

[8] Includes nickel content ferronickel, refined nickel, and nickel oxide.

[9] Nickel content of ferronickel or matte only; no refined nickel was produced.

because of raw materials shortages.

The construction of a new nickel smelter in Jinchuan Province in China reportedly was expected to be completed by the end of 1990, doubling the 1985 production capacity of the facility.

A large nickel deposit was reported to have been discovered in the Xinjiang Uygur Autonomous Region in western China. The deposit was thought to be the second largest in China, containing about 900,000 tons of nickel as well as quantities of other metals.

Dominican Republic

In November 1987, the Dominican Government imposed a sliding scale of duty on exports of minerals. The export tax amounted to about 25% of the value of shipments of ferronickel produced by Falconbridge Dominicana, a subsidiary of Falconbridge Ltd. of Canada. The company considered the duty prohibitive, and in December, suspended ferronickel shipments. In 1988, Falconbridge Dominicana began shipping ferronickel again on a limited basis while holding talks with the Dominican Government. In April, although seemingly close to an agreement, the Dominican Government stopped all ferronickel exports until a final agreement could be worked out. Falconbridge Dominicana shut down its operations and on April 20, the company notified its customers that it was declaring a force majeure on ferronickel shipments from the Dominican Republic. In late May, an agreement was reached and Falconbridge Dominicana resumed ferronickel shipments. Under the new contract, a formula linked the company taxes to market prices for nickel rather than to overall corporate earnings.

Finland

Outokumpu Oy, the state-owned nickel producer, reopened the Hitura nickel mine to take advantage of price increases. The mine had high unit costs and was closed in 1986 owing to low prices at the time. The mine was to remain open as long as justified by nickel prices.

Indonesia

Inco Ltd. announced plans to increase the production capacity of its subsidiary, P.T. Inco. Construction, which was to increase capacity from 80 million pounds per year to 105 million pounds per year of nickel contained in matte, was scheduled to be completed in 1990. Additionally, Inco reached an agreement with Sumitomo Metal Mining Co. Ltd. whereby Sumitomo would purchase a 20% share of P.T. Inco and purchase about 20% of its annual output. Sumitomo was one of several Japanese companies that together had a 2% share of P.T. Inco; the balance was held by Inco Ltd. Nearly all of the Indonesian facility's output was refined and sold in Japan.

P.T. Inco experienced several production setbacks during the year. In March, an earthquake damaged a canal supplying water to an electric power generator. The problem was compounded when the country received the lowest levels of rainfall in many years. In December, an electric furnace experienced a short circuit in a transformer. This was expected to reduce capacity by a million pounds per month through mid-1989. The operation produced 63 million pounds of nickel in matte despite its problems.

Japan

Nippon Nickel Co. Ltd. was forced to close its nickel smelter in Tsuraiga City owing to a lack of feedstock. Nippon Nickel had been toll-smelting for another Japanese nickel producer, Tokyo Nickel Co. Ltd. After Tokyo Nickel doubled production capacity at its Matsusaka facility, the company terminated its tolling contract with Nippon Nickel. Because of the very strong demand for nickel and the resulting high demand for nickel feedstock, Nippon Nickel was unable to locate another source of feed material for its plant.

Sumitomo was considering expanding the production capacity of its Niihama nickel refinery from about 48 million pounds per year to about 66 million pounds per year.

Pacific Metals Co. brought a shipment of more than 50 million pounds of nickel ore from the Taginito Mine in the Philippines for testing purposes. The mine, located in northern Mindanao, was opened on an exploratory basis. The deposit was reported to have large resources and a nickel content of 2.4%. The ore was shipped to Hachinoe on northern Honshu where Pacific Metals operated an integrated facility that produced stainless steel. The company expected to send two or three shiploads of ore per year from Taginito until the mine was fully developed.

New Caledonia

An Australian company was considering forming a joint venture to develop a new mine at Goro, located in the extreme south of the main island. A pilot plant had tested the ore from the site. (See Australia section.)

Philippines

The Philippine Government placed Nonoc Mining and Industrial Corp., a nickel producer, on its list of state-owned mining companies it wanted to privatize by yearend. The Government also transferred the company assets to the Assets Privatization Trust (APT) to be sold. The APT set a January 12, 1989, date for the auction of the mine and refinery.

Zimbabwe

Bindura Nickel Corp. (BNC) averted the closure of its mines and refinery owing to increased nickel demand and resultant high prices. BNC, a high-cost nickel producer, had been forced to borrow money to maintain operations during the period of low nickel prices. After its source of funds was cut off, the company halted all exploration and development work and announced that it planned to close its operations and lay off about 4,000 workers unless it received financial help from the Government. However, high prices enabled BNC to continue operating and resume underground development.

TECHNOLOGY

Mining and Processing

The proceedings of a major symposium on the extractive metallurgy of nickel and cobalt in market economy countries was published.[2] Following are brief summaries of some of the papers presented at the symposium. The first section, Industry Overview, contained a paper, that presented estimates of increases and decreases in primary nickel production on a geographic basis. Another paper discussed the causes of structural changes in the markets for high-technology alloying metals in terms of technological, economic, and financial trends. Changes in the structure of the international nickel industry in the early 1980's in response to problems such as overcapacity, relatively flat demand, and low prices were discussed in another paper. Then a brief overview was presented of the known significant health effects of nickel and cobalt. Nickel production and usage patterns, nickel first use and end use, and examples of nickel applications in modern technology were covered.

The second section, Reviews, contained a paper, which described the character, occurrence, and genesis of the three types of nickel deposits: sulfides, laterites and deep-sea nodules. Then a review was given of the extractive processes used in the production of nickel and the factors, many outside the nickel industry itself, which determined the direction of process research. The paper concluded with an attempt to forecast the nature of the most effective nickel process of the future. The chemistry of the main unit processes in nickel extractive pyrometallurgy was reviewed. Also included was a brief discussion of current nickel smelters. The next paper reviewed the innovations in the technology of hydrometallurgical and electrometallurgical extractive processes.

The third section, Nickel Processing, contained 12 papers that discussed various aspects of nickel production, from primary metallurgical extraction through refining, which were taking place in several countries.

End Uses

Ford Motor Co. placed verbal orders for zinc-nickel coated sheet steel with Japanese steel mills. The zinc-nickel sheet was to be used in a 1990 model. The electroplated coating contained about 13% nickel; the balance was zinc. Zinc-nickel coated steel was already extensively used in Japan and Europe. After the initial 3 months of production Ford would be looking for domestic sources. Bethlehem Steel Corp., Pittsburgh, PA, was the only domestic steel producer known to have scheduled commercial production of zinc-nickel coated sheet steel for automobile applications. The Bethlehem production was initially slated to be shipped to Japan and to Japanese automobile plants in the United States.

Armco Inc., a specialty steel producer and one of the largest U.S. steel producers, was awarded the rights for commercial production of nickel aluminide.[3] Nickel aluminide was found to be a material that became stronger as it got hotter, a property that had obvious advantages for use in jet engines. However, another of the properties of the compound, brittleness, was a serious drawback because it made the compound subject to cracking. The Oak Ridge National Laboratory, which developed the intermetallic, also found that the addition of small quantities of boron caused the alloy to become ductile. Possible applications included turbine engines, heat exchangers, and dies and molds for forging, forming, and casting at high temperatures.

The Nickel Development Institute performed a review of information published from 1983 onward on the relative merits of zinc-nickel and zinc-iron electrocoated steels.[4] The review concluded that the zinc-nickel combination had properties that were clearly superior to zinc, including corrosion resistance.

A nickel foam was being produced under the trade name Celmet by Sumitomo Electronic Industries Ltd. of Japan.[5] The foam was made by conductively coating polyurethane foam with graphite, electrodepositing nickel, and then removing the polyurethane and graphite from the foam after heat treatment. It was reported that when the material is used in nickel-cadmium of alkaline batteries their capacities increase 30%.

A device using a nickel alloy, which may replace chlorofluorocarbon coolants, was under development.[6] The principle involved a bed of nickel alloy that absorbed hydrogen when heated, cooled off when hydrogen was released, and chilled the air that flowed over it. Heat was discharged to the atmosphere. The quantity of nickel that would be used in an automobile air conditioning unit was estimated to be 9 to 15 pounds.

A nickel fiber was developed that could be incorporated into plastics or laminated onto fabrics for shielding against electromagnetic and radio frequency interference.[7]

The nickel-hydrogen battery was developed in the 1970's, primarily as an energy storage device for satellites.[8] It was highly successful as a virtually maintenance-free, high-performance battery with an exceptionally long life. This battery would have been desirable for a large number of terrestrial applications, except for its high cost. The U.S. Department of Energy sponsored research to reduce the cost of the nickel-hydrogen battery without sacrificing its performance.

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[1] Physical scientist, Branch of Ferrous Metals.

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NITROGEN

By Raymond L. Cantrell[1]

U.S. manufacturers of anhydrous ammonia operated at 97% of rated capacity during 1988, producing 17 million short tons of 82.2% nitrogen product. This volume represented an increase of 5% above 1987 levels and 17% above the depressed output of 1986. Heavy demand for anhydrous ammonia and downstream nitrogen products was experienced throughout the year, moving the industry into a supply-demand balance. Record-high levels of ammonia were imported during the year, and producer inventories of anhydrous ammonia were at record-low levels by yearend. Prices for urea and ammonium nitrate increased as the year progressed, and ammonia prices increased during the fourth quarter. Ammonia prices, f.o.b. barge, New Orleans, LA, moved up from $90 per short ton during October to $130 per ton by late December. Spot shortages of ammonia available for export on the U.S. gulf coast occurred during the year. U.S. ammonia production was valued at $1.7 billion wholesale, based on an average annual export price of $100 per ton, f.o.b. gulf coast.

A number of factors led to the surge in U.S. nitrogen production and demand during 1988. Industry restructuring played a major role in returning the United States to a cost-competitive position. The price stabilized for natural gas, the major feedstock and cost item for production of anhydrous ammonia, and many plants reduced energy consumption and improved efficiency through modifications in plant design, known in the industry as "revamps" or "retrofits." Provisions in the Food Security Act of 1985, Public Law 99-198, encouraged U.S. farmers to limit production and reduce surplus-grain inventories through the mechanisms of the Conservation Reserve Program and export-enhancement initiative. Urea antidumping actions imposed in 1987 prevented the German Democratic Republic, Romania, and the U.S.S.R. from shipping urea to the United States at prices below fair market value, thereby protecting domestic producers. Demand for U.S. ammonium phosphates continued to surge during 1988, consuming in excess of 3 million tons of ammonia. Adverse weather in 1988 played a major role in correcting the grain surplus problem that had plagued the U.S. agricultural sector for most of the decade. Severe drought during the summer of 1988 dramatically reduced crop yields and grain inventories and improved grain futures prices. The U.S. farmer was encouraged by the improved outlook and planned to bring an additional 20 to 30 million acres of fallow land back into cultivation during 1988-89, with a concomitant increase in fertilizer nutrient consumption of between 0.6 and 1.0 million tons nitrogen.

TABLE 1

SALIENT AMMONIA STATISTICS[1]

(Thousand short tons of contained nitrogen unless otherwise specified)

	1984	1985	1986	1987	1988[p]
United States:					
Production	[r]13,729	[r]14,236	[r]11,909	[r]13,230	13,930
Exports	438	1,010	531	848	642
Imports for consumption	2,699	2,306	2,048	2,357	3,032
Consumption, apparent[2]	15,708	15,441	13,714	15,193	16,353
Stocks, Dec. 31: Producers'	1,704	1,795	1,507	1,053	1,020
Price per ton, yearend, f.o.b. gulf coast[3]	$147	$108	$75	$90	$120
Net import reliance[4] as a percent of apparent consumption	13	8	13	13	15
Natural gas price: Wellhead[5]	$2.66	$2.51	$1.94	$1.67	$1.71
World:					
Production	[r]97,612	[r]100,428	100,671	[p]103,944	[e]109,022
Trade[6]	8,430	9,040	7,920	[p]9,080	[e]9,990

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Synthetic anhydrous ammonia; excludes coke oven byproduct.
[2]Calculated from production plus imports minus exports plus/minus industry stock changes.
[3]Green Markets, Fertilizer Market Intelligence Weekly.
[4]Defined as imports minus exports plus adjustments for industry stock changes.
[5]Monthly Energy Review, U.S. Department of Energy. Average annual cost at wellhead in dollars per thousand cubic feet.
[6]International Fertilizer Industry Association statistics—World Anhydrous Ammonia Trade.

DOMESTIC DATA COVERAGE

Domestic production data for anhydrous ammonia were developed by the Bureau of the Census, U.S. Department of Commerce. Preliminary monthly data are published under product code 28731 31 in Current Industrial Reports, Inorganic Fertilizer Materials and Related Products, M28B. Final monthly data are subsequently published annually under the same product code and title in publication MA28B. The Bureau of the Census surveyed approximately 270 known producers of inorganic fertilizer materials during 1988. Production data are shown in table 1.

DOMESTIC PRODUCTION

U.S. anhydrous ammonia was produced by 35 firms operating 48 plants during the year. Minor quantities of byproduct ammonium sulfate and ammonia liquor were recovered from coke oven off-gases. Geographically, Louisiana, Oklahoma, and Texas accounted for about 60% of U.S. ammonia production capability; the Southeast and Midwest, 15% each; and the Western States, 10%. Approximately 90% of domestic ammonia production was utilized by the fertilizer industry and the remaining 10% by the industrial chemical industry. The basic method of ammonia production in the United States involves the reaction of natural gas with steam and air (reforming) to produce a mixture of hydrogen and nitrogen suitable for synthesis of ammonia (NH_3), a product containing 82.2% nitrogen.

Urea, ammonium nitrate, ammonium phosphates, and ammonium sulfate are the major downstream nitrogen products synthesized from anhydrous ammonia feedstock in the United States. Urea dominates the U.S. nitrogen market because of its high analysis (46% N) and excellent properties for both fertilizer and industrial use. Urea is a solid organic material resulting from the reaction of ammonia and carbon dioxide, the major byproduct of ammonia synthesis. Ammonium nitrate (35% N) is derived from nitric acid and ammonia. The material enjoys widespread use in the fertilizer and explosives industries. Ammonium phosphates result when ammonia is reacted in varying ratios with phosphoric acid. Diammonium phosphate (18% N) and monoammonium phosphate (11% N) are principal sources for domestic fertilization and foreign trade. Acrylonitrile and caprolactam are industrial products. Significant quantities of byproduct ammonium sulfate (21% N) are generated from caprolactam production.

U.S. anhydrous ammonia producers experienced heavy demand for product throughout 1988, and only three plants remained idle. Chevron Chemical Co.'s plant at Pascagoula, MS, was the major U.S. plant held idle for the entire year. Farmland Industries Inc. and Hawkeye Chemical Co. brought idle plants into production.

TABLE 2

FIXED NITROGEN PRODUCTION IN THE UNITED STATES

(Thousand short tons of contained nitrogen)

	1984	1985	1986	1987	1988^{p}
Anhydrous ammonia, synthetic:[1]					
Fertilizer	12,397	13,024	10,852	12,016	12,633
Nonfertilizer	1,332	1,212	1,057	1,214	1,297
Total	**^{r}13,729**	**^{r}14,236**	**^{r}11,909**	**^{r}13,230**	**13,930**
Byproduct ammonia, coke plants:[2]					
Ammonium sulfate	^{r}57	^{e}50	^{e}50	^{e}50	^{e}60
Ammonia liquor	5	^{e}5	^{e}4	^{e}5	^{e}5
Total	**62**	**^{e}55**	**^{e}54**	**^{e}55**	**^{e}65**
Grand total	**13,791**	**14,291**	**11,963**	**13,285**	**13,995**

^{e}Estimated. ^{p}Preliminary. ^{r}Revised.

[1] Current Industrial Reports, MA28B and M28B, Bureau of the Census.

[2] Quarterly Coal Report, U.S. Department of Energy. (1985–88).

Major restructuring of the U.S. nitrogen industry was highly visible during 1988. W. R. Grace & Co., a major force in the industry since the early 1950's, exited the U.S. fertilizer business by divesting its extensive holdings in production facilities and distribution centers. Western Branch Holding Co. (Nitrex) agreed to purchase W. R. Grace's nitrogen production facilities at Woodstock, TN, and Wilmington, NC, during April. The Woodstock plant has capacity for ammonia and 400,000 tons per year of urea. Wilmington produces ammonium nitrate and nitrogen solutions. Terra International Inc. exercised its option to purchase W. R. Grace's shares in jointly owned plants at Woodward, OK, during August. Terra assumed full ownership by purchasing W. R. Grace's 63% share in Oklahoma Nitrogen Co. and 33% share in Bison Nitrogen Products Co. Oklahoma Nitrogen produces ammonia, while Bison Nitrogen was equipped for urea-ammonium nitrate (UAN) solution production. Chemical Marketing International of Vero Beach, FL, purchased Arcadian Corp.'s idled Helena, AR, nitrogen complex during September. At yearend, the firm was starting up a 210,000-ton-per-year ammonia plant. Cepex Inc. sold its ammonia plant at Beatrice, NE, to Farmland Industries during September.

Columbia Nitrogen Corp. of Augusta, GA, was reactivating a mothballed urea plant during the year, and was operating its explosives-grade ammonium nitrate plant at Savannah, GA. Union Chemical Co. (Unocal) announced plans for the closure of its obsolete ammonia and urea plants at Brea, CA, during 1989. The firm's planned nitric acid and nitrogen solutions plants in West Sacramento, CA, were scheduled to go on-stream by late 1991. In the interim, Unocal will serve the western market from its larger, more modern plants in Kenai, AK.

CONSUMPTION AND USES

Consumption of nitrogen materials produced in the United States during 1988 was 7% above that of 1987. Nitrogen fertilizer materials accounted for about 80% of the domestic supply, and the remaining 20% was consumed by the industrial sector.

Urea and ammonium nitrate enjoy widespread use in both the agricultural and industrial sectors. Significant

TABLE 3

MAJOR DOWNSTREAM NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES

(Thousand short tons)

Compound[1]	1984	1985	1986	1987	1988[p]
Urea:					
Gross weight	[r]7,752	[r]6,975	[r]6,264	7,433	7,878
Nitrogen content	3,566	3,209	2,881	3,419	3,624
Ammonium nitrate:					
Gross weight	[r]7,165	[r]7,149	[r]6,091	6,547	7,186
Nitrogen content	2,508	2,502	2,132	2,291	2,515
Ammonium phosphates:[2]					
Gross weight	[r]14,794	[r]13,738	[r]11,001	13,333	14,356
Nitrogen content	2,457	2,310	1,861	2,289	2,458
Ammonium sulfate:[3]					
Gross weight	[r]2,067	[r]2,093	[r]2,080	2,189	2,337
Nitrogen content	434	440	437	460	491
Nitric acid, direct use:[4]					
Gross weight	2,156	2,015	1,939	2,069	2,228
Nitrogen content	479	448	431	460	495
Acrylonitrile:					
Gross weight	[r]1,110	[r]1,174	1,157	1,275	1,288
Nitrogen content	293	310	305	337	340
Caprolactam:					
Gross weight	514	545	425	580	631
Nitrogen content	64	68	53	72	78
Total:					
Gross weight	**35,558**	**33,689**	**28,957**	**33,426**	**35,904**
Nitrogen content	**9,801**	**9,287**	**8,100**	**9,328**	**10,001**

[p] Preliminary. [r] Revised.
[1] Ranked in relative order of importance.
[2] Diammonium phosphate (DAP), monoammonium phosphate (MAP), and other ammonium phosphates.
[3] Excludes coke plant ammonium sulfate.
[4] Gross nitric acid production adjusted for use in production of ammonium nitrate.

Sources: Bureau of the Census and International Trade Commission.

quantities of these materials are blended in liquid form to produce two popular UAN fertilizer solutions, containing 28% N and 32% N. Urea is a nonprotein nitrogen source in ruminate animal feeds and finds extensive use in the production of urea-formaldehyde resins, consumed primarily in adhesives. Low-density solid ammonium nitrate is mixed with fuel oil to produce the explosive product ANFO, and most of its use in the industrial sector is for this purpose. Although nitric acid is consumed predominately in the production of ammonium nitrate for fertilizers and explosives, about 0.5 million tons of the acid in terms of N is used for other purposes, including organic chemical synthesis and metal treatment. Acrylonitrile is used principally in the production of acrylic fibers, resins, and plastics. Caprolactam is converted into the polymer nylon-6, a significant industrial fiber.

According to the National Fertilizer Development Center Economics and Marketing Staff in Muscle Shoals, AL, U.S. nitrogen fertilizer consumption amounted to 10.5 million tons contained nitrogen (N) for the fertilizer year ended June 30, 1988, representing an increase of 3% over the prior year. Illinois continued to lead the Nation in total fertilizer use, accounting for 8.4% of total consumption. In decreasing order, Illinois, California, Iowa, Texas, Indiana, and Minnesota consumed 40% of all fertilizers. Nitrogen fertilizer consumption was expected to increase by 0.6 to 1.0 million tons N (6% to 10%) during the 1988-89 fertilizer year, due to the improved outlook for agriculture.

Nitrogen is the predominate fertilizer nutrient consumed in the United States, and it accounted for 54% of primary nutrient demand during 1987-88. The ratios of nitrogen demand to phosphate demand and to potash demand were 2.5:1 and 2.1:1, respectively. Approximately 80% of U.S. nitrogen fertilizer was applied in single-nutrient form. The remaining 20% was applied in multiple-nutrient form—fertilizers containing more than one nutrient, processed through chemical reaction or bulk blending. Direct application of anhydrous ammonia accounted for about 36% of total nitrogen consumption.

STOCKS

Producers' stocks in all forms at the beginning of 1988 were 1.8 million tons N. Stocks remained relatively constant throughout the year due to heavy demand. At yearend, producers' stocks were also 1.8 million tons N. Anhydrous ammonia stocks amounted to 1.0 million tons N and downstream nitrogen conversion products, 10.8 million tons N, at yearend.

TRANSPORTATION

The U.S. Department of Transportation proposed that anhydrous ammonia be reclassified from a nonflammable gas to poisonous gas, effective March 10, 1989, to conform with United Nations standards. Several agricultural groups protested that the proposed reclassification would result in dramatic increases in the cost of transporting nitrogen fertilizer and would adversely affect the strong trade relationship between Canada and the United States.

Ammonia in the United States is most commonly transported by rail, barge, or pipeline. Two major pipeline systems link ammonia producers in the gas-rich States of Louisiana, Oklahoma, and Texas to the farmers in the Midwest. A third pipeline serves the phosphate producers in central Florida.

Santa Fe Southern Pacific Corp. sold the Gulf Central Pipeline to Koch Industries Inc. of Wichita, KS, in late January. The pipeline extends 1,900 miles from the gulf coast, through Louisiana, Arkansas, and Missouri, and then splits into two branches, one running east through Illinois and Indiana, the other north and west to Iowa and Nebraska. The annual capacity of this pipeline is 1.8 million tons ammonia. Storage tanks along its length have an additional capacity of 1.1 million tons.

The Mid-America Pipeline Co. (Mapco) system is more than 1,000 miles long and has capacity of 900,000 tons per year ammonia. It runs from northwestern Texas through Oklahoma, Kansas, Nebraska, and Iowa and terminates in Minnesota.

During July, Seminole Fertilizer Corp. purchased the W. R. Grace phosphate fertilizer division. Included in the sale was W. R. Grace's interest in the Florida ammonia pipeline, as well as refrigerated storage capacity at the Royster terminal in Tampa, FL.

TABLE 4

DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 1988

(Thousand short tons per year of ammonia)

Company	Location	Capacity[1]
Freeport-McMoran Inc. (Agrico)	Blytheville, AR	407
Do.	Donaldsonville, LA	468
Do.	Verdigris, OK	840
Air Products and Chemicals Inc.	New Orleans, LA	245
Do.	Pace Junction, FL	100
Allied Chemical Corp.	Hopewell, VA	390
American Cyanamid Co.	Fortier, LA	386
Arcadian Corp.	Geismar, LA	352
Do.	La Platte, NE	172
Borden Chemical Co.	Geismar, LA	400
Carbonaire Co. Inc.	Palmerton, PA	35
C. F. Industries Inc.	Donaldsonville, LA	1,590
Do.	Terre Haute, IN	[2]150
Chevron Chemical Co.	El Segundo, CA	20
Do.	Pascagoula, MS	[2]530
Do.	St. Helens, OR	80
Do.	Finley, WA	140
Columbia Nitrogen Corp.	Augusta, GA	510
Cominco American Incorporated	Borger, TX	400
E. I. du Pont de Nemours & Co. Inc.	Beaumont, TX	520
Farmland Industries Inc.	Beatrice, NE[3]	237
Do.	Dodge City, KS	210
Do.	Enid, OK	840
Do.	Fort Dodge, IA[4]	210
Do.	Hastings, NE	[2]140
Do.	Lawrence, KS	340
Do.	Pollock, LA	420
First Mississippi Corp. (Ampro)[5]	Donaldsonville, LA	400
Green Valley Chemical Corp.	Creston, IA	35
Hawkeye Chemical Co.	Clinton, IA[4]	256
IMC Fertilizer Group Inc.	Sterlington LA	1,050
Jupiter Chemicals	West Lake, LA	30
LaRoche Industries Inc.	Cherokee, AL	175
Mississippi Chemical Corp.	Yazoo City, MS	393
Monsanto Co.	Luling, LA	460
Occidental Chemical Co.	Tacoma, WA	28
Olin Corp.	Lake Charles, LA	490
Pennwalt Chemical Co.	Portland, OR	8
Phoenix Chemical Co.[6]	East Dubuque, IL	238
PPG Industries Inc.	Natrium, WV	50
J. R. Simplot Co.	Pocatello, ID	108
Sohio Chemical Co. (B P International Ltd.)	Lima, OH	510
Tennessee Valley Authority	Muscle Shoals, AL	71

See footnotes at end of table.

TABLE 4—Continued

DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 1988

(Thousand short tons per year of ammonia)

Company	Location	Capacity[1]
Terra International Inc.	Port Neal, IA	230
Do. (Oklahoma Nitrogen)[7]	Woodward, OK	450
Triad Chemical Co.	Donaldsonville, LA	364
Union Chemical Co. (Unocal)	Kenai, AK	[8]1,200
Do.	Brea, CA	280
Western Branch Holding Co. (Nitrex)[9]	Woodstock, TN	340
Wil-Grow Fertilizer Co.[6]	Pryor, OK	94
Wycon Chemical Co.	Cheyenne, WY	163
Total		[10]**17,555**

[1] Engineering design capacity adjusted for 340 days per year of effective production capability.
[2] Plant idle; routine maintenance provides for startup as required.
[3] Purchased from Cepex Corp., fall 1988.
[4] Resumed full production during 1988 following downtime during 1987.
[5] First Mississippi Corp. increased its 50% share in Ampro joint venture through acquisition of Rosewood Resources/Hunt Petroleum's 18% share; it planned to acquire 100% ownership via purchase of Placid Oil's 32% share.
[6] Former N-Ren Corp. plants.
[7] Exercised option to purchase W. R. Grace Co.'s 62.5% share in Oklahoma Nitrogen, Aug. 1988.
[8] 100,000 ton expansion.
[9] Purchased from W. R. Grace, spring 1988.
[10] Center Plains Industries Inc., Dumas, TX, not included, closed Oct. 1987.

Source: Economics and Marketing Research Section, Tennessee Valley Authority. World Fertilizer Capacity, Ammonia. Muscle Shoals, AL, Jan. 1989.

PRICES

Urea and ammonium nitrate prices increased as the year progressed. By yearend, urea prices on the U.S. gulf coast had improved by about $30 per ton and closed near $150 per ton. Domestic urea prices followed a similar trend and closed at about $165 per ton in the Corn Belt. Ammonium nitrate trended upwards by about $35 per ton during the year in the Corn Belt and closed at near $145 per ton. Anhydrous ammonia f.o.b. barge, New Orleans, LA, moved up from $90 per ton during October to $130 per ton by late December. Domestic nitrogen products in all forms were in short supply at yearend.

FOREIGN TRADE

U.S. exports of nitrogen compounds were down about 6% in 1988, primarily because of a decline in anhydrous ammonia trade. Agrico Chemical Co., Arcadian, and Columbia Nitrogen formed the UAN Solutions Export Association under the Webb-Pomerene trade regulations. The U.S. nitrogen-trade deficit increased from 0.6 million tons N in 1987 to 1.7 million tons N in 1988.

Record U.S. import tonnage was established during 1988 due to heavy demand for anhydrous ammonia. Total ammonia imports amounted to 3.7 million tons product (3.0 million tons N), or approximately 30% above that of 1987. Ammonia imports from Canada, Mexico, Trinidad, and the U.S.S.R. were up substantially. The U.S. purchase of 56,000 tons of ammonia product from Saudi Arabia was significant. There had been no ammonia shipments out of the Persian Gulf to the United States since a delivery by Qatar in 1985. Urea imports were down 11% during 1988, reflecting the positive effect of antidumping actions imposed in 1987 against the German Democratic Republic, Romania, and the U.S.S.R. These three countries were absent from the market during 1988, and domestic urea production improved significantly.

The U.S. Department of Commerce, International Trade Commission, and Customs Service determined that all tonnage data for anhydrous ammonia exports and imports would be protected from public disclosure beginning in January 1989 because of the proprietary nature of ammonia imports from the U.S.S.R.; import value data by country would continue to be public information. The private sector protested the loss of tonnage data necessary for the calculation of domestic ammonia consumption and price trends.

Representatives from 96 countries met in Montreal, Quebec, Canada, in December to discuss the liberalization of world trade policy established under the 40-year-old multilateral trade compact known as the General Agreement on Tariffs and Trade (GATT). This meeting marked the midpoint of a 4-year period of negotiations called the Uruguay Round after the country in which they began. Major differences between the United States and the European Community over liberalization of agricultural trade policies ended in a standoff and hampered progress in other areas of negotiation. The United States proposed a gradual elimination of farm subsidies between the years 1990 and 2000, culminated by an eventual "decoupling" of farm subsidies from global agricultural commodity prices. The agricultural issue was referred to committee for debate in Geneva, Switzerland, in April 1989.

WORLD CAPACITY

The data in table 9 are rated capacity for ammonia plants as of December 31, 1988. Rated capacity is defined as the

TABLE 5

CONSUMPTION TRENDS FOR MAJOR NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES[1]

(Thousand short tons of contained nitrogen)

	1984	1985	1986	1987	1988[p]
Fertilizer materials:					
Urea:					
Solid	2,087	1,746	1,529	1,904	1,989
Solution	1,187	1,156	1,033	1,137	1,246
Total	**3,274**	**2,902**	**2,562**	**3,041**	**3,235**
Ammonium phosphates[2]	2,457	2,310	1,861	2,289	2,458
Ammonium nitrate:					
Solid	889	850	623	626	784
Solution	1,043	1,198	963	985	1,220
Other[3]	118	7	43	81	-26
Total	**2,050**	**2,055**	**1,629**	**1,692**	**1,978**
Ammonium sulfate:					
Synthetic and byproduct	434	440	437	460	491
Coke oven byproduct	57	[e]52	[e]47	[e]51	[e]59
Total	**491**	**492**	**484**	**511**	**550**
Total fertilizer	**8,272**	**7,759**	**6,536**	**7,533**	**8,221**
Nonfertilizer materials:					
Urea:[2]					
Feed	138	131	107	142	102
Industrial	154	175	212	237	288
Total	**292**	**306**	**319**	**379**	**[4]389**
Ammonium nitrate[2]	458	447	503	600	537
Nitric acid	479	448	431	460	495
Acrylonitrile	293	310	305	337	340
Caprolactam	64	68	53	72	78
Total nonfertilizer	**1,536**	**1,579**	**1,611**	**1,848**	**[4]1,839**
Grand total[4]	**9,858**	**9,339**	**8,147**	**9,379**	**10,060**

[e]Estimated. [p]Preliminary.
[1]Ranked in relative order of importance.
[2]Solid and solution.
[3]Unaccounted distribution.
[4]Data may not add to totals shown because of independent rounding.

Source: Current Industrial Reports, MA28B and M28B, Bureau of the Census.

TABLE 6

U.S. NITROGEN FERTILIZER CONSUMPTION, BY PRODUCT TYPE[1]

(Thousand short tons nitrogen)

Fertilizer material[2]	1987	1988
Single-nutrient:[3]		
Anhydrous ammonia	3,763	3,775
Aqua ammonia	93	96
Urea	1,536	1,510
Ammonium nitrate	569	591
Ammonium sulfate	134	156
Nitrogen solutions[4]	1,961	2,074
Other	44	116
Total	**8,100**	**8,318**
Multiple-nutrient:[5]	2,110	2,157
Grand total	**10,210**	**10,475**

[1]Fertilizer years ending June 30.
[2]Ranked in relative order of importance by product type.
[3]Materials containing nitrogen nutrient only.
[4]Principally urea-ammonium nitrate (UAN) solutions.
[5]Various combinations of nitrogen (N), phosphate (P), and potassium (K): N-P-K, N-P and N-K.

Source: Economics and Marketing Research Section, Tennessee Valley Authority. Commercial Fertilizers, Dec. 1988.

maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

World ammonia capacity reached 158 million short tons of product during 1988, distributed across 66 countries around the globe. Ammonia supply capability is critically dependent on hydrocarbon feedstock availability; the geographic distribution of plants, in general, follows this trend. Natural gas is the most popular feedstock source. Refinery off-gases and condensates, naphtha, and fuel oil are also popular sources. Coal and coke oven gases are significant in certain countries, particularly China. World capacity growth during the past few years has been dominated by the energy-rich, less-developed and developing countries and the centrally planned economies, while capacity in the developed regions of Western Europe and North America has contracted. This trend is expected to continue.

The global ammonia industry was in the midst of a major round of capacity expansion that would result in the net addition of 7.5 million short tons of annual capacity between 1987 and 1989. Roughly 3 million net tons of capacity was added during 1988, with

TABLE 7

PRICE QUOTATIONS FOR MAJOR NITROGEN COMPOUNDS AT YEAREND

(Per short ton product)

Compound	1987	1988
Ammonium nitrate: Delivered Corn Belt	$100–$120	$140–$145
Ammonium sulfate: F.o.b. Corn Belt	100– 120	100– 120
Anhydrous ammonia:		
Delivered Corn Belt	130– 140	155– 160
F.o.b. gulf coast[1]	[r]103– 106	126– 129
Diammonium phosphate: F.o.b. central Florida	170– 173	165– 173
Urea:		
Delivered Corn Belt, prilled	125– 135	155– 170
F.o.b. gulf coast, granular	118– 122	153– 155
F.o.b. gulf coast, prilled	114– 117	139– 145

[r]Revised

[1] Barge, New Orleans.

Source: Green Markets, Fertilizer Market Intelligence Weekly, Dec. 28, 1987, and Dec. 26, 1988.

the startup of 5 million tons of new capacity and the closure of 2 million tons of obsolete capacity. Asia added 2.6 million annual tons to world capacity in 1988: India brought 1.5 million tons on-stream; China, 0.7 million tons; and Bangladesh, 0.4 million tons. Indian Farmers Fertilizers Cooperative (IFFCO), National Fertilizer Limited (NFL), and Indo-Gulf Fertilizers started up three identical 500,000-ton-per-year ammonia plants along the new Hazira-Bijaipur-Jagdishpur natural gas pipeline in remote southeastern India. Each plant was equipped to produce 800,000 tons of urea annually. In Eastern Europe, the U.S.S.R. added 450,000 tons per year at Salavat, while Bulgaria started up a new 400,000-ton-per-year ammonia plant at the Dimitrovgrad Chemical Combine. In Latin America, the Government of Trinidad and W. R. Grace of the United States started up the Tringen II project, a 500,000-ton-per-year joint-venture ammonia plant. Peace returned to the Persian Gulf area during late August, allowing Iraq to start up new 370,000-ton-per-year-ammonia and 360,000-ton-per-year-urea plants at Baiji. In the United Kingdom, Imperial Chemical Industries Ltd. started up a new 340,000-ton-per-year ammonia project at Severnside and closed an obsolete 230,000-ton-per-year plant at Immingham. Kemira Oy started a new 230,000-ton-per-year ammonia plant at Hull at yearend.

WORLD REVIEW

Global ammonia production amounted to 109 million tons N during 1988, representing an increase of 5% over that of 1987. About 85% of total world production was dedicated to fertilizer use, while about 15% was consumed by the industrial sector. World ammonia trade accounted for about 10% of total production. According to the Food and Agriculture Organization of the United Nations (FAO), nitrogen fertilizer supplies were expected to exceed world demand by a maximum of 2.2 million tons N during the 1988-89 fertilizer year and decline steadily thereafter. Balance between supply and demand was expected to be reached by 1992 or 1993.[2]

Many countries experienced severe drought. Canada, India, Morocco, Pakistan, the Philippines, the Republic of South Africa, Tunisia, and the United States were particularly hard hit. The process of consolidation of fertilizer companies in Western Europe was nearing completion. The U.S.S.R. crop was below expectations, and grain imports increased markedly. Production of ammonia and urea at Marsa-El-Brega, Libya, resumed at the end of October; an explosion in May had severely damaged the older of the two 370,000-ton-per-year ammonia plants.

Several new ammonia and urea projects were scheduled to be completed during the period 1989-92. In Asia, capacity was to increase in Bangladesh, China, India, Indonesia, and Pakistan. Egypt, Iraq, and Saudi Arabia were to increase capacity in the Middle East. Several Latin American countries, including Argentina and Chile, were considering new plants, but Venezuela appeared to have the only immediate potential for implementation of a firm project. Greece was expected to construct a new ammonia and urea plant by 1991.

TECHNOLOGY

Fixed nitrogen in the form of anhydrous ammonia drives a significant downstream industry consisting of two distinct sectors, agricultural and industrial. Anhydrous ammonia in the United States is typically produced by a sequence of high-pressure, high-temperature catalytic processes involving the steam reforming of natural gas, shift conversion, carbon dioxide removal, methanation, and final ammonia synthesis. About 34 million British thermal units (Btu) of natural gas is required to produce 1 ton of ammonia in the United States.

The quest for energy efficiency transformed ammonia processing about 25 years ago, when large plants using centrifugal gas compressors began to replace smaller reciprocal-compressor plants, doubling yields while halving production costs. Innovations in ammonia plant design since 1980 have reduced energy requirements by 24%, from an average of 33 million Btu per ton of ammonia to less than 25 million Btu in today's new plants, according to M. W. Kellogg, Houston, TX. Because all steps except byproduct carbon dioxide removal are catalytic, catalyst improvement has been a key step to improved efficiency. Catalyst improvements have lowered operating temperatures and pressures and improved reactivity. Waste-heat recovery systems that cogenerated electricity for plant operation have dramatically reduced production costs.

Fixed nitrogen is the primary nutrient consumed for global agricultural crop production, providing the base for plant synthesis of essential amino acids and proteins. The significant growth in nitrogen fertilizer demand during past years has led to much speculation as to the fate of residual nitrogen and its potential impact on the environment. The environmental impact of residual nitrate leaching into ground waters and runoff into tributaries is currently the focus of intense study by the scientific community, environmentalists, and government agencies. The European Commission ruled in 1988 that nitrate levels in drinking water should be kept below 50 milligrams per liter. The World Health Organization has a standard of 100 milligrams per liter.

Several concepts for ground water control, including Low Input Sustainable Agriculture (LISA), an organic farming method, are under consideration in the United States. Several States have established ground water programs to monitor and control residual pesticide and nitrate leaching. Agrico Chemical introduced a line of liquid and solid nitrogen fertilizers containing dicyandiamide to reduce leaching loss by stabilizing nitrogen in

TABLE 8

U.S. EXPORTS AND IMPORTS FOR CONSUMPTION OF MAJOR NITROGEN COMPOUNDS IN 1988

(Thousand short tons and thousand dollars)

Compound	Gross weight	Nitrogen content	Value[1]
EXPORTS			
Fertilizer materials:			
Ammonium nitrate	64	22	NA
Ammonium sulfate	870	183	NA
Anhydrous ammonia	781	642	NA
Diammonium phosphate	6,563	1,181	NA
Monoammonium phosphate	945	104	NA
Nitrogen solutions	714	214	NA
Sodium nitrate	6	1	NA
Urea	1,065	490	NA
Mixed chemical fertilizers	21	3	NA
Other ammonium phosphates	43	7	NA
Other nitrogenous fertilizers	138	21	NA
Total	**11,210**	**2,868**	**NA**
Industrial chemicals:			
Ammonia, aqua (ammonia content)	4	3	254
Ammonium nitrate	26	9	2,305
Ammonium phosphate	7	1	7,081
Ammonium sulfate	2	([2])	108
Total	**39**	**13**	**9,748**
Grand total[3]	**11,250**	**2,881**	**NA**
IMPORTS			
Fertilizer materials:			
Ammonium nitrate	294	98	23,575
Ammonium nitrate-limestone mixtures	1	([2])	128
Ammonium sulfate	371	78	27,281
Anhydrous ammonia	3,645	2,996	350,654
Calcium nitrate	171	26	19,464
Diammonium phosphate	11	2	2,430
Natural fertilizers	30	2	6,921
Nitrogen solutions	586	176	46,625
Potassium nitrate	41	5	9,691
Potassium nitrate-sodium nitrate mixtures	48	7	6,502
Sodium nitrate	144	23	17,725
Urea	2,224	1,023	229,635
Mixed chemical fertilizers	144	17	22,582
Other ammonium phosphates	109	20	17,571
Other nitrogenous fertilizers	85	17	15,303
Total	**7,904**	**4,490**	**796,087**
Industrial chemicals: Ammonium bromide	2	([2])	2,403

See footnotes at end of table.

TABLE 8—Continued

U.S. EXPORTS AND IMPORTS FOR CONSUMPTION OF MAJOR NITROGEN COMPOUNDS IN 1988

(Thousand short tons and thousand dollars)

Compound	Gross weight	Nitrogen content	Value[1]
Ammonium nitrate	101	34	9,474
Ammonium perchorate	(2)	(2)	71
Ammonium perrhenate	(2)	(2)	5,124
Ammonium phosphate	3	1	2,448
Calcium cyanamide	4	1	1,592
Anhydrous ammonia and chemical-grade aqua	45	37	4,731
Other ammonium compounds	14	3	15,722
Other nitrogen materials[4]	6	1	2,135
Total	**175**	**77**	**43,700**
Grand total[3]	**8,076**	**4,568**	**839,787**

NA Not available.
[1] Export values f.o.b.; Import values c.i.f.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
[4] Ammonium compounds, including carbonate-bicarbonate, chloride, silicofluoride, and sulfate.

Source: Bureau of the Census.

the ammonia form. The control of residual nitrate leaching will be dependent upon sound agronomic practices by the U.S. farmer.

[1] Physical scientist, Branch of Industrial Minerals.

[2] Current World Fertilizer Situation and Outlook, 1986/87-1992/93, Food and Agricultural Organization of the United Nations, Rome, 1988.

TABLE 9

WORLD ANHYDROUS AMMONIA ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons per year of ammonia)

	Rated capacity[1]
North America:	
Canada	4,700
Mexico	3,330
United States	17,555
Total	**[2]25,580**
Latin America:	
Argentina	120
Brazil	1,410
Colombia	140
Cuba	440
Peru	180
Trinidad and Tobago	1,950
Venezuela	900
Total	**5,140**
Western Europe:	
Austria	570
Belgium	530
Finland	90
France	3,000
Germany, Federal Republic of	2,770
Greece	470
Iceland	10
Ireland	510
Italy	2,180
Netherlands	4,110
Norway	680
Portugal	450
Spain	950
Sweden	(3)
Switzerland	60
United Kingdom	2,380
Total	**18,760**
Eastern Europe:	
Albania	100
Bulgaria	1,830
Czechoslovakia	1,210
German Democratic Republic	1,820
Hungary	1,090
Poland	3,020
Romania	4,820
U.S.S.R.	35,080
Yugoslavia	1,630
Total	**50,600**

TABLE 9—Continued

WORLD ANHYDROUS AMMONIA ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons per year of ammonia)

	Rated capacity[1]
Africa:	
Algeria	1,130
Egypt	1,190
Libya	380
Nigeria	380
South Africa, Republic of	830
Zambia	100
Zimbabwe	110
Total	**4,120**
Asia:	
Afghanistan	80
Bangladesh	1,100
Burma	280
China	24,360
India	10,650
Indonesia	3,400
Japan	2,380
Korea, North	1,200
Korea, Republic of	1,060
Malaysia	430
Pakistan	1,610
Taiwan	340
Vietnam	70
Total	**46,960**
Middle East:	
Abu Dhabi	380
Bahrain	380
Iran	490
Iraq	810
Israel	90
Kuwait	1,120
Qatar	670
Saudi Arabia	1,170
Syria	380
Turkey	520
Total	**6,010**
Oceania:	
Australia	730
New Zealand	100
Total	**830**
Total world	**158,000**

[1] Includes capacity at operating plants as well as plants on standby basis. Rated capacity based on 340 days per year effective operation.
[2] Data do not add to total shown because of independent rounding.
[3] Plant closed in 1987.

Sources: Division of International Minerals, Bureau of Mines, and International Fertilizer Industry Association (IFIA).

TABLE 10

AMMONIA: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons of contained nitrogen)

Country	1984	1985	1986	1987[p]	1988[e]
Afghanistan[e]	[2]45	50	44	44	44
Albania[e]	88	88	88	88	88
Algeria[e]	[2]161	165	165	[r]265	400
Argentina	54	72	69	79	[2]96
Australia	414	446	375	456	[2]425
Austria[e]	550	550	[r]495	[r]495	495
Bahrain	—	[r]121	318	304	[2]340
Bangladesh	389	395	430	480	[2]742
Belgium	498	[r]428	337	336	331
Brazil	963	1,042	972	1,049	[2]1,031
Bulgaria	1,254	1,254	1,203	1,180	1,157
Burma[e]	63	139	147	[r]130	138
Canada	[r]3,165	[r]3,280	3,208	3,182	[2]3,634
China[e]	15,400	16,500	17,000	16,000	17,800
Colombia	103	110	103	98	[2]93
Cuba	[r]186	180	180	[r e]176	176
Czechoslovakia	[r]905	[r]895	838	855	850
Egypt	756	754	789	869	830
Finland	76	72	77	77	[2]47
France	2,582	2,217	2,229	2,236	2,019
German Democratic Republic	1,326	1,329	1,315	1,450	1,488
Germany, Federal Republic of	2,164	2,103	1,731	2,130	[2]1,929
Greece	281	268	266	280	[2]290
Hungary	[r]924	[r]871	840	867	[2]761
Iceland	[e]8	8	9	[e]9	9
India[3]	[r]4,224	[r]4,707	5,438	5,842	6,840
Indonesia	1,828	2,268	2,534	2,606	[2]2,609
Iran	24	[r]30	73	131	[2]121
Iraq[e]	88	66	66	66	77
Ireland	409	372	391	440	[2]460
Israel	63	63	63	68	[2]63
Italy	[r]1,609	[r]1,622	1,693	1,647	[2]1,720
Japan	[r]1,846	[r]1,814	1,662	1,715	[2]1,680
Korea, North[e]	500	500	500	500	500
Korea, Republic of	512	487	470	524	[2]558
Kuwait	319	356	497	637	[2]530
Libya	545	453	388	386	300
Malaysia	43	59	276	354	[2]331
Mexico	1,954	2,049	1,766	1,922	2,279
Netherlands	[r]2,626	[r]2,773	2,968	3,117	[2]3,258
New Zealand	64	[r]80	80	[e]80	80
Nigeria	—	—	—	142	[2]342
Norway	702	505	330	383	[2]467

See footnotes at end of table.

TABLE 10—Continued

AMMONIA: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons of contained nitrogen)

Country	1984	1985	1986	1987[p]	1988[e]
Pakistan	1,243	1,220	1,272	1,300	[2]1,325
Peru[e]	94	94	[r]110	[r]88	105
Philippines	18	[e]19	([4])	—	—
Poland	[r]2,008	1,997	2,341	2,400	2,425
Portugal	176	170	130	170	[2]210
Qatar	572	[r]578	600	618	[2]657
Romania	3,154	3,175	3,352	3,073	3,086
Saudi Arabia	458	481	514	702	[2]956
Somalia	26	[e]26	[e]15	—	—
South Africa, Republic of[e]	[2]639	639	639	[r]606	[2]520
Spain	738	664	512	495	[2]525
Sri Lanka	78	6	—	—	—
Sweden	54	20	51	37	—
Switzerland[e]	[r]36	[r]34	33	43	39
Syria	[r]123	146	151	102	[2]87
Taiwan	296	228	292	268	306
Tanzania[e]	7	7	7	7	7
Trinidad and Tobago	1,190	[r]1,196	1,258	1,243	[2]1,528
Turkey	320	239	218	364	364
U.S.S.R.	19,510	[r]20,172	21,605	22,050	22,600
United Arab Emirates	249	311	320	333	[2]331
United Kingdom	2,024	1,948	1,530	1,560	[2]1,218
United States[5]	[r]13,729	[r]14,236	11,909	13,230	[2]13,930
Venezuela[e]	[r]518	[r]452	[r]530	577	[2]481
Vietnam Democratic Republic[e]	40	40	40	40	40
Yugoslavia[e]	[r]548	[r]694	[r]738	847	[2]778
Zambia	31	19	27	37	[2]18
Zimbabwe	76	76	54	59	58
Total	**[r]97,612**	**[r]100,428**	**100,671**	**103,944**	**109,022**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through May 17, 1989.
[2] Reported figure.
[3] Data are for years beginning Apr. 1 of that stated.
[4] Revised to zero.
[5] Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

PEAT

By Raymond L. Cantrell[1]

U.S. peat production within the 48 contiguous States declined 6% in 1988. Producers' sales volume and average price received per ton, decreased 3% and 2%, respectively. Ending stocks at the producer level increased 5%. Apparent domestic consumption was 5% below the record 1.5 million tons established during 1986 and 1987. Peat imports increased 15% and reached a record 0.6 million tons, representing 40% of apparent domestic consumption. Canada shipped over 99% of the total.

Sphagnum moss sales tonnage increased 142% during the year principally due to development of new high-quality deposits in Minnesota. A significant decline in humus production and sales was experienced. Production and sales of peat from Florida, the Nation's leading producer, declined about 25%. Canadian producers were faced with surplus inventories; they increased sphagnum moss sales volume and reduced prices. Shipments to the United States increased 14%, and the downward pressure on prices resulted in an average decline of $11.50 per ton, 8% below that of the prior year. Bord na Mona, the Irish peat agency, began shipments of fuel-grade peat briquets to the United States during the year.

DOMESTIC DATA COVERAGE

Domestic production data for peat are developed by the Bureau of Mines from a voluntary survey of U.S. peat operations. Of the 110 operations to which a survey request was sent, 9 reported that they were idle or out of business. Of the remaining 101 operations, 80 responded, representing 93% of the total production shown in table 1. Production for 8 nonrespondents was estimated using prior year production levels adjusted for regional production trends and inflation.

DOMESTIC PRODUCTION

Peat was produced by 88 domestic operations in 22 States during 1988. Approximately 75% of total production was from operations of 15,000 tons per year or larger, as shown in table 2. Florida, Michigan, Indiana, and Minnesota, in decreasing order, accounted for 71% of total U.S. peat production. Reed-sedge peat represented 61% of production, humus 23%, sphagnum moss 10%, hypnum moss 4%; and other forms, 2%.

The Bureau of Mines established a cooperative effort with the State Division of Geological and Geophysical Surveys in Fairbanks, AK, for the purpose of identification of producers and for quantification of peat production. Six known producers in the Anchorage and Fairbanks areas, surveyed by telephone, indicated that 55,000 cubic yards of peat valued at $385,000 was produced in 1988, representing a 10% increase in volume and value from 1987 levels.

TABLE 1
SALIENT PEAT STATISTICS

		1984	1985	1986	1987	1988
United States:						
Number of active operations		101	99	92	92	88
Production	thousand short tons	800	839	912	955	900
Sales by producers	do.	814	882	1,038	958	929
Bulk	do.	373	396	522	499	457
Packaged	do.	441	486	516	459	472
Value of sales	thousands	$19,907	$21,892	$23,988	r$21,020	$19,933
Average per short ton		$24.47	$24.81	$23.11	r$21.94	$21.46
Average per short ton, bulk		$20.47	$20.29	$16.44	r$17.72	$18.14
Average per short ton, packaged or baled		$27.85	$28.49	$29.86	r$26.51	$24.68
Imports for consumption	thousand short tons	485	477	553	515	590
Consumption, apparent[1]	do.	1,146	1,255	1,548	1,544	1,468
Stocks, Dec. 31: Producers'	do.	577	638	555	481	503
World: Production	do.	r210,973	r204,517	216,392	p207,779	e207,597

e Estimated. p Preliminary. r Revised.
[1] Apparent consumption equals U.S. primary production plus imports minus exports plus adjustments for industry stock changes.

Minnesota Sphagnum Inc. opened a new high-quality sphagnum moss operation near Floodwood, MN, during June. The firm received a 25-year lease in 1986 for 640 acres at a prime location in the "Arlberg Bog." Hyde Park Inc., a horticultural products distributor in New York, contracted to market 100% of the output. Initial output was rated at 4,800 cubic feet per day. A maximum of 2 inches per year will be mined from the surface by large vacuum machines. The site was expected to support a quality harvest for the next 30 to 50 years.

Premier Ltd. of Riviere-du-Loup, Quebec, Canada, bought the Peatrex operation in Carlton County, MN, from VAPO OY of Finland in October. Premier is one of the two largest peat producers in Canada and one of the 10 largest in the world. Peatrex harvested sphagnum peat on about 270 acres leased from the State and Carlton County. For the past 2 years, Peatrex contracted with nearby Michigan Peat Co. to bale and process its harvested peat. In November, Peatrex announced that it would build a $2 million peat-processing factory. Aside from building the plant, the firm was contemplating leasing more State land for peat harvesting. Sphagnum peat was sold to nurseries and other growers in the Southern and Eastern United States.

Hyponex Corp., a leading producer and marketer of peat in the United States, was purchased by the O.M. Scott & Sons Co. in November. Hyponex mines and processes peat at 10 sites in 8 States. O.M. Scott produces a popular line of lawn and garden fertilizers and related products under the Scott Fertilizer brand name.

TABLE 2

RELATIVE SIZE OF PEAT OPERATIONS IN THE UNITED STATES

Size in short tons per year	Active operations		Production (thousand short tons)	
	1987	1988	1987	1988
25,000 and over	10	11	475	418
15,000 to 24,999	13	14	250	257
10,000 to 14,999	7	6	83	71
5,000 to 9,999	9	10	67	75
2,000 to 4,999	19	20	60	62
1,000 to 1,999	9	7	13	10
Under 1,000	25	20	8	7
Total	**92**	**88**	**[1]955**	**900**

[1] Data do not add to total shown because of independent rounding.

CONSUMPTION AND USES

U.S. peat was sold principally for general soil improvement, as an ingredient for potting soils, and for use by

TABLE 3

U.S. PEAT SALES BY PRODUCERS IN 1988, BY USE

Use	In bulk		In packages		Total[1]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Earthworm culture medium	2,022	$35	2,441	$121	4,463	$156
General soil improvement	183,947	2,839	444,307	10,337	628,254	13,176
Golf courses	27,743	657	243	14	27,986	672
Ingredient for potting soils	175,935	2,987	8,692	429	184,627	3,415
Mixed fertilizers	3,000	35	2,928	111	5,928	146
Mushroom beds	6,200	103	70	6	6,270	109
Nurseries	48,351	1,372	1,105	90	49,456	1,462
Packing flowers, plants, shrubs, etc.	854	14	350	30	1,204	44
Seed inoculant	682	34	5,815	191	6,497	225
Vegetable growing	625	10	10	([2])	635	11
Other	8,018	211	5,494	307	13,512	518
Total[1]	**457,377**	**8,296**	**471,455**	**11,636**	**928,832**	**19,933**

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

nurseries. Sales tonnage, whether in bulk or packaged form, was about the same. The average price of peat sold in packaged or baled form was 36%, or $6.54 per ton, above that of bulk forms. Producers' sales and the average value per ton declined 3% and 2%, respectively, from 1987 levels. Reed-sedge was the most popular form of peat sold for use in general soil improvement and as an ingredient in potting soils; humus was the material of choice for nursery use. Sales of domestic peat for general soil improvement and as an ingredient in potting soils increased over prior-year levels, while nursery use declined 58%. Sphagnum moss sales increased 142% in terms of tonnage, and most was used for general soil improvement. Humus sales declined 30% due to a reduction in nursery use. A surplus of imported sphagnum moss in the marketplace during 1988 may have contributed to this situation.

TABLE 4

U.S. PEAT PRODUCTION AND SALES BY PRODUCERS IN 1988, BY STATE

State	Active operations	Production	Sales		
		Quantity (thousand short tons)	Quantity (thousand short tons)	Value[1] (thousands)	Percent packaged
California	1	—	2	$119	99
Colorado	4	W	W	W	60
Florida	12	266	266	5,091	14
Georgia	2	W	W	W	96
Illinois	4	W	W	W	99
Indiana	5	53	54	W	73
Iowa	2	14	14	433	52
Maine	2	W	W	W	—
Maryland	1	7	7	W	17
Massachusetts	1	W	W	W	100
Michigan	14	249	342	6,256	68
Minnesota	9	74	29	1,027	62
Montana	2	W	W	W	1
New Jersey	4	W	43	797	60
New York	2	W	W	5	—
North Carolina	1	21	21	W	52
North Dakota	1	W	W	W	18
Ohio	3	W	W	W	—
Pennsylvania	8	22	21	736	51
South Carolina	1	W	W	W	—
Washington	4	9	5	142	—
West Virginia	1	W	W	W	—
Wisconsin	4	27	11	270	33
Total or average	**88**	**900**	**[2]929**	**19,933**	**51**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Values are f.o.b. producing plant.
[2] Data do not add to total shown because of independent rounding.

STOCKS

Producers' stocks at yearend were 5% above those of the prior year. Sphagnum moss stocks increased 93% principally due to stockpiling by new producers in Minnesota. Humus stocks declined 58%.

PRICES AND SPECIFICATIONS

The average reported price per ton for all types of peat, f.o.b. plant, decreased 2% in 1988 compared with that of 1987. The unit price for bulk peat increased 2% and packaged or baled forms declined by 7%. Canadian producers increased exports by reducing prices owing to surplus inventories. The result was an 8% decline in the average U.S. import price during 1988.

FOREIGN TRADE

Peat imports for domestic consumption increased 15% in quantity but declined 8% in unit value during 1988. Canadian sphagnum moss shipments accounted for 99.9% of total U.S. imports. Fertilizer-grade peat shipments composed 98% of the total; poultry-grade material composed the remainder. Canadian sphagnum moss was in demand because of its special agricultural and horticultural properties, consumer name recognition, and insufficient domestic supplies. Canadian sphagnum accounted for about 40% of U.S. apparent domestic consumption during 1988. Production and shipments of Canadian peat originated in Quebec, New Brunswick, and Alberta Provinces, in decreasing order. Canada exported about 70% of its domestic supply, approximately 90% of which went to the United States. Approximately 45% of U.S. peat imports en-

TABLE 5

U.S. PEAT SALES BY PRODUCERS IN 1988, BY USE

Use	Sphagnum moss			Hypnum moss			Reed-sedge		
	Quantity		Value (thousands)	Quantity		Value (thousands)	Quantity		Value (thousands)
	Weight (short tons)	Volume[1] (cubic yards)		Weight (short tons)	Volume (cubic yards)		Weight (short tons)	Volume (cubic yards)	
Earthworm culture medium	68	90	([2])	2,321	6,189	$119	1,081	2,065	$22
General soil improvement	42,729	280,273	$1,030	22,316	51,916	550	426,411	896,203	9,711
Golf courses	306	1,020	9	8,500	18,500	173	14,170	29,382	310
Ingredient for potting soils	1,880	5,185	64	2,505	5,520	167	148,174	289,711	2,741
Mixed fertilizers	—	—	—	—	—	—	2,928	6,165	111
Mushroom beds	70	296	6	1,200	3,000	45	5,000	9,455	58
Nurseries	355	1,500	9	300	600	6	18,917	37,566	451
Packing flowers, plants, shrubs, etc.	499	2,031	35	—	—	—	—	—	—
Seed inoculant	—	—	—	—	—	—	6,497	13,173	225
Vegetable growing	—	—	—	11	50	([2])	154	312	3
Other	8,139	45,919	340	2,673	6,100	97	2,700	5,400	81
Total[3]	**54,046**	**336,314**	**1,493**	**39,826**	**91,875**	**1,157**	**626,032**	**1,289,432**	**13,713**

Use	Humus			Other			Total[3]		
	Quantity		Value (thousands)	Quantity		Value (thousands)	Quantity		Value (thousands)
	Weight (short tons)	Volume (cubic yards)		Weight (short tons)	Volume (cubic yards)		Weight (short tons)	Volume (cubic yards)	
Earthworm culture medium	993	1,775	$15	—	—	—	4,463	10,119	$156
General soil improvement	131,984	185,308	1,861	4,814	9,628	$24	628,254	1,423,328	13,176
Golf courses	5,010	7,930	180	—	—	—	27,986	56,832	672
Ingredient for potting soils	32,068	49,725	443	—	—	—	184,627	350,141	3,415
Mixed fertilizers	3,000	5,000	35	—	—	—	5,928	11,165	146
Mushroom beds	—	—	—	—	—	—	6,270	12,751	109
Nurseries	29,884	50,094	995	—	—	—	49,456	89,760	1,462
Packing flowers, plants, shrubs, etc.	705	1,210	8	—	—	—	1,204	3,241	44
Seed inoculant	—	—	—	—	—	—	6,497	13,173	225
Vegetable growing	470	940	8	—	—	—	635	1,302	11
Other	—	—	—	—	—	—	13,512	57,419	518
Total[3]	**204,114**	**301,982**	**3,546**	**4,814**	**9,628**	**24**	**928,832**	**2,029,231**	**19,933**

[1] Volume of nearly all sphagnum moss was measured after compaction and packaging.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

TABLE 6

U.S. PEAT PRODUCTION AND PRODUCERS' YEAREND STOCKS IN 1988, BY KIND

Kind	Active operations	Production (short tons)	Percent of production	Yearend stocks (short tons)
Sphagnum moss	12	89,821	10.0	78,099
Hypnum moss	8	37,350	4.1	16,125
Reed-sedge	42	550,402	61.2	355,872
Humus	27	203,878	22.7	39,410
Other	3	18,314	2.0	13,500
Total	**[1] 88**	**899,765**	**100.0**	**503,006**

[1] Data do not add to total shown because some plants produce multiple kinds of peat.

TABLE 7

PRICES[1] FOR PEAT IN 1988

(Dollars per unit)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other	Average
Domestic:						
Bulk:						
Per short ton	21.56	20.04	18.75	16.81	—	18.14
Per cubic yard	7.66	9.55	9.38	11.60	—	9.98
Packaged or baled:						
Per short ton	29.29	35.76	24.09	20.42	4.90	24.68
Per cubic yard	4.09	14.53	11.47	12.41	2.45	9.71
Average:						
Per short ton	27.63	29.04	21.91	17.37	4.90	21.46
Per cubic yard	4.44	12.59	10.64	11.74	2.45	9.82
Imported, total, per short ton[2]	**126.46**	**XX**	**XX**	**XX**	**XX**	**126.46**

XX Not applicable.
[1] Prices are f.o.b. plant.
[2] Average customs value.

TABLE 8

AVERAGE DENSITY OF DOMESTIC PEAT SOLD IN 1988

(Pounds per cubic yard)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other
Bulk	710	953	1,000	1,381	—
Packaged	279	812	952	1,215	1,000
Bulk and packaged	321	867	971	1,352	1,000

tered the country through two customs districts in New York. Large quantities also entered through customs districts in Maine, Michigan, Montana, and North Dakota.

WORLD CAPACITY

The data in table 11 are the rated capacity for peat operations as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

World peat capacity at yearend was rated at 216.8 million tons per year. The U.S.S.R. accounted for 92% of world capacity. Ireland, Finland, the Federal Republic of Germany, the United States, and Canada, in decreasing order, were also significant contributors to the world peat supply. These five countries have an aggregate capacity of 15.8 million tons per year, representing 7% of total world capacity.

WORLD REVIEW

World peat production was essentially unchanged from that of 1987. The global peat industry continued to operate at about 96% of rated capacity, which was typical for an industry of this nature. Peat operations usually produce at near rated capacity if weather conditions are normal during the harvest season. Relatively long lead times are usually required to physically prepare new bog sites for commercial

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF PEAT MOSS IN 1988, BY COUNTRY

Country	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	96	$15	—	—	96	$15
Canada	12,127	1,426	576,838	$73,020	588,965	74,446
Germany, Federal Republic of	50	13	108	17	158	30
United Kingdom	56	8	70	11	126	19
Other[1]	140	31	161	24	301	55
Total	**12,469**	**1,493**	**577,177**	**73,072**	**589,646**	**74,565**

[1] Includes Cameroon, Finland, Hong Kong, Ireland, Japan, Netherlands, Sweden, Switzerland, and Vatican City.

Source: Bureau of the Census.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF PEAT MOSS IN 1988, BY CUSTOMS DISTRICT

Customs district	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Boston, MA	48	$11	—	—	48	$11
Buffalo, NY[1]	777	130	58,202	$7,039	58,979	7,169
Detroit, MI[1]	8,398	957	45,155	6,151	53,553	7,108
Duluth, MN[1]	—	—	7,114	927	7,114	927
Great Falls, MT[1]	—	—	90,517	13,538	90,517	13,538
Laredo,TX	—	—	16	3	16	3
Los Angeles, CA	—	—	1	2	1	2
Miami, FL	18	2	—	—	18	2
Minneapolis, MN[1]	44	6	108	17	152	23
New York, NY	164	26	81	14	245	40
Ogdensburg, NY[1]	450	61	195,059	23,153	195,509	23,214
Pembina, ND	—	—	82,907	10,203	82,907	10,203
Portland, ME[1]	1,818	173	54,435	5,926	56,253	6,099
St. Albans, VT[1]	22	1	26,820	3,526	26,842	3,527
San Francisco, CA	15	2	—	—	15	2
San Juan, PR[1]	618	99	17	4	635	103
Savannah, GA	45	15	14	2	59	17
Seattle, WA[1]	25	3	16,731	2,567	16,756	2,570
Tampa, FL	7	5	—	—	7	5
U.S. Virgin Islands	20	2	—	—	20	2
Total[1]	**12,469**	**1,493**	**577,177**	**73,072**	**589,646**	**74,565**

[1] Predominantly of Canadian origin.

Source: Bureau of the Census.

operation and to comply with environmental regulations.

Global peat reserves are extensive and should suffice in meeting world demand for a protracted period. World resources of peat are estimated at 2.1 trillion tons, of which the U.S.S.R. has about 850 billion tons and Canada about 560 billion tons. Domestic deposits of peat occur in all 50 States with estimated resources of about 340 billion tons or about 16% of the world total.

TECHNOLOGY

North America's first peat-base electrical powerplant was nearing completion late in the year. Down East Peat Co.'s 22.8-megawatt peat-fired powerplant at Deblois, ME, was scheduled to be commissioned by yearend. Down East planned to fuel the boilers with woodchip feedstock until adequate supplies of fuel-grade peat could be obtained from an adjacent peat bog. Boston Edison had previously signed a 20-year contract to market the electrical output.

First Colony Farms Inc. of Creswell, NC, a producer of fuel-grade peat, experienced financial difficulty and filed for protection under Chapter 11 of the Federal Bankruptcy Code. The firm's planned construction of a 200-megawatt powerplant on-site was postponed indefinitely. Equity participants were reportedly planning either to sell the property outright or to seek joint-venture arrangements.

Prodex Inc. of Ravenna, OH, was founded in 1987 to identify and develop valuable products from peat for use in agriculture, water and wastewater treatment, wood preservation, and pharmaceuticals. Prodex has patented technology allowing economic extraction of peat humic substances for direct use and also for secondary processing into derivatives. This unique technology also can be applied to the conditioning of peat to improve mechanical dewatering, potentially an important achievement that may allow economic wet mining and processing of peat for many uses. Prodex markets three peat humic substance (PHS) products, two to agricultural markets and one to the wastewater treatment market under the trade name Biogene, which is used to stimulate sludge digestion processes. Prodex has a continuous world literature search keyed to "humic acid" that has yielded many potential applications for these products in several industries. The firm's goal is to become a world leader in the development of economic applications for peat extracts and their derivatives.[2]

The chemical composition and particulate nature of peat make it an effective adsorbent and filtration medium in the purification of wastewater. Various types of peat filtration have proven effective in the treatment of dyestuffs, oil spills, phosphate eutrophication, organics, surfactants, slaughterhouse wastewaters, and textile effluents.[3] Peat-sand filters in combination with various forms of vegetation have been shown to be particularly effective in the treatment of secondary sewage and stormwater effluents. Peat-sand filter beds have accomplished almost complete removal of fecal coliform bacteria and phosphorus. Significant amounts of wastewater nitrogen have also been removed. The high iron, aluminum, and ash content of peat in the filter contributes to its highly efficient removal of phosphorus. Microbial immobilization in the peat also contributes to nitrogen and phosphorus removal during the first 2 to 3 years of wastewater treatment after which the uptake by vegetation becomes increasingly important. A system of this nature is in operation in the Mayo Peninsula area of Anne Arundel County, MD.[4]

The International Peat Society (IPS) held its 8th International Peat Congress in Leningrad, U.S.S.R., in August. Representatives from 27 countries were in attendance, and 151 papers were presented. Papers dealt with the study and use of peat and peatlands for energy, agriculture, horticulture, forestry, chemical processing, medicine, and for environmental protection. Copies of the proceedings were published in four volumes, and were available from the IPS Secretariat in Helsinki, Finland. The IPS Council decided that the 9th International Peat Congress should take place in Uppsala, Sweden, in June 1992. The U.S. Section of the IPS scheduled an IPS Symposium in Minnesota for August 1991.[5]

[1] Physical scientist, Branch of Industrial Minerals.

[2] Allread, P. G. (Prodex Inc.). Private communication, Mar. 1989, p. 1; available upon request from Prodex Inc., 6112 Knapp Rd., Ravenna, OH 44266.

[3] McKay, G. Peat—An Adsorbent/Filtration Medium for Wastewater Treatment. J. Water Pollut. Control Fed. v. 52, June 1980, pp. 357-359.

[4] Lombardo, P., and T. Neel. "Natural" Processes and On-Site Treatment Combined in Innovative Wastewater. Dep. Public Utilities, Anne Arundel County, MD, Oct. 1986, pp. 1-3.

[5] Bull. Int. Peat Soc. No. 20; Helsinki, Finland, 1989, pp. 8-15.

TABLE 11

WORLD PEAT ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons per year)

	Rated capacity[1]
North America:	
Canada	820
United States	[2] 1,000
Total	**1,820**
Latin America: Argentina	5
Europe:	
Denmark	60
Finland	4,000
France	250
Germany, Federal Republic of	2,500
Hungary	100
Ireland	7,000
Netherlands	500
Norway	50
Poland	300
Spain	60
Sweden	70
U.S.S.R.	200,000
Total	**214,890**
Asia: Israel	30
Africa: Burundi	20
Oceania: Australia	20
World total	**216,785**

[1] Includes capacity at operating plants as well as at plants on standby basis.
[2] Includes rated capacity of 17 idle plants.

Source: Division of International Minerals, and Chemical Materials Section, Bureau of Mines.

TABLE 12

PEAT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina: Agricultural use	3	4	3	3	3
Australia[3]	15	17	8	10	13
Burundi	15	11	14	[e]14	14
Canada: Agricultural use (shipments)	596	709	814	714	[4]780
Denmark: Agricultural use (sales)	35	43	53	[e]55	55
Finland:					
Agricultural use	248	378	[e]385	[e]385	385
Fuel	2,991	3,461	[e]3,500	[e]3,500	3,500
France: Agricultural use[e]	250	220	240	230	220
Germany, Federal Republic of:					
Agricultural use	1,575	1,671	2,223	2,207	2,200
Fuel	305	313	271	265	220
Hungary: Agricultural use[e]	77	77	77	77	77
Ireland:					
Agricultural use	[r]320	[r]350	360	[e]370	390
Fuel	[r]8,544	[r]2,944	5,193	[e]5,500	6,000
Israel: Agricultural use[e]	22	22	22	22	22
Netherlands[e]	496	500	440	440	440
Norway:[e]					
Agricultural use	33	33	33	33	33
Fuel	1	1	1	1	1
Poland: Fuel and agricultural use[e]	220	220	220	[r]275	220
Spain	61	60	57	[r][e]57	58
Sweden: Agricultural use[e]	66	44	66	66	66
U.S.S.R.:					
Agricultural use[e]	[r]175,000	[r]175,000	[r]180,000	[r]180,000	180,000
Fuel	19,300	17,600	21,500	12,600	12,000
United States:					
Agricultural use	789	828	912	955	[4]900
Fuel	11	11	—	—	—
Total	**[r]210,973**	**[r]204,517**	**216,392**	**207,779**	**207,597**
Fuel peat included in total	[r]31,372	[r]24,550	30,685	22,141	21,941

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through June 7, 1989.

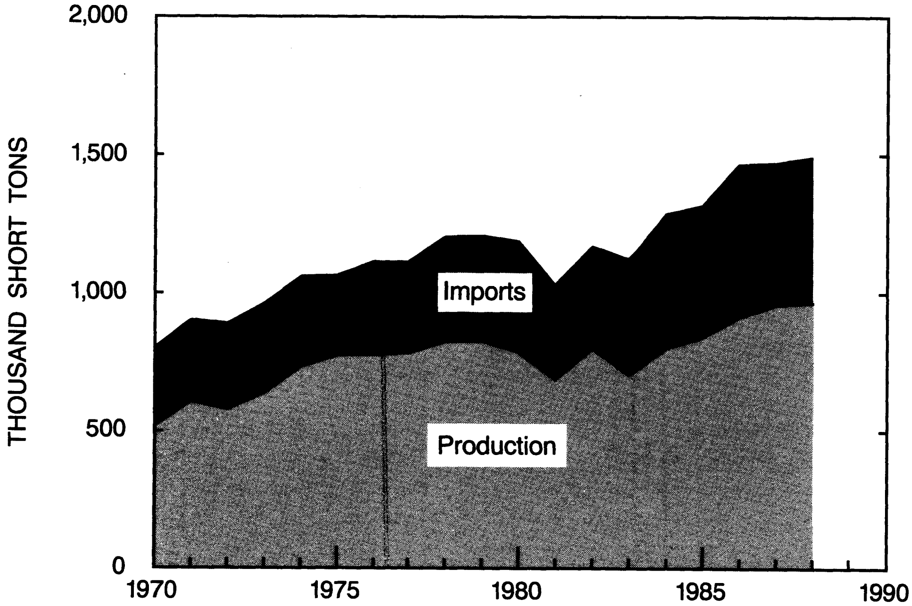
[2]In addition to the countries listed, Austria, Iceland, and Italy produce negligible quantities of fuel peat, and the German Democratic Republic and Venezuela are major producers, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.

[3]Excludes data from some states.

[4]Reported figure.

FIGURE 1

PRODUCTION AND IMPORTS OF PEAT IN THE UNITED STATES



PERLITE

By Arthur C. Meisinger[1]

U.S. production of processed perlite increased 8% in quantity and 7% in value. Expanded perlite sales increased slightly in quantity and 9% in value. Apparent consumption of processed perlite increased 7%. Construction-related uses of expanded perlite accounted for 67% of total perlite domestic sales in 1988.

DOMESTIC DATA COVERAGE

Domestic production data for perlite are developed by the Bureau of Mines from two separate voluntary surveys, one for domestic mine operations and the other for plant operations. Of the 14 mining operations to which a request was sent, 12 responded, of which 8 were active and represented 57% of the total processed ore sold and used shown in table 1. Data for the two nonrespondents were estimated using reported prior-year production levels adjusted by trends in employment and other guidelines. Of the 65 expanding plants canvassed, 61 were active; of these, 39 plants, or 64% responded, representing 57% of the total expanded perlite sold and used shown in table 1. Plant data for the 22 nonrespondents were estimated using reported prior-year production levels adjusted by trends in employment and other guidelines.

DOMESTIC PRODUCTION

Processed Perlite

Perlite mined for processing from 10 operations by 9 companies in 6 Western States totaled 830,000 short tons. New Mexico operations accounted for 85%. The remaining 15% came from Arizona, California, Colorado, Idaho, and Nevada.

Production of processed perlite sold and used increased 8% in quantity and 7% in value compared with that of 1987. New Mexico operations accounted for 80% of the U.S. total.

Ore producers were Harborlite Corp. and Nord Perlite Co. in Arizona; American Perlite Co. in California; Persolite Products Inc. in Colorado; National Perlite Co. in Idaho; Delamar Perlite Co. in Nevada; and Grefco Inc., Manville Products Corp., and USG Corp. in New Mexico. Silbrico Corp. closed its Uniperl mining operations in Taos County, NM, and three smaller mines were idle during the year—two in Arizona and one in Nevada.

Expanded Perlite

The quantity of expanded perlite sold and used from 61 plants in 33 States increased slightly compared with that of 1987. Value of expanded perlite sales increased 9%. Leading States, in descending order of sales, were Mississippi, Pennsylvania, Illinois, California, Georgia, Kentucky, Florida, Minnesota, and Virginia. California and Texas each had six active expanding plants.

CONSUMPTION AND USES

Apparent domestic consumption of processed perlite increased 7% to 602,000 tons in 1988. Domestic consumption of expanded perlite was slightly higher than that of 1987. Construction-related uses, the major market for the expanded material, increased 4% from 309,700 tons to 320,900 tons. Expanded perlite used as a filter aid, fillers, and in agricultural markets totaled 139,300 tons, a slight increase over the 1987 total of 137,000 tons.

TABLE 1

PERLITE MINED, PROCESSED, EXPANDED, AND SOLD AND USED BY PRODUCERS IN THE UNITED STATES

(Thousand short tons and thousand dollars)

Year	Perlite mined[1]	Processed perlite: Sold to expanders: Quantity	Processed perlite: Sold to expanders: Value	Processed perlite: Used at own plant to make expanded material: Quantity	Processed perlite: Used at own plant to make expanded material: Value	Processed perlite: Total quantity sold and used	Expanded perlite: Quantity produced	Expanded perlite: Sold and used: Quantity	Expanded perlite: Sold and used: Value
1984	653	310	10,395	188	6,243	498	440	439	74,000
1985	678	309	10,714	209	6,821	518	461	459	81,000
1986	735	303	9,536	204	6,110	507	480	479	83,700
1987	778	333	10,471	200	6,023	533	464	466	81,800
1988	830	375	11,588	201	6,064	576	480	479	88,900

[1] Crude ore mined and stockpiled for processing.

TABLE 2

EXPANDED PERLITE PRODUCED AND SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	1987 Quantity produced (short tons)	1987 Sold and used: Quantity (short tons)	1987 Sold and used: Value (thousands)	1987 Sold and used: Average value per ton[1]	1988 Quantity produced (short tons)	1988 Sold and used: Quantity (short tons)	1988 Sold and used: Value (thousands)	1988 Sold and used: Average value per ton[1]
California	41,900	42,900	$7,922	$185	40,700	41,600	$7,841	$188
Florida	26,600	26,700	4,638	174	26,600	26,600	5,509	206
Indiana	21,000	21,400	5,186	243	19,400	19,400	5,499	283
Kansas	1,100	1,100	290	274	1,100	1,100	380	354
Massachusetts	2,200	2,000	714	361	W	W	W	W
Pennsylvania	47,800	47,800	8,801	184	50,300	50,200	9,776	194
Texas	18,300	19,100	4,582	240	16,000	15,600	4,108	263
Utah	1,900	1,900	575	306	900	900	239	274
Wisconsin	1,200	1,200	301	242	W	W	W	W
Other[2]	302,100	302,100	48,772	161	324,900	323,290	55,548	172
Total[3]	**464,000**	**466,000**	**81,800**	**176**	**480,000**	**479,000**	**88,900**	**186**

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Average value based on unrounded data and rounded to nearest dollar.
[2] Includes Alabama, Arizona, Arkansas, Colorado, Georgia, Idaho, Illinois, Iowa, Kentucky, Louisiana, Maine, Michigan, Minnesota, Mississippi, Missouri, Nevada, New Jersey, New York, North Carolina, Ohio (1988), Oregon, Tennessee, Virginia, Wyoming, and data indicated by symbol W.
[3] Data may not add to totals shown because of independent rounding.

TABLE 3

EXPANDED PERLITE SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Short tons)

Use	1987	1988
Concrete aggregate	7,600	10,400
Fillers	28,900	27,100
Filter aid	66,000	62,900
Formed products[1]	277,200	283,100
Horticultural aggregate[2]	42,100	49,300
Low-temperature insulation	3,500	6,200
Masonry and cavity-fill insulation	13,300	10,400
Plaster aggregate	8,100	10,800
Other[3]	19,300	18,800
Total	**466,000**	**479,000**

[1] Includes acoustic ceiling tile, pipe insulation, roof insulation board, and unspecified formed products.
[2] Includes fertilizer carriers.
[3] Includes fines, high-temperature insulation, paint texturizer, refractories, and various nonspecified industrial uses.

Other uses of expanded perlite declined slightly during the year.

PRICES

The average prices of processed perlite sold to expanders and used by captive expanders were $30.90 per ton and $30.17 per ton, respectively. The average value of all processed perlite sold and used was $30.65 per ton, a $0.30 per ton decrease from that of 1987. The value of expanded perlite sold and used averaged nearly $186 per ton, a $10.00 per ton increase over that of 1987.

FOREIGN TRADE

Perlite exports, primarily to Canada, were estimated to be 36,000 tons, compared with 35,000 tons in 1987. Imports of perlite ore from Greece were estimated to be 62,000 tons, compared with 65,000 tons in 1987.

WORLD CAPACITY

The data in table 4 are rated annual capacity for perlite processing plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, material, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Plant capacity for perlite is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines.

TABLE 4

WORLD PERLITE ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons)

	Rated capacity
North America:	
Mexico	55
United States	755
Total	**810**
Europe:	
Greece	350
Italy	175
Turkey	250
U.S.S.R.	700
Other	225
Total	**1,700**
Africa	20
Asia	150
Oceania	5
South America	15
World total	**2,700**

[1] Includes capacity at operating plants as well as at plants on standby basis.

WORLD REVIEW

Estimated world production of perlite exceeded 2 million tons, a record total, and was 6% greater than the 1987 total. Perlite output from Turkey increased 64% and exceeded 200,000 tons for the first time. Etibank is the largest perlite producer in Turkey, with installed plant capacity to produce 175,000 tons of crushed perlite per year.

[1] Industry economist, Branch of Industrial Minerals.

TABLE 5

PERLITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Australia[3]	4	3	4	[e]4	4
Czechoslovakia[e]	49	49	[4]46	[r]46	50
Greece	196	178	203	230	230
Hungary[3]	104	104	121	124	110
Italy[e]	88	88	[r]81	[r]77	78
Japan[e]	83	83	83	83	83
Mexico[3]	35	41	51	43	40
Philippines	17	4	[e]4	[e]4	4
Turkey	67	[e]66	[e]66	123	[4]202
U.S.S.R.[e]	660	660	660	660	660
United States (processed ore sold and used by producers)	498	518	507	533	[4]576
Total	**1,801**	**1,794**	**1,826**	**1,927**	**2,037**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Unless otherwise specified, figures represent processed ore output. Table includes data available through May 31, 1989.
[2] In addition to the countries listed, Algeria, Bulgaria, China, Iceland, Mozambique, the Republic of South Africa, and Yugoslavia are believed to have produced perlite, but output data are not reported, and available information is inadequate for the formulation of reliable estimates of output levels.
[3] Crude ore.
[4] Reported figure.

PHOSPHATE ROCK

By William F. Stowasser[1]

After the rapid growth of phosphate fertilizer production and consumption in the 1970's, the phosphate industry entered a recessionary period in the 1980's by reacting to the world recession in the early 1980's and the decline in demand for agricultural products in the mid-1980's. The recession in the phosphate industry lasted through 1987. Phosphate rock consumed in the domestic fertilizer market improved markedly in 1988, although phosphate rock exports continued their gradual decline.

The domestic market for phosphate fertilizers and phosphate rock responded to changing Government policies and pressure to reduce farm subsidies. Although the demand for phosphate fertilizer improved at the beginning of 1988, the drought, particularly in the corn belt, reduced phosphate fertilizer consumption during the year. The depletion of grain inventories as a result of the drought increased optimism for higher phosphate fertilizer demand in 1989.

Although U.S. phosphate rock exports were slightly less than those of 1987, they were second only to those from Morocco. As existing reserves of phosphate rock in Florida are consumed, the level of impurities in future products is expected to increase. It will become more difficult for U.S. products to compete in the export market.

Low prices and sales caused several companies to declare bankruptcy, and several others made the decision to leave the industry. Acquisitions and corporate reorganizations were completed to improve the competitiveness of U.S. phosphate fertilizer in world trade.

TABLE 1

SALIENT PHOSPHATE ROCK STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Mine production (crude ore)	163,012	175,227	135,683	148,426	162,299
Marketable production	49,197	50,835	40,320	40,954	45,389
P_2O_5 content	14,889	15,634	12,248	12,470	13,833
Value	$1,182,244	[2]$1,235,800	[2]$897,131	[2]$793,280	$887,809
Average per metric ton	[3]$24.03	[4]$24.31	[4]$22.25	[4]$19.37	[4]$19.56
Sold or used by producers[5]	53,277	46,634	41,776	43,673	48,441
P_2O_5 content	16,244	14,363	12,750	13,286	14,760
Value	$1,278,356	[2]$1,133,675	[2]$929,621	[2]$845,812	$947,721
Average per metric ton[4 6]	$23.99	$24.31	$22.25	$19.37	$19.56
Exports[7]	11,528	9,136	7,848	8,454	8,092
P_2O_5 content	3,646	2,931	2,521	2,737	2,608
Value	$324,784	[2]$263,631	[2]$211,701	[2]$194,691	[2]$206,984
Average per metric ton[4]	$28.17	$28.86	$26.97	$23.03	$25.58
Imports for consumption	[8]9	[8]34	528	464	673
C.i.f. value	$274	$1,747	$25,435	$22,134	$25,911
Average per metric ton	$31.71	[9]$51.54	[9]$48.18	$47.70	$38.48
Consumption[10]	41,758	37,532	34,456	35,683	41,022
Stocks, Dec. 31: Producers	11,897	15,534	13,277	10,884	9,323
World: Production	[r]151,855	[r]148,842	138,870	[p]144,228	[e]163,673

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2] The total value is based on a weighted value.
[3] Arithmetic average of sold or used values.
[4] Computer-calculated average value based on the weighted sold or used values.
[5] Includes domestic sales and exports.
[6] Weighted average of sold or used values.
[7] Exports reported to the Bureau of Mines by companies.
[8] Bureau of the Census data, excluding reported Canadian and Israeli imports.
[9] Average unit value obtained from unrounded data.
[10] Expressed as sold or used plus imports minus exports.

DOMESTIC DATA COVERAGE

Domestic production data for phosphate rock are developed by the Bureau of Mines from two separate voluntary surveys of U.S. operations. Typical of these surveys is the semiannual "Phosphate Rock Survey." Of the 25 operations to which a survey request was sent, all responded, representing 100% of the U.S. production data shown in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

The U.S. International Trade Commission determined that industrial phosphoric acid imported from Belgium and Israel was subsidized by the Government of Israel and that imports of industrial phosphoric acid from these countries were sold in the United States at less than fair value.

The passage of budget reconciliation legislation in December 1987 changed the farm programs and the demand for phosphate fertilizers in 1988. Target prices were reduced from previously announced levels. Loan rates from the U.S. Government on crops placed in storage were reduced to 3% rather than the scheduled 5%. The 0/92 acreage diversion provision permitted wheat and feed grain farmers to plant no crop and receive 92% of the newly projected deficiency payment on all acres over those required under the regular acreage reduction program.

Of the 15 wastes the Environmental Protection Agency (EPA) proposed to study under the Bevill Exclusion Amendment, phosphogypsum from phosphoric acid production and slag from elemental phosphorus production were included. EPA was studying these wastes to determine if they should be regulated as hazardous under subtitle C or nonhazardous under subtitle D of the Resource Conservation and Recovery Act. The program was a direct result of a U.S. appeals court decision overturning EPA's decision not to list mineral-processing wastes as hazardous until EPA had an opportunity to complete its study of the wastes.

Participants in agricultural trade talks between the United States and the European Community (EC), known as the "Uruguay Round," conducted under the auspices of the General Agreement on Tariffs and Trade, were not able to agree on new trade rules. The inability of those meeting in Montreal, Canada, to reach agreement may promote pressure in the United States and in the EC for additional farm subsidies designed to promote the respective groups' sales of farm commodities in the world. The EC contend they cannot eliminate farm subsidies as demanded by the United States because they have more numerous but inefficient farms. The domestic demand for phosphate rock and phosphate fertilizers will fluctuate with the success or failure of U.S. farm commodities competing in international markets.

DOMESTIC PRODUCTION

Production of marketable phosphate rock in the United States increased 11% in 1988 to 45 million metric tons[2] compared with that of 1987. Most of the gain in production occurred in Florida and North Carolina, where production increased 8%. Production increased 31% in Tennessee and the Western States.

Florida and North Carolina

Phosphate rock was produced in central Florida by Agrico Chemical Co., CF Industries Inc., Estech Inc., Gardinier Inc., W. R. Grace & Co., Hopewell Land Partners Ltd., IMC Fertilizer Inc. (IMC), Mobil Mining and Minerals Co., and U.S. Agri-Chemicals Corp. In Hamilton County, northern Florida, Occidental Chemical Agricultural Products Inc. produced phosphate rock.

Manko Co., Howard Phosphate Co., and Loncala Phosphate Co., recovered soft phosphate rock from hard-rock phosphate mine tailing ponds in north-central Florida. The low-fluorine soft rock was sold as an animal feed supplement.

Texasgulf Chemical Co., a subsidiary of Elf Aquitaine Inc., operated the Lee Creek Mine on the Pamlico River in eastern North Carolina. Texasgulf requested the U.S. Army Corps of Engineers to deepen the harbor at Morehead City from 12.2 meters (40 feet) to 13.7 meters (45 feet) to permit bulk ocean navigation in larger, deeper draft vessels. The study for justifying the request was in progress.

Agrico, a subsidiary of Freeport-McMoRan Resources Partners Ltd. Inc., operated the Payne Creek and Fort Green Mines, Florida.

CF Industries extracted phosphate rock from its Hardee Complex Mine on a reduced operating schedule.

Estech operated the Watson and Silver City Mines. Estech announced that the Watson Mine, jointly owned with Zen Noh Phosphate Corp., had exhausted its reserves and would close March 1, 1989. The Silver City Mine was sold to G&G Holdings Inc. and was expected to continue operating.

W. R. Grace sold its phosphate operations in Polk County, Florida, to Seminole Fertilizer Corp. Included in the sale was the Hookers Prairie phosphate mine, the Ridgewood chemical complex, and a half-share of the Fort Meade Chemical Products Co. W. R. Grace announced that it would sell its half-share of the idle Four Corners Mine to IMC.

The Lithia phosphate rock mine of Hopewell Land Corp., a Noranda Group Co., was sold to investors and will operate as the Hopewell Land Partnership.

IMC operated the Clear Springs,

Kingsford, Noralyn-Phosphoria, and Haynsworth Mines in central Florida. The Lonesome Mine was idle. IMC planned to operate the Four Corners Mine in 1989 after acquiring W. R. Grace's share.

Mobil produced phosphate rock from its Fort Meade Mine. The Big Four and Nichols Mine were idle in 1988.

Occidental Chemical Co. operated the Suwannee River and Swift Creek Mines in Hamilton County, northern Florida.

USX Agri-Chemicals, a subsidiary of USX Corp., agreed to sell certain assets of USX's Agri-Chemical Div. to Sinochem U.S.A. Inc. The assets included a half-share of the Rockland phosphate rock mine and its share of the Fort Meade Chemical Products phosphoric acid joint venture with Seminole Fertilizer Corp.

Tennessee

Occidental and Stauffer Chemical Co., a subsidiary of Rhône-Poulenc Inc., mined phosphate rock from various locations in Giles, Hickman, Maury, and Williamson Counties. All of the phosphate rock was smelted in electric furnaces to produce elemental phosphorus.

Western States

Phosphate rock was mined in Idaho, Montana, and Utah. Phosphate rock from Montana was exported to Canada for fertilizer production. Phosphate rock from Idaho was used to produce phosphate fertilizer and elemental phosphorus. Utah phosphate rock was pumped north into Wyoming where it was converted into diammonium phosphate.

Nu-West Industries purchased Beker Industries Corp. share in the Conda Partnership and produced phosphate rock from a number of deposits in Idaho.

Cominco American Incorporated operated the only underground phosphate rock mine in the United States near Garrison, MT. The ore from the mine was crushed, classified, and washed to produce a -3/8-inch product. The -3/8-inch product was dried and ground prior to shipping to Canada.

Chevron Resources Co. operated the open pit phosphate rock mine at Vernal, UT, to produce phosphate concentrates for its chemical complex at Rock Springs, WY. The phosphate rock was ground, slurried, and pumped to Rock Springs as a 35% passing 325-mesh, 58% solids slurry.

J. R. Simplot Co. operated the Gay Mine on the Fort Hall Indian Reservation and the Smoky Canyon Mine in the Caribou National Forest. The Gay Mine, opened in 1946, was expected to close by 1994, when reserves are depleted. The production will be replaced by the new Dry Valley Mine. The Gay Mine supplied Simplot's Pocatello, ID, fertilizer plant and FMC Corp.'s Pocatello electric-furnace plant.

Simplot planned to install a 97-kilometer (60-mile) pipeline between its

TABLE 2

PRODUCTION OF PHOSPHATE ROCK IN THE UNITED STATES, BY REGION[1]

(Thousand metric tons and thousand dollars)

Region	Mine production		Marketable production							Ending stocks
			Used directly		Beneficiated		Total[2]			
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Value[3 4]	
1987	148,426	19,423	2,783	r742	r38,171	11,728	40,954	r12,470	r793,280	10,884
1988:										
January–June:										
Florida and North Carolina	74,115	9,006	—	—	18,967	5,833	18,967	5,833	345,569	8,422
Idaho, Montana, Tennessee, Utah	3,931	945	1,361	357	1,400	434	2,761	791	55,348	1,491
Total[2]	**78,046**	**9,952**	**1,361**	**357**	**20,367**	**6,266**	**21,729**	**6,623**	**400,916**	**9,914**
July–December:										
Florida and North Carolina	79,323	9,755	382	121	19,806	6,094	20,188	6,215	423,988	7,809
Idaho, Montana, Tennessee, Utah	4,929	247,870	2,089	567	1,384	427	3,472	994	68,630	1,514
Total[2]	**84,252**	**257,625**	**2,471**	**689**	**21,190**	**6,521**	**23,661**	**7,209**	**492,618**	**9,323**
Grand total[2]	**162,299**	**267,577**	**3,832**	**1,045**	**41,557**	**12,787**	**45,389**	**13,833**	**887,809**	**XX**

r Revised. XX Not applicable.

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.

[2] Data may not add to totals shown because of independent rounding.

[3] Computer-calculated value based on the weighted sold or used value.

[4] The total value is based on a weighted value. The total value does not equal the sum of the regional or 1/2-year totals because weighted regional or overall 1/2-year unit values were used in the calculations. The regional and 1/2-year values are approximate.

Conda, ID, plant and its Pocatello, ID, plant by 1991. The pipeline will extend the 43-kilometer (27 mile) slurry pipeline from the Smoky Canyon Mine to Conda.

Stauffer Chemical Co., a subsidiary of Rhône-Poulenc, mined phosphate rock from its Wooley Valley, ID, mine for shipment to its electric-furnace plant at Silver Bow, MT. Monsanto Co. produced phosphate rock from the Henry Mine for its electric furnace plant at Soda Springs, ID.

CONSUMPTION AND USES

Phosphate rock is the raw material used to manufacture phosphate fertilizers, animal feed supplements, and elemental phosphorus. A limited quantity of phosphate rock was exported to countries without the raw material base, industry, or infrastructure to produce phosphate fertilizers. More phosphate rock was converted by countries with phosphate rock reserves into higher value products for export rather than export phosphate rock. In the United States, more than 50% of the mined phosphate rock was exported as phosphate rock or phosphate fertilizer.

In the United States, farmers removed large acreages from production to qualify for Government subsidies. Although the farmers benefited by Government subsidy programs, the suppliers of fertilizer were penalized with no Government programs to reward farmers' suppliers. Internationally, other grain-exporting countries did not reduce planted acreage, and several countries planted more acres to increase production.

The impact of the drought on fertilizer consumption was negligible in 1988 as fertilizer was applied at planting. Farm commodity stocks were reduced, and crop prices increased. Crop acreage and fertilizer consumption in 1989 may increase as demand improves.

TABLE 3

U.S. PHOSPHATE ROCK SOLD OR USED GRADE DISTRIBUTION PATTERN

Grade (percent BPL[1] content)	Distribution (percent)				
	1984	1985[2]	1986	1987	1988
74 or more	4.7	2.9	4.5	3.4	2.0
72 to less than 74	2.0	4.2	4.0	5.4	5.6
70 to less than 72	10.1	12.0	7.8	7.1	8.8
66 to less than 70	63.0	62.9	57.5	61.6	59.7
60 to less than 66	8.1	13.1	20.3	17.5	14.9
Less than 60	12.1	4.8	5.9	5.0	9.0

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[2] Data do not add to 100% because of independent rounding.

TABLE 4

FLORIDA AND NORTH CAROLINA PHOSPHATE ROCK SOLD OR USED GRADE DISTRIBUTION PATTERN

Grade (percent BPL[1] content)	Distribution (percent)				
	1984	1985[2]	1986	1987	1988
74 or more	5.4	3.4	5.1	3.8	2.3
72 to less than 74	2.4	4.8	4.6	6.0	6.4
70 to less than 72	9.9	12.6	9.0	7.6	8.2
66 to less than 70	67.5	65.9	60.7	65.3	64.0
60 to less than 66	7.0	12.8	20.6	17.3	14.4
Less than 60	7.8	.6	—	(3)	4.7

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[2] Data do not add to 100% because of independent rounding.
[3] Less than 0.1 of 1%.

TABLE 5

TENNESSEE AND WESTERN STATES PHOSPHATE ROCK SOLD OR USED GRADE DISTRIBUTION PATTERN

Grade (percent BPL[1] content)	Distribution (percent)				
	1984[2]	1985[2]	1986	1987	1988
70 to less than 72	NA	NA	—	3.5	12.5
66 to less than 70	NA	NA	36.1	33.9	29.8
60 to less than 66	NA	NA	18.5	19.3	18.2
Less than 60	NA	NA	45.4	43.3	39.5

NA Not available.
[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[2] Data for Tennessee and Western States were reported separately in the 1985 and 1986 Minerals Yearbook chapter.

TABLE 6

PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GRADE AND REGION[1]

(Thousand metric tons and thousand dollars)

Grade (percent BPL[2] content)	Florida and North Carolina			Tennessee and Western States[3]			Total		
	Rock	P_2O_5 content	Value[4 5]	Rock	P_2O_5 content	Value[4 5]	Rock	P_2O_5 content	Value[4 5]
January–June 1987	r19,028	r5,852	381,088	2,186	613	34,044	21,214	6,465	415,132
July–December 1987	19,664	6,039	383,972	2,795	783	46,708	22,459	6,821	430,680
January–June 1988:									
74 or more	179	61	5,882	—	—	—	179	61	5,882
72 to less than 74	1,577	525	38,733	—	—	—	1,577	525	38,733
70 to less than 72	1,491	486	39,582	374	123	13,590	1,865	609	53,172
66 to less than 70	13,870	4,258	222,225	806	252	22,183	14,676	4,510	244,408
60 to less than 66	3,355	945	62,802	627	177	5,927	3,982	1,122	68,729
Below 60	—	—	—	1,043	265	12,273	1,043	265	12,273
Total[6]	**20,472**	**6,275**	**369,224**	**2,850**	**817**	**53,973**	**23,322**	**7,092**	**423,197**
July–December 1988:									
74 or more	784	291	23,159	—	—	—	784	291	23,159
72 to less than 74	1,119	371	27,512	—	—	—	1,119	371	27,512
70 to less than 72	2,007	656	54,616	381	126	13,862	2,388	782	68,478
66 to less than 70	13,253	4,094	249,141	999	309	29,434	14,252	4,403	278,575
60 to less than 66	2,769	814	51,479	470	132	5,631	3,239	946	57,110
Below 60	1,990	536	54,831	1,347	340	14,859	3,337	876	69,690
Total[6]	**21,922**	**6,762**	**460,738**	**3,197**	**907**	**63,786**	**25,119**	**7,669**	**524,524**

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[3] Includes Idaho, Montana, and Utah.
[4] F.o.b. Mine.
[5] The total value is based on a weighted value. The total value does not equal the sum of the regional totals because weighted regional unit values were used in the calculations. The regional values are approximate.

TABLE 7

PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

(Thousand metric tons)

Use	1987 total		1988					
			January–June		July–December		Total[2]	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
Domestic:[3]								
Wet-process phosphoric acid	30,868	9,329	17,722	5,338	18,999	5,745	36,721	11,083
Normal superphosphate	50	16	32	11	14	5	46	15
Triple superphosphate	927	303	722	235	713	234	1,435	469
Defluorinated rock	186	65	66	22	—	—	66	22
Direct applications	9	3	—	—	1	(4)	1	(4)
Elemental phosphorus	3,013	791	987	268	1,057	285	2,044	553
Ferrophosphorus	166	42	19	5	17	4	36	9
Total[2]	**35,219**	**10,549**	**19,548**	**5,879**	**20,801**	**6,273**	**40,349**	**12,152**
Exports[5]	8,454	2,737	3,774	1,213	4,319	1,395	8,092	2,608
Grand total[2]	**43,673**	**13,286**	**23,322**	**7,092**	**25,119**	**7,668**	**48,441**	**14,760**

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes rock converted to products and exported.
[4] Less than 1/2 unit.
[5] Exports reported to the Bureau of Mines by companies.

PRICES

Phosphate rock was sold under contracts negotiated between buyers and sellers. Although list selling prices were occasionally published by producing organizations, actual negotiated prices were not published.

Phosphate rock export prices from Tampa and Jacksonville, FL, included a freight, loading, and weighing cost of $6.52 and $7.90 per ton, respectively, effective April 1, 1988. The severance tax included in the export price was $1.49 per ton.

The weighted averaged prices or values, f.o.b. mine, for each grade of phosphate rock and for each producing region were calculated and published by the Bureau of Mines from prices and values obtained from the semiannual survey of producers.

FOREIGN TRADE

Export tonnage of phosphate rock was about 4% less than that of 1987. Although there was some improvement in export prices, the average price was about the same as that obtained in 1979, which probably explains the necessity to convert phosphate rock into higher value products rather than export this commodity.

Phosphate rock imports increased in 1988 over that of 1987. Phosphate rock was imported into plants on the Mississippi River to produce phosphoric acid, liquid fertilizer, and diammonium phosphate. The phosphate rock was imported from Moroccan mines in the Khouribga district and Bu Craa in the Western Sahara.

WORLD CAPACITY

The data in table 24 are rated capacity for mines as of December 31, 1988.

TABLE 8

PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE AND REGION[1]

(Thousand metric tons)

Use	Florida and North Carolina		Tennessee and Western States[2]		Total[3]	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
1987	38,692	11,892	4,980	1,396	43,673	13,286
1988:						
January–June:						
Domestic:[4]						
Agricultural	16,792	5,092	1,750	514	18,542	5,607
Industrial	22	6	985	266	1,006	273
Total	**16,814**	**5,098**	**2,735**	**780**	**19,548**	**5,880**
Exports[5]	3,660	1,177	114	36	3,774	1,213
Total	**20,474**	**6,275**	**2,849**	**816**	**23,322**	**7,093**
July–December:						
Domestic:[4]						
Agricultural	17,685	5,392	2,042	592	19,727	5,984
Industrial	17	5	1,056	284	1,074	289
Total	**17,702**	**5,397**	**3,098**	**876**	**20,801**	**6,273**
Exports[5]	4,219	1,364	100	31	4,319	1,395
Total	**21,921**	**6,761**	**3,198**	**907**	**25,120**	**7,668**
Grand total[3]	**42,395**	**13,036**	**6,047**	**1,723**	**48,441**	**14,760**

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2] Includes Idaho, Montana, and Utah.
[3] Data may not add to totals shown because of independent rounding.
[4] Includes rock converted to products and exported.
[5] Exports reported to the Bureau of Mines by companies.

TABLE 9

FLORIDA AND NORTH CAROLINA PHOSPHATE ROCK SOLD OR USED BY PRODUCERS[1]

Year	Rock (thousand metric tons)	P_2O_5 content (thousand metric tons)	Value: Total[2] (thousands)	Value: Average per ton f.o.b. mine
1984	46,411	14,309	$1,089,647	$23.48
1985	40,857	12,702	972,748	23.81
1986	36,333	11,236	810,429	22.31
1987	38,692	11,891	765,061	19.77
1988	42,395	13,036	829,963	19.58

[1] Data for the same items appearing in this or other tables may not reconcile because of computer rounding.
[2] The total value is based on a weighted value.

TABLE 10

TENNESSEE AND WESTERN STATES[1] PHOSPHATE ROCK SOLD OR USED BY PRODUCERS[2]

Year	Rock (thousand metric tons)	P_2O_5 content (thousand metric tons)	Value	
			Total[3] (thousands)	Average per ton f.o.b. mine
1984[4]	NA	NA	NA	NA
1985[4]	NA	NA	NA	NA
1986	5,443	1,515	$119,192	$21.90
1987	4,981	1,395	80,751	16.21
1988	6,047	1,723	117,758	19.47

NA Not available.
[1] Includes Idaho, Montana, and Utah.
[2] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[3] The total value is based on a weighted value.
[4] Data for Tennessee and Western States were reported separately in the 1985 and 1986 Minerals Yearbook chapter.

Rated capacity is defined as the maximum quantity of phosphate rock that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for phosphate rock is based on 350 working days per year, 3 shifts per day, as calculated from available data on ore throughput, ore grade, and physical characteristics of the plant.

WORLD REVIEW

The world phosphate rock industry restrained production to meet demand rather than operate at full capacity throughout the year. The U.S. phosphate rock industry produced about 28% of the world supply. This was a substantial part of the world supply and was principally that which was produced in Florida and North Carolina and used in international trade of either phosphate rock or phosphate fertilizer. As the mines in Florida are mined out and closed during the balance of this century, the projected inability of the U.S. industry to export phosphate rock and fertilizers will have a serious impact on the world supply of P_2O_5.

Some countries with reserves of phosphate rock were expanding phosphate-rock-mining capacity and planning new mines and fertilizer plants to replace supplies from the United States during the next decade. The most publicized activities are those in Morocco and Jordan.

Brazil

Industries de Fosfatos Catarinense, a joint venture among Adubos Trevo, Fertisul, and Quimbrasil and possibly with Petrobas Fertilizantes planned to produce phosphate rock and phosphoric acid in the southern part of the country. Plans were to mine 900,000 tons per year at Anitopolis to produce phosphoric acid. The Tapira phosphate mine was being expanded from 1.4 million tons per year to 2 million tons per year.[3]

TABLE 11

MARKETABLE PHOSPHATE ROCK YEAREND STOCKS

(Million metric tons)

Year	Quantity
1979	14.5
1980	13.7
1981	19.6
1982	18.3
1983	14.5
1984	11.9
1985	15.5
1986	13.3
1987	10.9
1988	9.3

TABLE 12

PHOSPHATE ROCK ESTIMATED EXPORT PRICES[1] PER METRIC TON, UNGROUND, F.O.B. VESSEL TAMPA RANGE OR JACKSONVILLE, FL, BY GRADE

Grade (percent BPL[2] content)	1985[3]	1986[4]	1987[5]	1988[6]
75	$34.00	$33.00	$32.00	$33.00
72	30.50	31.00	29.00	31.00
70	28.00	27.00	27.50	28.00
68	26.00	25.50	24.00	26.00

[1] Prices include severance taxes, rail freight costs from mine to port, and port loading and weighing charges.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.
[3] Estimated selling price including $2.52 severance tax.
[4] Estimated selling price including $2.51 severance tax.
[5] Estimated selling price including $2.46 severance tax.
[6] Estimated selling price including $1.49 severance tax.

TABLE 13

MOROCCAN PHOSPHATE ROCK EXPORT PRICES, U.S. DOLLARS PER METRIC TON, F.A.S. SAFI OR CASABLANCA,[e] BY GRADE

Grade (percent BPL[1] content)	1985	1986	1987	1988
Khouribga:				
76 to 77	47.00	45.00	42.00	45.00
70 to 71	36.00	36.00	34.00	38.00
Youssoufia:				
74 to 75	43.00	40.50	39.50	45.00
68 to 69	30.00	30.50	30.00	34.00

[e] Estimated.
[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

TABLE 14

PRICE OR VALUE OF FLORIDA AND NORTH CAROLINA PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1987			1988		
	Domestic	Export	Average	Domestic	Export	Average
74 or more	26.73	24.48	25.05	29.40	30.51	30.15
72 to less than 74	19.90	23.68	22.49	20.31	26.35	24.57
70 to less than 72	23.64	24.26	24.21	25.97	27.30	26.92
66 to less than 70	18.62	21.06	18.87	16.94	22.16	17.38
60 to less than 66	19.26	17.10	19.13	18.67	18.59	18.66
Less than 60	21.66	—	21.66	27.56	—	27.56
Average	**18.93**	**22.87**	**19.77**	**18.29**	**25.24**	**19.58**

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

TABLE 15

PRICE OR VALUE OF TENNESSEE AND WESTERN STATES[1] PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[2] content)	1987			1988		
	Domestic	Export	Average	Domestic	Export	Average
70 to less than 72	35.27	—	35.27	36.38	—	36.38
66 to less than 70	22.62	31.50	23.47	27.33	38.08	28.60
60 to less than 66	10.70	—	10.70	10.53	—	10.53
Less than 60	11.47	—	11.47	11.35	—	11.35
Average	**15.70**	**31.50**	**16.21**	**18.79**	**38.08**	**19.47**

[1] Includes Idaho, Montana, and Utah.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

China

The Government planned to develop the Wengfu Mine in Guizhow Province. The mine will produce 2.5 million tons per year of run-of-mine rock, which will be concentrated at a plant at the minesite. The slurry concentrate will be pumped at a rate of 1.8 million tons per year to Manchangping, a distance of 45 kilometers, then dewatered and loaded into rail cars.

Jordan

Jordan Phosphate Mines Co. started producing phosphate rock from the Shidiya Mine, 120 kilometers (75 miles) east of Aqaba. Shidiya's production replaced phosphate rock from the El Abiad and El Hassa Mines, 136 kilometers (85 miles) south of Amman.

Morocco

The planned expansion at the Jorf Lasfar chemical complex will require an additional 4 million tons per year of phosphate rock. The Sidi Chennane Mine and Mera El Arech Mine at Khouribga are expected to supply phosphate rock for the Jorf Lasfar expansion. The new phosphoric acid plants, Maroc Phosphore 5 and 6, will produce 4.55 million tons per year of sulfuric acid and 1.32 million tons per year of 54% phosphoric acid. The new units were scheduled to operate in 1991 and 1992.

Saudi Arabia

Feasibility studies were in progress to determine the potential for developing the Al Jalamid phosphate deposit. Phosphate rock concentrates, if produced at Al Jalamid, will be pumped 1,100 kilometers (713 miles) to Al Jubail on the Arabian Gulf. Plans were to use Al-Jalamid phosphate rock, recovered sulfur, and manufactured ammonia to produce diammonium phosphate at Al Jubail.

Togo

The EC agreed to supply funding to Togolais des Phosphates to offset the

TABLE 16

PRICE OR VALUE OF U.S. PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1987			1988		
	Domestic	Export	Average	Domestic	Export	Average
74 or more	26.73	24.48	25.05	29.40	30.51	30.15
72 to less than 74	19.90	23.68	22.49	20.31	26.35	24.57
70 to less than 72	28.32	24.26	24.83	30.45	27.30	28.60
66 to less than 70	18.88	21.69	19.15	17.57	23.54	18.08
60 to less than 66	18.12	17.10	18.07	17.33	18.59	17.43
Less than 60	11.55	—	11.55	18.71	—	18.71
Average	**18.49**	**23.03**	**19.37**	**18.36**	**25.58**	**19.56**

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

TABLE 17

U.S. EXPORTS OF PHOSPHATE ROCK, BY COUNTRY

(Thousand metric tons and thousand dollars)
(Schedule B No. 480.4500)

Country	1987		1988	
	Quantity[1]	Value	Quantity[1]	Value
Australia	52		383	
Austria	34		62	
Belgium-Luxembourg	317		388	
Brazil	9		151	
Canada	1,384		1,186	
Finland	64		85	
France	699		855	
Germany, Federal Republic of	592		542	
India	344		404	
Italy	394		194	
Japan	1,036	NA	1,028	NA
Korea, Republic of	1,344		1,361	
Mexico	412		519	
Netherlands	668		872	
New Zealand	162		107	
Philippines	—		1	
Poland	604		542	
Romania	150		42	
Sweden	98		151	
Other	322		203	
Total[2]	**8,454**	**194,691**	**8,092**	**206,984**

NA Not available.
[1] Individual country exports furnished by Bureau of the Census will not add to totals.
[2] Total quantity and value reported to the Bureau of Mines, f.o.b. mine.

loss of future phosphate rock export earnings. The EC reduced acceptable cadmium levels in phosphate rock and limited imports of high-cadmium product, 172 grains or more per ton, from Togo. The funds will be used to determine the optimum method of cadmium removal and to develop another carbonatite phosphate deposit with very low levels of cadmium.[4]

Turkey

Etibank, Turkey's only producer of phosphate rock, constructed a new concentrator at its Mazidagi phosphate plant. The new plant was programmed to produce 200,000 tons per year in 1988 and 550,000 tons per year by 1990.[5]

TECHNOLOGY

The industry leaders in principal phosphate rock-producing regions in the United States attempted to find answers to problems associated with mining, beneficiating, and processing phosphate rock. The impact of low-input sustainable agriculture on the demand for phosphate fertilizers is expected to become a major issue in the 1990's.

The Florida phosphate industry has demonstrated its ability to reclaim wetlands after mining the phosphate mineral. Reclaimed land types include replacement of hardwood forests, herbaceous marsh wetlands, and stream and lake wetland acres.

The Florida phosphate industry has also demonstrated that by controlled ditching and draining, the ponds used to store the colloidal clay rejected by the washing plant can be dewatered after the pond is filled. In North Carolina, flocculated colloidal clays are mixed with phosphogypsum from the adjacent phosphoric acid plant and returned to the mined-out excavation where they dewater rapidly. This proce-

TABLE 18

U.S. EXPORTS OF SUPERPHOSPHATES, MORE THAN 40% P_2O_5, BY COUNTRY

(Thousand metric tons and thousand dollars)
(Schedule B No. 480.7050)

Country	1987 Quantity	1987 Value[1]	1988 Quantity	1988 Value[1]
Argentina	11		3	
Australia	79		(2)	
Bangladesh	29		205	
Belgium-Luxembourg	30		—	
Brazil	172		78	
Bulgaria	23		—	
Burma	15		40	
Canada	434		148	
Chile	170		206	
Colombia	21		13	
Costa Rica	6	NA	10	NA
Czechoslovakia	26		—	
Dominican Republic	11		11	
France	3		—	
Japan	60		57	
Mexico	24		—	
Pakistan	—		17	
Peru	15		25	
Poland	—		15	
Uruguay	14		4	
Other	46		85	
Total	**1,160**	**192,308**	**917**	**NA**

NA Not available.
[1] All values f.a.s. (free alongside ship).
[2] Less than 1/2 unit.
Source: Bureau of the Census.

TABLE 19

U.S. EXPORTS OF SUPERPHOSPHATES, LESS THAN 40% P_2O_5, BY COUNTRY

(Schedule B No. 480.7030)

Country	1987 Quantity (metric tons)	1987 Value[1] (thousands)	1988 Quantity (metric tons)	1988 Value[1] (thousands)
Canada	2,404	NA	18,868	NA
Other	376	NA	4,302	NA
Total	**2,780**	**$94**	**23,170**	**NA**

NA Not available.
[1] All values f.a.s. (free alongside ship).
Source: Bureau of the Census.

dure not only eliminates clay retention ponds but also reduces the need to maintain phosphogypsum stacks. The North Carolina solution for disposal of beneficiated and processing wastes is feasible because the wastes are produced at the same location and the mined-out pit is sufficiently deep to bury the wastes under an overburden cover.

In Florida, over 500 million tons of phosphogypsum have been stockpiled in 28 stacks adjacent to phosphoric acid plants. Studies were being conducted to determine if ground water is affected by stack fluid discharges and if the level of radionuclide emissions from the stacks is excessive. Emphasis was being placed on studies to determine if phosphogypsum can be used as a compacted subbase for highways, secondary roads, and parking areas. Phosphogypsum can be calcined to release and recover sulfur dioxide gas and produce a cement-type clinker. The acceptability of processing phosphogypsum to recover sulfur will be dependent on the processing costs competing with purchased sulfur prices.

Proponents of low-input sustainable agriculture intend to reduce the purchases of off-farm inputs, specifically manufactured fertilizer. Opponents to the philosophy argue that without manufactured fertilizers, at least 50 million additional acres would have to be planted to produce the present level of farm products. Farm production would feed only 40% of the population if only "natural" sources of nitrogen, phosphorus, and potassium were used.

[1] Physical scientist, Branch of Industrial Minerals.
[2] All quantities are in metric tons unless otherwise specified.
[3] European Chemical News. V. 50, No. 1313, Feb. 29, 1988, p. 30.
[4] Industrial Minerals (London). Oct. 1988, p. 19.
[5] Department of State Telegram, Ankara 02887, Mar. 1988.

TABLE 20

U.S. EXPORTS OF DIAMMONIUM PHOSPHATES, BY COUNTRY

(Thousand metric tons and thousand dollars)
(Schedule B No. 480.8005)

Country	1987 Quantity	1987 Value[1]	1988 Quantity	1988 Value[1]
Argentina	72		92	
Australia	181		133	
Belgium-Luxembourg	594		332	
Brazil	101		60	
Canada	162		256	
Chile	71		90	
China	1,441		1,778	
Colombia	133		160	
Costa Rica	22		29	
Dominican Republic	43		27	
Ecuador	30		35	
France	146		99	
Germany, Federal Republic of	137		31	
Guatemala	13		98	
India	—		582	
Iran	116	NA	293	NA
Ireland	54		21	
Italy	326		149	
Japan	343		396	
Kenya	80		53	
Mexico	39		22	
New Zealand	34		23	
Pakistan	32		576	
Peru	48		51	
Spain	163		102	
Thailand	32		46	
Turkey	44		201	
Uruguay	37		34	
Venezuela	224		45	
Yugoslavia	55		39	
Other	874		101	
Total	**5,647**	**890,801**	**5,954**	**NA**

NA Not available.
[1] All values f.a.s. (free alongside ship).
Source: Bureau of the Census.

TABLE 21

U.S. EXPORTS OF PHOSPHORIC ACID, LESS THAN 65% P_2O_5, BY COUNTRY

(Thousand metric tons and thousand dollars)
(Schedule B No. 480.7015)

Country	1987 Quantity	1987 Value[1]	1988 Quantity	1988 Value[1]
Australia	61		31	
Canada	2		2	
Colombia	3		13	
India	179	NA	233	NA
Indonesia	65		22	
Japan	58		20	
Venezuela	79		75	
Other	53		38	
Total	**500**	**85,912**	**434**	**NA**

NA Not available.
[1] All values f.a.s.(free alongside ship).
Source: Bureau of the Census.

TABLE 22

U.S. EXPORTS OF ELEMENTAL PHOSPHORUS, BY COUNTRY

(Schedule B No. 415.3500)

Country	1987 Quantity (metric tons)	1987 Value[1] (thousands)	1988 Quantity (metric tons)	1988 Value[1] (thousands)
Brazil	5,621	$10,368	690	$1,348
Canada	133	210	11	14
Japan	6,170	9,339	8,543	12,628
Korea, Republic of	1,277	1,715	3,076	4,486
Mexico	6,481	8,424	5,302	7,407
Taiwan	84	103	4	26
Other	536	637	1,016	1,630
Total	**20,302**	**30,796**	**18,642**	**27,539**

[1] All values f.a.s. (free alongside ship).
Source: Bureau of the Census.

TABLE 23

U.S. IMPORTS FOR CONSUMPTION OF PHOSPHATE ROCK AND PHOSPHATIC MATERIALS

(Thousand metric tons and thousand dollars)

Phosphatic materials	TSUS No.[1]	1987 Quantity	1987 Value[2]	1988 Quantity	1988 Value[2]
Phosphates, crude and apatite[3]	4804500	464	18,816	673	[4]25,911
Phosphatic fertilizers and fertilizer materials	4807070–4808095	55	7,820	27	6,802
Dicalcium phosphate	4182800	1,960	2,086	2,379	2,447
Phosphorus	4153500	4,463	6,609	[p]249	NA
Phosphoric acid, fertilizer-grade	4807010	1	1,667	1	98
Normal superphosphate	4807030	3	585	([5])	67
Triple superphosphate	4807050	49	6,262	105	16,350

[p] Preliminary. NA Not available.
[1] Tariff schedule of the United States.
[2] Declared customs valuation.
[3] Excludes reported imports from Canada and Israel.
[4] C.i.f. value.
[5] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 24

WORLD PHOSPHATE ROCK PRODUCTION CAPACITY, DECEMBER 31, 1988

(Million metric tons per year)

	Rated capacity[1]
North America:	
Mexico	1.0
United States	59.9
Total	**60.9**
South America	8.7
Europe:	
U.S.S.R.	35.9
Other	1.0
Total	**36.9**
Africa:	
Algeria	2.3
Morocco (Sahara)	31.8
Senegal	2.5
South Africa, Republic of	4.7
Togo	3.2
Tunisia	10.0
Other	1.3
Total	**55.8**
Asia:	
China	19.0
Israel	4.0
Jordan	7.8
Korea, North	1.0
Vietnam	1.0
Other	3.0
Total	**35.8**
Oceania:	
Australia	1.0
Nauru	2.0
Total	**3.0**
World total	**201.1**

[1] Includes capacities of operating plants as well as plants on standby basis.

TABLE 25

PHOSPHATE ROCK, BASIC SLAG AND GUANO: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Commodity and country[2]	Gross weight					P_2O_5 content				
	1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987[p]	1988[e]
Phosphate rock:										
Algeria	[e]1,000	1,207	1,203	[e]1,073	[3]1,332	309	[e]381	[e]380	[e]336	404
Australia	15	33	34	11	6	4	7	7	2	1
Brazil	3,855	4,214	4,509	4,777	4,672	1,345	1,475	1,620	1,694	1,663
Chile	5	7	7	10	8	(4)	1	1	[e]1	1
China[e]	11,800	6,970	6,700	9,000	15,000	3,186	1,882	1,810	2,700	4,050
Christmas Island (Indian Ocean)	1,259	1,187	880	842	—	443	418	310	[e]295	—
Colombia	11	[r]23	27	34	35	[r]3	[r]6	7	8	9
Egypt	1,043	[e]1,074	1,271	1,167	1,146	253	270	315	[e]312	293
Finland	477	512	527	[e]553	583	176	189	195	[e]195	206
India	892	929	667	679	657	294	307	222	226	197
Indonesia	2	1	1	2	2	1	1	1	1	1
Iraq[e]	1,000	1,000	1,000	1,500	1,273	218	218	218	[r]330	382
Israel	3,312	4,076	3,673	3,798	[3]3,479	995	1,210	1,110	[e]1,214	1,092
Jordan	6,263	6,067	6,249	6,800	5,666	2,042	2,010	2,072	2,260	1,868
Korea, North[e]	500	500	500	500	500	160	160	160	160	160
Mexico[5]	[r]653	[r]787	747	689	655	[r]196	[r]236	224	207	201
Morocco[6]	21,245	20,737	21,178	[r][e]20,000	24,783	[e]6,762	[e]6,574	[e]6,714	[e]6,650	7,885
Nauru	1,358	1,508	1,494	1,376	1,540	523	[e]581	[e]575	[e]530	593
Pakistan	—	—	50	32	36	—	—	16	10	10
Peru	13	12	5	61	60	4	[e]4	2	20	18
Philippines	7	6	[e]6	[e]8	8	2	2	[e]2	[e]2	2
Senegal[7]	1,912	1,814	1,850	[e]1,880	[3]2,296	583	[e]617	[e]641	[e]680	791
South Africa, Republic of	2,585	2,433	2,920	2,623	2,850	[e]939	[e]883	[e]1,060	[e]950	1,010
Sri Lanka	14	14	15	[e]21	23	5	5	5	[e]7	7
Sweden	133	187	192	[e]221	127	51	74	72	[e]82	47
Syria	1,514	1,270	1,606	1,986	[3]2,342	461	380	485	[e]606	715
Tanzania	15	[e]15	[e]10	18	15	4	[e]4	[e]3	[e]4	4
Thailand	3	4	5	5	5	1	1	1	2	2
Togo	2,696	2,452	2,314	2,644	[3]3,464	979	890	840	[e]960	1,257
Tunisia	5,346	4,530	5,951	[e]6,390	[3]6,103	1,554	[e]1,303	[e]1,712	[e]1,836	1,813
Turkey	96	[e]37	3	[e]19	74	29	[e]12	[e]1	[e]6	23
U.S.S.R.[e]	33,300	33,750	33,900	34,100	38,820	10,550	10,650	10,700	10,750	12,010
United States	49,197	50,835	38,710	40,954	[3]45,389	14,889	15,674	11,857	12,491	[3]13,833
Vietnam[e]	200	516	530	300	600	66	170	175	105	133
Zimbabwe (concentrate)	[r]134	135	136	155	124	[r][e]47	[r][e]47	[e]48	[r][e]54	43
Total	**[r]151,855**	**[r]148,842**	**138,870**	**144,228**	**163,673**	**[r]47,074**	**[r]46,628**	**43,550**	**45,686**	**50,724**
Basic (Thomas converter) slag:										
Argentina	1	[e]1	(4)	(4)	(4)	[e](4)	[e](4)	[e](4)	[e](4)	(4)
Belgium	254	143	[r][e]180	[e]175	170	46	26	[r][e]32	[e]32	31
Egypt[e]	[3]10	10	8	8	8	2	2	2	2	2
France	1,194	1,165	855	[e]1,000	1,000	215	210	154	[e]180	180

See footnotes at end of table.

TABLE 25—Continued

PHOSPHATE ROCK, BASIC SLAG AND GUANO: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Commodity and country[2]	Gross weight					P_2O_5 content				
	1984	1985	1986	1987[p]	1988[e]	1984	1985	1986	1987[p]	1988[e]
Germany, Federal Republic of	446	491	374	[e]370	400	62	67	[e]55	[r e]52	55
Luxembourg	728	701	620	542	540	131	126	112	98	95
United Kingdom	4	[e]4	—	—	—	1	[e]1	—	—	—
Total	**2,637**	**2,515**	**2,037**	**2,095**	**2,119**	**457**	**432**	**355**	**364**	**363**
Guano:										
Chile	3	3	8	[e]7	5	([4])	([4])	1	[e]1	([4])
Kenya	([4])	([4])	([8])	([8])	—	([4])	([4])	([8])	([8])	—
Philippines	1	1	[e]1	[e]1	1	([4])	([4])	[e]([4])	[e]([4])	([4])
Seychelles Islands[e]	5	5	5	5	5	[3]2	2	2	2	2
Total	**9**	**9**	**14**	**13**	**11**	**2**	**2**	**3**	**3**	**2**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 10, 1989. Data for major phosphate rock producing countries derived in part from the International Fertilizer Industry Association; other figures are from official country sources where available.
[2]In addition to the countries listed, Belgium and Uganda may have produced small quantities of phosphate rock and Namibia may have produced small quantities of guano, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.
[3]Reported figure.
[4]Less than 1/2 unit.
[5]Includes only output used to manufacture fertilizers.
[6]Production from Western Sahara area included with Morocco.
[7]Excludes aluminum phosphate production, gross weight, in thousand tons: 1984–279; 1985–355; 1986–131; 1987–191; and 1988–200 (estimated).
[8]Revised to zero.

PLATINUM-GROUP METALS

By J. Roger Loebenstein[1]

The Republic of South Africa remained the leading producer of platinum and the U.S.S.R. remained the leading producer of palladium. In the future, most new production capacity for platinum-group metals (PGM) is expected to come from the Republic of South Africa.

For years, the United States and Japan have consumed approximately equal quantities of platinum. Beginning in 1987 and continuing in 1988, Japanese consumption of platinum has far surpassed U.S. consumption. The most important application for platinum in Japan was in fabricating jewelry. Strong demand for platinum in Japan can be attributed partly to the strength of the Japanese currency and economy.

PGM were used for a number of advanced material applications. For example, platinum-iridium alloys were used in crucibles for growing crystals used in computer memory devices and lasers. Platinum was used as a catalyst in the electrodes of phosphoric acid fuel cells, used for generating electricity for space applications and research.

Two new platinum bullion coins were introduced in 1988, the Australian Koala and the Canadian Maple Leaf, both considered legal tender. These coins have become popular since the minting of the Noble, the first platinum bullion coin, introduced by the Isle of Man in 1983.

DOMESTIC DATA COVERAGE

Domestic production data for PGM are developed by the Bureau of Mines from a voluntary survey of U.S. refiners. Of the 20 refiners to which a survey request was sent, 12 responded. These represent 86% of the total refined metal production shown in tables 1 and 2. Production for the nonrespondents was estimated using reported prior year levels adjusted for general industry trends.

LEGISLATION AND GOVERNMENT PROGRAMS

An advisory panel of the American Society of Metals recommended that the Government should add rhodium and ruthenium to the National Defense Stockpile.[2]

DOMESTIC PRODUCTION

The only PGM mine in the United States, southwest of Billings, MT, was operated by the Stillwater Mining Co. (SMC). In November, Chevron Corp. and Manville Corp. purchased Lac Minerals Ltd.'s one-third interest in SMC for $40 million. Under the terms of the buyout, Chevron and Manville each would own a 50% share in SMC. According to published estimates, production of platinum in 1988 was about 40,000 ounces and production of palladium was about 120,000 ounces, up from the estimated 25,000 ounces of platinum and 75,000 ounces of palladium produced in 1987. SMC completed test work for a new $6 million smelter. Currently, PGM concentrate is sent to Belgium for smelting and refining. SMC expects to significantly reduce the cost and the amount of the time required for producing refined metals by construction of the smelter. Once funding is approved and all necessary permits are granted, construction of the smelter could be completed in 1 year.[3] SMC used a tunnel-boring machine that drills a horizontal hole 13.5 feet in diameter at about 100 feet per day. This single piece of equipment helped to reduce costs and to speed development. In addition, a very small quantity of PGM was produced as a byproduct of copper refining by ASARCO Incorporated and BP Minerals America.

Environmental Protection Agency regulations requiring automobile shredders to reject cars that have not had autocatalysts and exhaust systems removed are resulting in more scrapped autocatalysts being processed. Autocatalysts and exhaust systems contain residual quantities of lead, which must be removed before disposal of the shredded waste material. Unlike conditions several years ago, supplies of scrapped autocatalysts are tight and most are now being collected.

Texas Gulf Minerals & Metals Inc., Anniston, AL, was the largest domestic processor of scrapped autocatalysts. An executive with the company estimated that 110,000 ounces to 150,000 ounces per year of platinum was reclaimed in 1988. Between 4 and 5 million converters were collected in 1988, averaging 3.75 pounds of catalyst per unit and 500 to 550 parts per million platinum, indicating that from 0.027 to 0.030 ounces of platinum could be recovered from each scrapped converter. However, the executive noted that from 65% to 75% of scrapped autocatalysts is exported to Japan and other countries.[4]

U.S. Platinum Inc., headquartered in Vancouver, British Columbia, Canada, moved its refinery from Golden, CO, to Denver, CO. U.S. Platinum recovered PGM from spent autocatalysts and petroleum catalysts using hydrometallurgical methods. The company expected to recover 40,000 ounces of platinum in 1988.[5]

CONSUMPTION AND USES

Platinum, palladium, and rhodium were used in emission catalysts for light trucks (trucks weighing 14,000 pounds or less, gross weight) and automobiles. A typical emission catalyst in 1988 contained approximately 0.057 ounce of platinum, 0.015 ounce of palladium, and 0.006 ounce of rhodium. These average quantities have not changed since 1985. There was variation in the quantities of PGM contained in each catalyst for any given year, depending

TABLE 1

SALIENT PLATINUM-GROUP METALS[1] STATISTICS

(Thousand troy ounces unless otherwise specified)

		1984	1985	1986	1987	1988
United States:						
Mine production[2]		15	W	W	W	W
Value[3]	thousand dollars	$2,456	W	W	W	W
Refinery production:						
Primary refined		24	7	4	6	10
Secondary:						
Nontoll-refined		340	259	354	165	154
Toll-refined		1,157	1,038	1,155	[r]1,445	1,492
Total refined metal		**1,521**	**1,304**	**[r]1,514**	**1,615**	**1,655**
Stocks, Dec. 31:						
Industry (refined)		1,319	1,129	1,292	1,235	1,142
National Defense Stockpile:						
Platinum		453	453	453	453	453
Palladium[4]		1,262	1,265	1,265	1,265	1,265
Iridium[5]		30	30	30	30	30
Exports: Refined[6]		599	526	382	432	653
Total		**1,162**	**889**	**751**	**708**	**926**
Imports for consumption: Refined[6]		3,928	3,438	3,727	3,179	3,567
Total		**4,474**	**3,990**	**4,477**	**3,807**	**3,997**
Imports, general		4,485	3,990	4,399	3,807	3,997
Consumption (reported sales to industry)		2,200	2,271	2,080	[r]1,938	2,283
Consumption, apparent[7]		3,299	3,358	3,536	2,969	3,161
Net import reliance[8] as a percent of apparent consumption		89	92	90	94	95
Price, dealer, average, per ounce:						
Platinum		$357	$291	$461	$553	$523
Palladium		$148	$107	$116	$130	$123
World: Mine production[9]		7,653	7,941	8,314	[p]8,593	[e]8,668

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] The platinum group comprises six metals: platinum, palladium, iridium, osmium, rhodium, and ruthenium.

[2] Byproduct of copper refining plus production from Stillwater Mining Co. for 1987–88.

[3] Value based on dealer prices.

[4] Includes 7,200 ounces purchased in 1984 and 2,400 ounces purchased in 1985, but not added to inventory in those years.

[5] Includes 2,400 ounces purchased in 1984, but not added to inventory in that year.

[6] Excludes ores, scrap, and platinum grains and nuggets.

[7] 1984 includes mine production plus nontoll-refined production plus refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks. The 1985–88 mine production excluded to avoid disclosing company proprietary data.

[8] Refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks.

[9] The 1985–88 totals exclude U.S. mine production to avoid disclosing company proprietary data.

on the year the vehicle was manufactured, the engine size of the vehicle, the normal operating temperature of the vehicle engine, and the manufacturer of the catalyst. In 1988, there were 10.9 million vehicles produced in the United States that were subject to emissions control and outfitted with catalytic converters, of which about one-third was light trucks and the balance was automobiles.

In electronic applications, ruthenium was the principal PGM used in thick film resistors, and palladium was the principal PGM used in thick film conductors, multilayer ceramic capacitors, and connectors.

For glass applications, most of the PGM, specifically platinum, rhodium, and palladium, were used in bushings for the extrusion of textile or continuous filament glass fiber.

In other applications, platinum and iridium crucibles were used for growing oxide single crystals such as gadolinium gallium garnet (GGG) and yttrium aluminium garnet (YAG). GGG and YAG are used for computer memory devices and solid-state lasers. Platinum in conjunction with titanium and columbium was used for cathodic protection of steel reinforcing bars in bridge and highway concrete to prevent their corrosion by deicing salts used on roadways.

The Bureau of Mines does not collect data on domestic investor demand for platinum, but according to Johnson Matthey PLC, the midrange estimate for platinum investment demand in North America increased to about 125,000 ounces, from 85,000 ounces in 1987.[6]

STOCKS

In addition to the reported stocks held by refiners, importers, and dealers, end users of PGM held sizable quantities of PGM that were not reported to the Bureau of Mines.

PRICES

Average monthly dealer prices for platinum ranged from a low of $452

TABLE 2

PLATINUM-GROUP METALS REFINED IN THE UNITED STATES

(Troy ounces)

	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
PRIMARY METAL							
Nontoll-refined:							
1984	1,430	13,003	—	—	—	—	14,433
1985	524	3,463	—	—	—	—	3,987
1986	613	3,742	—	—	—	—	4,355
1987	1,032	5,095	—	—	—	—	6,127
1988	1,475	7,989	75	—	13	—	9,552
Toll-refined:							
1984	1,153	4,895	1,000	250	—	2,000	9,298
1985	1,100	—	—	—	—	2,200	3,300
1986	—	—	—	—	—	—	—
1987	—	—	—	—	—	—	—
1988	—	—	—	—	—	—	—
SECONDARY METAL							
Nontoll-refined:							
1984	89,702	243,347	735	27	3,668	2,047	339,526
1985	52,383	201,362	252	—	3,126	1,474	258,597
1986	70,867	277,366	297	—	4,316	1,313	354,159
1987	37,939	120,351	115	604	3,944	1,567	164,520
1988	36,413	113,974	132	—	3,337	61	153,917
Toll-refined:							
1984	524,158	568,489	7,826	49	37,584	19,288	1,157,394
1985	490,595	490,948	7,007	3	36,336	13,356	1,038,245
1986	674,412	398,270	3,584	1,415	57,618	19,701	1,155,000
1987	725,961	616,311	3,269	796	60,930	37,430	1,444,697
1988	735,738	672,703	8,095	619	58,706	16,043	1,491,904
1987 TOTALS							
Total primary	**1,032**	**5,095**	**—**	**—**	**—**	**—**	**6,127**
Total secondary	**763,900**	**736,662**	**3,384**	**1,400**	**64,874**	**38,997**	**1,609,217**
Total refined metal	**764,932**	**741,757**	**3,384**	**1,400**	**64,874**	**38,997**	**1,615,344**
1988 TOTALS							
Total primary	**1,475**	**7,989**	**75**	**—**	**13**	**—**	**9,552**
Total secondary	**772,151**	**786,677**	**8,227**	**619**	**62,043**	**16,104**	**1,645,821**
Total refined metal	**773,626**	**794,666**	**8,302**	**619**	**62,056**	**16,104**	**1,655,373**

per ounce to a high of $566 per ounce, for a spread of $114. Average monthly dealer prices for palladium ranged from a low of $119 per ounce to a high of $131 per ounce, for a spread of $12. In December, the market reacted strongly to an announcement by Ford Motor Co. that it had developed a platinum-free autocatalyst (see discussion in "Technology" section). Spot platinum prices fell $100 per ounce on the day of the announcement, and futures prices in New York fell the limit of $25 per ounce for 2 consecutive days.[7]

The London platinum and palladium market expanded the number of firms that participate in twice-daily price fixes for platinum and palladium from two firms to eight firms. The eight companies were Samuel Montagu & Co., Aryton Metals Ltd., Sharps Pixley Ltd., Mase Wespac Ltd., Engelhard Corp., Credit Suisse, Swiss Bank Corp., and Union Bank of Switzerland. All eight companies were members of the London-Zurich Good Delivery Agreement that sets standards for platinum and palladium trading in Europe. The new fixing system makes delivery of metal possible in London, England, or Zurich, Switzerland. The fixing will take the form of a telephone conference call, as is the case with the London gold and silver fix.[8]

Trading volume on the New York Mercantile Exchange for platinum increased while trading volume for palladium decreased in 1988.

WORLD CAPACITY

Capacity for PGM is generally cited in terms of platinum capacity. The data in table 10 represent rated capacity, defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure. Nearly all the growth in capacity is projected to occur in the Republic of South Africa. Northam Platinum Ltd., owned by Gold Fields of South Africa Ltd., expects to produce about 200,000 ounces of platinum annually by 1995. In addition, Lefkochrysos Ltd., owned by Barplats Investments Ltd. and Rand Mines Ltd., expects to produce about 150,000 ounces of platinum annually by 1990.

TABLE 3

PLATINUM-GROUP METALS[1] SOLD TO CONSUMING INDUSTRIES IN THE UNITED STATES

(Troy ounces)

Year and industry	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1984	876,227	1,150,500	7,117	1,072	76,253	88,619	2,199,788
1985	1,025,765	1,060,319	10,664	885	88,252	85,574	2,271,459
1986	981,004	889,949	12,282	689	93,429	102,964	2,080,317
1987:							
Automotive[2]	605,000	160,000	(3)	—	63,000	—	r828,000
Chemical	61,719	34,682	884	—	3,446	2,242	102,973
Dental and medical	15,387	333,601	3,252	919	334	341	353,834
Electrical	58,545	318,301	882	—	5,775	24,857	408,360
Glass	9,157	—	55	—	1,772	24	11,008
Jewelry and decorative	5,706	7,099	626	—	7,391	259	21,081
Petroleum	r17,449	41,344	—	—	—	—	r58,793
Miscellaneous	45,962	100,239	2,330	—	4,823	630	153,984
Total	**r818,925**	**995,266**	**r8,029**	**919**	**86,541**	**28,353**	**r1,938,033**
1988:							
Automotive[2]	622,000	164,000	11	—	67,000	—	853,011
Chemical	102,363	117,973	3,772	—	3,495	19,420	247,023
Dental and medical	18,664	212,905	72	683	64	107	232,495
Electrical	112,326	419,539	6,112	—	3,947	34,309	576,233
Glass	21,896	350	11	—	2,748	36	25,041
Jewelry and decorative	12,366	6,289	654	—	5,704	436	25,449
Petroleum	34,462	46,228	2,427	—	45	—	83,162
Miscellaneous	76,618	133,604	2,859	58	22,837	4,236	240,212
Total	**1,000,695**	**1,100,888**	**15,918**	**741**	**105,840**	**58,544**	**2,282,626**

r Revised.
1 Comprises primary and nontoll-refined secondary metals.
2 The 1984–88 platinum, palladium, and rhodium sales to the automotive industry are estimated based on U.S. light truck sales and U.S. automobile production.
3 Revised to zero.

TABLE 4

REFINER, IMPORTER, AND DEALER STOCKS OF REFINED PLATINUM-GROUP METALS[1] IN THE UNITED STATES, DECEMBER 31

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1984	648,130	524,924	19,600	1,302	53,120	71,571	1,318,647
1985	571,725	454,999	16,930	274	47,133	37,618	1,128,679
1986	656,718	545,206	19,649	381	47,417	22,664	1,292,035
1987	611,000	558,005	16,275	36	32,018	17,653	1,234,987
1988	592,800	477,020	13,904	259	37,443	20,391	1,141,817

1 Includes metal in depositories of the New York Mercantile Exchange (NYMEX); on Dec. 30, 1988, this comprised 180,850 troy ounces of platinum and 35,100 troy ounces of palladium.

WORLD REVIEW

As shown in table 11, estimated industrial demand plus investment demand for platinum exceeded supply by about 490,000 ounces in market economy countries. Johnson Matthey reported world investment demand for platinum increased from 490,000 ounces in 1987 to a projected 620,000 ounces in 1988. Japan accounted for well over one-half of world investment demand in 1988. Supply exceeded demand for palladium by about 320,000 ounces. Rhodium supply and demand were roughly in balance.

TABLE 5

AVERAGE PRODUCER AND DEALER PRICES[1] OF PLATINUM-GROUP METALS

(Dollars per troy ounce)

	Platinum		Palladium		Rhodium		Iridium		Ruthenium[2]	Osmium[2]
	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Dealer	Dealer
1984	475	357	147	148	625	607	600	424	103	455
1985	475	291	127	107	915	929	600	438	101	915
1986	519	461	131	116	1,196	1,157	600	414	73	704
1987:										
January	600	515	150	123	1,200	1,124	600	397	74	650
February	600	515	150	120	1,200	1,180	600	394	71	650
March	600	525	150	123	1,200	1,157	600	384	71	650
April	600	585	150	136	1,200	1,201	600	375	72	626
May	600	605	150	145	1,200	1,245	600	384	72	625
June	600	565	150	137	1,220	1,225	600	379	72	625
July	600	568	150	140	1,275	1,230	507	345	67	632
August	600	608	150	140	1,275	1,273	600	350	68	650
September	600	586	150	137	1,275	1,272	420	354	68	650
October	600	564	150	129	1,275	1,270	420	332	68	650
November	600	494	150	111	1,275	1,246	420	330	67	600
December	600	500	150	121	1,275	1,243	420	335	67	590
Average	**600**	**553**	**150**	**130**	**1,239**	**1,222**	**532**	**363**	**70**	**633**
1988:										
January	600	492	150	124	1,275	1,187	420	333	67	602
February	600	452	150	119	1,275	1,238	420	326	65	610
March	600	491	150	121	1,275	1,235	420	310	62	603
April	600	492	150	124	1,275	1,230	420	315	62	509
May	600	545	150	122	1,275	1,231	420	310	60	580
June	600	576	150	127	1,275	1,266	420	309	61	590
July	600	543	150	124	1,275	1,185	420	304	65	625
August	600	529	150	124	1,275	1,214	420	302	45	625
September	600	506	150	119	1,275	1,218	420	305	67	625
October	600	522	150	120	1,275	1,191	420	286	63	580
November	600	566	150	125	1,275	1,232	420	287	60	580
December	600	557	150	131	1,275	1,190	420	287	60	580
Average	**600**	**523**	**150**	**123**	**1,275**	**1,218**	**420**	**306**	**61**	**592**

[1] Average prices calculated at the low end of the range and rounded to the nearest dollar.
[2] Producer prices suspended in 1984.

The Bureau of Mines published an Open File Report (OFR 19-88) that examined the costs of a U.S. import embargo of certain minerals produced in the Republic of South Africa. In the report, the Bureau estimated that the average annual cost of an embargo on South African platinum, palladium, rhodium, chromium, manganese, titanium, vanadium, and cobalt to be $1.85 billion. About 94% of the cost would be for two metals, platinum and rhodium. One of the conclusions of the report was that alternative world sources to the Republic of South Africa for platinum and rhodium probably would not meet U.S. industrial demand. Non-South African world supply sources could be expected to meet about 40% of domestic platinum consumption requirements and 50% of rhodium re-

TABLE 6

NYMEX TRADING VOLUME FOR FUTURES CONTRACTS, DECEMBER 31

(Number of contracts)

	1985	1986	1987	1988
Platinum[1]	693,256	1,624,635	1,361,546	1,460,455
Palladium[2]	133,223	145,562	160,284	139,883

[1] 50 troy ounces per contract.
[2] 100 troy ounces per contract.

quirements. However, there would be adequate alternative world sources to the Republic of South Africa for palladium, chromium, manganese, titanium, vanadium, and cobalt. This study was conducted in order to assess the impact of certain provisions of the Comprehensive Anti-Apartheid Act of 1986.[9]

The Bureau of Mines published a followup study to the study mentioned above, OFR 54-88, that examined the impact on the gross national product (GNP) and the employment losses that

TABLE 7

U.S. EXPORTS OF PLATINUM-GROUP METALS, BY YEAR AND COUNTRY

Year and country	Ores and concentrates (troy ounces)	Waste, scrap, and sweepings (troy ounces)	Metal not rolled (troy ounces)			Metal rolled (troy ounces)		Total	
			Platinum	Palladium	Other platinum-group	Platinum	Other platinum-group	Troy ounces	Value (thousands)
1984	40,920	522,425	177,401	182,692	167,635	43,484	27,475	1,162,032	$274,775
1985	3,967	358,417	182,487	215,626	87,727	4,526	35,901	888,651	187,161
1986	29,375	339,373	93,112	175,605	86,474	11,043	15,693	750,675	201,807
1987	5,530	271,197	82,349	183,997	140,109	7,859	17,256	708,297	224,969
1988:									
Australia	—	—	14,408	1,320	4,301	—	162	20,191	10,582
Austria	—	385	—	2,539	—	—	—	2,924	253
Belgium	—	20,031	100	1,443	1,436	—	45	23,055	7,618
Brazil	—	—	7	224	3,562	749	92	4,634	3,142
Canada	3,643	19,347	51,537	35,136	7,241	3,498	2,762	123,164	50,980
China	—	46	15,347	3,006	6,356	986	4,182	29,923	9,867
France	—	2,651	564	341	823	200	296	4,875	1,426
Germany, Federal Republic of	375	13,032	47	16,700	20,586	117	3,447	54,304	17,323
Hong Kong	—	—	4	436	2,125	26	2	2,593	602
Italy	—	7,635	—	614	2,439	—	733	11,421	4,091
Japan	225	3,596	115,671	72,648	15,692	—	3,566	211,398	77,490
Korea, Republic of	284	—	162	663	1,454	58	3	2,624	731
Netherlands	165	2,904	—	22,791	900	19	231	27,010	6,983
Singapore	—	—	—	3,780	673	—	—	4,453	1,127
Sweden	—	5,229	—	234	2,129	—	—	7,592	2,416
Switzerland	—	4,705	2,000	1,353	8,709	1,166	218	18,151	9,027
Taiwan	—	—	108	9,047	3,343	—	25	12,523	2,778
U.S.S.R.	—	—	—	—	2,000	—	—	2,000	602
United Kingdom	46	188,059	45,157	96,436	20,717	1,589	1,652	353,656	99,990
Other	289	188	68	947	4,072	2,731	750	9,045	2,811
Total	**5,027**	**267,808**	**245,180**	**269,658**	**108,558**	**11,139**	**18,166**	**925,536**	**309,839**

Source: Bureau of the Census.

would result from a U.S. embargo on South African PGM supplies. The study concluded that, assuming no change in the current emission control standards of the Clean Air Act, a decline in the level of automobile production and some substantial GNP losses were estimated to result from embargoing South African rhodium supplies. The loss of rhodium supplies would cost $384 million in direct losses, $12 billion in GNP losses, and employment losses of over 200,000 per year for the period 1988–92.[10]

New platinum coins were introduced in 1988. Australia and Canada issued platinum bullion coins with legal tender status, the platinum Koala and the platinum Maple Leaf, respectively. The 99.95%-pure coins were issued in a variety of sizes, ranging from 1/10 ounce to 1 ounce. In addition, China introduced a proof coin, the platinum Panda, issued in limited quantities for

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY YEAR AND COUNTRY

Year and country	Unwrought (troy ounces)										
	Platinum grains and nuggets	Platinum sponge	Palladium	Iridium	Osmium	Osmiridium	Rhodium	Ruthenium	Unspecified combinations	Platinum-group metals from precious metal ores	Sweepings, waste, and scrap
1984	19,786	1,527,841	1,795,939	18,225	1,630	150	155,671	198,257	8,822	—	526,738
1985	20,827	1,464,645	1,396,810	20,972	5,153	—	201,028	162,887	10,330	218	530,724
1986	10,465	1,713,971	1,387,131	30,368	5,776	4,500	179,068	176,580	19,864	1,870	737,813
1987	821	1,124,018	1,529,161	11,814	2,048	5,800	211,466	84,399	7,983	1,789	624,916
1988:											
Australia	—	—	—	—	—	—	673	—	—	—	4,934
Belgium	1,035	47,394	162,630	—	—	—	3,026	—	—	—	3,836
Canada	674	15,225	40,558	—	—	—	247	—	—	135	168,706
Colombia	6,600	10,200	—	—	—	—	—	—	46	—	3,600
Dominican Republic	—	—	22,964	—	—	—	—	9,857	161	—	5
France	—	5,720	—	—	—	—	1,225	—	—	—	15
Germany, Federal Republic of	—	42,628	33,087	2,381	—	—	1,531	351	—	—	4,356
Hong Kong	—	1,964	34,720	—	—	—	570	—	—	—	35,387
Israel	—	—	—	—	—	—	—	—	—	—	2,084
Italy	—	7,625	10,652	—	—	—	334	—	—	—	—
Ivory Coast	—	—	850	—	—	—	—	—	—	—	—
Japan	—	—	9,192	—	—	—	—	250	—	—	764
Mexico	—	79	50	—	—	—	—	—	—	297	74,451
Netherlands	—	27,566	17,165	100	—	—	3,828	500	4	—	31
Norway	—	10,001	855	—	—	—	—	—	—	—	4,610
South Africa, Republic of	1,700	916,454	656,442	14,512	1,600		121,755	99,610	—	—	—
Somalia	—	—	3,474	—	—	—	—	—	—	—	—
Sweden	—	—	—	—	—	—	—	—	—	—	17,539
Switzerland	—	2,098	—	—	—	—	—	50	—	—	1,928
Taiwan	1,509	—	24,180	—	—	—	—	—	—	—	38,009
U.S.S.R.	2,457	35,820	251,928	—	—	—	38,035	—	—	—	—
United Kingdom	5,198	248,630	216,039	1,295	1,064	—	59,007	9,763	15	—	46,399
Other	172	300	2,954	—	—	—	100	—	944	—	3,616
Total	**19,345**	**1,371,704**	**1,487,740**	**18,288**	**2,664**	**—**	**230,331**	**120,381**	**1,170**	**432**	**410,270**

TABLE 8—Continued

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY YEAR AND COUNTRY

Year and country	Semimanufactured (troy ounces)					Platinum-group metals in materials not elsewhere specified (troy ounces)	Total	
	Platinum	Palladium	Iridium	Rhodium	Unspecified combinations		Troy ounces	Value (thousands)
1984	60,140	158,012	164	2,389	10	332	4,474,106	$1,118,088
1985	78,206	84,492	3,700	145	1,480	7,977	3,989,594	1,025,692
1986	94,655	114,596	4	1	2	513	4,477,177	1,346,715
1987	45,804	151,499	65	829	3,878	257	3,806,547	1,240,080
1988								
Australia	—	—	—	—	—	—	5,607	3,531
Belgium	2,272	—	—	—	—	49	220,242	51,437
Canada	13,060	—	103	—	—	462	239,170	53,046
Colombia	—	—	—	—	—	—	20,446	9,740
Dominican Republic	—	—	—	—	—	—	32,987	5,961
France	—	—	—	—	—	—	6,960	4,445
Germany, Federal Republic of	40,776	1,758	10	—	—	—	126,878	55,363
Hong Kong	—	—	—	—	—	—	72,641	11,557
Israel	—	—	—	—	—	—	2,084	512
Italy	—	—	—	—	—	—	18,611	5,233
Ivory Coast	—	2,150	—	—	—	—	3,000	270
Japan	1,600	—	—	376	—	—	12,182	3,221
Mexico	—	—	—	—	—	44	74,921	1,165
Netherlands	70	—	—	—	—	—	49,264	15,008
Norway	—	—	—	—	—	—	15,466	6,218
South Africa, Republic of	5,916	2,013	—	—	—	—	1,820,002	738,025
Somalia	—	—	—	—	—	—	3,474	445
Sweden	—	—	—	—	—	—	17,539	12,500
Switzerland	113	203	—	—	—	—	4,392	1,320
Taiwan	—	3,651	—	643	—	—	67,992	7,443
U.S.S.R.	9,590	111,145	—	4,490	—	—	453,465	113,945
United Kingdom	39,268	90,999	980	640	6	—	719,303	244,978
Other	522	450	1,300	112	—	—	10,470	2,564
Total	**113,187**	**212,369**	**2,393**	**6,261**	**6**	**555**	**3,997,096**	**1,347,927**

Source: Bureau of the Census.

the numismatic market. The 1-ounce Panda was not considered legal tender. The U.S.S.R., through MTB Banking Corp., New York, NY, marketed two 99.9%-pure proof coins, a ½-ounce platinum coin and a 1 ounce palladium coin. Johnson Matthey, a leading producer of precious metals, marketed a 1 ounce 99.95%-pure medallion coin, called the Dragon, commemorating the Chinese year of the dragon. The popularity of these coins follows the minting of the first platinum bullion coin, the Noble, first issued by the Isle of Man in 1983. World investment demand for platinum, including coins, was the third largest end use, following autocatalysts and jewelry.[11]

Belgium

Johnson Matthey, United Kingdom, worked on construction of a $17 million autocatalyst plant near Brussels that was planned to start production in the second half of 1989. The new plant was capable of producing 4.5 million autocatalysts and was expected to help supply growing demand for autocatalysts in Europe. Johnson Matthey

TABLE 9

ESTIMATED U.S. IMPORTS OF PLATINUM, PALLADIUM, AND RHODIUM, BY YEAR AND COUNTRY[1]

(Thousand troy ounces)

Country	Platinum		Palladium		Rhodium	
	1987	1988	1987	1988	1987	1988
South Africa, Republic of	883	924	702	658	109	122
U.S.S.R.	22	48	315	363	43	43
United Kingdom	209	316	267	330	31	60
Other	376	422	716	555	29	13
Total[2]	**1,490**	**1,710**	**2,000**	**1,906**	**212**	**237**

[1] This table is based on the figures shown in table 8. Estimates are based on the explicit categories of platinum, palladium, and rhodium plus estimates of the metal content in the following categories: unspecified combinations, ores and scrap, and materials not elsewhere specified.
[2] Data may not add to totals shown because of independent rounding.

compared with about 5 million catalysts manufactured each year in Europe. European production was expected to catch up with U.S. production in 1990.[12]

Canada

Madeleine Mines Ltd. of Toronto continued development of its open pit Lac des Iles deposit in northwestern Ontario. The company expected that it would produce 150,000 ounces of PGM in 1988.[13]

Japan

Japanese platinum imports rose an estimated 35% to about 2.25 million ounces in 1988, according to the Plati-

owned another autocatalyst plant in Royston, United Kingdom, that supplied the European market. The company claimed to supply one-half of the U.S. autocatalyst market and one-third of the European market. Johnson Matthey estimated that 20 million to 25 million autocatalysts were manufactured each year in the United States,

TABLE 10

PLATINUM ANNUAL MINE CAPACITY OF MAJOR PRODUCING COMPANIES, AS OF DECEMBER 31, 1988

(Thousand troy ounces)

	Capacity
North America:	
Inco Ltd.	120
Falconbridge Ltd.	40
Stillwater Mining Co.[1]	40
Total	**200**
Africa:	
Rustenburg Platinum Mines Ltd.[2]	1,400
Impala Platinum Holdings (Pty.) Ltd.[3]	1,100
Western Platinum Ltd.	160
Total (rounded)	**2,700**
World total (rounded)	**2,900**

[1] Jointly owned by Chevron Corp. and Manville Corp.
[2] Owns Lebowa Platinum Mines Ltd.
[3] Owns the Karee Mine and Messina Mine.

TABLE 11

SUPPLY AND DEMAND FOR PLATINUM, PALLADIUM, AND RHODIUM IN 1988

(Thousand troy ounces)

	Platinum	Palladium	Rhodium
SUPPLY			
Mine production (market economy countries):			
South Africa, Republic of[e]	2,600	1,100	130
Canada	158	166	15
United States[1]	40	120	—
Other	53	59	—
Total	**2,851**	**1,445**	**145**
Secondary from old scrap:			
Japan	45	200	7
United States	36	114	3
Other	10	150	2
Total	**91**	**464**	**12**
Soviet sales to market economy countries	400	1,800	100
Total	**3,342**	**3,709**	**257**
DEMAND			
Industrial:			
Japan	1,500	1,500	110
United States	1,001	1,101	106
Western Europe	515	600	20
Other	200	185	5
Total	**[2]3,216**	**3,386**	**241**

[e] Estimated.
[1] Metals Week, Dec. 5, 1988, p. 3.
[2] Excludes approximately 620,000 ounces of investment demand.
Sources: Johnson Matthey PLC, CPM Group Ltd., and Bureau of Mines estimates.

TABLE 12

PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY[1]

(Troy ounces)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Australia, metal content, from domestic nickel ore:[3]					
Palladium	16,815	15,304	13,760	[e]15,800	13,200
Platinum	2,122	3,054	3,697	[e]4,200	3,400
Canada: Platinum-group metals from nickel ore	348,216	337,088	391,917	351,407	[4]368,383
Colombia: Placer platinum	10,106	11,650	14,368	20,500	26,200
Ethiopia: Placer platinum[e]	125	150	150	150	150
Finland:					
Palladium	1,093	1,125	3,086	2,862	3,000
Platinum	1,061	1,125	3,858	3,860	4,000
Japan, metal recovered from nickel-copper ores:[5]					
Palladium	33,802	43,703	46,699	45,568	38,500
Platinum	19,523	22,216	21,312	24,202	20,900
South Africa, Republic of: Platinum-group metals from platinum ore[e 6]	3,500,000	3,700,000	3,960,000	4,220,000	4,285,000
U.S.S.R.: Placer platinum and platinum-group metals recovered from nickel-copper ores[e]	3,700,000	3,800,000	3,850,000	3,900,000	3,900,000
United States: Placer platinum and platinum-group metals from gold-copper ores	14,635	W	W	W	W
Yugoslavia:[e]					
Palladium	[4]3,476	3,300	3,100	[r]3,200	3,200
Platinum	[4]386	250	250	[r]95	100
Zimbabwe:					
Palladium	1,222	965	1,125	932	1,000
Platinum	772	611	836	579	600
Total	**[r]7,653,354**	**7,940,541**	**8,314,158**	**8,593,355**	**8,667,633**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1] Table includes data available through May 2, 1989. Platinum-group metal production by the Federal Republic of Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

[2] In addition to the countries listed, China, Indonesia, Papua New Guinea, and the Philippines are believed to produce platinum-group metals, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. However, a part of this output not specifically reported by country is presumably included in this table credited to Japan. (See footnote 5.)

[3] Partial figure; excludes platinum-group metals recovered in other countries from nickel ore of Australian origin; however, a part of this output may be credited to Japan. (See footnote 5.)

[4] Reported figure.

[5] Japanese figures do not refer to Japanese mine production, but rather represent Japanese smelter-refinery recovery from ores originating in a number of countries; this output cannot be credited to the country of origin because of a lack of data. Countries producing and exporting such ores to Japan include (but are not necessarily limited to) Australia, Canada, Indonesia, Papua New Guinea, and the Philippines. Output from ores of Australian, Indonesian, Papua New Guinean, and Philippine origin are not duplicative, but output from Canadian material might duplicate a part of reported Canadian production.

[6] Includes osmiridium produced in gold mines.

num Guild International in Tokyo. Most of the increase was absorbed by the jewelry industry, which used over 1 million ounces, mostly in rings and wedding bands. The automotive industry consumed an estimated 400,000 ounces. Investment in coins and small bars was also very active, sparked by the strength of the yen against the U.S. dollar.[14]

South Africa, Republic of

Golden Dumps Ltd. sold its interest in the Lefkochrysos (Lefko) platinum mine to Barplats Investments. Barplats was controlled by Rand Mines. Financial problems due to cost overruns at Lefko were reportedly the reason for the sale. Barplats merged its own Rhodium Reefs platinum mine with Lefko, and the combined output from both mines was expected to reach 150,000 ounces of platinum per year by 1992. Lefko was to be developed first, followed by Rhodium Reefs.[15]

Impala Platinum Holdings (Pty.) Ltd., the second largest producer of PGM in the Republic of South Africa, purchased control of Messina Ltd. Messina's properties were in the black South African homeland of Lebowa.[16]

TECHNOLOGY

Six different methods for recovering PGM from spent automobile catalysts have been developed over the past 10 years. One method depends on crushing catalyst pellets and dissolving the material in sulfuric acid. In a second method, acids are used to leach PGM from spent catalyst monoliths. A third method, which was not in use commercially, employs dry chlorination. Another method uses copper as a collector. An extension of the copper collection process is the introduction of the catalyst directly into a copper or nickel smelter. A sixth method, plasma fusion, was the major recovery method used in the United States. Difficulties that all processors of spent automotive catalyst must overcome include a frequently high (1% to 10%) lead content, the presence of alumina in soluble and insoluble forms, the need for recovery of greater than 90% to assure an economical process, and handling the highly corrosive reagents required.[17]

Platinum Lake Technology Inc., Downsview, Ontario, Canada, tested a new leaching method for recycling PGM in catalytic converters from scrapped cars at a prototype plant in Mississauga, Ontario. The process is called Catalyzed Reagent Organic Redox Hydrometallurgical Leaching System (CRO/REDOX). It is a chlorine-base leaching system, which is an alternative to cyanide-base leaching of precious metals. The CRO/REDOX system has a fast turnaround time, requiring only 24 hours to leach precious metal salts that later can be sold to refiners.[18]

A paper discussing "The Changing Patterns of PGM Use in Autocatalyst" was presented at a meeting of the Society of Automotive Engineers. The paper traced the history of the use of autocatalysts in North America, Japan, and Western Europe, and the changes that have occurred since the introduction of autocatalysts in 1974. The most common autocatalyst in use today is the three-way catalyst in which the reduction of nitrogen oxides and oxidation of carbon monoxide and unburnt hydrocarbons occur over a single catalyst bed. The earliest autocatalysts used were single-bed oxidation catalysts containing combinations of platinum and palladium. In North America, the ratio of platinum to rhodium for three-way catalysts ranges from 10:1 to 5:1. In Western Europe, different operating conditions require that the ratio of platinum to rhodium in three-way catalysts be closer to 5:1. In Japan, autocatalysts made for the domestic market are different than autocatalysts produced for export to North America. Autocatalysts produced in Japan for export to North America are similar in composition to North American autocatalysts. Autocatalysts produced for the Japanese domestic market tend to have higher loadings of palladium.[19]

In December, Ford Motor Co. announced that it had developed a platinum-free autocatalyst that had passed certification for use in California and would be tested on selected 1989 model cars.[20] Although Ford would not say exactly what metals were used, most industry experts agreed that the catalyst probably contained a mixture of palladium and rhodium, with cerium added for thermal stability. Automobile catalyst manufacturers have been researching different formulations for catalysts for many years. If there is a possibility of lead in the fuel, or if performance requirements are especially stringent, platinum is the preferred metal over palladium because platinum is more resistant to poisoning by lead than palladium, and because the performance of platinum as a catalyst is unmatched by palladium. The Bureau believes that it is unlikely that palladium can be substituted completely for platinum because of the tight supply situation for both metals and the fact that palladium is produced as a byproduct of platinum in the Republic of South Africa. Although industry-wide autocatalyst formulations are expected to change over time, the changes are expected to be gradual rather than radical and will require time to be proven effective.

Pollution control technology applied to automobiles was also applied to control of pollution generated from diesel-fueled standby generators. Diesel fumes are controlled using a catalytic diesel exhaust purifier, which is a ceramic honeycomb coated with a washcoat containing finely divided PGM.[21]

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POTASH

By James P. Searls[1]

U.S. potash production in terms of potassium oxide (K_2O) equivalent rose 21% relative to that of 1987, and apparent consumption rose 3%. Spring production was 50% of the annual total. Sales by U.S. producers fell 4% for the year, but average prices rose 28% on the basis of K_2O equivalent. Yearend stocks rose 60% due to a decline in fall sales, which, in turn, was due to the drought. U.S. net import reliance as a percent of apparent consumption was 71%. Canada provided an amount equal to 70% of the domestic apparent consumption. U.S. exports decreased, with exports to Mexico and Japan continuing to fall, whereas exports to Brazil rose.

DOMESTIC DATA COVERAGE

Domestic production data for potash are developed by the Bureau of Mines from voluntary semiannual surveys of U.S. operations. Of the 10 operations to which a survey request was sent, 9 responded, representing 98% of total production shown in table 1.

DOMESTIC PRODUCTION

Domestic K_2O production rose 21% in 1988 compared with that of 1987. Of the total production for the year, 78% was standard, coarse, and granular muriate of potash, also known as potassium chloride, and 8% was sulfate of potash, also known as potassium sulfate. The remaining production comprised manure salts, soluble, and chemical grades of muriate of potash and sulfate of potash-magnesia, also known as potassium magnesium sulfate. The terms "standard," "coarse," and "granular" refer to the particle sizes of the finished product. "Standard," "coarse," and "granular," are the "three muriates," a term that ignores manure salts and soluble and chemical grades of muriate of potash. "Sulfates" is a term for the combination of sulfate of potash and sulfate of

TABLE 1

SALIENT POTASH[1] STATISTICS

(Thousand metric tons and thousand dollars unless otherwise specified)

		1984	1985	1986	1987	1988
United States:						
Production		3,039	2,569	2,381	2,464	2,999
K_2O equivalent		1,564	1,296	1,202	1,262	1,521
Sales by producers		3,184	2,505	2,291	2,904	2,802
K_2O equivalent		1,639	1,266	1,147	1,485	1,427
Value[2]		$241,800	$178,400	$144,900	[e]$197,700	$240,300
Average value per ton of product	dollars	$75.95	$71.22	$63.24	$67.98	$85.75
Average value per ton of K_2O equivalent	do.	$147.55	$140.89	$126.28	$131.73	$168.37
Exports[3]		836	973	1,025	926	783
K_2O equivalent		446	513	547	470	380
Value[4]		$85,660	NA	NA	NA	NA
Imports for consumption[3 5]		7,948	7,571	6,934	6,706	6,964
K_2O equivalent		4,829	4,593	4,212	4,073	4,217
Customs value		$658,100	$499,100	$385,100	$433,000	$623,000
Consumption, apparent[6]		10,296	9,103	8,200	8,683	8,983
K_2O equivalent		6,022	5,346	4,843	5,088	5,264
Yearend producers' stocks, K_2O equivalent		[7]312	[8]336	[9]378	155	248
World: Production, marketable K_2O equivalent		29,334	29,151	28,694	[p]30,470	[e]31,429

[e]Estimated. [p]Preliminary. NA Not available.
[1]Includes muriate and sulfate of potash, potassium magnesium sulfate, glaserite, and some parent salts. Excludes other chemical compounds containing potassium.
[2]F.o.b. mine.
[3]Excludes potassium chemicals and mixed fertilizers.
[4]F.a.s. U.S. port.
[5]Includes nitrate of potash.
[6]Calculated from production plus imports minus exports plus/minus industry and Government stock changes.
[7]Inventory adjustment of minus 4,000 tons.
[8]Inventory adjustment of minus 6,000 tons.
[9]Inventory adjustment of minus 12,900 tons.

potash-magnesia.

The New Mexico producers accounted for 89% of the total marketable potash salts production. Production of crude salts in New Mexico was 12.5 million metric tons[2] with an average K_2O content of 14.8%. The producers were AMAX Potash Corp. of AMAX Inc.; Eddy Potash Inc., which is owned by Trans-Resources Inc.; International Minerals & Chemical Corp. (IMC) of IMC Fertilizer Inc.; Mississippi Chemicals Corp.; New Mexico Potash Corp., which is owned by Trans-Resources; and Western Ag-Minerals Co., which is controlled by Rayrock Resources Ltd. of Canada. Cedar Chemicals Corp. of Fermenta AB of Sweden was sold in February to Nine West Corp. of New York, which became Trans-Resources. Cedar Chemicals Corp. owns New Mexico Potash Co. and Vicksburg Chemicals Co., the potassium nitrate producer in Vicksburg, MS. Trans-Resources also owns the potassium nitrate production facility in Israel. The Ideal Basic Corp. sold Lundberg Industries Ltd. to Trans-Resources in June. The Mississippi Chemical Corp. (MCC) potash plant, which had been shut down since January 1983, reopened in October. MCC can produce only standard muriate of potash but plans to use the compaction facilities of the former National Potash Co. plant, which MCC owns, to produce coarse and granular. All of the producers, except Western Ag-Minerals, mined sylvinite ore and beneficiated the ore into muriate of potash. Western Ag-Minerals and IMC mined langbeinite ore and beneficiated the ore to sulfate of potash-magnesia. IMC mined both types of ore and reacted fractions of each potash product to produce sulfate of potash.

Sulfate of potash was also manufactured at one plant in Texas and one in Utah. The plant in Dumas, TX, was operated by AMAX Potash and its production was reported in the Bureau of Mines sulfate of potash mine production totals shown in the tables. The Permian Chemical Corp. plant in Odessa, TX, did not produce during the year. The Climax Chemical Co. plant in Utah produced about 18,500 tons. This company was not included in the Bureau of Mines sulfate of potash mine production totals.

In Utah, Moab Salt Inc. produced muriate of potash for Texasgulf Chemicals Co. from underground bedded deposits by solution mining and solar evaporation. The salts from the solar pond were beneficiated by flotation to separate the sylvite (potassium chloride) from the halite (sodium chloride). Climax Chemical converted potassium chloride to potassium sulfate for sales by Texasgulf. The Kaiser Chemicals plant of Kaiser Aluminum & Chemical Corp. was sold to Reilly Tar & Chemical Corp. of Indianapolis, IN, and was renamed Reilly-Wendover, a division of Reilly Tar & Chemical Corp. This plant continues to produce muriate of potash and manure salts from near-surface brines at the west end of the Bonneville Salt Flats by solar evaporation and flotation. Magnesium chloride was a byproduct. Great Salt Lake Minerals & Chemicals Corp. reported no production but started to crystallize salts in their solar evaporation ponds.

In California, Kerr-McGee Chemical Corp. continued to produce both muriate and sulfate of potash along with other products from underground brines at Searles Lake.

Greensand, also known as glauconite, a natural silicate of potassium, aluminum, iron, and magnesium, was produced by Inversand Co., a subsidiary of Hungerford and Terry Inc., near Clayton, NJ, and by Contractors Sand & Gravel Co. near Middletown, DE. Production and sales information for greensand are withheld to avoid disclosing company proprietary data. Processed greensand continued to be sold as a filter media for the removal of manganese and iron from drinking water supply systems. Classified raw greensand was resold by Zook and Ranck Inc. as a soil conditioner and as a source of slowly released potash, with a K_2O equivalent between 5% and 10%, to the organic farmers of North America.

CONSUMPTION AND USES

Apparent domestic consumption of all forms of potash rose 3% compared with that of 1987. Consumption per quarter declined relative to the previous fall as farmers declined to add potash to the drought-stricken fields.

According to the Potash & Phosphate Institute, the major States for consumption of agricultural potash from Canadian and United States potash producers, in decreasing order, were Illinois, Iowa, Ohio, Minnesota, Indiana, Wisconsin, and Missouri. These seven States consumed 60% of the total from Canadian and United States producers. Domestic producers provided 2% of Illinois potash consumption, 8% of Iowa's consumption, 3% of Ohio's consumption, 1% of Minnesota's consumption, 5% of Indiana's consumption, 1% of Wisconsin's consumption, and 60% of Missouri's consumption. The major agricultural consumers of domestically produced potash, in decreasing order, were Missouri, Texas, California, Kansas, Florida, Arkansas, Iowa, and Louisiana. These eight States accounted for 70% of the total. The major consumers of domestically produced sulfates of potash, in decreasing order, were Florida, Georgia, California, Texas, Ohio, North Carolina, and South Carolina. These seven States accounted for 69% of the total.

STOCKS

Yearend producers' stocks of potash increased 60% from that of 1987. Yearend stocks represented 16% of an-

TABLE 2

PRODUCTION, SALES, AND INVENTORY OF U.S. PRODUCED POTASH, BY TYPE AND GRADE

(Thousand metric tons and thousand dollars)

Type and grade	Production				Sold or used						Stocks, end of 6-month period			
	Gross weight		K_2O equivalent		Gross weight		K_2O equivalent		Value[1]		Gross weight		K_2O equivalent	
	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988
January–June:														
Muriate of potash, 60% K_2O minimum:														
Standard	240	347	147	212	344	327	210	199	e17,700	e23,800	118	99	72	60
Coarse	107	116	66	71	122	112	75	68	e6,400	e9,400	19	11	12	7
Granular	403	497	245	300	522	506	316	306	e24,100	e41,800	120	89	73	54
Chemical	6	6	4	4	11	6	7	4	W	W	1	1	1	1
Potassium sulfate	95	110	48	56	107	119	55	61	e16,200	e20,000	36	21	18	11
Other potassium salts[2]	326	425	80	112	392	431	96	114	W	W	153	106	35	23
Total[3]	**1,177**	**1,501**	**590**	**755**	**1,498**	**1,502**	**759**	**752**	**e94,000**	**e127,300**	**446**	**327**	**210**	**156**
July–December:														
Muriate of potash, 60% K_2O minimum:														
Standard	298	407	182	249	338	342	206	209	21,300	25,500	78	164	47	100
Coarse	113	124	69	76	124	103	76	63	r8,600	8,400	7	32	5	20
Granular	471	459	285	278	493	452	299	273	31,700	38,300	97	96	59	58
Chemical	9	9	6	6	8	7	5	5	W	W	2	3	1	2
Potassium sulfate	101	119	52	61	106	94	54	48	16,800	16,800	31	46	16	23
Other potassium salts[2]	295	381	77	97	336	303	86	77	W	W	112	184	25	45
Total[3]	**1,287**	**1,498**	**671**	**766**	**1,405**	**1,300**	**726**	**675**	**101,700**	**113,000**	**328**	**525**	**155**	**248**
Grand total[3]	**2,464**	**2,999**	**1,262**	**1,521**	**2,904**	**2,802**	**1,485**	**1,427**	**e195,700**	**e240,300**	**XX**	**XX**	**XX**	**XX**

e Estimated. r Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1] F.o.b. mine.
[2] Includes soluble muriate, glaserite, manure salts, and potassium magnesium sulfate.
[3] Data may not add to totals shown because of independent rounding.

nual production, or 8.5 weeks of average production.

PRICES

The average annual price, f.o.b. mine, of U.S. potash sales of all types and grades was up 28% compared with that of 1987 to $168.37 per ton. The average price was $169.15 per ton for the first half of the year and $167.45 per ton for the second half of the year. The average annual price for the three grades of muriate rose to $131.69 per ton. Standard-grade muriate of potash averaged $121.04 per ton, coarse-grade muriate averaged $135.69 per ton, and granular-grade averaged $138.27 per ton. The average annual price for all grades of sulfate of potash rose to $335.74 per ton.

FOREIGN TRADE

Total U.S. potash exports reported by the Bureau of the Census decreased 16%, by ton product. The major destinations of potash exports to Latin America, which received 62% of the total exports, were, in decreasing order, Brazil, Colombia, Chile, Dominican Republic, Venezuela, and Costa Rica. These countries represented 82% of the exports to Latin America. Exports to Japan fell 47%. In decreasing order, Japan, Canada, Belgium, China, Malaysia, Australia, and Ireland represented 90% of exports to non-Latin American countries. Exports of sulfates rose from 45% of total exports to 49%.

Potash imports for consumption rose 4%. Muriate of potash imports from Canada declined 1%, but imports from all other sources increased. Canada supplied 88% of all muriate imports and 87%, by K_2O equivalent, of all potash imports. Israel was the second-largest source of imports with 4% of muriate of potash imports and 4%, by

K_2O equivalent, of total potash imports. Imports from the U.S.S.R. increased by 83% from those of 1987.

WORLD CAPACITY

The data in table 12 are rated annual capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for potash is based on 344 working days per year, 4 shifts per 2 weeks. Refinery capacity is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines. Capacity data for the U.S.S.R. are estimated.

WORLD REVIEW

World production increased slightly over that of 1987. World prices, as exemplified by the per ton price of standard muriate of potash, f.o.b. Vancouver, Canada, finished the year in the middle \$140's per ton K_2O, or the low \$90's per ton of product. These prices were reported by British Sulphur Corp. Ltd. and were up from approximately \$125 per ton K_2O or the middle \$70's per ton of product at yearend 1987. Prices climbed consistently throughout the year. The continued price rise reflected production cutbacks by a major Canadian producer.

TABLE 3

PRODUCTION AND SALES OF POTASH IN NEW MEXICO

(Thousand metric tons and thousand dollars)

Period	Crude salts[1] (mine production)		Marketable potassium salts				
			Production		Sold or used		
	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Value[2]
1987:							
January–June	5,615	820	1,088	539	1,345	669	[e]83,500
July–December	5,786	841	1,161	598	1,283	654	90,700
Total[3]	**11,400**	**1,661**	**2,249**	**1,136**	**2,627**	**1,323**	**174,200**
1988:							
January–June	5,965	899	1,352	668	1,373	678	114,300
July–December	6,543	954	1,371	690	1,162	593	99,500
Total[3]	**12,508**	**1,853**	**2,722**	**1,359**	**2,535**	**1,271**	**213,800**

[e] Estimated.
[1] Sylvinite and langbeinite.
[2] F.o.b. mine.
[3] Data may not add to totals shown because of independent rounding.

TABLE 4

SALIENT U.S. SULFATE OF POTASH[1] STATISTICS

(Thousand metric tons of K_2O equivalent and thousand dollars)

	1985	1986	1987	1988
Production	106	88	100	117
Sales by producers	103	97	109	109
Value[2]	\$36,465	[r]\$30,483	\$33,059	\$36,854
Exports[3]	46	[4]79	[4]118	[4]91
Value[5]	NA	NA	NA	NA
Imports[3]	25	27	26	46
Value[6]	\$10,400	\$9,900	\$10,500	\$19,300
Consumption, apparent[7]	82	[4]45	[4]16	[4]65
Yearend producers' stocks	34	25	16	23

[r] Revised. NA Not available.
[1] Excluding potassium magnesium sulfate.
[2] F.o.b. mine.
[3] Bureau of the Census.
[4] Preliminary export data pending verification by the Bureau of the Census.
[5] F.a.s. U.S. port.
[6] C.i.f. to U.S. port.
[7] Caculated from production plus imports minus exports plus/minus industry stock changes.

Argentina

Minera Tea S.A. reported resources of 300 million tons of 20% to 32% K_2O potash ore.[3] Solution mining and solar evaporation were being studied. The minesite is remote from utilities and is a long distance from markets or ocean shipping points.

Canada

During the Summer, Potash Corp. of Saskatchewan (PCS) reduced the production rate at Cory Mine by closing down all of the red potash capacity. This action reduced the plant to only 186,000 tons per year of white crystallized potash. The move furthered the efforts to reduce excess capacity, reduce surplus stocks, and raise potash prices in the world market. Only the Rocanville Mine of PCS operated on a four-shift schedule during the year; other PCS mines operated at three-shift schedules with some shutdowns during the year. Lanigan Mine did not run at its full capacity because PCS operated with only the new mill and idled the old mill.

Potash Co. of America operated a pilot plant at Patience Lake to demonstrate the solution mining of old mine workings and pond crystallization of muriate of potash on the surface during the winter. The product dredged from the pond was processed in the potash mill, probably for sizing and granulation. The company decided to construct large crystallization ponds for production during the winter of 1988-89.

Spain

Potasas de Subiza S.A, the successor to Potasas de Navarra S.A., was exploring a sylvinite resource at Javier, about 40 kilometers from Subiza.

Thailand

Thai Potash Co. withdrew from exploration of the Khon Kaen region because the sylvinite resource was too small for profitable development.[4] Thai Potash was a joint venture of CRA Exploration Pty. Ltd. of Austra-

TABLE 5

SALES OF NORTH AMERICAN POTASH, BY STATE OF DESTINATION

(Metric tons of K_2O equivalent)

State	Agricultural potash		Nonagricultural potash	
	1987	1988	1987	1988
Alabama	62,341	63,278	95,097	106,001
Alaska	1,625	274	57	—
Arizona	2,382	1,742	1,104	1,789
Arkansas	64,576	48,203	588	560
California	68,967	70,826	10,863	8,052
Colorado	7,181	7,871	3,183	2,278
Connecticut	3,752	3,650	148	69
Delaware	15,673	17,509	34,205	41,603
Florida	142,998	95,976	650	823
Georgia	109,765	110,228	1,369	2,249
Hawaii	14,670	9,093	—	1,141
Idaho	22,750	22,778	566	32
Illinois	680,434	604,351	2,373	1,791
Indiana	370,977	301,184	344	854
Iowa	492,891	450,110	432	1,725
Kansas	44,020	46,553	2,174	2,840
Kentucky	93,328	110,383	248	322
Louisiana	120,990	143,318	1,445	3,598
Maine	8,725	5,967	1,051	556
Maryland	27,639	28,533	192	158
Massachusetts	3,762	3,861	1,029	718
Michigan	210,073	174,549	3,582	5,392
Minnesota	360,272	318,475	1,371	2,023
Mississippi	35,421	27,466	39,325	41,670
Missouri	287,563	241,883	4,341	2,870
Montana	11,316	9,773	432	210
Nebraska	30,378	29,643	648	1,047
Nevada	13	66	243	80
New Hampshire	1,024	2,325	58	59
New Jersey	5,946	6,153	2,504	2,022
New Mexico	9,642	16,344	17,218	16,319
New York	58,901	64,900	14,720	19,565
North Carolina	70,853	87,801	431	727
North Dakota	23,444	19,450	279	15
Ohio	420,919	421,591	57,382	55,260
Oklahoma	23,106	22,170	5,541	3,486
Oregon	29,844	22,065	1,191	1,593
Pennsylvania	57,387	51,387	2,726	3,238
Rhode Island	1,588	2,455	13	45
South Carolina	53,942	73,328	13	73
South Dakota	13,590	15,007	12	—

TABLE 5—Continued

SALES OF NORTH AMERICAN POTASH, BY STATE OF DESTINATION

(Metric tons of K_2O equivalent)

State	Agricultural potash		Nonagricultural potash	
	1987	1988	1987	1988
Tennessee	128,035	86,152	269	1,004
Texas	146,036	131,720	26,008	33,347
Utah	7,755	7,390	14,918	7,516
Vermont	2,850	1,893	—	—
Virginia	76,226	79,845	151	117
Washington	38,211	34,765	632	806
West Virginia	2,887	1,793	995	841
Wisconsin	284,227	253,702	8,588	16,267
Wyoming	1,879	1,681	410	383
Total	**4,752,774**	**4,351,460**	**361,119**	**393,134**

Source: Potash & Phosphate Institute.

TABLE 6

SALES OF NORTH AMERICAN MURIATE OF POTASH TO U.S. CUSTOMERS, BY GRADE

(Thousand metric tons of K_2O equivalent)

Grade	1985	1986	1987	1988
Agricultural:				
Standard	346	319	328	259
Coarse	2,065	1,882	2,078	2,095
Granular	1,666	1,683	1,866	1,530
Soluble	392	336	360	339
Total	**4,469**	**4,220**	**4,632**	**4,223**
Nonagricultural:				
Soluble	138	98	88	104
Other	227	225	269	283
Total	**365**	**323**	**357**	**387**
Grand total	**4,834**	**4,543**	**4,989**	**4,610**

Source: Potash & Phosphate Institute.

lia, Siam Cement Co., and the Thai Government.

U.S.S.R.

The Berezniki four plant capacity was planned to be 1.2 million tons per year, and construction by Lurgi GmbH, the Federal Republic of Germany, was scheduled for completion in mid-1989.[5]

[1] Physical scientist, Branch of Industrial Minerals.

[2] All tonnages reported in metric tons, K_2O equivalent, unless otherwise specified.

[3] Phosphorus & Potassium. Plant and Project News. No. 156, July-Aug. 1988, p. 13.

[4] Fertilizer Week. International News. V. 2, No. 25, Oct. 31, 1988, p. 3.

[5] Work cited in footnote 3.

TABLE 7

PRICES[1] OF U.S. POTASH, BY TYPE AND GRADE

(Dollars per metric ton of K_2O equivalent)

Type and grade	1986		1987		1988	
	January–June	July–December	January–June	July–December	January–June	July–December
Muriate, 60% K_2O minimum:						
Standard	85.17	76.46	84.28	103.28	119.73	122.29
Coarse	92.63	81.16	86.35	113.05	137.28	133.95
Granular	84.75	77.73	76.11	106.21	136.62	140.12
All muriate[2]	87.85	80.11	80.24	106.06	130.84	132.65
Sulfate, 50% K_2O minimum	332.24	295.58	331.06	295.65	326.98	335.76

[1] Average prices, f.o.b. mine, based on sales.

[2] Excluding soluble and chemical muriates.

TABLE 8

U.S. EXPORTS OF POTASH

	Approximate average K_2O content (percent)	Quantity (metric tons)	
		Product	K_2O equivalent
1987:			
Potassium chloride, all grades	61	511,590	312,022
Potassium sulfate	51	230,899	117,849
Potassium magnesium sulfate	22	183,931	40,468
Total	**XX**	**926,420**	**470,339**
1988:			
Potassium chloride, all grades	61	400,831	244,507
Potassium sulfate	51	178,498	91,034
Potassium magnesium sulfate	22	203,529	44,776
Total	**XX**	**782,858**	**380,317**

XX Not applicable.

Source: Bureau of the Census.

TABLE 9

U.S. EXPORTS OF POTASH, BY COUNTRY[1]

Country	Metric tons of product					
	Potassium chloride		Potassium sulfates, all grades[2]		Total[3]	
	1987	1988	1987	1988	1987	1988
Argentina	30	330	1,500	4,150	1,530	4,480
Australia	2,700	190	7,400	14,390	10,100	14,580
Bahamas	—	—	500	380	500	380
Belgium-Luxembourg	—	38,570	—	—	—	38,570
Belize	1,530	1,950	40	—	1,570	1,950
Bolivia	—	280	—	—	—	280
Brazil	157,800	172,460	18,010	24,050	175,810	196,510
Canada	23,990	1,220	57,810	69,920	81,800	71,140
Chile	1,040	8,000	19,030	28,080	20,070	36,080
China	—	—	31,930	22,000	31,930	22,000
Colombia	14,870	25,490	40,850	51,470	55,720	76,960
Costa Rica	20,070	13,520	16,010	14,700	36,080	28,220
Denmark	—	—	20	—	20	—
Dominican Republic	34,750	25,260	3,450	6,590	38,200	31,850
Ecuador	6,890	11,030	3,320	3,178	10,210	14,208
El Salvador	—	20,750	12,000	2,160	12,000	22,910
France	210	170	1,230	110	1,440	280
Germany, Federal Republic of	5,020	—	—	—	5,020	—
Greece	—	230	5,850	—	5,850	230
Guatemala	—	—	370	—	370	—
Guyana	2,310	2,000	—	700	2,310	2,700
Haiti	—	—	50	—	50	—
Honduras	4,250	4,000	270	340	4,520	4,340
Hong Kong	38,410	—	—	—	38,410	—
Ireland	37,700	11,910	—	—	37,700	11,910
Italy	—	30	410	160	410	190
Japan	58,770	28,720	115,020	62,540	173,790	91,260
Korea, Republic of	70	1,130	180	90	250	1,220
Leeward and Windward Islands	8,070	—	—	—	8,070	—
Malaysia	—	—	13,220	16,630	13,220	16,630
Mexico	11,150	8,090	25,040	13,470	36,190	21,560
Netherlands	24,350	—	—	—	24,350	—
New Zealand	—	2,880	90	90	90	2,970
Pakistan	—	—	15,000	—	15,000	—
Panama	3,620	2,040	660	50	4,280	2,090
Peru	50,160	50	16,840	12,070	67,000	12,120
Philippines	50	—	—	300	50	300
Saudi Arabia	—	20	4,740	5,780	4,740	5,800
Singapore	—	—	—	110	—	110
South Africa, Republic of	—	30	—	2,200	—	2,230
Spain	3,180	9,300	3,010	40	6,190	9,340
Sweden	400	800	—	—	400	800
Taiwan	—	—	—	260	—	260
Thailand	—	—	—	5,250	—	5,250
Venezuela	—	9,880	—	20,050	—	29,930
Other	200	500	980	720	1,180	1,220
Total[3]	**511,590**	**400,831**	**414,830**	**382,027**	**926,420**	**782,858**

[1] The Bureau of the Census ceased publication of value data in 1985.
[2] Includes potassium magnesium sulfate.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF POTASH, BY COUNTRY

Country	Metric tons of product										Total value (thousands)			
	Potassium chloride		Potassium sulfate		Potassium nitrate		Potassium sodium nitrate		Total[1]		Customs		C.i.f.	
	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988
Belgium-Luxembourg	1,000	5,000	500	2,700	—	—	—	—	1,500	7,700	$200	$900	$200	$1,100
Canada	6,064,100	6,009,100	1,000	200	100	4,500	6,900	800	6,072,100	6,014,600	382,700	523,200	415,900	559,500
Chile	—	—	—	—	3,000	7,600	9,700	32,900	12,700	40,500	1,600	6,100	1,800	7,000
Dominican Republic	7,400	12,900	—	—	—	—	—	—	7,400	12,900	400	1,200	400	1,300
France	—	—	([2])	4,100	—	—	—	—	—	4,100	2	1,000	2	1,100
German Democratic Republic	106,700	154,300	—		—	—	—	—	106,700	154,300	5,600	13,300	6,700	15,200
Germany, Federal Republic of	5,400	29,100	49,200	79,200	—	—	—	—	54,600	108,300	9,500	18,300	10,800	20,600
Israel	270,100	288,500	—	—	16,800	23,400	—	—	286,900	311,900	22,400	31,300	25,200	36,700
Italy	—	28	200	60	—	—	—	—	200	88	10	30	10	30
Japan	—	38	—	—	—	—	700	—	700	38	50	20	80	20
Netherlands	1,000	8,800	—	1,000	—	—	—	—	1,000	9,800	200	1,200	200	1,300
Switzerland	21	—	—	—	—	—	—	—	21	—	2	—	2	—
Taiwan	—	—	19	—	—	—	—	—	19	—	8	—	11	—
U.S.S.R.	149,500	276,600	—	—	—	—	—	—	149,500	276,600	8,800	24,100	10,900	28,400
United Kingdom	12,300	23,000	—	—	—	—	600	—	12,900	23,000	1,200	2,200	1,500	2,500
Total[1]	**6,617,500**	**6,807,400**	**50,900**	**87,300**	**19,900**	**35,500**	**17,900**	**33,700**	**6,706,200**	**6,963,900**	**432,700**	**622,900**	**473,700**	**674,700**

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Source: Bureau of the Census, as adjusted by the Bureau of Mines.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF POTASH

	Approximate average K_2O content (percent)	Quantity (metric tons)		Value (thousands)	
		Product	K_2O equivalent[e]	Customs	C.i.f.
1987:					
Potassium chloride	61	6,617,500	4,036,000	$417,100	$456,400
Potassium sulfate	51	50,900	25,900	9,500	10,500
Potassium nitrate	45	19,900	9,000	4,200	4,800
Potassium sodium nitrate mixtures	14	17,900	2,500	2,200	2,400
Total	**XX**	**6,706,200**	**4,073,400**	**432,700**	**474,100**
1988:					
Potassium chloride	61	6,807,400	4,151,400	592,800	640,400
Potassium sulfate	51	87,300	44,500	17,300	19,300
Potassium nitrate	45	35,500	16,000	8,100	9,600
Potassium sodium nitrate mixtures	14	33,700	4,700	4,700	5,400
Total	**XX**	**6,963,900**	**4,216,600**	**622,900**	**674,700**

[e] Estimated. XX Not applicable.

Source: Bureau of the Census, as adjusted by the Bureau of Mines.

TABLE 12

WORLD POTASH ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand metric tons of K_2O equivalent)

	Rated capacity[1]
North America:	
Canada	11,520
United States	2,060
Total	**13,580**
South America:	
Brazil	150
Chile	43
Total	**[2]190**
Eastern Europe:	
German Democratic Republic	3,500
U.S.S.R.	13,700
Total	**17,200**
Western Europe:	
France	1,680
Germany, Federal Republic of	2,700
Italy	400
Spain	750
United Kingdom	490
Total	**6,020**
Asia:	
China	120
Israel	1,260
Jordan	720
Total	**2,100**
World total	**39,090**

[1] Includes capacity at operating plants as well as at plants on standby basis.

[2] Data do not add to total shown because of independent rounding.

TABLE 13

SALIENT CANADIAN POTASH STATISTICS

(Thousand metric tons of K_2O equivalent)

	1985	1986	1987	1988
Production[1]	6,637	6,697	7,267	8,327
Domestic sales by domestic producers[1]	434	327	499	416
Exports:				
United States[1]	4,163	4,091	4,223	4,248
Overseas[1]	1,928	2,612	3,133	3,792
Imports for consumption[2]	14	10	19	11
Domestic consumption[3]	448	337	518	427
Yearend producers' stocks[1]	1,766	1,537	1,135	1,356

[1] Data supplied by the Potash & Phosphate Institute.

[2] From Bureau of the Census export data. Sulfate of potash and nitrate of potash were landed on the Canadian east coast from European sources.

[3] Domestic sales by domestic producers plus imports.

TABLE 14

MARKETABLE POTASH: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons of K_2O equivalent)

Country	1984	1985	1986	1987[p]	1988[e]
Brazil	—	—	18	37	40
Canada[2]	7,527	6,661	6,752	7,668	[3]8,070
Chile[4]	18	21	20	21	26
China[e]	40	40	40	40	40
France	1,739	1,750	1,617	1,539	[3]1,502
German Democratic Republic	3,465	3,465	3,485	3,500	[3]3,510
Germany, Federal Republic of	2,645	2,583	2,161	2,199	[3]2,290
Israel	1,100	1,200	1,255	1,253	[3]1,244
Italy	163	205	158	[e]160	160
Jordan	295	561	660	734	800
Spain	677	659	702	740	[3]766
U.S.S.R.	9,776	10,367	10,228	10,888	11,000
United Kingdom	325	343	396	429	[3]460
United States	1,564	1,296	1,202	1,262	[3]1,521
Total	**29,334**	**29,151**	**28,694**	**30,470**	**31,429**

[e] Estimated. [p] Preliminary.

[1] Table includes data available through Apr. 26, 1989.

[2] Official Government figures. Potash & Phosphate Institute production data are given in table 13.

[3] Reported figure.

[4] Data represent officially reported output of potassium nitrate product (gross weight basis) converted assuming 14% K_2O equivalent.

PUMICE AND PUMICITE

By Arthur C. Meisinger[1]

Domestic production for pumice and pumicite declined slightly in quantity and 8% in value compared with 1987 production. Apparent consumption, however, increased 9%, primarily due to increased domestic sales of pumice aggregate and imported pumice used in concrete masonry products for the construction market. Greece continued to be the principal source of pumice imports with 86% compared with 83% in 1987.

DOMESTIC DATA COVERAGE

Domestic production data for pumice and pumicite are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 22 operations to which a survey request was sent, 18, or 82% responded, of which 14 were active and represented 47% of the quantity sold and used and 62% of the value shown in table 1. Production for the remaining nonrespondents was estimated using reported prior year data adjusted by trends in employment and other guidelines.

DOMESTIC PRODUCTION

Production of pumice and pumicite declined slightly from that of 1987, and was 389,000 short tons valued at $4.1 million. Output came from 18 mines and/or mills operated by 18 companies in 7 States. Oregon, New Mexico, Idaho, and California, in order of production, accounted for nearly all of the U.S. output.

Principal domestic producers were Glass Mountain Pumice Inc., Siskiyou Co., CA; Amcor Inc., Idaho Falls, ID; Hess Pumice Products, Malad City, ID; Producers Pumice, Meridian, ID; Copar Pumice Co. Inc., Santa Fe, NM; General Pumice Corp., Santa Fe, NM; Utility Block Co., Albuquerque, NM; Cascade Pumice Co., Bend, OR; and Central Oregon Pumice Co., Bend, OR. Together, these nine companies accounted for 94% of the tonnage and 63% of the value of U.S. pumice and pumicite production.

CONSUMPTION AND USES

U.S. apparent consumption increased 9% compared with that of 1987. Domestic and imported pumice aggregate used in concrete products increased 19% to 448,000 tons. Domestic pumice sold and used for abrasive uses increased 24%, primarily owing to the continued large demand for washing designer jeans. Landscaping uses of pumice increased 11%. Pumice used for decorative building block declined 16%. Some producers switched plant operations over to aggregate production for the stronger concrete products market. Other uses of pumice and pumicite decreased 11% compared with that of 1987.

TABLE 1

SALIENT PUMICE AND PUMICITE STATISTICS

(Thousand short tons and thousand dollars unless otherwise specified)

	1984	1985	1986	1987	1988
United States: Sold and used by producers:					
Pumice and pumicite	502	508	554	392	389
Value (f.o.b. mine and/or mill)	$4,929	$4,553	$5,756	$4,493	$4,129
Average value per ton	$9.82	$8.96	$10.39	$11.46	$10.61
Exports[e]	1	1	1	1	1
Imports for consumption	293	242	385	272	337
Consumption, apparent[1]	794	749	938	663	725
World: Production, pumice and related volcanic materials	[r]12,812	[r]11,866	11,332	[p]11,888	[e]11,945

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Production plus imports minus exports plus adjustments for Government and industry stock changes.

TABLE 2

PUMICE AND PUMICITE SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1987 Quantity	1987 Value	1988 Quantity	1988 Value
Arizona	1	7	1	7
California	42	1,539	35	1,245
New Mexico	87	991	84	852
Other[1]	262	1,956	268	2,025
Total	**392**	**4,493**	**[2]389**	**4,129**

[1] Includes Hawaii, Idaho, Kansas, and Oregon.
[2] Data do not add to total shown because of independent rounding.

TABLE 3

PUMICE AND PUMICITE SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY USE

(Thousand short tons and thousand dollars)

Use	1987 Quantity	1987 Value	1988 Quantity	1988 Value
Abrasives (includes cleaning and scouring compounds)	29	719	36	846
Concrete admixture and aggregate	122	622	144	739
Decorative building block	194	2,295	163	1,507
Landscaping	19	195	21	491
Other[1]	28	662	25	546
Total	**392**	**4,493**	**389**	**4,129**

[1] Includes pesticide carriers, road construction material, roofing granules, and miscellaneous uses.

PRICES

The average value, f.o.b. mine or mill, for domestic pumice and pumicite sold and used was $10.61 per ton, a 7% decrease compared with the 1987 value.

Prices quoted in Chemical Marketing Reporter for domestic grades of pumice were lower than 1987 prices. Bagged in 1-ton lots 1987 prices for pumice were, at yearend, $220 per ton for fine and $260 per ton for medium, coarse, and 2-extra coarse, compared with $270 and $300 per ton respectively the previous year. Yearend quoted prices on imported (Italian) pumice, f.o.b. east coast, bagged in 1-ton lots, were $500 per ton for fine, $700 per ton for medium, and $600 per ton for coarse. These prices represented a substantial increase over 1987 prices per ton of $280, $350, and $360, respectively.

The average declared customs value of pumice imported from Greece for use in concrete masonry products was $8.27 per ton, a slight decrease from the 1987 value.

FOREIGN TRADE

Pumice imported for consumption increased 24% compared with that of 1987. Pumice imports for use in concrete masonry products increased 20% in quantity and value compared with 1987 data. Greece with 86% was the principal source of imported pumice, followed by Mexico and Turkey.

[1] Industry economist, Branch of Industrial Minerals.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF PUMICE, BY CLASS AND COUNTRY

Country	Crude or unmanufactured		Wholly or partly manufactured		For use in the manufacture of concrete masonry products		Manu-factured, n.s.p.f.
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Value (thousands)
1987:							
Ecuador	—	—	—	—	1,588	$83	—
Greece	2,402	$449	170	$51	222,048	1,957	$155
Guatemala	3,762	301	264	22	—	—	6
Iceland	332	81	—	—	—	—	—
Italy	42	19	632	201	22,050	235	189
Mexico	7,536	899	—	—	7,051	589	81
Turkey	2,906	512	41	14	683	127	8
Other[1]	373	153	94	92	173	9	460
Total	**17,353**	**2,414**	**1,201**	**380**	**253,593**	**3,000**	**899**
1988:							
Ecuador	—	—	—	—	5,399	255	—
Greece	4,428	630	64	14	286,475	2,370	—
Guatemala	2,442	454	555	124	55	1	7
Italy	166	54	1,391	444	—	—	31
Mexico	19,251	2,495	—	—	55	8	3
Spain	1,025	93	—	—	—	—	72
Turkey	3,099	587	22	2	12,042	967	2
Other[2]	311	73	48	47	—	—	589
Total	**30,722**	**4,386**	**2,080**	**631**	**304,026**	**3,601**	**704**

[1] Includes Australia, Brazil, Canada, France, the Federal Republic of Germany, Indonesia, Japan, the Republic of Korea, the Netherlands, Norway, Singapore, Spain, Taiwan, and the United Kingdom.
[2] Includes Australia, Austria, Canada, China, France, the Federal Republic of Germany, Iceland, Indonesia, Japan, the Republic of Korea, Norway, Sweden, Taiwan, Thailand, the United Kingdom, and Venezuela.

Source: Bureau of the Census.

TABLE 5

PUMICE AND RELATED VOLCANIC MATERIALS: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina[3]	60	[r]49	25	43	47
Austria: Trass	11	8	6	8	7
Cameroon: Pozzolan	NA	116	186	[e]190	190
Cape Verde Islands: Pozzolan[e]	11	11	11	11	11
Chile: Pozzolan	190	227	245	267	275
Costa Rica[e]	2	2	2	[4]7	7
Dominica: Pumice and volcanic ash[e]	120	120	120	110	110
France: Pozzolan and lapilli	551	547	452	[e]500	500
Germany, Federal Republic of: Pumice (marketable)	386	228	237	226	220
Greece:					
Pumice	691	684	684	[e]690	690
Pozzolan	1,001	1,034	1,053	[e]1,040	1,050
Guadeloupe: Pozzolan[e]	275	240	244	243	240
Guatemala:					
Pumice	[e]15	[r]18	13	17	17
Volcanic ash	([5])	—	—	—	—
Iceland	61	62	58	[e]55	55
Italy:[e]					
Pumice and pumiceous lapilli	[4]995	825	770	800	800
Pozzolan	[4]6,296	5,500	5,000	5,500	5,500
Martinique: Pumice[e]	150	165	155	145	145
New Zealand[e]	[4]17	22	22	17	22
Spain[6]	915	936	1,067	[e]1,050	1,050
Turkey[e]	1	2	3	110	120
United States (sold and used by producers)	502	508	554	392	[4]389
Yugoslavia: Volcanic tuff	[r]562	562	425	467	500
Total	**[r]12,812**	**[r]11,866**	**11,332**	**11,888**	**11,945**

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through May 17, 1989.
[2]Pumice and related volcanic materials are also produced in a number of other countries, including (but not limited to) Ethiopia, Iran, Japan, Mexico, and the U.S.S.R., but output is not reported quantatively, and available information is inadequate for the formulation of reliable estimates of output levels.
[3]Unspecified volcanic materials produced mainly for use in construction products.
[4]Reported figure.
[5]Revised to zero.
[6]Includes Canary Islands.

QUARTZ CRYSTAL, STRONTIUM, WOLLASTONITE, AND ZEOLITES

By Joyce A. Ober, Michael J. Potter, and Robert L. Virta

QUARTZ CRYSTAL[1]

Cultured quartz crystal production and consumption increased in 1988 for the second consecutive year, although consumption of domestic lascas as feedstock for cultured quartz crystal decreased. The single domestic producer of lascas resumed mining and also supplied material to consumers from company stocks. Imports of lascas from Brazil increased. Demand for specimen-quality natural quartz continued at a high level; quartz crystal for this application is discussed in the Gem Stone chapter.

Domestic Data Coverage

Domestic production and consumption data for quartz crystal are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the seven companies canvassed for the production of cultured quartz crystal, all responded, and the six active operations represented 100% of total production shown in table 1. Of the 34 operations canvassed concerning consumption of quartz crystal, 30 responded, 2 of which were not active. These companies represented nearly 100% of total consumption, also shown in table 1. Consumption for the nonrespondents was estimated using reported prior-year consumption levels.

Legislation and Government Programs

The National Defense Stockpile contained 1.8 million pounds of natural quartz crystal, valued at $11 million. This quantity represented an excess of 1.2 million pounds above the goal set for the stockpile. Near yearend, authority for disposal of this excess was established, and studies were being conducted to evaluate the impact of releasing the surplus stocks into the market. The stockpile material, which primarily consists of large natural crystals, could be absorbed by the specimen and gem material industry. Very little, if any, of the material would be consumed in the same applications as synthetic quartz crystal.

Domestic Production

Coleman Quartz Inc., Jessieville, AR, the only domestic company known to produce lascas, supplied the feed material for cultured quartz crystal from mine production and from company stocks.

Production of cultured quartz crystal increased slightly in 1988. Six companies were active. The two largest producers, Sawyer Research Products Inc. of Eastlake, OH, and Thermo Dynamics Corp. of Merriam, KS, were independent growers that produced crystal bars for domestic and foreign consumers in the crystal device fabrication industry. Motorola Inc. of Chicago, IL, and Electro Dynamics Corp. of Overland Park, KS, produced quartz crystal for both internal consumption and the domestic device fabrication industry. P. R. Hoffman Material Processing Co. of Carlyle, PA, also reported outside sales. Bliley Electric Co. of Erie, PA, produced only for internal consumption.

Consumption and Uses

Consumption of lascas by the six domestic quartz crystal producers decreased about 10%, from 1.1 million pounds in 1987 to 1.0 million pounds in 1988. The 32 active device fabricating

TABLE 1

SALIENT U.S. ELECTRONIC- AND OPTICAL-GRADE QUARTZ CRYSTAL STATISTICS

(Thousand pounds and thousand dollars)

	1984	1985	1986	1987	1988
Production:					
Mine[e] [1]	2,500	1,000	1,200	—	600
Cultured	1,027	568	524	840	857
Exports:					
Natural:[2]					
Quantity	42	60	74	139	95
Value	$234	$290	$411	$708	$431
Cultured:[2]					
Quantity	277	185	324	448	417
Value	$11,021	$3,723	$5,686	$6,954	$7,162
Lascas:					
Quantity[e]	1,600	800	—	—	—
Imports of lascas:[3]					
Quantity	569	173	52	146	215
Value	$373	$99	$51	$157	$180
Consumption:					
Natural (electronic and optical-grade)	7	7	2	([4])	3
Cultured (lumbered)	77	44	43	55	62
Cultured (as grown)	391	224	428	552	646
Total	**475**	**275**	**473**	**607**	**711**

[e] Estimated.
[1] Excludes lascas produced for specimen and jewelry material uses.
[2] Bureau of the Census as adjusted by the Bureau of Mines.
[3] Bureau of the Census.
[4] Less than 1/2 unit.

companies in 11 States consumed 17% more quartz crystal in 1988 than in 1987. Of these companies, 30 consumed only cultured quartz crystal and 1 consumed both natural and cultured crystal. One company consumed only natural quartz crystal.

A small amount of imported natural quartz crystal continued to be required as seed material for growing cultured quartz. Cultured quartz crystal was used to make very accurate electronic timing devices. The crystals can be found in watches and clocks; in microprocessors in industrial, automotive, and consumer products; and in military, aerospace, and commercial electronic devices requiring very high selectivity and stability.

Stocks

Crystal growers' stocks of as-grown cultured quartz crystal were reported as 188,000 pounds at the beginning of 1988. At yearend, these stocks had decreased to 111,000 pounds.

Prices

The price for domestic lascas reported by Coleman Quartz was $0.40 per pound. The customs value of Brazilian lascas increased 33% to $1.26 per pound. Material from Namibia that was used for feedstock was imported as quartzite rather than lascas, and the customs value was $0.29 per pound. The average value of as-grown cultured quartz, based on reported sales of about 615,000 pounds, was $8.77 per pound, a decrease of 31% compared with that of 1987. Sales volume increased 21%. The average value of lumbered quartz, as-grown quartz that has been processed by sawing and grinding, decreased 6% to $54.53 per pound, based on reported sales of 140,000 pounds. Sales volume increased 18%.

Foreign Trade

Cultured quartz crystal exports, as reported by the Bureau of the Census, decreased 7% in 1988 to 416,974 pounds. The average f.a.s. value was $17.18 per pound, an 11% increase compared with exports in 1987. The Republic of Korea was the largest customer for this material, accounting for 208,582 pounds or 50% of cultured quartz crystal exports from the United States. The destination for 95,258 pounds, 23% of exported U.S. cultured quartz crystal, was Japan.

Imports of feedstock material including Brazilian lascas, designated as "Crude Brazilian Pebble," and quartzite from Namibia, both of which are used as feedstock for the domestic synthetic producers, increased 47% to 215,255 pounds with a customs value of $180,095.

STRONTIUM[2]

Demand for strontium minerals and compounds increased for the second consecutive year. Imports of celestite, a strontium ore consisting of at least 90% strontium sulfate, increased, indicating expanded domestic production of strontium compounds. Imports of most strontium compounds also grew. Chemical Products Corp. (CPC) of Cartersville, GA, was the only U.S. producer of strontium compounds from celestite. CPC produced compounds from imported material because there were no active celestite mines in the United States.

Domestic Data Coverage

Domestic production data for strontium are voluntarily provided to the Bureau of Mines by the sole U.S. producer. Production and stock data are withheld from publication to avoid disclosing company proprietary data.

The Bureau also calculates the distribution of strontium compounds by end use. Of the 10 operations to which a survey request was sent, 8 responded. The information collected from this survey represents nearly 100% of the end-use data shown in table 2. Consumption for the nonrespondents was estimated using reported prior-year consumption levels.

Domestic Production

CPC was the only domestic producer of strontium carbonate and strontium nitrate from imported celestite. Mallinckrodt Inc. of St. Louis, MO, produced strontium chloride and Mineral Pigments Corp. of Beltsville, MD, produced strontium chromate. A few other companies produced downstream strontium compounds but on a very small scale.

Consumption and Uses

The largest end use for strontium was in the manufacture of faceplate glass for color television picture tubes. Strontium, which is supplied as strontium carbonate and converted to strontium oxide during the manufacturing process, blocks X-ray emissions from the picture tube during operation of the television set. Strontium carbonate demand for this end use continued to be high. About two-thirds of all domestic strontium consumption is in television picture tube production.

Another expanding end use for strontium is strontium ferrites. These compounds are produced by heating a mixture of strontium carbonate and iron oxide. The resulting material is formed into permanent ceramic magnets that are used in fractional horsepower motors for automobile accessories, loudspeakers, computers, and other electronic equipment.

Use of strontium nitrate in pyrotechnics and signals was considered to be a mature but steady market. Strontium nitrate creates a brilliant red flame when it burns.

Smaller amounts of strontium compounds are used in a variety of applications. Strontium carbonate was used to remove lead from electrolytically refined zinc. Strontium chromate was used as a corrosion inhibitor in pigments and paint, strontium phosphate was used in fluorescent lights, and strontium chloride was an active ingredient in toothpaste for sensitive teeth. Strontium metal was used to improve castability of aluminum for use in the automobile industry. Strontium oxide was one of the materials used in high-temperature superconductor research.

Prices

The average customs value for celestite imported from Mexico was about $70 per short ton. Ore imported from Spain had a customs value of $172 per ton. Very small amounts of celestite were reported from France and the Federal Republic of Germany. The weighted average value for all imported strontium minerals was about $77 per ton. This value represented a decrease of about 10% from the average customs value reported for 1987. Values of imported strontium compounds varied according to the type of compound and the country of origin.

Foreign Trade

According to the Journal of Commerce Port Import/Export Reporting Service, U.S. exports of strontium compounds were about 6,500 tons, an increase of 86% over the exports reported in 1987. Of these exports, 89% was strontium carbonate that went to Japan, the world's leading consumer of strontium compounds. Other strontium compounds exported were chromate, ferrite, nitrate, oxalate, and phosphate, all in relatively small quantities.

According to the Bureau of the Census, the Federal Republic of Germany remained the most important source of imported strontium compounds, with Mexico nearly as important. Imports of strontium carbonate, precipitated and not precipitated, increased about 88%, with imports from Mexico more than three times the level reported in 1987. Imports of strontium nitrate decreased about 71%, the second consecutive year with significant decreases in imports. Canada, was once again the major supplier of strontium metal, although imports decreased about 8%.

World Capacity

The data in table 5 are annual rated capacity for chemical processing plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Two types of strontium capacity exist, ore production capacity and compound production capacity. Strontium compound capacity was deemed the more important for several reasons. Essentially all strontium is consumed in compound form, primarily as the carbonate and to a lesser extent as the nitrate. Strontium carbonate is also the intermediate product in production of downstream compounds. At least 12 countries mined celestite in 1988. Virtually all of the celestite mined annually is consumed in the production of strontium carbonate and other strontium compounds. Very little strontium was consumed directly in the mineral form.

Listing both ore and compound production capacity could be misleading, possibly resulting in double-counting of strontium capacity. Because most ore is produced for market by means of very simple sorting and beneficiation techniques, capacity can easily be raised to meet increased demand. Strontium carbonate production capacity is the limiting factor in strontium production, requiring complicated and sophisticated processing facilities. Therefore, stron-

TABLE 2

U.S. ESTIMATED DISTRIBUTION OF PRIMARY STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	1986	1987	1988
Electrolytic production of zinc	6	5	4
Ferrite ceramic magnets	11	11	11
Pigments and fillers	7	5	4
Pyrotechnics and signals	12	13	10
Television picture tubes	60	63	68
Other	4	3	3
Total	**100**	**100**	**100**

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM MINERALS,[1] BY COUNTRY

Country	1987		1988	
	Quantity (short tons)	Value[2] (thousands)	Quantity (short tons)	Value[2] (thousands)
China	297	$34	—	—
France	—	—	33	$9
Germany, Federal Republic of	—	—	37	29
Mexico	42,172	3,636	42,639	2,988
Spain	—	—	2,753	476
Total	**42,469**	**3,670**	**45,462**	**3,502**

[1] Celestite (strontium sulfate).
[2] Customs value.

Source: Bureau of the Census.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS AND METAL, BY COUNTRY

Country	1987 Pounds	1987 Value[1]	1988 Pounds	1988 Value[1]
Strontium carbonate, not precipitated:				
Germany, Federal Republic of	—	—	—	—
Mexico	44,092	$10,948	—	—
Spain	34,172	1,875	—	—
Total	**78,264**	**12,823**	**—**	**—**
Strontium carbonate, precipitated:				
Canada	—	—	39,683	$11,176
Germany, Federal Republic of	10,120,618	2,771,119	13,765,104	3,831,489
Italy	—	—	6,636	5,280
Japan	11,670	7,822	18,166	29,769
Mexico	4,263,566	1,139,916	13,332,424	3,122,012
United Kingdom	41,798	24,693	28,633	22,541
Total	**14,437,652**	**3,943,550**	**27,190,646**	**7,022,267**
Strontium chromate:[2]				
Australia	—	—	5,093	13,365
Belgium	21,826	23,760	54,275	83,080
Canada	29,765	41,509	14,000	17,923
France	160,932	186,625	138,889	181,945
Germany, Federal Republic of	39,684	44,843	39,600	44,748
Korea, Republic of	—	—	16,196	19,804
United Kingdom	10,400	10,776	—	—
Total	**262,607**	**307,513**	**268,053**	**360,865**
Strontium nitrate:				
Germany, Federal Republic of	1,357	8,220	—	—
Italy	1,183,671	455,589	272,076	175,028
Mexico	2,205	2,000	54,361	22,755
Spain	481,708	206,218	160,275	73,050
Total	**1,668,941**	**672,027**	**486,712**	**270,833**
Strontium compounds, other:				
Canada	3,489	31,956	93	1,284
France	—	—	97,369	158,334
Germany, Federal Republic of	6,614	8,129	53,127	132,519
Italy	—	—	2,633	1,169
Japan	546,742	1,206,432	495,057	457,535
Netherlands	148,546	150,299	40	4,680
United Kingdom	31,838	53,800	105,563	176,746
Total	**737,229**	**1,450,616**	**753,882**	**932,267**
Strontium salts (potassium oxalate and other):				
Belgium	—	—	2,772	7,000
Canada	—	—	44,533	7,960
China	37,478	1,253	—	—
Germany, Federal Republic of	6,614	7,891	—	—

See footnotes at end of table.

tium carbonate production capacity, reported in terms of contained strontium, was selected for tabulation.

Capacity data for the United States was estimated based on celestite imports, and assuming an 85% recovery of strontium from celestite containing a minimum ore grade of 90% strontium sulfate. Capacity information for other countries was compiled from published reports.

World Review

Corning Glass Works of the United States announced a joint venture with Asahi Glass Co. Ltd. of Japan to produce color television faceplate glass in Europe, Mexico, and the United States. Both companies are leaders in faceplate glass production and planned to share their technology. The glass manufactured as a result of this venture will require large quantities of strontium carbonate, thus further increasing global demand for this application.[3]

China.—The largest ore-dressing plant in China, with a capacity to produce 11,000 tons per year of celestite concentrate, was completed at the Nanjing strontium mine in the Jiang Su Province. Operations at the mine began in 1972 and the capacity expansion began in 1985. The goal of the project was to improve strontium recovery by modernizing the processing facility, as well as to increase production.[4]

Mexico.—Cía. Minera La Valenciana S.A. converted its strontium carbonate facilities to the black ash process from the soda ash process. The black ash process is capable of producing a higher quality strontium carbonate product. The company was also installing another kiln that would increase carbonate production capacity to about 24,000 tons per year when completed.[5] Sales y Oxidos, owned 51% by Mexican business interests and 49% by Church and Dwight Co. Inc. of Princeton, NJ, planned to double the strontium carbonate capacity at its facility

TABLE 4—Continued

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS AND METAL, BY COUNTRY

Country	1987 Pounds	1987 Value[1]	1988 Pounds	1988 Value[1]
Japan	—	—	1,323	$4,570
Switzerland	—	—	2,205	5,513
Total	**44,092**	**$9,144**	**50,833**	**25,043**
Strontium sulfate (other than celestite):				
Canada	—	—	42,000	2,843
Denmark	1	4,000	—	—
Germany, Federal Republic of	2,696,297	157,939	—	—
Total	**2,696,298**	**161,939**	**42,000**	**2,843**
Strontium metal, unwrought:				
Canada	82,724	747,805	75,711	694,973
Mexico	—	—	235	4,009
United Kingdom	11	1,131	—	—
Total	**82,735**	**748,936**	**75,946**	**698,982**

[1] Customs value.
[2] Imported as strontium chromate pigment (TSUS 473.19).
Source: Bureau of the Census.

TABLE 5

WORLD STRONTIUM CARBONATE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Short tons of contained strontium)

Country	Rated capacity[1]
North America:	
Mexico	12,500
United States[e 2 3]	15,000
Total	**27,500**
Europe:	
Germany, Federal Republic of[2]	9,800
Spain	5,200
U.S.S.R.	([4])
United Kingdom	([4])
Total	**15,000**
Asia:	
China	1,200
Japan[2]	20,000
Total	**21,200**
World total	**63,700**

[e] Estimated.
[1] Includes capacity at operating plants as well as plants on a standby basis.
[2] Production was entirely from imported celestite.
[3] Includes strontium nitrate production capacity.
[4] Strontium carbonate production capacity existed in these countries, but specific data were not available.

near Monterrey. The company was operating at capacity and produced about 8,000 tons of carbonate for export to Japan, the United States, and Europe, in decreasing order of importance.[6]

Spain.—The Aurora Mine, operated at the Montevive celestite deposit in the Province of Granada, was jointly owned by three families. Canteras Industriales S.A. mined celestite ore at this site using hand-sorting for beneficiation. The owners announced plans to install a mechanical washer that will raise the ore production capacity to 66,000 tons per year. Most of the production from this mine is exported to Japan and the Republic of Korea.[7]

Technology

Developments in high-definition television (HDTV) technology along with trends to larger, flatter picture tubes indicated that demand for strontium carbonate in these applications will continue to increase. One strontium producer suggested that the move toward HDTV prompted plans to increase celestite production capacity and to install additional strontium carbonate capacity.[8]

Research continued in the attempt to identify the best material or combination of materials for high-temperature superconductors. Superconductors lose all resistance to electricity at low temperatures, creating the potential for extremely efficient power transmission. New combinations of materials were discovered that possessed superconducting properties at temperatures higher than previously believed possible. High-purity strontium oxide was one superconducting compound mentioned in several research reports. It may be years, however, before the full benefits of high-temperature superconductors are fully realized.[9]

General Electric Co. of Schenectady, NY, developed a ceramic composite consisting of a matrix of strontium aluminum silicate with silicon carbide whisker and particulate reinforcement. The new composite material compared favorably with sintered and hot-pressed ceramics. Although it was not as strong as some forms of silicon carbide nor as resistant to high temperatures as alumina, it was shown to be more oxidation and corrosion resistant than carbides and more resistent to thermal shock than alumina. The improved process for forming the strontium aluminum silicate composite simplified the fabrication of complex shapes, required less energy, and thus cost less to manufacture than more traditional ceramics. The new composite may be useful in a wide variety of structural ceramic components employed at temperatures up to 1,000° C.[10]

TABLE 6

STRONTIUM MINERALS: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria[e]	6,000	6,000	6,000	6,000	6,000
Argentina	441	1,084	1,249	1,113	1,100
Cyprus (celestite)	—	1,543	8,119	6,945	5,500
Iran (celestite)[3]	[r]25,353	[r]22,046	24,251	[e]24,250	24,250
Italy	2,866	5,083	5,144	195	110
Mexico (celestite)	35,264	[r]35,627	26,502	52,623	49,600
Pakistan	622	791	1,099	1,194	1,200
Spain	[r]27,381	[r]43,101	38,030	[r,e]44,100	44,100
Turkey[e]	38,600	38,600	38,600	38,600	[4]59,525
United Kingdom	[r]17,724	[r]25,396	16,247	24,973	19,800
Total	**[r]154,251**	**[r]179,271**	**165,241**	**199,993**	**211,185**

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through June 7, 1989.

[2]In addition to the countries listed, China, Poland, and the U.S.S.R. produce strontium minerals, but output is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.

[3]Data are for year beginning Mar. 21 of that stated.

[4]Reported figure.

WOLLASTONITE[11]

Wollastonite is natural calcium silicate and has a theoretical composition of $CaO \cdot SiO_2$.

The tonnage of wollastonite sold or used by U.S. producers in 1988 increased slightly. Specific data were withheld to avoid disclosing company proprietary data. The two producers were NYCO, a division of Processed Minerals Inc., Essex County, NY, and R. T. Vanderbilt Co. Inc., Lewis County, NY.

Wollastonite is used as a filler in ceramic tile, paint, and plastics. It serves as an asbestos replacement in some applications such as a reinforcement filler for boards and panels in various heat containment applications including ovens, dryers, thermal ducting, and many other thermal applications. Wollastonite also replaces asbestos in certain cement formulations, in ceiling and floor tile, and in friction applications such as brake linings. NYCO introduced G-Wollastokup, a high-aspect-ratio reinforcement, which is a chemically modified wollastonite that can be a total or partial replacement for chopped and milled fiberglass up to ⅜-inch long.[12]

Prices from Industrial Minerals, December 1988, for wollastonite, ex-works, truck lots, per short ton, were \$214 for acicular, minus 200 mesh, and \$140 to \$160 for 325 to 400 mesh. Prices per short ton for wollastonite, f.o.b. plant, 200 to 325 mesh, were \$92 to \$137 bulk and \$110 to \$155 bagged materials.

Alpine AG opened an extensive test center at its existing plant in Augsburg, Federal Republic of Germany. The center contained numerous machines and systems for mechanical process technology, including size reduction, air classification, sorting, and mixing. The test center was designed for applications testing in a variety of industries including minerals. Of particular interest to the minerals industry is testing of fluidized-bed, opposed-jet mills, Circoplex classifier mills, and Turboplex ultrafine classifiers for wollastonite and other industrial minerals.[13]

In Greece, successful drilling and benefication research were carried out by Mevior S.A. on a wollastonite deposit near Kimmeria. Proven reserves so far were about 500,000 tons of ore with approximately 50% recoverable wollastonite. Initial beneficiation tests with wet, high-intensity magnetic separation after flotation yielded 0.3% iron oxide, making the product suitable for the ceramics industry. The company planned to continue exploration drilling and build a pilot plant in 1988.[14]

Although wollastonite deposits occur in the States of Chihuahua, Morelos, Puebla, and Zacatecas in Mexico, the only production was in Zacatecas. Most of the output, ranging from 10,000 tons to 15,000 tons per year, was consumed domestically by the ceramics industry. Wollastonita de México S.A. mined material in La Blanca, and General de Minerales S.A. extracted wollastonite from two open pit operations at Santa Fe and Panfilo Natura, both 30 to 35 miles from Guadalupe, Zacatecas. Ore was processed at the company's Guadalupe plant to produce 3-inch, 0.5-inch, 0.25-inch, and 200-mesh products for use in ceramics.[15]

Synthetic wollastonite was one of the lime-containing minerals produced by Rheinische Kalksteinwerke GmbH in Wulfrath, Federal Republic of Germany. These minerals are characterized by analytical purity, low compositional variance, and modest loss on ignition. However, synthetic wollastonite cannot substitute for natural wollastonite when long-grain structure is important, such as in filler applications and asbestos replacement.

Feedstock for synthetic wollastonite contained mixtures of lime-containing raw materials such as calcium carbonate, calcium hydrate, and quicklime. These were mixed with quartz and fired in a kiln at 2,640° F or higher. Low-iron and extremely low-iron wollastonites were produced. Ceramic end uses included white glazes, earthenware, and vitrified, or glassy, bodies. Other applications were in welding powders and in casting powders for steelmaking, which are important in regulating the cast speed and surface condition of continuous-cast steel.[16]

ZEOLITES[17]

Seven companies mined and sold chabazite and clinoptilolite from deposits in five States. Production and sales were approximately 12,000 short tons. Natural zeolites were used for air purification, animal feed supplements, aquaculture, aquarium filters, chemical carriers, desiccants, pet litter, and wastewater cleanup.

The Bureau of Mines continued research on the use of zeolites to remove dissolved metals and other cations from waste and process water. The cation exchange capacities for Pb^{2+} were determined for clinoptilolite, erionite, mordenite, and phillipsite samples from 19 locations. Exchange capacities ranged from 0.4 to 2.1 milliequivalents per gram. Capacities were lower than predicted because of impurities in the zeolite structure or blockage of pores by foreign materials. Exchange capacities for other cations were determined for two of the clinoptilolite samples. The order of preferential adsorption was Pb^{2+}, K^+, Ca^{2+}, NH_4^+, Cd^{2+}, Cu^{2+}, Co^{2+}, Zn^{2+}, Ni^{2+}, and Hg^{2+}. Pretreatment of industrial wastewaters to remove calcium, which decreases a zeolite's capacity for heavy metals, also was investigated. Simulated tailing water was treated with soda ash. Pretreatment reduced the Ca^{2+} concentration from 390 parts per million to less than 8. Soda ash rather than lime was used to avoid introducing additional calcium into solution.

The stability of chabazite, clinoptilolite, erionite, and mordenite, which is important if they are to be used to remove heavy metals from acidic mine drainage or acidic industrial wastes, was investigated. The order of stability of the zeolites tested in acidic solutions (from pH of 0.75 to 5) was mordenite, clinoptilolite, erionite, and chabazite. Additional tests on the erionite sample indicated that the acidic solutions removed significant amounts of Na^+ and Si^{4+} and smaller amounts of K^+, Fe^{n+}, Al^{3+}, and Ca^{2+} from the zeolite structure.[18]

Ammonium and zinc ions (NH_4^+ and Zn^{2+}) are present in municipal wastewater and it is necessary to remove NH_4^+ to avoid pollution of the ground water. The effectiveness of clinoptilolite and mordenite for removing NH_4^+ from dilute solutions containing Zn^{2+} was investigated. Mordenite and clinoptilolite removed 2 to 10 times more NH_4^+ than Zn^{2+} from dilute solutions containing 2 to 7 milliequivalents per liter. Mordenite had a larger cation exchange capacity for NH_4^+ than clinoptilolite. The exchange capacities for Zn^{2+} were similar for both zeolites. Absorption of NH_4^+ was not affected by the presence of Zn^{2+} in solution but Zn^{2+} absorption was lower when NH_4^+ was present.[19]

A mineral additive consisting of approximately 60% clinoptilolite and mordenite (FMA) was investigated as a means of producing super-high-strength concrete. A 9:1 ratio of cement and FMA produced concrete having a higher compressive strength than concrete made with either a portland cement, a cement and fly-ash mixture, or a cement and slag powder mixture. Mixtures of cement and FMA in ratios ranging from 19:1 to 6:1 produced concrete with higher compressive strengths than concrete containing only portland cement. Water-reducing agents were recommended to improve the strengthening effect of FMA. Concrete strength improved because the FMA reduced the formation of calcium hydroxide and decreased the number of pores exceeding 1,000 angstroms in width.[20]

A photochemical technique was used to investigate chemical reactions that occur on the surface and within the crystal structure of faujasite and a pentasil zeolite. The zeolites were treated with organic chemicals and then irradiated. The irradiation caused the chemicals to react, and the products were extracted and analyzed. By determining the ratio of the different reaction products, information on the reactions that occurred within the structure could be determined.[21]

Union Carbide Corp. developed a new molecular sieve that effectively adsorbs a variety of organic molecules including organic acids, aldehydes, ketones, mercaptans, ammonia, and indole without strongly adsorbing water. The molecular sieve is insoluble in water and organic solvents, cannot be oxidized, is chemically nonreactive in most systems, and is stable up to 800° C. Potential applications include personal-care items and household odor control.[22]

The growth in the use of synthetic zeolites in detergents, although not as rapid as in Europe, has doubled since 1986 in response to widening bans on phosphate use in detergents. The annual consumption rate was estimated to be 85,000 to 95,000 tons.[23]

A joint venture between PQ Corp. and Shell Polymers and Catalysts Enterprises Inc. was formed to manufacture and sell zeolite catalysts. The zeolites will be synthesized at the PQ facility in Kansas City, KS.[24]

European zeolite consumption is increasing as detergent makers continue to replace phosphates with zeolites. The use of phosphates decreased because of public pressure to reduce water pollution. As a result, European zeolite producers planned new construction or began expansion of existing plants for synthesizing zeolites.[25]

A joint venture between Union Chimique Belge (UCB), Solvay et Cie. S.A. and Audiset S.p.A. was formed to renovate a UCB phosphoric acid facility. The refurbished facility will be capable of producing 44,000 tons per year of 4A zeolite. The zeolite will be sold primarily as a replacement for sodium tripolyphosphate in detergents. Solvay will supply the raw materials, UCB will provide the manufacturing facilities, and Audiset will market the zeolites.[26]

Conteka BV, a joint venture between Northern Development Co. and Conteka Holding, invested over $16 million to build a new manufacturing facility in the Netherlands. The facility will produce zeolites for catalytic applications by the oil, petrochemical and other industries. The plant is scheduled to begin operation in 1989.[27]

TG Birac of Yugoslavia planned to double its production capacity by yearend from 110,000 tons per year to 220,000 tons per year. The company installed new drying units and made other modifications to the plant to improve the production capacity. The company sells zeolites to the detergent industry.[28]

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RARE-EARTH MINERALS AND METALS

By James B. Hedrick and David A. Templeton[1]

Domestic production of rare-earth concentrates decreased in 1988. Foreign sources of processed rare earths obtained a slightly larger share of the U.S. market, while domestic exports saw a marked increase compared to 1987 levels. Molycorp Inc. and Associated Minerals (USA) Inc. were the only domestic mine producers of commercial quantities of rare-earth minerals. Rare earths were used in high-technology applications such as laser crystals, high-strength permanent magnets, optical fibers, magnetic resonance imaging (MRI) scanners, and high-temperature superconductors.

DOMESTIC DATA COVERAGE

Domestic mine production data for rare earths are developed by the Bureau of Mines from the voluntary "Rare-Earths, Thorium and Scandium" survey. Of the two mines to which a survey form was sent, one responded. Additional data were compiled from rare-earth and yttrium processors. Production data are withheld to avoid disclosing company proprietary data.

LEGISLATION AND GOVERNMENT PROGRAMS

On February 25, 1988, the President signed Executive Order 12616, designating the Secretary of Defense to be the manager of the National Defense Stockpile (NDS), which contained modest inventories of the rare earths.[2] The Secretary delegated management of the NDS to the Defense Logistics Agency.

On November 10, 1988, Public Law 100-647, the Technical and Miscellaneous Revenue Act of 1988, was signed. It extended through 1993 the suspension of an import tariff on yttrium ores, materials, and compounds, including yttrium concentrate.

ENVIRONMENTAL ISSUES

A bill (Senate bill 7) which would have closed 8.5 million acres of California desert to mining exploration and development, which was defeated during the 1988 session. The desert area involved has a high potential for economic mineral discovery. Besides the rare earths, minerals known to occur in the region include gold, iron, lead, magnesium, molybdenum, silver, talc, tungsten, and zinc. The proposed area is also bordered by one of the world's largest producers of rare earths, the Mountain Pass Mine. Additionally, only one-tenth of the area has been studied for its mineral potential.[3]

DOMESTIC PRODUCTION

Two mines produced rare earths in 1988, Molycorp's Mountain Pass Mine in California and Associated Minerals' Green Cove Springs Mine in Florida. The United States was the second largest producer of rare earths in the world.

Molycorp, Rhône-Poulenc Inc., W. R. Grace & Co.'s Davison Chemical Div., and Research Chemicals Div. of Rhône-Poulenc were the principal processors of rare earths in the United States.

Molycorp was the only domestic producer of the mineral bastnasite, a rare-earth fluocarbonate. Production of bastnasite concentrates decreased substantially in 1988 but remained the

TABLE 1

SALIENT U.S. RARE EARTH STATISTICS

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

	1984	1985	1986	1987	1988
Production of rare-earth concentrates[1]	25,311	13,428	11,094	16,710	11,533
Exports:[e]					
Ore and concentrate	4,304	4,419	3,433	4,534	7,358
Ferrocerium and pyrophoric alloys	27	23	29	82	36
Imports for consumption:[e]					
Monazite	3,114	3,132	1,628	617	1,058
Metals, alloys, oxides, compounds	2,926	1,124	1,155	625	509
Stocks, Dec. 31: Producers and processors	W	W	W	W	W
Consumption, apparent[e]	21,400	12,100	11,800	9,400	8,800
Prices, Dec. 31: Dollars per kilogram:					
Bastnasite concentrate, REO basis	$2.14	$2.14	$2.14	$2.31	$2.43
Monazite concentrate, REO basis	$0.64	$1.09	$1.06	$0.90	$1.15
Mischmetal, metal basis	$12.35	$12.35	$12.35	$12.35	$12.35
Employment, mine and mill[e 2]	321	330	283	299	320
Net import reliance[e 3] as a percent of apparent consumption	([4])	([4])	5.94	([4])	([4])

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Comprises only the rare earths derived from bastnasite, as reported in Unocal Corp. annual reports.
[2]Employment at a rare-earth mine in California and at mineral sands operation in Florida. The latter mine produced monazite concentrate as a byproduct of mining ilmenite, rutile, and zircon, and employees were not assigned to specific commodities.
[3]Imports minus exports plus adjustments for Government and industry stock changes.
[4]Increase in industry stocks exceeded net imports.

principal source of rare earths in the United States. Molycorp reported an increase in sales of almost all refined rare earth and yttrium products, with the strongest demand coming from the magnet and electronic industries. As part of its continuing modernization and expansion program, Molycorp completed installation of new facilities to produce high-purity cerium oxide and neodymium oxide at Mountain Pass, CA. Additional capacity to produce erbium came on-line at Molycorp's Louviers, CO, plant. Further expansions, scheduled for completion in 1989, are an extraction circuit to separate dysprosium at Louviers and an expansion of capacity to produce rare-earth metals at Washington, PA.[4]

Australian-owned Associated Minerals was the only commercial minerals sands operation in the United States to recover monazite, a rare-earth phosphate mineral. Monazite was recovered at Associated Minerals' Florida operations as a byproduct of processing heavy-minerals sands for the titanium minerals ilmenite, rutile, and leucoxene, and for the zirconium mineral zircon. An auxiliary dry plant was set up in 1988 at Green Cove Springs to recover monazite and zircon from previously produced mineral sands tailings to meet increased demand for the products.

Rhône-Poulenc, in an effort to move into the rare-earth metal and alloy market, acquired the Research Chemicals Div. of Nucor Corp., Phoenix, AZ. The acquisition provided Rhône-Poulenc with the capacity to produce a complete range of rare-earth products, including metals, alloys, and compounds. Research Chemicals continued to expand its metal and alloy production capabilities by installing two alloy furnaces during the year.

CONSUMPTION AND USES

Domestic rare-earth processors consumed an estimated 8,800 metric tons of equivalent rare-earth oxides (REO) in various forms in 1988, 6% less than was consumed in 1987.

The glass industry's principal use of rare earths, mainly cerium concentrate or cerium oxide, was as polishing compounds for lenses, mirrors, cut crystal, television and cathode-ray tube (CRT) faceplates, gem stones, and plate glass. Purified rare-earth compounds were also used as additives to glass used in containers, television and CRT faceplates, radiation shielding windows, ophthalmic lenses, lasers, incandescent and fluorescent lights, and optical, photochromic, filter, and photographic lenses. The rare-earth additives acted as colorants, color correctors, and decolorizers, as stabilizers against discoloration from ultraviolet light and against browning caused by high-energy radiation, as dopants in laser glass, as modifiers to increase the refractive indices and decrease dispersion, and as absorbers of ultraviolet and visible light.

Phosphors containing rare earths were used in CRT's for color televisions, radar screens, avionic and data displays, X-ray intensifying screens, low- and high-pressure mercury vapor lights, electronic thermometers, and trichromatic fluorescent lamps.

The ceramics industry used purified rare earths in pigments, heating elements, dielectric and conductive ceramics, thermal and/or flash protective devices, stereoviewing systems, data printers, image storage devices, and as principal constituents and stabilizers in high-temperature refractories such as yttria-stabilized zirconia.

Purified rare-earth compounds also had applications in petroleum fluid cracking catalysts, other catalysts, oxygen-sensor electrolytes, computer bubble-domain memories, dyes and softeners for textiles, electronic components, nuclear fuel reprocessing, microwave applications, gas mantles, laser crystals, fiber optics, carbon arc lighting, synthetic gem stones, and superconductors.

Rare-earth permanent magnets were used in electric motors, alternators, generators, line printers, computer disk-drive actuators, proton linear accelerators, synchronous torque couples, eddy current brakes, microwave focusing, magnetrons, klystrons, medical and dental applications including nuclear (MRI), traveling wave tubes, metallic separators, aerospace applications including electric actuators for ailerons and rudders, and in speakers, headphones, microphones, and tape drives.

Metallurgical applications of rare earths included alloys and additives in high-strength low-alloy steels, gray and ductile iron, stainless and carbon steels, high-temperature and corrosion-resistant metals, hydrogen storage alloys used in heat exchangers and fuel cells, lighter flints, armaments, permanent magnets, neutron converter foils, special lead fuses, target materials for sealed-tube neutron generators, and high-voltage transmission cable.

STOCKS

U.S. Government stocks of rare earths in the NDS, all classified as excess to goal, remained at 457 tons throughout 1988. Rare-earth stocks held in the stockpile were contained in sodium sulfate and were inventoried on a contained-REO basis.

Industry stocks of rare-earth ores and concentrates held by six producing, processing, and consuming companies increased 28%. Bastnasite stocks held by the principal producer and four other processors increased 167% over the 1987 level. Yearend stocks of monazite increased 10%, while stocks of yttrium concentrates increased 21%.

Stocks of other rare-earth concentrates fell 86%. Stocks of mixed rare-earth compounds increased 23%, while stocks of purified compounds, mostly separated REO's, increased 17%. Yearend stocks of mischmetal, rare-earth silicide, and other alloys contain ing rare earths were down 96%, while inventories of high-purity rare-earth metals were off 82%.

PRICES

The price range of Australian monazite (minimum 55% REO including thoria, f.o.b./f.i.d.),[5] as quoted in Australian dollars (A$),[6] increased from A$660 to A$710 per ton at yearend 1987 to A$700 to A$780 per ton by yearend 1988. The U.S. price range, converted from Australian dollars, increased from $477 to $513 in 1987 to $598 to $666[7] in 1988. The average declared value of imported monazite increased in 1988 to $600 per ton, up $40 from the 1987 value.

The yearend price quoted in Industrial Minerals (London) for yttrium concentrate (60% Y_2O_3, f.o.b. Malaysia) was $32 to $33 per kilogram.

Prices quoted by Molycorp for unleached, leached, and calcined bastnasite in truckload quantities, containing 60%, 70%, and 85% REO, were $1.05, $1.10, and $1.30 per pound of contained REO, respectively, at yearend 1988.

The price of cerium concentrate quoted by American Metal Market was $1.40 per pound of contained cerium oxide at yearend 1988, unchanged for the fourth consecutive year. The price of lanthanum concentrate was also unchanged at $1.40 per pound of REO contained.

The mischmetal price (99.8%, lots over 100 pounds, f.o.b. shipping point) for 1988, quoted in American Metal Market, remained unchanged for the third consecutive year at $4.90 to $5.60 per pound.

Molycorp quoted prices for lanthanide (rare earth) and yttrium oxides, net 30 days, f.o.b. Louviers, CO, Mountain Pass, CA, or York, PA, effective October 1, 1988, as follows:

Product (oxide)	Percent[1] purity	Quantity (pounds)	Price per pound
Cerium	99.0	200	$8.00
Europium	99.99	25	745.00
Gadolinium	99.99	55	65.00
Lanthanum	99.99	300	8.75
Neodymium	96.0	300	6.75
Do.	99.9	50	40.00
Praseodymium	96.0	300	16.80
Samarium	96.0	55	85.00
Terbium	99.9	55	375.00
Yttrium	99.99	50	52.50

[1] Purity expressed as percent of total REO.

Molycorp also quoted prices for lanthanide (rare earth) compounds, net 30 days, f.o.b. York, PA, or Louviers, CO, effective February 1, 1988, as follows:

Product (compound)	Percent[1] purity	Quantity (pounds)	Price[2] per pound
Cerium carbonate	99.0	150	$4.00
Cerium fluoride	Tech grade	250	3.00
Cerium nitrate	95.0	250	2.15
Lanthanide chloride	46.0	525	1.00
Lanthanum carbonate	99.9	175	5.90
Lanthanum-lanthanide chloride	46.0	525	.95
Lanthanum-lanthanide carbonate	60.0	200	2.45
Lanthanum-lanthanide nitrate	39.0	250	1.75
Neodymium carbonate	96.0	300	4.00

[1] Purity expressed in terms of REO equivalent.
[2] Priced on a contained REO basis.

Rhône-Poulenc quoted rare-earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, effective April 1, 1988, as follows:

Product (oxide)	Percent purity	Quantity (kilograms)	Price per kilogram
Cerium	99.5	20	$23.00
Dysprosium	95.0	20	132.00
Erbium	96.0	20	190.00
Europium	99.99	10	1,960.00
Gadolinium	99.99	50	136.50
Holmium	99.9	5	510.00
Lanthanum	99.99	25	21.00
Lutetium	99.99	2	7,000.00
Praseodymium	96.0	20	38.85
Samarium	96.0	25	175.00
Terbium	99.9	5	880.00
Thulium	99.9	5	3,600.00
Yttrium	99.99	50	115.50
Ytterbium	99.0	10	200.00

Rhône-Poulenc also quoted prices for rare earths produced at its Freeport, TX, plant, net 30 days, f.o.b. Freeport, TX, effective April 1, 1988, as follows:

Product (compound)	Percent[1] purity	Quantity (kilograms)	Price[2] per kilogram
Cerium carbonate	95.0	20	$12.40
Cerium hydroxide	95.0	20	18.60
Cerium nitrate	95.0	200	12.40
Cerium oxide	99.5	20	18.60
Lanthanum carbonate	99.5	20	12.60
Lanthanum-neodymium carbonate	98.0	20	8.70
Lanthanum nitrate	99.5	200	11.90
Lanthanum oxide	99.5	20	16.50
Neodymium carbonate (dry)	95.0	20	9.25
Neodymium nitrate	95.0	200	13.20
Neodymium oxide	95.0	20	14.50

[1] Purity expressed as percent of total REO.
[2] Priced on a contained REO basis.

Nominal prices for various rare-earth oxides and metals were quoted per kilogram by Research Chemicals, net 30 days, f.o.b. Phoenix, AZ, for yearend 1988 as follows:

Element	Oxide[1] price per kilogram	Metal[2] price per kilogram
Cerium	$44	$175
Dysprosium	200	630
Erbium	300	725
Europium	1,900	7,600
Gadolinium	140	500
Holmium	500	1,600
Lanthanum	22	150
Lutetium	4,900	14,200
Neodymium	88	280
Praseodymium	140	400
Samarium	230	395
Terbium	1,200	2,800
Thulium	3,300	8,000
Ytterbium	250	1,000
Yttrium	118	510

[1] Minimum 99.9%-pure, 1- to 20-kilogram quantities.
[2] Ingot form, 1 to 5 kilograms, from 99.9%-grade oxides.

FOREIGN TRADE

Exports of rare-earth concentrates, produced primarily from bastnasite, originated mainly from Molycorp's Mountain Pass Mine in California. Exports of rare-earth metal ores, including bastnasite and a variety of mixed and individual rare-earth concentrates, but excluding monazite, increased from 4.5 million kilograms in 1987 to 7.4 million kilograms in 1988, valued at $14.9 million. Major destinations were Japan (55%), the United Kingdom (9%), and Austria (7%).

Exports of ferrocerium and other pyrophoric alloys containing rare earths totaled 35,715 kilograms, 56% lower than in 1987. Major destinations for these exports were Israel (39%), Japan (17%), and Mexico (16%). Exports in the trade category, "thorium ore, including monazite sand" were not available.

WORLD CAPACITY

The data in table 5 are rated annual production capacity for mines as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance.

WORLD REVIEW

Bastnasite, the world's principal source of rare earths, was mined as a primary product in the United States and as a byproduct of iron ore mining in China. Significant quantities of rare earths were also recovered from monazite, which was primarily a byproduct of mineral sands mined for titanium and zirconium minerals or tin minerals in Australia, Brazil, China, India, Malaysia, and the United States. Smaller amounts of rare earths, especially yttrium, were obtained from the mineral xenotime. Xenotime was recovered primarily as a byproduct of processing for tin minerals in Malaysia and Thailand. It also was a byproduct of processing titanium and zirconium minerals in Australia and China. Small quantities of rare earths, including yttrium, were produced from a residual clay in China and from spent uranium leach solutions in Canada.

World reserves of rare earths were estimated by the Bureau of Mines at 45

TABLE 2

U.S. IMPORTS FOR CONSUMPTION OF MONAZITE, BY COUNTRY

Country	1984		1985		1986		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	5,610	$2,156	5,694	$1,984	2,660	$978	—	—	382	$237
India	—	—	—	—	300	128	—	—	—	—
Indonesia	—	—	—	—	—	—	—	—	1,144	687
Malaysia	—	—	—	—	—	—	527	$298	197	125
South Africa, Republic of	51	46	—	—	—	—	—	—	—	—
Thailand	—	—	—	—	—	—	594	329	201	105
Total	**5,661**	**2,202**	**5,694**	**1,984**	**2,960**	**1,106**	**1,121**	**627**	**1,924**	**1,154**
REO content[e]	3,114	XX	3,132	XX	1,628	XX	617	XX	1,058	XX

[e] Estimated. XX Not applicable.

Source: Bureau of the Census. REO content estimated by the Bureau of Mines.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY

Country	1986 Quantity (kilograms)	1986 Value	1987 Quantity (kilograms)	1987 Value	1988 Quantity (kilograms)	1988 Value
Cerium chloride:						
Japan	—	—	—	—	76,249	$100,035
Malaysia	—	—	—	—	103,499	110,945
Mali	—	—	34,499	$39,240	103,499	110,940
Morocco	—	—	20,892	36,661	282,068	295,205
Singapore	34,500	$39,871	105,017	109,982	—	—
United Kingdom	—	—	1,624	5,603	2	1,110
Total	**34,500**	**39,871**	**162,032**	**191,486**	**565,317**	**618,235**
Cerium compounds:						
Canada	11,987	8,328	—	—	—	—
France	247,420	354,290	80	1,068	77,387	38,592
Germany, Federal Republic of	188	32,141	370	34,223	523	42,731
Japan	—	—	—	—	105	1,434
Switzerland	—	—	2	2,863	—	—
United Kingdom	—	—	—	—	1	1,530
Total	**259,595**	**394,759**	**452**	**38,154**	**78,016**	**84,287**
Cerium oxide:						
Austria	91	1,195	91	1,142	100	1,690
Canada	117	7,561	—	—	6,276	72,662
China	100	1,083	—	—	—	—
France	4,595	76,014	2,336	37,542	8,899	158,421
Germany, Federal Republic of	—	—	—	—	2,800	34,814
Japan	561	18,844	44,200	1,054,727	33,534	726,868
Total	**5,464**	**104,697**	**46,627**	**1,093,411**	**51,609**	**994,455**
Cerium salts:						
France	—	—	5,338	15,378	—	—
Japan	11	4,099	—	—	—	—
Netherlands	5,296	11,647	—	—	—	—
Total	**5,307**	**15,746**	**5,338**	**15,378**	**—**	**—**
Rare-earth oxide excluding cerium oxide:						
Belgium	963	31,269	—	—	—	—
Brazil	500	15,383	—	—	—	—
Canada	22	3,270	430	54,197	—	—
Chile	—	—	100	8,334	—	—
China	41,943	2,082,324	9,319	1,015,770	5,470	377,200
France	200,601	12,535,724	216,869	13,995,531	52,197	4,597,098
Germany, Federal Republic of	1,839	486,350	10,848	263,889	334	38,893
Hong Kong	981	63,551	20	29,188	—	—
Italy	3	3,750	—	—	—	—
Ivory Coast	514	90,074	—	—	—	—
Japan	10,130	1,094,614	5,595	611,937	2,343	318,210
Malaysia	—	—	5,980	119,364	—	—
Netherlands	—	—	3,815	915,912	754	135,174
Norway	2,478	402,216	3,073	426,143	1,460	152,624
South Africa, Republic of	—	—	3	38,594	—	—
Sweden	—	—	—	—	1,000	84,721
Switzerland	35	13,050	—	—	—	—
U.S.S.R.	22,776	1,809,588	26,516	1,663,127	7,764	484,079
United Kingdom	5,468	311,050	744	328,392	11,567	1,052,925
Total	**288,253**	**18,942,213**	**283,312**	**19,470,378**	**82,889**	**7,240,924**

TABLE 3—Continued

U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY

Country	1986 Quantity (kilograms)	1986 Value	1987 Quantity (kilograms)	1987 Value	1988 Quantity (kilograms)	1988 Value
Rare-earth alloys:[1]						
Argentina	—	—	2,000	$14,231	—	—
Brazil	47,359	$239,274	129,632	609,135	107,998	$609,769
Canada	—	—	4,535	72,551	—	—
China	—	—	56	13,440	36,510	303,159
Germany, Federal Republic of	3,665	49,148	3,194	63,388	454	6,250
Hong Kong	—	—	—	—	150	16,500
Japan	11	1,130	737	30,746	93	38,138
United Kingdom	15,100	119,729	102	18,367	1,115	74,941
Total	**66,135**	**409,281**	**140,256**	**821,858**	**146,320**	**1,048,757**
Rare-earth metals including scandium and yttrium:						
Austria	786	24,395	1,284	35,487	—	—
Canada	—	—	—	—	3,147	27,692
China	5,655	299,929	6,619	392,069	12,677	392,468
Germany, Federal Republic of	—	—	1,541	114,011	—	—
Hong Kong	—	—	5	12,738	1,000	62,018
Ivory Coast	97	15,611	—	—	—	—
Japan	1,000	76,099	1,724	181,385	125	18,432
Kiribati	—	—	—	—	100	4,900
U.S.S.R.	9,666	805,497	500	32,469	403	59,765
United Kingdom	2,354	615,271	1,817	581,821	2,635	341,608
Total	**19,558**	**1,836,802**	**13,490**	**1,349,980**	**20,087**	**906,883**
Other rare-earth metals:						
Australia	—	—	—	—	752	22,282
Austria	—	—	3,733	97,314	4,108	201,193
China	—	—	—	—	1,818	24,500
France	7,066	149,562	17,971	593,959	23,853	666,018
Germany, Federal Republic of	2	1,207	469	13,211	946	20,577
Japan	80	4,695	72	5,872	1,011	30,196
United Kingdom	60	2,842	([2])	1,272	—	—
Total	**7,208**	**158,306**	**22,245**	**711,628**	**32,488**	**964,766**
Ferrocerium and other pyrophoric alloys:						
Austria	655	10,032	—	—	3,258	81,084
Brazil	32,799	434,340	35,890	475,256	39,075	516,944
Canada	—	—	10,142	75,057	—	—
France	50,123	640,986	43,701	656,671	43,714	702,545
Germany, Federal Republic of	765	15,092	890	24,633	—	—
Hong Kong	892	2,943	—	—	—	—
Italy	—	—	—	—	12,600	29,610
Japan	796	14,953	202	5,203	—	—
Korea, Republic of	8,778	21,276	—	—	—	—
Netherlands	58	1,153	3,280	43,434	—	—
Taiwan	—	—	319	1,273	—	—
Thailand	—	—	257	2,329	—	—
United Kingdom	396	13,526	148	10,301	2,015	18,270
Total	**95,262**	**1,154,301**	**94,829**	**1,294,157**	**100,662**	**1,348,453**

[1] Essentially all mischmetal.
[2] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 4

WORLD ANNUAL RARE-EARTH MINERAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Metric tons of rare-earth oxides)

	Rated capacity
North America:	
Canada:[e] Monazite[2]	1,000
United States:	
Bastnasite	26,000
Monazite[1]	W
South America:[e]	
Brazil: Monazite[1]	2,200
Europe:	
U.S.S.R.:[e]	
Monazite[3]	500
Other[4]	1,000
Africa:[e]	
Mozambique: Monazite[5]	2
South Africa, Republic of:	
Monazite[1]	NA
Monazite[4]	NA
Zaire: Monazite[4]	55
Asia:	
China:[e]	
Bastnasite[6]	18,000
Monazite[1]	2,200
Xenotime[1]	50
Other[7]	1,000
India:[e] Monazite[2]	2,200
Malaysia:[e]	
Monazite[5]	3,300
Xenotime[5]	600
Sri Lanka:[e] Monazite[2]	110
Thailand:[e]	
Monazite[5]	1,100
Xenotime[5]	75
Oceania:	
Australia:	
Monazite[1]	11,000
Xenotime[1]	20
World total (REO)	**70,000**

[e] Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1] Byproduct of processing for titanium and zirconium minerals.
[2] Byproduct of processing for uranium, recovered as yttrium concentrate.
[3] Byproduct of processing for gold.
[4] Byproduct of processing for phosphorites.
[5] Byproduct of processing for tin minerals.
[6] Byproduct of processing for iron minerals.
[7] Residual weathering product in clay.

million tons of contained REO, of which 23% is in market economy countries.[8] China, with 76%, had the largest share of world reserves.

Australia

The Mineral Sands Div. of Renison Goldfields Consolidated Ltd. (RGC), the largest producer of monazite in Australia, announced it operated its mines at full capacity in 1988. At its Eneabba Mine, Western Australia, RGC converted from surface mining by scrapers to a dredging operation to reduce costs and increase recoveries by allowing the use of a lower cutoff grade. RGC also announced it would upgrade its mineral sands processing plant at Narngulu, Western Australia, to allow increased recovery of all minerals, including monazite. At its Capel Mine, RGC, in association with the Government and University of Western Australia, planned development of a wetlands refuge as part of a reclamation project to utilize lakes created by mineral sands mining.[9]

Wimmera Industrial Minerals, a subsidiary of CRA Ltd., announced the commissioning of a 120-ton-per-day pilot plant at its mineral sands deposit near Horsham, Victoria. The deposit, designated WIM 150, contains reserves of 1 billion tons of sand grading in excess of 3% heavy minerals, including 600,000 tons of monazite.[10]

Mineral Deposits Ltd. (MDL) announced plans to expand its mineral sands production to Queensland, primarily to meet strong demand for zircon and rutile. In addition to doubling its capacity to produce these minerals, MDL's new mine at Rocky Point, Queensland, reportedly would produce up to 100 tons of monazite per year. Completion of the mine was expected by the end of 1990.[11]

Kerr-McGee Chemical Corp. and TiO_2 Corp., joint-venture partners in a heavy-mineral sands deposit at Cooljarloo, Western Australia, announced mining would commence in early 1990.[12] Monazite content of the heavy-minerals concentrate from Cooljarloo was reportedly 1%. A 12-million-ton-per-year dredge and wet mill was planned with an expected output of 700,000 tons per year of heavy mineral concentrate. Planned dry mill capacity for monazite was 1,000 tons per year. Reserves at Cooljarloo were 569 million tons grading 3.2% economic heavy minerals.[13]

Carr Boyd Minerals Ltd. agreed to acquire from The Broken Hill Pty. Ltd. (BHP) and its U.S. subsidiary, Utah Minerals Corp., a controlling interest in the Mount Weld rare-earth carbonatite deposit near Laverton, Western Australia.[14] In addition to rare earths and yttrium, the carbonatite deposit contains niobium, tantalum, strontium, titanium, and zirconium. Reserves at Mount Weld were delineated at 7.4 million tons of ore grading 9.4% REO (cerium plus lanthanum basis).[15]

SX Holdings Ltd. announced plans to develop a three-stage rare-earth processing operation at Port Pirie, South Australia. The initial project was to treat rare-earth concentrates from China using Chinese technology to produce experimental rare-earth fertilizers. The second stage of the project was to recover rare earths and scandium from tailings from the Radium Hill Mine by in situ leaching. The project's final phase was to build a monazite separation plant to process 2,000 tons of monazite concentrate per year.[16]

A heavy-minerals deposit was discovered by Dominion Mining and Southern Ventures on the Gascoyne tenements south of Carnarvon, Western Australia. Heavy-mineral concentrations from 1.5% to 6.1%, containing monazite in association with ilmenite, rutile, and zircon, were reported.[17]

In one of Australia's largest corporate asset exchanges, North Broken Hill Holdings Ltd. sold its stake in the mineral sands producer R.Z. Mines (Newcastle) Pty. Ltd. and other mineral and energy interests to Elders Resources NZFP Ltd. Elders now holds a 50% interest in R.Z. Mines; the other half remains held by Coffs Harbour Rutile NL. R.Z. Mines operates four suction dredges in the Tomago-Campvale area of Port Stephens and a dry mine at Nabiac. The company's current yearly production is approximately 36,000 tons each of rutile and zircon, 10,000 tons of ilmenite, and 300 tons of monazite.[18]

Brazil

SA Mineração Trinidade (Samitri) announced plans to construct a new mineral sands processing plant south of Minas Gerais. Capacity of the plant was engineered for 2,000 tons of monazite per year. The plant was scheduled for completion in mid-1990.[19]

Production of monazite concentrates in 1986 was 3,618 tons, of which 197 tons came from the State of Espírito Santo, a decrease from the 281 tons produced in 1985, and 3,421 tons from the State of Rio de Janeiro, a decrease from the 1985 production of 3,672 tons.

Measured reserves of monazite were 16,709 tons. Estimated REO content of these reserves was 6,789 tons. The reserves were located in the States of Bahia, Espírito Santo, Paraná, and Rio de Janeiro.[20]

Canada

Joint venture partners Hecla Mining Co. and Highwood Resources continued development of their beryllium-yttrium-niobium-rare-earth deposit at Thor Lake, Northwest Territories. Of the five mineralized zones at Thor Lake, only two have been sufficiently drilled to establish reserves. At yearend, reserves totaled 507,000 tons grading 0.17% yttrium oxide.[21] A decision on whether to proceed with commercial development of the project reportedly was expected in 1989.[22]

China

The China Rare Earth Information Centre reported that production of rare-earth mineral products increased 38% to 18,660 tons of equivalent REO in 1988, primarily from increased production of ion-adsorption-type ore in Jiangxi Province, and rare-earth-containing ore from the Baiyunebo Mine in the Nei Monggol Autonomous Region. As a result of the higher production, for the first time in history China ranked first in overall production of rare earths, a position previously held by the United States. China reportedly consumed 6,000 tons of equivalent REO, up 25% from that of 1987. Exports of rare-earth products also increased, from 6,500 tons REO in 1987 to 8,320 tons REO in 1988. Rare-earth consumption in fertilizers reportedly gained 20%, to 300 tons REO, and were used on about 1.2 million hectares of cropland, 28% more area than in 1987.[23]

A rare-earth deposit was reportedly discovered in northeastern Guangxi Province in southern China. The deposit was claimed to contain 100,000 tons of high-grade ore.[24]

Can-Pacific Rare Earths & Metals Corp. finalized a 1987 agreement with the Ganzhou Metallurgical Industries Corp. and formed the joint venture company, Ganjia Rare Earths Co., to build a rare-earths separation plant and refinery in Ganzhou District, Jiangxi Province. The refinery reportedly will produce high-purity metals and compounds, including yttrium. Completion of the project was scheduled for the second half of 1989.[25] Can-Pacific and a joint venture partner, Galactic Resources Ltd, announced the formation of a new company, Galactic Resources (China) Ltd., to develop additional ventures, including rare-earth projects, in China.[26]

The Yue Long rare-earth plant in Shanghai reportedly doubled its capacity to 4,000 tons of rare-earth oxides per year. The separation facility is the largest in China and produces high-purity rare-earth compounds, metals, and alloys, including those used in permanent magnets.[27]

A 100-ton-per-year mixed REO processing plant began operating in the Shenzhen Special Economic Zone. The consortium responsible for developing the plant was comprised of four concerns: Shenzhen Commercial Trading Co., Shenzhen Nantou Construction Services Co., Jiangxi Import & Export Co., and Xunwu Rare Earth Industry Co. Concentrates produced were expected to be exported.[28]

Egypt

Exploration of the Rosetta heavy-minerals sands deposit by the Egyptian Geological Survey of Egypt (EGSE) reportedly was in progress. A review of the literature and recent data from the EGSE indicated a substantial potential for economic mineralization along the Mediterranean coast of Egypt, offshore, and within the Nile's delta and its distributaries. Data on the Rosetta area compiled by the Egyptian Atomic Energy Commission delineated measured and indicated reserves of 26.7 million tons of ore containing 213,000 tons of monazite. Extrapolation of the reserves along the entire coast of Egypt would theoretically indicate over 2 billion tons of minerals sands containing 10.8 million tons of monazite.[29]

Greenland

The Danish company A/S Carl Nielson completed field studies on a rare-earth and zirconium deposit in southwest Greenland. The deposit reportedly contains 3 million tons of ore. The rare earths and zirconium are contained in the mineral eudialyte, a zirconium silicate mineral. Four separate ore bodies were delineated, grading 4% yttrium and other rare-earth elements, and from 2% to 3.5% zirconia. Feasibility studies of the deposit were scheduled.[30]

A consortium comprising Platinova Resources Ltd. (40%), Highwood Resources Ltd. (30%), and Aber Resources Ltd. (30%), were studying a eudialyte deposit approximately 10 miles east of Narassaq. The deposit, designated the Gardar Prospect, contained consistent grades of 1.2% zirconia, 0.12% yttria, and 0.7% lanthanide oxides.[31]

Japan

Imports of rare earths in 1988 were reported in the Japan Metal Journal, as follows:

Product	Quantity (kilograms)
Cerium oxide	480,630
Other cerium compounds	2,607,884
Ferrocerium and other pyrophoric alloys	427,383
Lanthanum oxide	195,808
Rare-earth chloride	5,245,147
Rare-earth metals including yttrium and scandium	468,274
Yttrium oxide	687,671

Data on Japanese demand for rare earths in 1988 were reported as follows:[32] cerium oxide, 3,100 tons; europium oxide, 11 tons; lanthanum oxide, 400 tons; mischmetal, 230 tons; rare-earth fluoride, 50 tons; samarium oxide, 370 tons; yttrium oxide, 270 tons; and other REO's, 500 tons.

Nippon Rare Earths, the joint venture company of Rhône-Poulenc of France and Sumitomo Metal Mining Co. of Japan, began production of refined rare-earth products in Japan.

Madagascar

QIT-Fer et Titane Inc. (QIT) of Canada and the Government of Madagascar announced a joint venture to produce mineral sands, including monazite, in Madagascar. QIT reportedly will commence mineral sands production in Madagascar in 1993.

Malaysia

Production of xenotime from Malaysia through 1987 was reported by the Malaysia Department of Statistics as follows:

	Quantity (metric tons)
1983	13
1984	384
1985	1,124
1986	145
1987	31

Since the collapse of the International Tin Agreement in 1985 production of tin concentrate has been relatively flat and the production of other heavy minerals, including monazite and xenotime, has been of increased importance to the economy of Malaysia. Heavy-minerals production is derived from amang, a byproduct mixed heavy-minerals concentrate produced after removal of the tin-bearing minerals. Mineral concentrates produced from the amang constituted about one-fourth the total value of tin mine production 1988.

Mozambique

Kenmare Resources PLC of Ireland and the Geological Survey of Yugoslavia were 50-50 partners in a venture to recover mineral sands at the Congolone deposit northwest of Angoche. Measured and indicated reserves at Congolone were 123 million tons of ore grading 4% heavy-minerals.[33] Analysis of the heavy minerals concentrate indicated a monazite content of 1.3%.[34]

Sri Lanka

The Sri Lanka National Aquatic Research Agency announced the discovery of monazite deposits off the north and southwestern coasts. The deposits reportedly occur at depths of 10 to 15 meters, which is well within the limits of placer dredging methods.[35]

Thailand

Monazite and xenotime were produced as byproducts of processing mineral sands for tin. According to the latest available data, monazite was produced in 1987 in the central region at Prachuap Khiri Khan (30 tons), and in the southern region at Chumphon (120 tons), Phuket (272 tons), and Ranong (36 tons).[36] Thailand reportedly exported 428 tons of monazite in 1987 to France, the United Kingdom, and the United States. During the same year, xenotime was produced from mines at Phuket (5 tons) and Ranong (25 tons), but no exports were reported. Production of xenotime concentrates through 1987 was reported by the Department of Mineral Resources of Thailand as follows:[37]

Year	Quantity (metric tons)
1983	38
1984	28
1985	158
1986	28
1987	30

TECHNOLOGY

A magnetically levitated (maglev) transportation and haulage system, being designed for use in underground coal mines by researchers at Ruhrkohle AG in the Federal Republic of Germany, was improved by using neodymium-iron-boron permanent magnets rather than samarium-cobalt (SmCo) magnets. The neodymium-iron-boron magnets are 10% less dense and 30% stronger than SmCo magnets. The greater magnetic strength provides two improvements to the system: a larger air gap, which allows improved guideway tolerance, and shortening of the bogies to which the magnets are mounted, permitting a smaller turning radius.[38]

An MRI system developed by Hitachi Medical Corp., Tokyo, Japan, incorporates neodymium-iron-boron permanent magnets rather than the more costly low-temperature superconducting magnets. The advantage of the neodymium-iron-boron MRI system is that it requires no cooling and consumes no power to create the magnetic

TABLE 5

MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Australia	16,260	18,735	14,822	12,813	13,500
Brazil	3,622	1,895	1,947	1,560	2,000
India[e]	4,000	4,000	4,000	4,000	4,000
Malaysia	4,980	5,808	5,959	2,908	3,900
Mozambique[e]	4	4	4	4	4
South Africa, Republic of[e]	1,000	1,000	1,000	1,200	1,200
Sri Lanka[e]	[3]147	200	200	200	200
Thailand	298	[r]663	1,609	458	500
United States	W	W	W	W	W
Zaire	2	—	7	97	100
Total	**[r]30,313**	**[r]32,305**	**29,548**	**23,240**	**25,404**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total."
[1]Table includes data available through Apr. 27, 1989.
[2]In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and the U.S.S.R. may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.
[3]Reported figure.

field. Operating costs are reportedly one-tenth that of conventional superconducting magnet MRI systems having equal image quality.[39]

TABLE 6

RARE EARTHS: WORLD PRODUCTION, BY COUNTRY

(Metric tons of REO equivalent)

Country	1986	1987[p]	1988[e]
Australia	8,152	7,047	6,600
Brazil	1,071	858	1,100
Canada	NA	NA	NA
China	11,860	15,100	20,640
India[e]	2,200	2,200	2,200
Malaysia	3,364	1,618	2,200
Mozambique[e]	2	2	2
Sri Lanka[e]	110	110	110
Thailand	902	825	270
United States[1]	11,094	16,710	11,533
Total	**38,755**	**44,470**	**44,655**

[e]Estimated. [p]Preliminary. NA Not available.
[1]Comprises only the rare earths derived from bastnasite as reported in Unocal Corp. annual report, 1988.

A new metallic glass composed of 90% aluminum, 5% iron, and 5% cerium was created independently by scientists at the University of Virginia, Charlottesville, VA, and Tohoku University, Sendai, Japan. The glass, quenched at an extremely rapid rate to inhibit crystallization, was reported to have the strength of steel at one-third the weight and a tensile strength almost twice as great as the strongest aluminum metal alloy. Because of its light weight and high strength, the new metallic glass has potential applications in the aerospace industry and as fiber components in composite materials.[40]

Researchers at GTE Laboratories, Waltham, MA, developed a fluorozirconate optical fiber containing neodymium that functions as an amplifier in laser-transmitted telecommunication. Operating at standard telecommunications wavelengths, the oxygen-free glass fiber effectively produces signal gain. When the new active fiber is spliced into existing fiber-optic cables, and is pumped by an ancillary light or laser source, the standard signal is boosted, producing gain, thus enabling greater transmission distances between signal regeneration points.[41]

Several announcements were made at the seventh Congress of the International Society for Laser Surgery and Medicine by companies and researchers who had developed yttrium-aluminum garnet (YAG) laser systems designed to ablate kidney stones and gallstones. A joint venture by Karl Storz and Meditec of the Federal Republic of Germany produced an Nd:YAG laser system that delivers 30 to 50 millijoules to the stones in 5- to 20-nanosecond pulses through a quartz fiber 600 micrometers in diameter. Another similar system developed by the Swiss firm Lasag, delivers 0.5- to 2-joule pulses of millisecond duration through fibers as small as 200 micrometers in diameter. Use of these rare-earth laser systems will reportedly reduce the need for invasive surgery.[42]

Ford Motor Co. announced it had developed, in conjunction with Johnson Matthey PLC, a new automotive catalytic converter that would eliminate the need for costly platinum.[43] Although Ford would not reveals exactly what metals were used, most industry experts agreed that the catalyst contained a mixture of palladium and rhodium, with cerium added for thermal stability. While cerium's usage in converter technology is not new, its potential new application as a thermal stabilizer would be. Ford initiated a large-scale test program in California on its 1989 cars.

Researchers at the Baotou Research Institute of Rare Earth developed a neodymium-iron-boron magnet that retains a large fraction of its strength at elevated temperatures. After an hour's exposure to 200° C air, the magnet lost less than 10% of its permanent flux. Less than 5% was lost after 15 hours of exposure at 150° C.[44] The magnets were of interest for use in electric motors designed to operate at high temperature and are currently being manufactured for this purpose.

Scientists from the Research Institute of Chemical Engineering at the South

China University of Technology improved the recovery of rare earths from leach solutions derived from ion-adsorption type ores. When a liquid-permeable membrane was used, the rare-earth concentration of the leachate increased from 1 gram of REO per liter to 111 grams per liter, reducing the volume of leachate to be processed. The operating cost of recovery was estimated to be one-sixth that of conventional methods.[45]

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[1] Physical scientists, Branch of Nonferrous Metals.

[2] Federal Register. Presidential Documents. Executive Order 12616. National Defense Stockpile Manager. V. 53, No. 39, Feb. 29, 1988, p. 6114.

[3] Mineral Summary. Background Data for the California Desert Protection Act of 1987. BuMines and U.S. Geol. Surv., Vols. 1 and 2, 433 pp.

[4] Unocal Corp. Annual Report 1988, p. 22.

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SALT

By Dennis S. Kostick[1]

The United States remained the world's largest producer of salt, representing about 19% of total world production. U.S. production and domestic sales of salt improved because of increased salt demand for manufacturing chemicals, water softening, and highway deicing. The organizational structure of the U.S. salt industry changed with consolidations and acquisitions of companies. Apparent consumption and production increased as salt imports decreased and exports increased. Salt continued to be one of the most heavily traded chemical industry ores in the world, representing about 66% of world seaborne mineral trade.[2]

DOMESTIC DATA COVERAGE

Domestic production data for salt are developed by the Bureau of Mines from two voluntary surveys of U.S. operations. Typical of the surveys is the salt company survey. Of the 67 operations to which a survey request was sent, 66 responded, representing 98% of the total production shown in table 1. Production for the one nonrespondent and the nonsurveyed facilities was estimated on the basis of their prior response to the 1988 production estimate survey or brine production capabilities for chloralkali manufacture.

DOMESTIC PRODUCTION

The total quantity of all types of salt produced and sold increased about 7% compared with that of the previous year. Most of the gain was in brine production for the chloralkali industry. According to the Bureau of Mines survey for 1988, 27 companies operated 66 salt-producing plants in 15 States. Nine of the companies and 13 of the plants produced more than 1 million short tons each and accounted for 87% and 67%, respectively, of the U.S. total. Many individual companies and plants produced more than one type of salt. In 1988, 12 companies (18 operations) produced solar-evaporated salt; 6 companies (18 operations), vacuum pan salt; 10 companies (14 operations), rock salt; and 13 companies (27 operations), salt brine.

The five leading States in quantity of salt sold or used were Louisiana, 38%; Texas, 21%; New York, 12%; Ohio, 10%; and Kansas, 3%. Although Louisiana, New York, and Ohio were major rock salt-producing States, a significant amount of the salt was produced in Alabama, Kansas, Louisiana, New York, North Dakota, Ohio, Texas, Utah, and West Virginia, as brine for the chemical industry.

The percentage of salt sold or used by U.S. producers, by type, was salt in brine, 50%; mined rock, 33%; vacuum pan salt, 10%; and solar-evaporated salt, 7%.

Consolidations of salt operations continued in 1988 as various salt companies acquired other smaller producers. International Salt Co., owned by Akzo NV of the Netherlands, purchased Diamond Crystal Salt Co. for $65 million. The acquisition reduced International's dependence on rock salt sales for highway deicing by incorporating Diamond's sales to industrial and consumer markets.[3] The purchase included Diamond's salt facilities in Michigan, North Dakota, Ohio, and Utah. International announced on July 26 that it planned to close the Williston, ND, plant effective November 1 because of increased production, operating, and maintenance costs.[4] Akzo's total salt production capacity worldwide was increased to about 15 million tons, establishing it as the world's largest salt-producing company.

G. Harris and Associates, an investment group, acquired American Salt Co. from General Host Corp. early in the year for $31 million. American owned a solar salt facility in Utah and a rock salt and vacuum pan plant in Kansas. The group later purchased Carey Salt Co. from Processed Minerals Inc.[5] Also, Morton Thiokol Inc. acquired Ocean Salt Co., a solar salt importer in California.

Olin Corp. agreed to develop an underground salt cavity for Alabama Electrical Cooperative for the Nation's

TABLE 1

SALIENT SALT STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Production[1]	39,181	39,217	37,282	36,943	39,170
Sold or used by producers[1]	39,225	40,067	36,663	36,493	38,940
Value	$675,099	$739,609	$665,400	$684,170	$699,323
Exports	820	904	1,165	541	884
Value	$15,299	$15,988	$16,928	$8,217	$10,858
Imports for consumption	7,545	6,207	6,665	5,716	5,474
Value	$74,100	$65,593	$79,709	$66,936	$77,357
Consumption, apparent[2]	45,950	45,370	42,163	41,668	43,530
World: Production	r190,258	r191,494	194,132	p196,956	e203,848

e Estimated. p Preliminary. r Revised.
1 Excludes Puerto Rico.
2 Sold or used plus imports minus exports.

first compressed air energy storage power plant at McIntosh, AL. The $65 million plant will provide power to 16 distribution cooperatives, 4 municipalities, and 2 industries in Alabama and Florida by early 1991. The facility is expected to generate 110 megawatts of electricity. Olin will solution mine the salt dome and use the brine to produce chlorine and caustic soda.[6]

According to the Bureau of Mines salt survey, 4,284 people were employed in the mining and processing of salt in the United States in 1988. The quantity employed by type of salt and by mine and mill activity was, as follows: rock salt, 1,021 in the mine and 278 in the mill; solar salt, 105 in harvesting and 610 in the processing plant; vacuum pan salt, 2,197 in the processing plant; and salt brine, 54 in solution mining and 19 in the processing plant.

TABLE 2

SALT PRODUCTION IN THE UNITED STATES

(Thousand short tons)

	Vacuum pans and open pans	Solar	Rock	Brine	Total
1984	3,629	2,705	13,653	19,195	[1]39,181
1985	3,613	2,549	13,990	19,065	39,217
1986	3,637	2,679	13,333	17,633	37,282
1987	3,776	3,120	12,230	17,817	36,943
1988	3,824	3,379	12,750	19,218	39,170

[1] Data do not add to total shown because of independent rounding.

TABLE 3

SALT PRODUCED IN THE UNITED STATES, BY PRODUCT FORM AND TYPE

(Thousand short tons)

Product form	Vacuum pans and open pans	Solar	Rock	Brine	Total
1987					
Bulk	682	2,220	11,671	17,817	32,390
Compressed pellets	984	99	XX	XX	1,083
Packaged	1,787	712	488	XX	2,987
Pressed blocks	324	90	71	XX	485
Total [1]	**3,776**	**3,120**	**12,230**	**17,817**	**36,943**
1988					
Bulk	686	2,516	12,142	19,218	34,562
Compressed pellets	1,023	108	XX	XX	1,130
Packaged	1,803	672	539	XX	3,014
Pressed blocks	312	83	69	XX	463
Total [1]	**3,824**	**3,379**	**12,750**	**19,218**	**39,170**

XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Production of chlorine increased about 3% because of the rise in demand for polyvinyl chloride in the export market. Domestic demand for chlorine began to decline because of impact on the environment, chlorine in chlorofluorocarbons, and paper bleaching chemicals that contained dioxins. This caused a shortage of caustic soda for many consumers, some of whom substituted soda ash because of its greater availability and more affordable prices.

The chlorine and caustic soda industry consumed about 19.8 million tons of salt for feedstock, based on the industry average ratio of 1.75 tons of salt required to produce 1.0 ton of chlorine and 1.1 tons of coproduct caustic soda. Production of chlorine gas and sodium hydroxide, as reported by the Bureau of the Census, was as follows, in thousand short tons:

	1987[r]	1988
Chlorine gas (100%)	11,019	11,330
Sodium hydroxide, liquid (100%)	11,486	11,985

[r] Revised.

Table 15 lists the domestic chlorine-producing facilities that used only salt as feedstock. Based on the annual chlorine production capacities and the Bureau of the Census chlorine production data, the U.S. salt-based chlorine industry operated at 94% of capacity. Because chlorine was also produced from nonsalt sources, i.e., from the electrolysis of magnesium chloride and the oxidation of hydrochloric acid, this data may vary from other reported chlorine capacity utilization information.

TABLE 4

SALT SOLD OR USED[1] IN THE UNITED STATES, BY PRODUCT FORM AND TYPE

(Thousand short tons and thousand dollars)

Product form	Vacuum pans and open pans		Solar		Rock		Brine		Total[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1987										
Bulk	661	26,521	1,731	23,927	11,331	141,637	18,124	89,363	31,847	281,448
Compressed pellets	983	95,840	99	6,983	XX	XX	XX	XX	1,082	102,823
Packaged:										
Less-than-5-pound units	156	NA	1	NA	32	NA	XX	XX	189	NA
More-than-5-pound units	1,653	NA	705	NA	529	NA	XX	XX	2,888	NA
Total[2]	**1,809**	**202,940**	**706**	**33,512**	**561**	**28,863**	**XX**	**XX**	**3,076**	**265,315**
Pressed blocks:										
For livestock	156	NA	54	NA	1	NA	XX	XX	211	NA
For water treatment	167	NA	36	NA	72	NA	XX	XX	275	NA
Total[2]	**323**	**22,857**	**90**	**6,090**	**73**	**5,637**	**XX**	**XX**	**487**	**34,584**
Grand total	**3,776**	**348,158**	**2,627**	**70,513**	**11,965**	**176,137**	**18,124**	**89,363**	**36,493**	**684,170**
1988										
Bulk	682	29,482	1,684	25,028	12,222	155,046	19,601	70,084	34,189	279,640
Compressed pellets	1,022	103,315	107	7,814	NA	XX	XX	XX	1,130	111,129
Packaged:										
Less-than-5-pound units	155	NA	1	NA	35	NA	XX	XX	194	NA
More-than-5-pound units	1,648	NA	742	NA	574	NA	XX	XX	2,966	NA
Total[2]	**1,803**	**209,860**	**743**	**34,531**	**609**	**30,469**	**XX**	**XX**	**3,159**	**274,861**
Pressed blocks:										
For livestock	150	NA	49	NA	1	NA	XX	XX	200	NA
For water treatment	161	NA	33	NA	67	NA	XX	XX	261	NA
Total[2]	**311**	**22,830**	**82**	**5,580**	**68**	**5,284**	**XX**	**XX**	**462**	**33,693**
Grand total[2]	**3,822**	**365,487**	**2,617**	**72,953**	**12,900**	**190,799**	**19,601**	**70,084**	**38,940**	**699,323**

NA Not available. XX Not applicable.

[1] As reported at salt production locations. The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by the plant or company. Because data do not include salt imported, purchase, and/or sold from inventory from regional distribution centers, salt sold or used by type may differ totals shown in tables 7 and 8, which are derived from company reports.

[2] Data may not add to totals shown because of independent rounding.

The reported percent distribution of salt by major end use in 1988 was chemicals, 48%; ice control, 26%; distributors, 9%; food and agricultural, 7%; industrial, 5%; water treatment, 1%; and other combined with exports, 4%. For a complete end-use analysis as shown in table 7, specific sectors of distribution, such as agricultural and water conditioning, can be combined with the primary agricultural and water treatment categories.

STOCKS AND PURCHASES

Total yearend stocks reported by producers were 2.7 million tons. Most of these stocks were rock salt and solar salt. Many States, municipalities, distributors, and road-deicing contractors stockpiled additional quantities of salt in anticipation of adverse weather conditions.

Intraindustry purchases of salt amounted to 1.8 million tons, of which 59% was salt brine; rock salt, 29%; vacuum pan salt, 7%; and solar salt, 5%.

PRICES

Price quotations are not synonymous with average values reported to the Bureau of Mines. The quotations do not necessarily represent prices at which transactions actually occurred, nor do they represent bid and asked prices. They are quoted here to serve only as a reference to yearend price levels. The following yearend prices were quoted in Chemical Marketing Reporter.[7]

Salt, evaporated, common, 80-pound bags, carlots or truckloads, North, works, 80 pounds	$4.02
Salt, chemical-grade, same basis, 80 pounds	4.30
Salt, rock, medium, coarse, same basis, 80 pounds	2.70
Bulk, same basis, per ton	$18.00–25.00
Sodium chloride, USP granular bags, per pound	.29

FOREIGN TRADE

The United States imported more than six times the quantity of salt that it exported. Although this would indicate that the United States relied on imports to meet its salt requirements, the majority of imported salt was brought into the country by foreign subsidiaries of major domestic salt producers. Generally, imported salt can be purchased and delivered to many customers at lower costs than the comparable domestic product.

According to the Journal of Commerce's Port Import/Export Reporting Service, Carey Salt Co., Cargill Inc., Domtar Industries Inc., International Salt Co., and Morton Thiokol Inc. imported 53% of the total imports of 5.56 million tons. Four companies in the chloralkali industry, which was the single largest domestic salt market, consumed 26% of total imports, which were mainly solar salt. These companies were LCP Chemicals & Plastics Inc., Occidental Chemical Corp., Pennwalt Corp., and Weyerhaeuser Co.

The Bureau of the Census reported imports of 5.47 million tons. Although total imports decreased 4% compared with those of the previous year, imports

TABLE 5

SALT SOLD OR USED[1] BY PRODUCERS IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1987		1988	
	Quantity	Value	Quantity	Value
Kansas[2]	1,689	70,148	1,778	72,965
Louisiana	12,498	108,999	14,274	108,982
Michigan	W	W	W	W
New York	4,918	119,962	4,614	127,994
Ohio	3,276	104,099	3,795	115,860
Texas	7,810	60,857	8,202	64,425
Utah	1,108	34,264	1,055	35,730
West Virginia	W	W	W	W
Other[3]	5,194	185,841	5,222	173,367
Total	**36,493**	**684,170**	**38,940**	**699,323**
Puerto Rico[e]	40	900	40	900

[e] Estimated. W Withheld to avoid to disclosing company proprietary data; included with "Other."
[1] The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by the plant or company.
[2] Quantity and value of brine included with "Other."
[3] Includes Alabama, Arizona, California, Kansas (brine only), Nevada, New Mexico, North Dakota, Oklahoma, and data indicated by symbol W.

TABLE 6

EVAPORATED SALT SOLD OR USED[1] BY PRODUCERS IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1987		1988	
	Quantity	Value	Quantity	Value
Kansas	893	61,263	915	63,572
Louisiana	212	20,086	213	20,405
Michigan	W	W	W	W
New York	775	63,184	771	65,647
Utah	1,055	33,734	992	34,652
Other[2]	3,466	240,403	3,548	254,164
Total	**[3]6,403**	**418,670**	**6,439**	**438,440**
Puerto Rico[e]	40	900	40	900

[e] Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by the plant or company.
[2] Includes Arizona, California, New Mexico, North Dakota, Ohio, Oklahoma, and Texas.
[3] Data do not add to total shown because of independent rounding.

TABLE 7

DISTRIBUTION OF DOMESTIC AND IMPORTED SALT BY PRODUCERS IN THE UNITED STATES, BY END USE AND TYPE

(Thousand short tons)

End Use	SIC	Vacuum pans and open pans		Solar		Rock		Salt in brine	Total[1]		
		Domestic	Imported	Domestic	Imported	Domestic	Imported		Domestic	Imported[2]	Grand
1987											
Chemical:											
Chloralkali producers	2812	48	—	355	W	1,361	W	16,066	17,830	125	17,955
Other chemical	28 (excludes 2812, 2899)	[r]335	W	94	41	216	W	[r]42	687	73	760
Total		**383**	**W**	**449**	**41**	**1,577**	**W**	**16,108**	**18,517**	**198**	**18,715**
Food-processing industry:											
Meat packers	201	172	W	46	8	216	W	—	434	18	452
Dairy	202	103	—	3	2	3	W	([3])	108	2	110
Canning	2091, 203	133	W	38	26	92	W	1	264	32	296
Baking	205	139	—	9	W	9	W	—	157	1	158
Grain mill products	204 (excludes 2047)	64	—	1	W	11	—	—	76	([3])	76
Other food processing	206–208, 2047, 2099	148	W	25	10	40	W	([3])	213	16	229
Total[1]		**759**	**5**	**122**	**46**	**371**	**17**	**1**	**1,252**	**69**	**1,321**
General industrial:											
Textiles and dyeing	22	95	W	11	33	39	W	5	150	87	237
Metal processing	33, 34, 35, 37	14	W	11	12	269	W	([3])	294	17	311
Rubber	2822,30 (excludes 3079)	1	—	3	W	3	W	138	145	W	145
Oil	13,29	44	—	267	W	66	W	201	577	20	597
Pulp and paper	26	25	W	228	36	82	W	13	348	39	387
Tanning and/or leather	311	14	W	39	W	68	W	—	120	4	124
Other industrial	9621	100	W	63	17	58	W	3	224	23	247
Total[1]		**293**	**56**	**622**	**119**	**585**	**16**	**361**	**1,858**	**191**	**2,049**
Agricultural:											
Feed retailers and/or dealers-mixers		401	W	201	37	345	W	—	947	48	995
Feed manufacturers	2048	66	—	95	W	233	W	—	394	22	416
Direct-buying end users	02	18	—	13	W	10	W	—	41	1	42
Total		**485**	**W**	**309**	**59**	**588**	**W**	**—**	**1,382**	**71**	**1,453**
Water treatment:											
Government (Federal, State, local)	2899	22	—	27	13	162	W	2	212	15	227
Commercial or other	2899	18	—	81	14	40	W	11	150	15	165
Total[1]		**40**	**—**	**108**	**27**	**202**	**W**	**13**	**362**	**30**	**392**
Ice control and/or stabilization:											
Government (Federal, State, local)	9621	5	1	138	168	7,645	1,508	3	7,791	1,676	9,467
Commercial or other	5159	13	1	28	16	272	82	—	313	98	411
Total		**18**	**2**	**166**	**184**	**7,917**	**1,590**	**3**	**8,104**	**1,774**	**9,878**
Distributors:											
Agricultural distribution	5159	78	W	71	W	105	W	—	254	48	302
Grocery wholesalers and/or retailers	514, 54	646	W	175	W	121	W	—	942	65	1,007
Institutional wholesalers and end users	58, 70	28	—	4	W	99	W	([3])	130	7	137

See footnotes at end of table.

TABLE 7—Continued

DISTRIBUTION OF DOMESTIC AND IMPORTED SALT BY PRODUCERS IN THE UNITED STATES, BY END USE AND TYPE

(Thousand short tons)

End Use	SIC	Vacuum pans and open pans		Solar		Rock		Salt in brine	Total [1]		
		Domestic	Imported	Domestic	Imported	Domestic	Imported		Domestic	Imported [2]	Grand
Water-conditioning distribution	7399	309	W	276	W	229	W	(3)	814	249	1,063
U.S. Government resale	9199	7	—	3	W	1	W	(3)	11	1	12
Other wholesalers and/or-retailers	5251	703	W	114	W	647	W	(3)	1,463	197	1,660
Total [1]		**1,771**	**18**	**643**	**471**	**1,202**	**79**	**(3)**	**3,614**	**567**	**4,181**
Other n.e.s. [4]		104	4	348	27	162	24	1,080	1,694	55	1,749
		3,851	116	2,767	975	12,603	1,867	17,567	36,788	2,957	39,747
1988											
Chemical:											
Chloralkali producers	2812	55	—	351	—	1,277	135	18,150	19,833	135	19,968
Other chemical	28 (excludes 2812, 2899)	359	24	91	37	218	2	35	703	63	766
Total		**414**	**24**	**442**	**37**	**1,495**	**137**	**18,185**	**20,536**	**198**	**20,734**
Food-processing industry:											
Meat packers	201	183	14	53	9	196	4	—	432	28	460
Dairy	202	107	—	3	2	4	—	—	114	2	116
Canning	2091, 203	131	—	40	23	78	4	1	250	28	278
Baking	205	128	—	11	1	11	—	—	150	2	152
Grain mill products	204 (excludes 2047)	67	—	1	(3)	7	—	—	75	—	75
Other food processing	206–208, 2047, 2099	154	3	37	8	43	6	—	234	17	251
Total		**770**	**17**	**145**	**44**	**337**	**15**	**1**	**1,255**	**77**	**1,332**
General industrial:											
Textiles and dyeing	22	90	54	10	35	33	1	6	139	90	229
Metal processing	33, 34, 35, 37	14	1	20	15	318	6	(3)	352	22	374
Rubber	2822, 30 (excludes 3079)	2	—	4	(3)	2	—	19	27	—	27
Oil	13, 29	44	—	334	23	81	—	337	796	23	819
Pulp and paper	26	22	5	230	41	72	—	6	330	46	376
Tanning and/or leather	311	11	—	42	2	67	1	—	120	3	123
Other industrial	9621	89	—	65	18	71	5	—	225	23	248
Total		**272**	**60**	**705**	**135**	**645**	**16**	**368**	**1,989**	**207**	**2,196**
Agricultural:											
Feed retailers and/or dealers-mixers											
Feed manufacturers	2048	434	1	203	28	332	—	—	969	29	998
Direct-buying end user	02	69	—	89	17	262	—	—	420	17	437
		18	—	15	—	6	—	—	39	—	39
Total		**521**	**1**	**307**	**46**	**600**	**—**	**—**	**1,428**	**46**	**1,474**
Water treatment:											
Government (Federal, State, local)	2899	24	—	28	12	181	2	3	236	14	250
Commercial or other	2899	20	—	110	23	41	—	19	190	23	213
Total		**44**	**0**	**138**	**34**	**222**	**2**	**22**	**426**	**37**	**463**

See footnotes at end of table.

TABLE 7—Continued

DISTRIBUTION OF DOMESTIC AND IMPORTED SALT BY PRODUCERS IN THE UNITED STATES, BY END USE AND TYPE

(Thousand short tons)

End use	SIC	Vacuum pans and open pans: Domestic	Vacuum pans and open pans: Imported	Solar: Domestic	Solar: Imported	Rock: Domestic	Rock: Imported	Salt in brine	Total[1]: Domestic	Total[1]: Imported[2]	Total[1]: Grand total
Ice control and/or stabilization:											
Government (Federal, State, local)	9621	6	1	160	85	8,168	2,171	1	8,335	2,257	10,592
Commercial or other	5159	12	—	77	11	379	53	1	469	64	533
Total		**18**	**1**	**236**	**96**	**8,547**	**2,224**	**2**	**8,804**	**2,321**	**11,125**
Distributors:											
Agricultural distribution	5159	101	15	85	21	108	23	—	294	59	353
Grocery wholesalers and/or retailers	514,54	630	—	162	58	105	—	—	897	58	955
Institutional wholesalers and end users	58,70	29	—	33	5	113	—	—	175	5	180
Water-conditioning distribution	7399	309	2	294	167	220	58	1	824	227	1,051
U.S. Government resale	9199	7	—	3	—	—	—	—	10	—	10
Other wholesalers and/or retailers	5251	673	10	114	149	618	9	—	1,405	168	1,573
Total		**1,749**	**27**	**690**	**400**	**1,164**	**91**	**1**	**3,605**	**517**	**4,122**
Other n.e.s.[4]		96	7	217	12	378	51	883	1,574	70	1,644
Grand total[1]		**3,884**	**137**	**2,879**	**805**	**13,388**	**2,537**	**19,462**	**39,613**	**3,479**	**43,092**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total" and "Grand totals."

[1] Data may not add to totals shown because of independent rounding. Because data includes salt imported, produced and/or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 1, 4, 5, and 6, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 8 because of changes in inventory and/or incomplete data reporting.

[2] Imported for distribution by U.S. producers only; included in totals in tables 11, 12, and 13.

[3] Less than 1/2 unit.

[4] Includes exports.

of mainly rock salt from Canada and vacuum pan salt from the Netherlands increased 33% and 68%, respectively, whereas imports from the Bahamas, Chile, and Mexico decreased 50%, 16%, and 19%, respectively.

Canada was the largest supplier of salt to the United States, representing 49% of the total, with Mexico comprising 21% and the Bahamas 9%. More than 99% of total imports was bulk rock salt and solar salt.

Salt exports increased 64% in 1988 compared with those of the previous year. Canada represented 78% of the total exports, with most of the balance shipped to Mexico and Saudi Arabia.

WORLD CAPACITY

Each type of salt produced in the world has unique mining, processing, and marketing characteristics that determine the criteria for deriving rated capacities. The data shown in tables 14 through 16 are rated capacities for mines and refineries, and salt requirements for salt-based chlorine facilities as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Tables14 and 15 list the annual production capacities of domestic rock salt, solar salt, vacuum pan salt and salt brine producers. Table 16 incorporates the domestic capacity data with foreign salt capacities. Capacity data were derived from industry sources, published reports, and estimates based on production trends.

Rock

Because the majority of rock salt was used for deicing, the operating rate of rock salt facilities fluctuated with the demand for deicing salt, again dependent on the severity of winter weather conditions. During periods of strong demand, production levels often achieve, or exceed in certain situations, the rated capacities. Full mine capacity generally is a function of the hoisting capabilities of the mines. Assuming that the work week is five days (250 work-days per year), two working shifts and one maintenance shift per day, and at least one short-term planned turnaround for the mine and mill per year, tables 14 and 16 list the production capacities for domestic and foreign rock salt operations.

Solar

Solar salt, also known as marine and sea salt, is obtained from the solar evaporation of seawater, of landlocked bodies of saline water, and of discharged brines. Because evaporation rates must exceed the precipitation rates, the climatic conditions and geographic location of solar evaporation facilities are critical to the successful production and harvesting of solar salt. Therefore, rated capacities generally are based on the historical evaporation patterns within a region and vary depending on the location and the surface areas of the evaporation ponds. Only unpredictable seasonal precipitation and market conditions usually affect the production rates of the facilities.

Vacuum Pan

The mechanical evaporation of salt by the vacuum pan process is dependent on the number and size of the vacuum crystallizers operating in series. Rated capacities are usually easier to establish because of the proven design performance of the equipment.

Brine

Brine capacities are difficult to derive because they are based on the

TABLE 8

DISTRIBUTION OF DOMESTIC AND IMPORTED EVAPORATED AND ROCK SALT[1] IN THE UNITED STATES, BY DESTINATION

(Thousand short tons)

Destination	1987			1988		
	Evaporated		Rock	Evaporated		Rock
	Vacuum pans and open pans	Solar		Vacuum pans and open pans	Solar	
Alabama	52	(2)	354	55	(2)	363
Alaska	1	W	—	1	W	—
Arizona	7	61	W	8	74	W
Arkansas	33	W	60	33	W	86
California	157	900	W	162	894	W
Colorado	19	101	80	21	121	73
Connecticut	11	11	283	11	11	225
Delaware	2	14	28	17	12	21
District of Columbia	1	(2)	W	1	(2)	W
Florida	93	67	29	97	51	28
Georgia	77	28	88	80	30	92
Hawaii	W	W	—	W	W	—
Idaho	6	60	W	6	71	W
Illinois	372	67	1,002	378	91	1,453
Indiana	154	40	605	161	45	737
Iowa	162	43	211	166	44	249
Kansas	96	20	299	95	11	315
Kentucky	41	W	440	40	W	393
Louisiana	54	W	352	57	W	357
Maine	6	64	150	6	54	116
Maryland	47	107	237	57	94	165
Massachusetts	36	8	656	39	37	508
Michigan	242	19	927	236	21	1,330
Minnesota	168	130	282	173	129	420
Mississippi	21	(2)	115	22	(2)	128
Missouri	120	19	418	116	22	415
Montana	2	42	W	2	46	W
Nebraska	93	35	133	90	4	152
Nevada	W	186	W	1	192	W
New Hampshire	2	22	191	2	27	96
New Jersey	118	172	281	127	166	270
New Mexico	5	W	2	6	W	2
New York	258	97	2,092	266	75	2,172
North Carolina	173	102	71	173	100	53
North Dakota	53	11	7	38	14	5
Ohio	328	24	1,351	347	29	1,787
Oklahoma	40	W	69	42	W	80
Oregon	11	56	1	12	64	—
Pennsylvania	172	119	1,039	152	111	1,078

See footnotes at end of table.

TABLE 8—Continued

DISTRIBUTION OF DOMESTIC AND IMPORTED EVAPORATED AND ROCK SALT[1] IN THE UNITED STATES, BY DESTINATION

(Thousand short tons)

Destination	1987 Evaporated: Vacuum pans and open pans	1987 Evaporated: Solar	1987 Rock	1988 Evaporated: Vacuum pans and open pans	1988 Evaporated: Solar	1988 Rock
Rhode Island	5	3	105	6	23	11
South Carolina	40	9	13	46	12	11
South Dakota	44	26	35	42	36	40
Tennessee	69	(2)	610	67	(2)	629
Texas	160	92	208	180	98	229
Utah	4	192	W	5	289	W
Vermont	6	W	152	5	W	190
Virginia	77	117	201	71	49	154
Washington	18	222	(2)	18	278	(2)
West Virginia	14	W	181	12	W	178
Wisconsin	223	53	707	231	55	939
Wyoming	1	28	1	1	33	1
Other[3]	71	375	404	56	303	489
Total[4]	**3,965**	**3,742**	**14,470**	**4,036**	**3,816**	**16,040**

W Withheld to avoid disclosing company proprietary data; included with "Other".
[1] Each salt type includes domestic and imported quantities. Brine is excluded because brine usually is not shipped out of State.
[2] Less than 1/2 unit.
[3] Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, some shipments to unspecified destinations, and shipments to States indicated by symbol W.
[4] Data may not add to totals shown because of independent rounding. Because data include salt imported, purchased and/or sold from inventory from regional distribution centers, evaporated and rock salt distributed by State may differ from totals shown in tables 1,4,5, and 6, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 7 because of changes in inventory and/or incomplete data reporting.

TABLE 9

AVERAGE VALUES[1] OF SALT, BY PRODUCT FORM AND TYPE

(Dollars per short ton)

	Vacuum pans and open pans	Solar	Rock	Brine
1987				
Bulk	40.12	13.82	12.50	4.93
Compressed pellets	97.50	70.54	XX	XX
Packaged	112.18	47.47	51.45	XX
Average[2]	94.21	25.40	14.34	4.93
Pressed blocks	70.76	67.67	77.22	XX
1988				
Bulk	43.22	14.86	12.69	3.58
Compressed pellets	101.09	73.02	XX	XX
Packaged	116.39	46.48	50.03	XX
Average[2]	97.71	26.59	14.46	3.58
Pressed blocks	73.41	68.05	77.71	XX

XX Not applicable.
[1] Net selling value, f.o.b. plant, excluding container costs.
[2] Salt value data previously reported were an aggregate value per ton of bulk, compressed pellets, and packaged salt. For time series continuity, an average of these three types of product forms is presented, which is based on the aggregated values and quantities of the product form for each type of salt shown in table 4.

variabilities of the injection rate of the solvent and the solubility rates of the underground salt bodies. Both determine the quantity of brine produced. In addition, production levels are dependent on the demand for the products that the brine is being used to manufacture. Therefore, individual company and country brine capacities are not included in tables 14 and 16, except in cases where capacities were derived from actual published brine statistics and the assumption made that

TABLE 10

U.S. EXPORTS OF SALT, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1987 Quantity	1987 Value	1988 Quantity	1988 Value
Argentina	1	13	2	17
Australia	(1)	30	2	18
Bahamas	1	28	1	41
Bahrain	(1)	9	7	74
Brazil	—	—	2	17
Canada	477	6,839	717	8,469
Costa Rica	(1)	8	2	27
Denmark	(1)	22	1	9
Dominican Republic	3	65	7	58
Honduras	(1)	14	1	14
Japan	1	32	3	124
Mexico	26	489	41	646
Netherlands Antilles	(1)	27	3	47
Panama	1	10	2	118
Saudi Arabia	24	421	48	606
Taiwan	—	—	—	117
United Arab Emirates	1	12	1	11
United Kingdom	—	—	(1)	71
Venezuela	(1)	4	6	54
Other	6	194	38	320
Total	**541**	**8,217**	**884**	**10,858**

[1] Less than 1/2 unit.

Source: Bureau of the Census; figures adjusted by the Bureau of Mines.

brine capacity was equal to brine production. Table 15 lists the quantity, type, and source of the salt required to manufacture chlorine. The amount of brine purchased or used captively agrees closely with the quantity of brine used for chloralkali production as noted in table 7.

Country capacities in table 16 may include data on solution-mined brine or natural-occurring brine, which were incorporated with other salt production statistics.

WORLD REVIEW

World production of salt increased about 3% in 1988 compared with that of the previous year, exceeding 200 million tons. The percent distribution of salt production, on a regional basis, was North America, 28%; Western Europe, 24%; Asia, 20%; Eastern Europe, 16%; Oceania and South America, 4% each; Africa, 2%; the Caribbean and Middle East, 1% each; and Central America, less than 1%.

Australia

Dampier Salt Ltd., of which 64.9% is owned by CRA Ltd, increased its export sales to Brazil and Nigeria in order to expand business. Dampier had been exporting about three-fourths of its solar salt production to Japan.[8]

Canada

Canadian Salt Co. (CSC), a subsidiary of Morton Thiokol Inc. of the United States, purchased for $35 million (Canadian dollars), the rock salt mine of Mines Seleine Inc. from SOQUEM, a corporation of the Quebec government. CSC will invest about $16 million (Canadian dollars) during the next 5 years to modernize and to increase capacity from 1.38 million tons to 1.65 million tons. The facility has an integrated distribution system that provides for ship transport, stockpiling, and delivery of highway deicing salt throughout Quebec and the East Coast of the United States.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF SALT

(Thousand short tons and thousand dollars)

	Salt in brine[1]		In bags, sacks, barrels, or other packages		Bulk	
	Quantity	Value	Quantity	Value	Quantity	Value
1984	3	195	71	2,386	7,471	71,519
1985	4	117	66	3,794	6,138	61,682
1986	(2)	34	70	3,170	6,595	76,505
1987	1	67	44	5,122	[3]5,671	61,747
1988	2	125	78	6,682	5,394	70,550

[1] Anhydrous salt content.
[2] Less than 1/2 unit.
[3] Data was adjusted to correct for erroneous notation of shipment from Italy in August.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF SALT, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1987		1988	
	Quantity	Value	Quantity	Value
Bahamas	965	7,765	478	6,885
Canada[1]	2,002	24,330	2,659	33,221
Chile	415	3,682	348	3,083
France[2]	66	546	7	497
German Democratic Republic	14	63	83	306
Germany, Federal Republic of[3]	7	394	5	563
Italy[4]	[5]204	417	58	894
Mexico[6]	1,409	16,212	1,139	16,332
Netherlands	203	4,002	341	8,198
Netherlands Antilles	230	3,350	200	3,168
Spain[7]	41	446	22	252
Other	160	5,729	134	3,958
Total	**5,716**	**66,936**	**5,474**	**77,357**

[1] Includes salt in bags, sacks, and barrels through 10 customs districts, 32,050 short tons ($2,242,384) in 1987; and through 9 customs districts, 70,892 short tons ($3,077,427) in 1988.
[2] Includes salt in bags, sacks, and barrels through three customs districts, 222 short tons ($77,933) in 1987; and through four customs districts, 135 short tons ($107,304) in 1988.
[3] Includes salt in bags, sacks, and barrels through six customs districts, 2,542 short tons ($304,426) in 1987; and through eight customs districts, 2,918 short tons ($528,926) in 1988.
[4] Includes salt in bags, sacks, and barrels through two customs districts, 85 short tons ($28,123) in 1987; none in 1988.
[5] Adjusted to correct erroneous notation of shipment in August.
[6] Includes salt in bags, sacks, and barrels through one customs district, 273 short tons ($38,155) in 1987; and through two customs district, 292 short tons ($30,052) in 1988.
[7] Includes salt in bags, sacks, and barrels through two customs districts, 32 short tons ($14,279) in 1987; and through two customs districts, 11 short tons ($10,053) in 1988.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF SALT, BY CUSTOMS DISTRICT

(Thousand short tons and thousand dollars)

Customs district	1987		1988	
	Quantity	Value	Quantity	Value
Anchorage, AK	([1])	12	([1])	159
Baltimore, MD	269	2,643	278	2,473
Boston, MA	11	924	216	3,248
Buffalo, NY	5	85	100	987
Chicago, IL	165	2,125	388	5,321
Charleston, SC	13	2,187	79	3,115
Cleveland, OH	48	616	29	449
Detroit, MI	640	8,234	683	9,574
Duluth, MN	79	798	107	1,174
Great Falls, MT	([1])	1	([1])	7
Laredo, TX	([1])	67	1	77
Los Angeles, CA	127	1,949	126	1,959
Miami, FL	2	61	2	117
Milwaukee, WI	456	5,435	642	9,607
New Orleans, LA	203	2,545	63	653
New York, NY	508	5,678	408	5,046
Norfolk, VA	144	1,262	133	1,020
Ogdensburg, NY	118	1,318	31	460
Pembina, ND	13	27	1	35
Philadelphia, PA	[2]579	3,182	129	1,410
Portland, ME	465	5,092	432	6,031
Portland, OR	427	5,361	290	4,775
Providence, RI	255	2,682	177	1,651
St. Albans, VT	1	54	1	71
San Diego, CA	—	—	([1])	22
San Francisco, CA	([1])	5	([1])	268
San Juan, PR	16	287	39	355
Savannah, GA	396	3,625	359	5,116
Seattle, WA	464	5,369	435	6,786
Tampa, FL	56	1,066	104	1,474
Washington, DC	([1])	4	([1])	1
Wilmington, NC	255	4,242	220	3,915
Total[3]	**5,716**	**66,936**	**5,474**	**77,357**

[1] Less than 1/2 unit.
[2] Adjusted to correct erroneous notation of shipment from Italy in August.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

The company agreed to operate the mine at least through 1998 and to maintain the same proportion of employees from the Magdalen Islands. In return, CSC was awarded a 10-year contract to furnish rock salt for provincial highway deicing, including a 5% discount on the price of salt sold to the province. The acquisition makes CSC the largest salt producer in Canada and increases its annual production capacity from 4.7 million tons to 6.2 million tons, or 45% of the total Canadian production capacity.[9]

China

Construction began at Laizhou Gulf in Shandong Province on two salt operations that will have a combined annual production capacity of 1 million tons. The project was the largest to be built since 1949. Shandong will have a total salt output of about 6.6 million tons.[10]

France

The French government evaluated the report of a committee that investigated various solutions to reduce salt discharges into the Rhine River from potash mining. One option involved transporting the salt by rail to Dunkirk where it would be stored or dumped into the sea. Other alternatives specified temporarily storing the salt for future use or discharging small quantities of salt into the Rhine after the year 2000. Additional studies will be required to evaluate the environmental impact of the two proposals.[11]

Iran

The Mines and Minerals Department of West Azarbaijan Province funded a project to recover potassium chlorate and calcium sulfate with byproduct salt at Lake Urumieh. Between March 21, 1987 and March 20, 1988, about 44,000 tons of salt were produced, of which the majority was exported to Turkey.[12]

[1] Physical scientist, Branch of Industrial Minerals.
[2] Minor Ores and Minerals. Drewry Shipping Consultants Ltd., London, England, 1988.

[3] Industrial Minerals (London). Akzo Gets Go-Ahead To Buy Diamond Salt. No. 248, 1988, p. 15.

[4] Daily News (Minot, ND). Salt Plant Closure Leaves 38 Workers Without Jobs, Aug. 28, 1988.

[5] Industrial Minerals (London). American Salt Co. Acquired. No. 248, 1988, p. 13.

[6] Chemical Marketing Reporter. Olin To Develop Salt Cavern at McIntosh Chemicals Plant. V. 234, No. 9, Aug. 29, 1988, p. 7.

[7] Chemical Marketing Reporter. Chemical Prices, v. 235, No. 1, Jan. 2, 1989, p. 33.

[8] Industrial Minerals (London). Dampier Salt Expands Market Horizons. No. 250, 1988, p. 9.

[9] Minerals Yearbook-Salt. Energy, Mines, & Resour., Prud'homme, Michel. p. 50.1-50.9.

[10] Industrial Minerals. (London). Mineral Notes. Chinese Salt. No. 246, 1988, p. 66.

[11] European Chemical News. France Mulls Proposed Rhine Salt Solutions. V. 50, No. 1314, Mar. 7, 1988, p. 28.

[12] Industrial Minerals. (London). Mineral Notes. Iranian Salt. No. 252, 1988, p. 90.

TABLE 14

U.S. SALT ANNUAL PRODUCTION CAPACITIES IN 1988

(Thousand short tons)

Company	Plant	Type of salt			Total
		Rock	Solar	Vacuum pan	
American Salt Co.	Lyons, KS	250	—	300	550
Do.	Grantsville, UT	—	300	—	300
Carey Salt Co.	Hutchinson, KS	300	—	225	525
Cargill Inc.	Hutchinson, KS	—	—	250	250
Do.	Breaux Bridge, LA	—	—	150	150
Do.	Lansing, NY	1,300	—	—	1,300
Do.	Watkins Glen, NY	—	—	250	250
Do.	Amboy, CA	—	75	—	75
Do.	Napa, CA	—	275	—	275
Do.	Newark, CA	—	750	150	900
Do.	Redwood City, CA	—	350	—	350
Do.	Freedom, OK	—	75	—	75
Domtar Industries Inc.	Baldwin, LA	1,700	—	—	1,700
Great Salt Lake Minerals and Chemicals Corp.	Ogden, UT	—	1,500	—	1,500
Huck Salt Co.	Fallon, NV	15	—	—	15
Independent Salt Co.	Kanopolis, KS	350	—	—	350
International Salt Co.	Avery Island, LA	2,000	—	—	2,000
Do.	St. Clair, MI	—	—	395	395
Do.	Manistee, MI	—	—	325	325
Do.	Retsof, NY	4,000	—	—	4,000
Do.	Watkins Glen, NY	—	—	335	335
Do.	Williston, ND	—	—	75	75
Do.	Akron, OH	—	—	300	300
Do.	Cleveland, OH	2,000	—	—	2,000
Do.	Lakepoint, UT	—	150	—	150
Moab Salt Inc.	Moab, UT	—	75	—	75
Morton Thiokol Inc.	Glendale, AZ	—	75	—	75
Do.	Trona, CA	—	75	—	75
Do.	Hutchinson, KS	—	—	350	350
Do.	Weeks, LA	1,500	—	125	1,625
Do.	Manistee, MI	—	—	360	360
Do.	Silver Springs, NY	—	—	275	275
Do.	Fairport, OH	2,000	—	—	2,000
Do.	Rittman, OH	—	—	600	600
Do.	Grand Saline, TX	400	—	100	500
Do.	Salt Lake City, UT	—	150	—	150
New Mexico Salt and Mineral Corp.	Carlsbad, NM	—	20	—	20
Pacific Salt & Chemical Co.	Trona, CA	—	150	—	150
Redmond Clay & Salt Co. Inc.	Redmond, UT	80	—	—	80
Salt Products Co.	Milligan, CA	—	10	—	10

TABLE 14—Continued

U.S. SALT ANNUAL PRODUCTION CAPACITIES IN 1988

(Thousand short tons)

Company	Plant	Type of salt			Total
		Rock	Solar	Vacuum pan	
United Salt Corp.	Carlsbad, NM	—	250	—	250
Do.	Hockley, TX	150	—	—	150
Do.	Houston, TX	—	—	100	100
Western Salt Co.	Chula Vista, CA	—	75	—	75
Williams Brine Service	Carlsbad, NM	—	10	—	10
Total		**16,045**	**4,365**	**4,665**	**25,075**
Brine producers[1]	Various locations	—	—	—	18,818
Grand total		**16,045**	**4,365**	**4,665**	**43,893**

[1] Includes brine for sale and for captive use. Brine production capacity is assumed to be equal to the quantity of annual brine production, as shown in tables 2 and 3. Brine producers include those chloralkali manufacturers that purchase brine or use captive brine, as listed in table 15.

TABLE 15

U.S. CHLORINE FACILITIES THAT REQUIRE SALT[1]

(Thousand short tons)

Company	Location	Annual chlorine production capacity[2]	Salt requirements[3]	Source of salt requirements
Akzo Chemicals, Inc.	Lemoyne, AL	74	129	Purchased.
Brunswick Pulp and Paper Co.	Brunswick, GA	36	63	Imported.
Dow Chemical USA	Freeport, TX [4]	2,856	4,998	Captive brine.
Do.	Pittsburg, CA	199	348	Purchased.
Do.	Plaquemine, LA	997	1,745	Captive brine.
E. I. DuPont de Nemours & Co. Inc.	Niagara Falls, NY	84	147	Purchased.
Formosa Plastics Corp. USA	Baton Rouge, LA	200	350	Purchased brine.
Fort Howard Corp.	Green Bay, WI	9	16	Imported.
Do.	Muskogee, OK	9	16	Purchased.
General Electric Co.	Burkville, AL	27	47	Do.
Do.	Mt. Vernon, IN	70	123	Do.
Georgia Gulf Corp.	Plaquemine, LA	452	791	Purchased brine.
Georgia Pacific Corp.	Bellingham, WA	91	159	Purchased.
BF Goodrich Group	Calvert City, KY	128	224	Do.
LaRoche Chemicals	Gramercy, LA	219	383	Captive brine.
LCP Chemicals & Plastics Inc.	Acme, NC	53	93	Imported.
Do.	Brunswick, GA	108	189	Do.
Do.	Moundsville, WV	91	159	Captive brine.
Do.	Orrington, ME	80	140	Imported.
Do.	Syracuse, NY	110	192	Captive brine.
Niachlor (DuPont-Olin)	Niagara Falls, NY	240	420	Purchased brine.
Occidental Chemical Corp.	Convent, LA	296	518	Do.
Do.	Corpus Christi, TX	460	805	Do.
Do.	Deer Park, TX	383	670	Do.
Do.	Delaware City, DE.	139	243	Imported.
Do.	LaPorte, TX	515	901	Purchased brine.
Do.	Muscle Shoals, AL.	146	255	Purchased.
Do.	Niagara Falls, NY	350	613	Purchased brine.
Do.	Tacoma, WA	237	415	Imported.
Do.	Taft, LA	611	1,069	Purchased brine.
Olin Corp.	Augusta, GA	115	201	Captive brine.
Do.	Charleston, TN	256	448	Purchased.
Do.	McIntosh, AL	365	639	Captive brine.
Do.	Niagara Falls, NY	91	159	Purchased.
Pennwalt Corp.	Portland, OR	150	263	Imported.
Do.	Tacoma, WA	91	159	Do.
Pioneer Chlor-Alkali Co. Inc.	Henderson, NV	119	208	Purchased.
Do.	St. Gabriel, LA	173	303	Do.
PPG Industries Inc.	Lake Charles, LA	1,150	2,012	Captive and purchased brine.
Do.	Natrium, WV	280	490	Captive brine.
RMI Co.	Ashtabula, OH	37	65	Do.
Vulcan Chemicals	Geismar, LA	246	431	Purchased brine.
Do.	Port Edwards, WI	73	128	Imported.
Do.	Wichita, KS	273	478	Captive brine.
Weyerhaeuser Co.	Longview, WA	130	228	Imported.
Total		**12,819**	**22,433**	

[1] Includes only those chlorine plants that use salt directly as a feedstock. Does not include plants that produce byproduct chlorine from MgCl and HCl oxidation or plants using KCl.
[2] Based on 365 days per year.
[3] Based on 1.75 tons of salt required to manufacture 1.0 ton of chlorine. Salt may be from natural brines, rock, or solar sources, domestic or imported.
[4] An additional 730,000 tons are available on standby basis; included in "Total."

TABLE 16

WORLD SALT ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons)

	Rock	Solar[2]	Vacuum pan[3]	Total[4]
North America:				
Bahamas	—	1,650	—	1,650
Canada	[5]9,116	—	1,069	13,602
Mexico	—	8,900	NA	[6]9,600
United States	16,045	[5]4,365	4,665	43,893
Puerto Rico	—	40	—	40
Total	**25,161**	**14,955**	**5,734**	**68,785**
Caribbean:				
Cuba	—	300	—	300
Dominican Republic	[7]70	NA	—	70
Jamaica[8]	—	20	—	20
Leeward & Windward Islands[8]	—	60	—	60
Netherlands Antilles	—	400	—	400
Total	**70**	**780**	**—**	**850**
Central America:				
Costa Rica	—	30	—	30
El Salvador	—	20	—	20
Guatemala	—	50	—	50
Honduras	—	35	—	35
Nicaragua	—	60	—	60
Panama	—	90	—	90
Total	**—**	**285**	**—**	**285**
South America:				
Argentina	1	1,000	265	1,400
Bolivia	—	20	—	20
Brazil	1,500	4,000	100	5,600
Chile	1,650	—	—	1,650
Colombia	450	1,000	—	1,450
Peru	150	400	—	550
Venezuela	—	550	—	550
Total	**3,751**	**6,970**	**365**	**11,220**
Europe, Western:				
Austria	1	—	550	800
Belgium	—	—	—	500
Denmark	—	—	—	600
France	[9]1,600	1,900	1,150	11,450
Germany, Federal Republic of	[5]8,000	—	925	14,425
Greece	—	200	—	200
Iceland	—	—	—	[10]2
Ireland	275	—	—	275
Italy	1,980	1,550	1,000	5,630
Malta	—	([11])	—	([11])
Netherlands	—	—	NA	4,400
Portugal	125	NA	—	650
Spain	[12]1,700	1,650	NA	3,370
Switzerland	—	—	—	440
Turkey	100	1,050	—	1,400
United Kingdom	[5]2,810	—	[13]2,670	11,875
Total	**16,591**	**6,350**	**6,295**	**56,017**

See footnotes at end of table.

TABLE 16 —Continued

WORLD SALT ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons)

	Rock	Solar[2]	Vacuum pan[3]	Total[4]
Europe, Eastern:				
Albania	—	—	—	80
Bulgaria	—	—	—	100
Czechoslovakia	—	—	—	350
German Democratic Republic	[5]3,500	—	—	3,600
Poland	1,650	—	—	4,000
Romania	2,000	—	—	6,000
U.S.S.R.	[5]10,100	2,000	1,760	20,600
Yugoslavia	300	110	—	700
Total	**17,550**	**2,110**	**1,760**	**35,430**
Africa:				
Algeria	—	200	—	200
Angola	—	50	—	50
Benin	—	([11])	—	([11])
Egypt	—	1,500	—	1,500
Ethiopia	20	150	—	170
Ghana	—	—	55	55
Kenya	—	60	—	60
Libya	—	15	—	15
Madagascar	—	35	—	35
Mali	—	5	—	5
Mauritania	—	6	—	6
Mauritius	—	7	—	7
Morocco	1,100	30	—	1,130
Mozambique	—	35	—	35
Namibia	—	200	—	200
Niger	—	3	—	3
Senegal	—	170	—	170
Sierra Leone	—	—	—	220
Somalia	—	35	—	35
South Africa, Republic of	—	900	—	900
Sudan	—	—	—	[14]80
Tanzania	—	30	—	30
Tunisia	—	500	—	500
Uganda	—	6	—	6
Zambia	—	—	—	([15])
Total	**1,120**	**3,937**	**55**	**5,412**
Middle East:				
Cyprus	—	30	—	30
Iraq	—	100	—	100
Iran	70	500	—	570
Israel	—	200	50	250
Jordan	—	[5]60	—	60
Kuwait	—	—	[16]25	[17]25
Lebanon	—	10	—	10
Saudi Arabia	—	—	—	([17])
Syria	125	—	—	125
Yemen (Aden)	—	80	—	80
Yemen (Sanaa)	100	—	—	100
Total	**295**	**980**	**75**	**1,350**

See footnotes at end of table.

TABLE 16 —Continued

WORLD SALT ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons)

	Rock	Solar[2]	Vacuum pan[3]	Total[4]
Asia:				
Afghanistan	20	—	—	20
Bangladesh	—	600	—	600
Burma	—	—	—	400
China	8,000	25,000	—	33,000
India	6	14,000	—	20,000
Indonesia	—	1,000	—	1,000
Japan	—	1,600	—	1,600
Kampuchea	—	45	—	45
Korea, North	—	—	—	700
Korea, Republic of	—	900	—	900
Laos	35	—	—	35
Pakistan	600	NA	—	1,000
Philippines	—	600	—	600
Sri Lanka	—	140	—	140
Taiwan	—	620	—	620
Thailand	12	188	—	200
Vietnam	—	500	—	500
Total	**8,673**	**45,193**	**—**	**61,360**
Oceania:				
Australia	—	8,600	—	8,600
New Zealand	—	100	—	100
Total	**—**	**8,700**	**—**	**8,700**
World total	**73,211**	**90,260**	**14,284**	**249,409**

NA Not available.

[1] Capacities were derived from industry sources, published reports, and estimates based on production trends. Salt brine capacities are not meaningful because they vary with production levels of brine feedstock to chemical plants. Therefore, salt brine capacities are not included in the list, except for certain countries that incorporate brine statistics with other types of salt. In these exceptions, brine capacities are assumed to be equal to the quantity of brine produced in 1988.

[2] Also known as marine salt.

[3] Some countries report "refined salt," which may or may not be vacuum pan salt, but washed or screened rock or solar salt. Efforts were made to categorize refined salt into the appropriate type of salt.

[4] May include brine or salt from undisclosed sources.

[5] Contains salt produced as a byproduct or coproduct from potash mining. Additional salt may be recovered but discharged as a waste product.

[6] Contains salt produced as a byproduct or coproduct from sulfur mining.

[7] Contains salt produced as a byproduct or coproduct from gypsum mining.

[8] Salt is imported, washed, repackaged, and exported.

[9] Byproduct salt from potash mining is 8.5 million tons, of which only about 880,000 tons are sold and the remainder discharged.

[10] Recovered from geothermal brines.

[11] Less than 1/2 unit.

[12] Byproduct salt from potash mining is 2.65 million tons, of which only about 500,000 tons are sold and the remainder discharged.

[13] Includes about 220,000 tons of sea salt recovered using open pan process.

[14] From evaporating brine from salt springs or wells over wood fires.

[15] Plants from brine marshes are washed to obtain a salt solution, which is heated in containers to recover salt.

[16] From mechanical evaporation of seawater at petrochemical complex.

[17] Salt is obtained from several seawater desalination plants but amount of recovery is uncertain.

TABLE 17

SALT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Afghanistan[e]	11	11	11	11	37
Albania[e]	80	80	82	83	80
Algeria	193	185	209	220	220
Angola[e]	55	11	11	11	11
Argentina:					
Rock salt	1	1	1	1	1
Other salt	1,032	1,595	1,342	1,048	[3]920
Australia (marine salt and brine salt)	6,278	6,432	6,758	7,150	7,165
Austria:					
Rock salt	1	1	2	2	2
Evaporated salt	462	483	536	534	535
Salt in brine	263	254	276	265	275
Bahamas	[e]960	[e]940	991	811	[3]988
Bangladesh[4]	741	539	[e]550	459	440
Benin[e]	([5])	([5])	([5])	([5])	([5])
Brazil:					
Rock salt	1,046	[r]1,053	661	1,047	1,100
Marine salt	3,944	1,911	1,764	3,968	4,000
Bulgaria	98	98	100	101	100
Burma[6]	309	353	[e]354	376	365
Cambodia[e]	45	45	45	45	45
Canada	11,282	11,117	11,389	11,165	11,736
Chile	690	831	1,138	954	620
China[e]	17,950	[3]15,924	19,070	19,800	24,250
Colombia:					
Rock salt	299	260	250	226	[3]235
Marine salt	732	545	552	496	[3]516
Costa Rica (marine salt)	[e]120	33	[e]33	14	[3]300
Cuba	204	244	293	[r e]300	300
Cyprus	—	8	7	([7])	7
Czechoslovakia	379	385	373	[r e]370	370
Denmark	577	586	[r e]620	[r e]585	585
Dominican Republic[e]	70	[3]52	60	60	[3]19
Egypt	953	1,170	[e]1,400	1,115	1,200
El Salvador	[e]3	[e]3	3	3	3
Ethiopia:[e 4]					
Rock salt	17	17	17	17	17
Marine salt	130	130	130	130	130
France:					
Rock salt	249	407	425	1,627	1,650
Brine salt	1,240	1,272	1,240	[r e]1,180	1,200
Marine salt	1,522	1,569	1,775	[r e]1,795	1,820
Salt in solution	4,869	4,593	4,368	[r e]4,040	4,050

See footnotes at end of table.

TABLE 17 —Continued

SALT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
German Democratic Republic:					
Rock salt[e]	3,390	3,395	3,390	3,390	3,300
Marine salt	64	64	65	65	65
Germany, Federal Republic of: Marketable:					
Rock salt and other[8]	7,837	10,642	13,777	14,178	14,330
Marine salt[9]	5,624	3,765	666	666	667
Ghana[e]	55	55	55	55	55
Greece	146	215	[r e]210	[r e]210	210
Guatemala	[e]18	19	43	41	[3]47
Honduras[e]	35	35	35	35	35
Iceland	1	1	[e]2	[e]2	2
India:					
Rock salt[e]	6	4	2	2	2
Marine salt	8,514	10,885	11,151	10,913	9,260
Indonesia[e]	[3]408	660	660	[r]660	660
Iran[10]	762	775	[e]770	[e]770	770
Iraq[e]	90	80	80	80	80
Israel[e]	160	170	170	170	170
Italy:					
Rock salt and brine salt	3,588	3,501	3,784	4,072	4,080
Marine salt[11]	797	628	[r e]880	[r e]880	880
Japan[12]	1,053	[e]1,300	1,510	1,540	1,545
Jamaica	17	17	14	17	17
Jordan	24	35	[e]35	20	20
Kenya:					
Rock salt	80	73	[e]70	[r e]53	68
Other	31	28	39	[r e]26	35
Korea, North[e]	630	630	630	630	630
Korea, Republic of	571	709	804	732	[3]1,124
Kuwait	23	23	31	39	40
Laos[e]	9	11	33	33	33
Lebanon[e]	6	6	6	6	6
Leeward and Windward Islands[e]	55	55	55	55	55
Libya[e]	13	13	13	13	13
Madagascar[e]	33	33	33	33	33
Mali[e]	5	5	5	5	5
Malta	(5)	[e](5)	[e](5)	[e](5)	(5)
Mauritania[e]	6	6	6	6	6
Mauritius[e]	7	7	7	7	7
Mexico	6,798	7,129	6,840	6,833	[3]7,678
Mongolia[e]	18	18	18	18	18
Morocco	69	102	106	119	[3]146
Mozambique[e]	30	30	30	30	30

See footnotes at end of table.

TABLE 17 —Continued

SALT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	[r]1986	1987[p]	1988[e]
Namibia (marine salt)	97	[r]169	148	138	[3]138
Netherlands	4,050	4,579	4,148	4,386	[3]4,071
Netherlands Antilles[e]	390	390	390	390	390
New Zealand	63	57	([7])	[e]70	70
Nicaragua[e]	17	17	17	17	17
Niger[e]	3	3	3	3	3
Pakistan:[4]					
Rock salt	659	643	635	[r e]530	580
Other salt	[e]200	296	267	[r e]340	275
Panama (refined salt)	20	18	11	[e]11	11
Peru	279	226	440	440	390
Philippines	442	464	866	492	550
Poland:					
Rock salt	1,306	1,323	1,346	1,357	1,320
Other salt	3,887	4,040	4,630	5,442	4,960
Portugal:					
Rock salt	502	[e]512	506	566	550
Marine salt	180	236	[r e]220	[r e]220	220
Romania	5,373	5,532	5,903	5,945	5,950
Senegal	182	176	160	[e]110	110
Sierra Leone[e]	220	220	220	220	220
Somalia[e]	33	33	33	33	33
South Africa, Republic of	679	796	829	778	[3]773
Spain:					
Rock salt	2,376	2,381	[e]2,300	[e]2,300	2,300
Marine salt and other evaporated salt	1,359	1,190	1,102	[e]1,100	1,100
Sri Lanka	118	85	115	127	[3]118
Sudan[e]	80	[3]42	44	[3]57	55
Switzerland	410	412	429	430	[3]432
Syria[e]	[3]96	100	100	100	100
Taiwan	241	206	150	110	[3]123
Tanzania	24	23	24	[e]25	25
Thailand:					
Rock salt	11	14	2	[e]5	5
Other salt[e]	180	180	180	180	180
Tunisia	364	421	457	468	[3]535
Turkey	1,422	1,311	1,292	1,342	1,490
Uganda[e]	6	6	6	[3]4	[3]6
U.S.S.R.	18,200	17,747	16,865	16,975	17,100
United Kingdom:					
Rock salt	1,730	2,238	[e]2,200	[e]2,200	2,200
Brine salt[13]	1,569	1,711	[e]1,700	[e]1,700	1,700
Other salt[13]	4,557	3,928	[e]3,900	[e]3,900	3,900

See footnotes at end of table.

TABLE 17 —Continued

SALT: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
United States including Puerto Rico:					
Rock salt	13,355	14,690	12,598	11,965	[3]12,900
Other salt:					
United States	25,871	25,377	24,065	24,527	[3]26,040
Puerto Rico[e]	30	35	40	40	40
Venezuela[e]	360	390	463	440	440
Vietnam[e]	880	320	500	250	330
Yemen (Aden)[e]	80	80	80	80	80
Yemen (Sanaa)	[e]160	165	331	180	180
Yugoslavia	419	450	556	550	[3]424
Total	**[r]190,258**	**[r]191,494**	**193,132**	**196,956**	**203,848**

[e]Estimated. [p]Preliminary. [r]Revised.
[1] Table includes data available through July 5, 1989.
[2] Salt is produced in many other countries, but quantities are relatively insignificant and reliable production data are not available. Some salt brine production data for manufacture of chlorine, caustic soda, and soda ash are not reported because of incomplete data reporting by many countries.
[3] Reported figure.
[4] Year ending June 30 of that stated.
[5] Less than 1/2 unit.
[6] Brine salt production as reported by the Burmese Government was as follows, in short tons: 1984–89,470; 1985–49,061; 1986–57,413; 1987–70,220; and 1988–73,260.
[7] Revised to zero.
[8] Rock salt only for 1984–85.
[9] Marine salt and other for 1984–85.
[10] Data are for year begining Mar. 21 of that stated.
[11] Does not include production from Sardinia and Sicily, estimated at 220,000 short tons annually.
[12] Data are for fiscal year ending Mar. 31 of that stated.
[13] Data captioned "Brine salt" for the United Kingdom are the quantities of salt obtained from the evaporation of brines; those captioned "Other salt" are the salt content of brines used for purposes other than production of salt by evaporation.

Construction Sand and Gravel

By Valentin V. Tepordei[1]

A total of 923 million short tons of construction sand and gravel was produced in the United States in 1988, an increase of 3% over the estimated 1987 total. This tonnage was the fourth largest production ever recorded in the United States and the fourth consecutive year of production over 800 million tons.

Foreign trade of construction sand and gravel remained relatively minor. Exports decreased 15.1% to 965,000 tons valued at $11 million, while imports for consumption increased 24% to 351,000 tons valued at $3.2 million. Domestic apparent consumption of construction sand and gravel was 923 million tons.

DOMESTIC DATA COVERAGE

Domestic production data for construction sand and gravel are developed by the Bureau of Mines from voluntary surveys of U.S. producers. Full surveys of construction sand and gravel producers are conducted for even-numbered years only. For odd-numbered years, a preliminary survey that collects production information on a sample basis is used to generate only annual preliminary estimates at the State level. A new quarterly sample survey for sand and gravel and crushed stone was implemented by the Bureau of Mines in 1989 to provide, for the first time, production estimates by quarters for each State and the nine geographic regions beginning with 1988. The quarterly survey canvasses most of the large companies in each State, accounting for up to 80% of the State's total tonnage. The survey's results are published quarterly in the publication titled "Mineral Industry Surveys." Of the 7,341 construction sand and gravel operations canvassed for the biennial survey, 6,848, or 93.3%, responded. This percentage represents the highest response rate ever recorded. Of the total operations surveyed, 5,687, or 77.5%, were active; 1,161 operations, or 15.8%, were idle; and 493 were closed down. Of the total active operations, 4,516 reported a total of 801 million tons, or 86.8% of the total, while a total of 122 million tons, or 13.2%, was estimated as produced by 1,171 nonrespondents. The significant increase in the response rate was due mostly to the information collected through the quarterly survey.

LEGISLATION AND GOVERNMENT PROGRAMS

On November 10, 1988, the U.S. Congress enacted the Technical Corrections and Miscellaneous Revenue Act of 1988 (Public Law 100-647), which includes a provision reinstating the diesel fuel tax exemption for all off-road users. The law becomes effective January 1, 1989. The bill also provides for a special one-time, interest-bearing refund of diesel taxes paid between March 31, 1988, and January 1, 1989.

On August 25, 1988, the Mine Safety and Health Administration (MSHA) published its final rules for Loading, Hauling & Dumping, and Machinery & Equipment, which became effective October 24, 1988. The final rules required that seatbelts be installed and worn in quarry off-highway haulers.

Responding to requests made by the industry, the Occupational Safety and Health Administration (OSHA) has again extended a partial stay to July 21, 1989, for the new provisions of its revised asbestos standards for nonasbestiform varieties of actinolite, anthophyllite, and tremolite minerals originally published on June 20, 1986. The stay was issued to allow OSHA time to review or complete additional studies and to collect more data, including that on the feasibility of regulating these nonasbestiform minerals. The extension of the stay was needed because of the range of affected industries and the lack of mineralogic and exposure data in these industries. The former asbestos standard remains in effect for the extent of the stay.

The introduction of the revised OSHA regulations for airborne asbestos standards, which include nonasbestiform varieties of actinolite, anthophyllite, and tremolite, is expected to have a significant impact on the aggregates and the construction industries. The consequences could include in-

TABLE 1

SALIENT U.S. CONSTRUCTION SAND AND GRAVEL STATISTICS[1]

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
Sold or used:					
Construction sand and gravel:					
Quantity	773,900	[e]800,100	883,000	[e]896,200	923,400
Value	$2,244,000	[e]$2,438,000	$2,747,200	[e]$3,002,500	$3,126,000
Exports:					
Quantity	1,845	1,513	1,166	1,137	965
Value	$10,325	$8,935	$7,838	$10,533	$11,048
Imports for consumption:					
Quantity	151	246	205	283	351
Value	$1,603	$1,572	$1,412	$2,367	$3,163

[e] Estimated.
[1] Puerto Rico excluded from all sand and gravel statistics.

creased construction costs and disruption of the supply of aggregates.

The International Agency for Research on Cancer (IARC) of the World Health Organization published in 1987 the "IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans—Silica and Some Silicates."[2] The document states that there is "sufficient evidence" that crystalline silica is carcinogenic to experimental animals, and "limited evidence" of its carcinogenicity to humans. Under IARC rules, all material safety data sheets for products containing 0.1% or more of crystalline silica must contain a cancer warning. Following the publication of this ruling, OSHA decided that "Information regarding the evidence of carcinogenicity must be included on required labels and material safety data sheets for crystalline silica, and for products containing crystalline silica, where employee exposure to crystalline silica may occur," as part of OSHA Hazard Communication Standard requirements.[3] Although OSHA's standard does not directly regulate the aggregates industry, it does affect the industry customers. It may also serve as a model for State hazardous communication programs, as well as the one currently being developed by MSHA, which will directly regulate the aggregates industry.

The National Council on Public Works Improvement, which was created by the Public Works Improvement Act of 1984 (Public Law 98-501), submitted to the President and the U.S. Congress on February 24, 1988, its final report titled "Fragile Foundations: A Report on America's Public Works."[4] According to the report, America's public works are barely adequate to meet current needs and are insufficient to support economic growth. Transportation, water, and waste-disposal systems need an infusion of capital to meet the demands created by a growing economy, while solid- and hazardous-waste-disposal systems have serious and growing problems that require immediate action. The Council concludes that the causes for the poor state of the Nation's infrastructure are largely monetary. The Council recommends a national commitment, shared by all levels of Government, the private sector, and the public, to vastly improve America's infrastructure. Such a commitment could require an increase of up to 100% in the amount of capital the Nation invests each year in new and existing public works.

California's Surface Mining and Reclamation Act (SMARA) was passed in 1975. The main purpose of SMARA was to identify and protect mineral resources in areas of high land use and to ensure reclamation of mined lands. The act requires that aggregate resources be quantified and compared with forecasted demand in specific market regions. High-quality deposits are legally designated as "regionally significant." This designation ensures that such resources will be available in the future for aggregate production. Although the effectiveness of the SMARA classification program is difficult to measure at this time, owing to the long-term nature of its goals, the aggregate classification reports have been well received. Government agencies, aggregate producing companies as well as other interested companies and individuals are now using the existing reports and requesting accelerated classification of other regions. The information provided by these reports helped in the decisionmaking process regarding land use and long-range planning.[5]

DOMESTIC PRODUCTION

U.S. production of construction sand and gravel increased 4.6% in 1988 compared with that of 1986, when the last full annual survey was conducted. Of

FIGURE 1

PRODUCTION OF CONSTRUCTION SAND AND GRAVEL IN THE UNITED STATES IN 1988, BY GEOGRAPHIC REGION

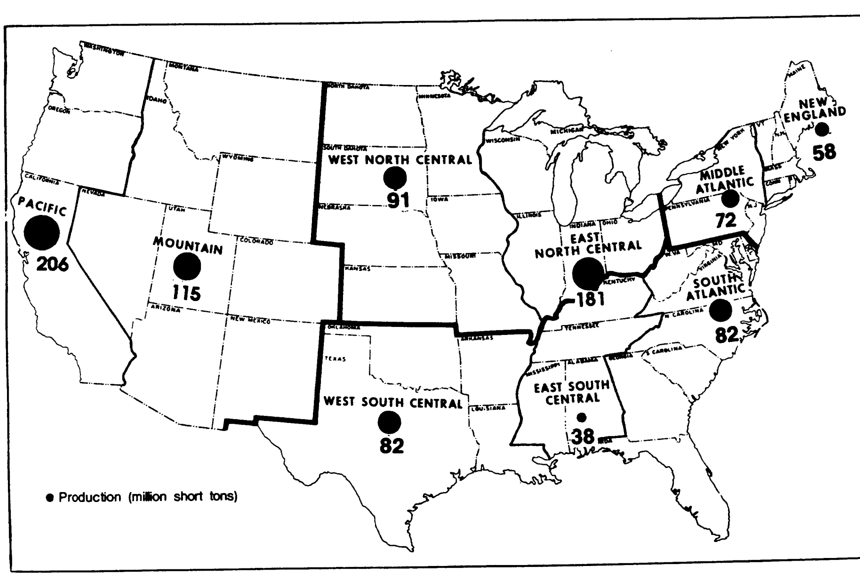


TABLE 2

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GEOGRAPHIC REGION

Geographic region	1987				1988			
	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total
Northeast:								
New England	[e]55,300	6	[e]$189,400	6	57,614	6	$202,413	7
Middle Atlantic	61,400	7	247,000	8	72,027	8	290,490	9
Midwest:								
East North Central	150,300	17	457,700	15	180,681	20	528,057	17
West North Central	95,500	11	255,000	9	90,555	10	222,723	7
South:								
South Atlantic	90,100	10	297,300	10	82,187	9	292,308	9
East South Central	40,000	4	126,700	4	38,216	4	118,810	4
West South Central	78,100	9	270,300	9	81,598	9	272,842	9
West:								
Mountain	117,700	13	399,800	14	114,635	12	377,300	12
Pacific	207,800	23	759,300	25	205,848	22	821,055	26
Total[1]	**[e]896,200**	**100**	**[e]3,002,500**	**100**	**923,400**	**100**	**3,126,000**	**100**

[e] Estimated.
[1] Data may not add to totals shown because of independent rounding.

TABLE 3

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1988, BY GEOGRAPHIC REGION AND QUARTERS

(Thousand short tons and thousand dollars)

Geographic	Quantity				Total[1]	Value	Number of companies[2]
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.			
Northeast:							
New England	8,400	17,200	17,500	14,400	57,614	202,413	31
Middle Atlantic	7,800	20,600	24,900	18,700	72,027	290,490	31
Midwest:							
East North Central	14,500	54,200	62,200	49,900	180,681	528,057	60
West North Central	6,300	29,300	33,800	21,200	90,555	222,723	52
South:							
South Atlantic	16,800	22,200	22,300	20,900	82,187	292,308	52
East South Central	6,400	10,200	10,900	10,700	38,216	118,810	27
West South Central	18,900	23,100	21,600	18,000	81,598	272,842	31
West:							
Mountain	21,800	29,900	31,200	31,700	114,635	377,300	47
Pacific[3]	40,800	46,400	53,300	47,600	205,848	821,055	30
Total[1]	**141,500**	**253,200**	**277,700**	**233,100**	**923,400**	**3,126,000**	**XX**

XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Number of companies reporting for the quarterly survey.
[3] Does not include Alaska and Hawaii in quarterly estimates.

the four major geographic regions, the West again led the Nation in production with 320 million tons, or 35% of the U.S. total, followed by the Midwest with 271 million tons, or 29% of the total, the South with 202 million tons, or 22%, and the Northeast with 130 million tons, or 14%. Compared with that of 1986, production increased 17% in the Northeast, 13% in the Midwest, and 2% in the West, but decreased 4% in the South.

Of the nine geographic regions, the Pacific again led the Nation with 206 million tons, or 22% of the U.S. total. Next was the East North Central with 181 million tons, or 20% of the total, followed by the Mountain with 115 million tons, or 12% of the total. Compared with that of 1986, production increased in six of the nine regions. The largest increases were recorded in the East North Central, 19.1%; the Middle Atlantic, 19%; and New England, 14%. At the same time, production decreased in the West South Central, 12.1%; in the East South Central, 5.4%; and in the Mountain, 2.8%.

The estimated production by quarters for 1988, provided for the first time this year, indicated that most of the construction sand and gravel in the United States was produced in the third quarter of 1988, followed by the second quarter and the fourth quarter. Estimated production information by each quarter of 1988 was also available for most of the States.

Based on the 1987 Bureau of the Census estimates on U.S. population, the 1988 U.S. per capita construction sand and gravel production was 3.8 tons. By major geographic regions, per capita production was 6.6 tons in the West, followed by the Midwest with 4.6 tons, the Northeast with 2.6 tons, and the South with 2.4 tons.

Construction sand and gravel was produced in every State, and the 10 leading States were, in descending order of tonnage, California, Michigan, Texas, Ohio, New York, Minnesota, Arizona, Washington, Illinois, and In-

TABLE 4

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1987[e]		1988	
	Quantity	Value	Quantity	Value
Alabama	10,300	35,600	11,742	41,417
Alaska	27,200	73,400	17,200	48,749
Arizona	38,100	141,300	32,399	123,854
Arkansas	7,200	23,900	7,722	26,201
California	141,600	561,300	141,946	622,074
Colorado	22,800	84,300	21,566	69,882
Connecticut	8,400	37,000	8,275	32,102
Delaware	2,300	6,400	1,933	5,988
Florida	30,000	74,900	18,654	53,083
Georgia	9,000	26,900	9,526	30,185
Hawaii	700	3,500	652	3,173
Idaho	7,200	28,000	6,914	19,897
Illinois	28,300	93,300	30,098	93,504
Indiana	18,900	65,200	25,923	79,985
Iowa	19,000	63,800	11,880	36,087
Kansas	15,600	37,800	10,760	25,329
Kentucky	7,100	15,200	6,325	15,243
Louisiana	12,200	43,600	14,233	52,820
Maine	8,600	22,100	10,183	33,007
Maryland	19,600	92,900	19,266	95,169
Massachusetts	21,800	75,300	22,168	79,364
Michigan	42,800	105,300	53,508	138,171
Minnesota	25,200	67,400	33,769	72,678
Mississippi	14,700	47,000	13,314	38,806
Missouri	10,900	30,400	11,217	32,941
Montana	6,800	18,800	7,984	20,225
Nebraska	10,300	26,300	11,229	28,928
Nevada	10,600	30,700	15,729	50,928
New Hampshire	9,100	33,300	9,089	32,614
New Jersey	15,200	61,200	18,318	74,183
New Mexico	8,600	31,000	8,787	31,367
New York	31,400	112,900	33,884	124,341
North Carolina	8,600	30,100	11,076	38,459
North Dakota	4,900	10,200	3,772	8,079
Ohio	36,400	136,900	46,104	156,318
Oklahoma	10,500	24,200	9,273	22,654
Oregon	13,000	42,200	14,880	52,657
Pennsylvania	14,800	72,900	19,826	91,966
Rhode Island	2,700	10,900	1,853	7,847
South Carolina	7,500	19,500	7,529	20,751

See footnote at end of table.

TABLE 4—Continued

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1987[e] Quantity	1987[e] Value	1988 Quantity	1988 Value
South Dakota	9,600	19,100	7,929	18,681
Tennessee	7,900	28,900	6,836	23,343
Texas	48,200	178,600	50,370	171,167
Utah	21,000	56,700	17,843	49,796
Vermont	4,700	10,800	6,047	17,478
Virginia	12,100	43,400	12,551	42,573
Washington	25,300	78,900	31,170	94,402
West Virginia	1,000	3,200	1,653	6,099
Wisconsin	23,900	57,000	25,048	60,080
Wyoming	2,600	9,000	3,413	11,351
Total[1]	**896,200**	**3,002,500**	**923,400**	**3,126,000**

[e] Estimated.
[1] Data may not add to totals shown because of independent rounding.

diana. Their combined production represented 52% of the national total.

Compared with 1986, production increased in 32 States, including 8 of the top 10. The increases were significant in the following major producing States: California, Indiana, Michigan, Minnesota, Ohio, and Washington. The top two States, California and Michigan, showed an increase of 10.5% and 25.9%, respectively, in their production, while Texas, the third State in order of volume, showed a 15.4% decrease in production.

A total of 4,175 companies produced construction sand and gravel at 5,687 operations, a decrease of 3.4% in the number of companies and 1.9% in the number of operations, as compared with the 1986 survey. Operations larger than 200,000 tons per year produced 73% of the total U.S. tonnage while representing only 22% of the total number of operations. Of these, 121 operations reported production larger than 1 million tons per year and produced a combined 23% of the total tonnage. The trend toward larger operations with a higher degree of mechanization and automation continued.

The top 10 producers of construction sand and gravel were, in descending order of tonnage, CalMat Co., Beazer Materials and Services Inc., ARC America Corp., Lone Star Industries Inc., Granite Construction Co., Dravo Basic Materials Co. Inc., Owl Rock Products Co., A. Teichert & Sons Inc., Florida Rock Industries Inc., and Meyer Material Co. Combined production of the 157 operations owned by the top 10 producers was 13.7% of the national total.

Owing to shortages of construction aggregates occurring in some areas—mostly major metropolitan areas, some offshore sand and gravel had been dredged and used as construction aggregates, fill, and for beach replenishment. Most of the sand and gravel mined offshore is not presently included in the Bureau of Mines survey. Information about such operations is available from some State agencies.

Acquisitions by foreign as well as domestic companies and mergers in the construction sand and gravel industry continued in 1988. C. H. Beazer PLC of Bath, United Kingdom, acquired Koppers Co. of Pittsburgh, PA, the second largest U.S. aggregates producer, and its subsidiaries: Kaiser Sand and Gravel of Pleasanton, CA; Cherokee Crushed Stone of Pembroke Pines, FL; Davidson Minerals of Lithonia, GA; France Stone Co. of Toledo, OH; Hoosier Stone and Concrete of Salem, IN; Kentucky Stone of Louisville, KY; Eastern Rock Products of Utica, NY; General Crushed Stone of Easton, PA; Berry Materials of North Vernon, IN; and Stone Man Inc. of East Ridge, IN. The acquisition included a total of 80 stone quarries and 24 sand and gravel operations in 13 States, as well as Koppers' chemical division. The newly formed organization will operate under the name of Beazer Materials and Services Inc. of Pittsburgh, PA, a member of The Beazer Group.

Redland PLC of Groby, United Kingdom, announced in June that it had acquired Koppers' 50% interest in Western-Mobile Inc., a Koppers-Redland joint venture that was established in 1986. Western-Mobile supplies construction aggregates and ready-mixed concrete in Colorado, New Mexico, Kansas, and Wyoming.

ARC America Corp. of Newport Beach, CA, a subsidiary of ARC Ltd. of Bristol, United Kingdom, acquired Ernst Aggregates Corp. of Dayton, OH, through its own subsidiary, American Aggregates of Greenville, OH. The acquisition included four sand and gravel pits owned by Ernst Aggregates and two crushed stone quarries leased from Southwestern Portland Cement Co. of Fairborn, OH.

English China Clays Ltd. (ECC) of Exeter, United Kingdom, the world's largest producer of kaolin, acquired the J.L. Shiely Co. of St. Paul, MN, and its wholly owned subsidiary, Cooley Gravel Co. of Denver, CO. Shiely and its subsidiary operate five sand and gravel pits supplying construction aggregates to the Minneapolis-St. Paul, MN, and Denver and Colorado Springs, CO, metropolitan areas.

Pioneer Concrete of America of Bedford, TX, acquired Davison Sand & Gravel Co. of New Kensington, PA, a major sand and gravel producer in the Pittsburgh area, as well as G & S Towing Co., a towboat and barge company that supports Davison's four dredging operations.

Cement-Roadstone Holdings PLC of Dublin, Ireland, announced that a newly formed corporation, Pike Holdings Inc., acquired Pike Industries Inc. of New England, which operates 4 quarries, 6 sand and gravel pits, and 30 asphalt plants in Maine, New Hampshire, and Vermont.

Tarmac America of Herndon, VA, a subsidiary of Tarmac PLC of Wolverhampton, United Kingdom, purchased the outstanding 40% equity in the Tarmac-Lone Star Inc. joint venture that was formed in January 1987.

Lone Star Industries of Greenwich, CT, formed a joint venture with Onoda Cement Co. of Tokyo, Japan, and acquired 50% interest in Northwest Aggregates Co. of Seattle, WA. The new company, called Lone Star Northwest, operates three sand and gravel pits in Alaska, Oregon, and Washington.

RMC Industries Corp. of Decatur, GA, a subsidiary of RMC Group PLC of Seltham, United Kingdom, entered into a joint venture with Lone Star Industries and formed RMC Lone-Star of Pleasanton, CA. The new company operates eight sand and gravel pits and one crushed stone quarry in California.

CalMat Co. of Los Angeles, CA, acquired Albuquerque Gravel Products Co. of Albuquerque, NM, and its subsidiary S & S Aggregates. The acquisition included one sand and gravel and one crushed stone operation, and four ready-mixed plants.

Vulcan Materials Co. of Birmingham, AL, acquired B. L. Anderson Co. of Cedar Rapids, IA. The purchase included 18 rock quarries and 2 dredging operations, all in Iowa. The company will operate under the Vulcan name as a member of its Midwest Division.

TABLE 5

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1988, BY STATE AND QUARTERS

(Thousand short tons and thousand dollars)

State	Quantity					Value	Number of companies[2]
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total[1]		
Alabama	2,000	2,800	3,500	3,500	11,742	41,417	9
Alaska[3]	—	—	—	—	17,200	48,749	—
Arizona	7,500	7,900	7,700	9,300	32,399	123,854	11
Arkansas	1,500	2,300	2,200	1,700	7,722	26,201	5
California	32,200	34,900	38,300	36,600	141,946	622,074	17
Colorado	1,700	6,500	7,500	5,800	21,566	69,882	8
Connecticut	1,300	2,400	2,600	2,000	8,275	32,102	8
Delaware	300	500	600	500	1,933	5,988	5
Florida	4,500	4,800	4,500	4,800	18,654	53,083	10
Georgia	2,100	2,700	2,500	2,300	9,526	30,185	9
Hawaii[3]	—	—	—	—	652	3,173	—
Idaho[3]	—	—	—	—	6,914	19,897	—
Illinois	2,000	9,000	9,500	9,400	30,098	93,504	8
Indiana	2,600	8,000	8,900	6,400	25,923	79,985	13
Iowa	700	3,500	4,500	3,200	11,880	36,087	7
Kansas	1,300	3,700	3,700	2,100	10,760	25,329	8
Kentucky	600	1,900	2,000	1,800	6,325	15,243	3
Louisiana	2,800	4,000	3,400	4,000	14,233	52,820	4
Maine[3]	—	—	—	—	10,183	33,007	—
Maryland	3,100	5,400	5,800	5,000	19,266	95,169	10
Massachusetts	4,300	6,300	6,100	5,500	22,168	79,364	10
Michigan	3,400	15,700	19,600	14,800	53,508	138,171	9
Minnesota	1,200	11,400	13,700	7,600	33,769	72,678	14
Mississippi	2,600	3,900	3,300	3,500	13,314	38,806	9
Missouri	1,300	3,600	3,800	2,600	11,217	32,941	6
Montana[3]	—	—	—	—	7,984	20,225	—
Nebraska	1,000	3,900	3,600	2,700	11,229	28,928	8
Nevada	3,100	3,800	4,300	4,500	15,729	50,928	7
New Hampshire	500	2,900	3,000	2,700	9,089	32,614	4
New Jersey	2,700	5,100	5,500	5,000	18,318	74,183	9
New Mexico	1,300	2,200	2,800	2,600	8,787	31,367	4
New York	3,500	9,100	13,000	8,400	33,884	124,341	10
North Carolina	2,100	2,900	3,200	2,900	11,076	38,459	5
North Dakota[3]	—	—	—	—	3,772	8,079	—
Ohio	3,900	14,000	16,100	12,100	46,104	156,318	16
Oklahoma	1,800	2,800	2,500	2,100	9,273	22,654	7
Oregon[3]	—	—	—	—	14,880	52,657	—
Pennsylvania	1,400	6,100	7,300	5,100	19,826	91,966	12
Rhode Island[3]	—	—	—	—	1,853	7,847	—
South Carolina	1,800	2,000	1,900	1,800	7,529	20,751	5

See footnotes at end of table.

TABLE 5—Continued

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1988, BY STATE AND QUARTERS

(Thousand short tons and thousand dollars)

State	Quantity					Value	Number of companies[2]
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total[1]		
South Dakota	600	2,500	3,100	1,800	7,929	18,681	7
Tennessee	1,400	1,800	1,900	1,700	6,836	23,343	6
Texas	13,000	13,900	13,100	10,300	50,370	171,167	15
Utah[3]	—	—	—	—	17,843	49,796	—
Vermont	700	2,000	2,200	1,200	6,047	17,478	4
Virginia	2,200	3,500	3,600	3,200	12,551	42,573	5
Washington	5,400	7,800	10,200	7,800	31,170	94,402	10
West Virginia	100	500	600	400	1,653	6,099	3
Wisconsin	2,400	7,300	8,400	7,000	25,048	60,080	14
Wyoming	300	1,300	1,300	400	3,413	11,351	8
Total[1]	**XX**	**XX**	**XX**	**XX**	**923,400**	**3,126,000**	**XX**

XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Number of companies reporting for the quarterly survey.
[3] Due to a very low number of reporting companies in some States, no production estimates by quarters were generated.

TABLE 6

CONSTRUCTION SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 1988, BY SIZE OF OPERATION

Size range	Number of operations	Percent of total	Quantity (thousand short tons)	Percent of total
Less than 25,000	1,725	30.5	18,222	1.8
25,000 to 49,999	854	15.0	31,190	3.4
50,000 to 99,999	990	17.4	71,113	7.7
100,000 to 199,999	888	15.6	126,105	13.7
200,000 to 299,999	420	7.4	103,104	11.2
300,000 to 399,999	239	4.2	82,382	8.9
400,000 to 499,999	147	2.6	64,472	7.0
500,000 to 599,999	98	1.7	53,383	5.8
600,000 to 699,999	64	1.1	41,533	4.5
700,000 to 799,999	48	.8	35,614	3.9
800,000 to 899,999	44	.8	37,208	4.0
900,000 to 999,999	49	.9	46,303	5.0
1,000,000 to 1,499,999	71	1.2	85,418	9.3
1,500,000 to 1,999,999	24	.4	39,506	4.3
2,000,000 to 2,499,999	12	.2	26,146	2.8
2,500,000 and over	14	.2	61,664	6.7
Total	**5,687**	**100.0**	**[1]923,400**	**100.0**

[1] Data do not add to total shown because of independent rounding.

As a result of these acquisitions, the foreign ownership of crushed stone and sand and gravel companies increased significantly. Five of the top twenty-five U.S. sand and gravel producers are owned by foreign companies. Their total production represents 6.2% of the U.S. total.

CONSUMPTION AND USES

Sand and gravel reported by producers to the Bureau of Mines is actually material that is sold or used by the companies and is defined as such. Stockpiled production is not reported until it is sold to a user or consumed by the producer outside its own operation. Because no consumption surveys are conducted by the Bureau of Mines, the sold or used tonnage is assumed to represent the amount produced for domestic consumption and export.

Of the 923 million tons produced, 25.1% was used as concrete aggregates, including concrete sand for airports, buildings, dams, and highways; 15.2% for road base and coverings and road stabilization; 8.9% as asphaltic concrete aggregates and other bituminous mixtures; 6.8% as construction fill; 1.1% for concrete products such as blocks, bricks, pipes, etc.; 1% in plaster and gunite sands; and the remainder for snow and ice control, railroad ballast, roofing granules, and other miscellaneous uses. Because some producers did not report a breakdown by end use, their total production, as well as the estimated production for nonrespondents, was included in "Unspecified uses," which represents 39% of the U.S. total. Two-thirds of this total was production reported by producers and one-third was production estimated for nonrespondents. The estimated production for nonrespondents represents only 13.1% of the U.S. total, a relatively small percentage, taking into account the number of producers covered by the survey.

TABLE 7

NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS[1] AND PROCESSING PLANTS IN THE UNITED STATES IN 1988, BY GEOGRAPHIC REGION

Geographic region	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No. plants or unspecified		
Northeast:						
New England	165	179	21	53	3	421
Middle Atlantic	246	202	39	64	24	575
Midwest:						
East North Central	393	383	72	103	72	1023
West North Central	308	462	41	108	189	1108
South:						
South Atlantic	176	42	9	100	90	417
East South Central	90	59	7	25	42	223
West South Central	204	69	9	158	78	518
West:						
Mountain	274	414	62	72	18	840
Pacific	288	150	30	76	18	562
Total	**2,144**	**1,960**	**290**	**759**	**534**	**5,687**

[1] An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

A review of consumption by major geographic regions indicates that most of the sand and gravel for concrete aggregates, including concrete sand, was used in the West, 32.8%, the South, 31.2%, and the Midwest, 25.4%, regions with high levels of construction activities. Most of the sand and gravel for road base and coverings was used in the West, 50.2%, and the Midwest, 30.1%, while most of the sand and gravel used for asphaltic concrete aggregates and other bituminous mixtures was used in the West, 45%, and the Midwest, 29.8%.

Additional information regarding production and consumption of construction sand and gravel by major uses in each State and by State districts is published in Volume II of the Bureau of Mines "Minerals Yearbook."

TRANSPORTATION

Of the total construction sand and gravel produced, 43% was transported from the plant to the consumer by truck, 3% by waterway, and 1% by rail. A significant number of producers did not indicate how their production was shipped, and therefore their production was included in unspecified method of shipment, 51%. Because most producers either did not keep records or did not report shipping distances or cost per ton per mile, no transportation cost data were available.

PRICES

Prices in this chapter are f.o.b. plant, usually the first point of sale or captive use. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, and in-plant transportation, plus profit.

Compared with that of 1986, when the last full annual survey was conducted, the 1988 average unit prices increased 9% to $3.39 per ton. By uses, the largest increases in unit prices were recorded for railroad ballast, 19.5%; plaster and gunite sands, 17.6%; snow and ice control, 13.1%; fill, 10.3%; concrete products and road base and coverings, 9.4% each; asphaltic concrete aggregates and other bituminous mixtures, 4.9%; road stabilization-cement, 3.8%; and concrete aggregates, 3.5%. Average unit prices for road stabilization-lime and roofing granules showed a decline of 29.1% and 26.5%, respectively. The decline in prices may have been influenced by a significantly smaller reported production for those uses.

FOREIGN TRADE

Exports

Exports of construction sand decreased 14.7% to 506,000 tons compared with that of 1987, while value decreased only 1.8% to $7.5 million. Canada was the major destination receiving about 71% of the total, while Mexico received about 11%. Exports of construction gravel decreased 15.6% to 459,000 tons, while value increased 22.2% to $3.6 million. Canada again was the major destination with 78% of the total, followed by Mexico with 11%.

Imports

Imports of construction sand and gravel increased 24% to 351,000 tons,

TABLE 8

CONSTRUCTION SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES IN 1988, BY MAJOR USE

Use	Quantity (thousand short tons)	Value (thousands)	Value per ton
Concrete aggregates (including concrete sand)	230,576	$887,422	$3.85
Plaster and gunite sands	9,227	43,226	4.68
Concrete products (blocks, bricks, pipe, decorative, etc.)	10,403	38,916	3.74
Asphaltic concrete aggregates and other bituminous mixtures	82,417	318,662	3.87
Road base and covering	136,597	413,330	3.03
Road stabilization (cement)	2,390	6,452	2.70
Road stabilization (lime)	984	2,592	2.63
Fill	62,611	134,709	2.15
Snow and ice control	5,974	20,086	3.36
Railroad ballast	638	2,849	4.47
Roofing granules	623	2,517	4.04
Filtration	69	372	5.39
Other	20,578	72,443	3.52
Unspecified:			
Actual	238,924	828,733	3.47
Estimated	121,352	353,689	2.91
Total[1] or average	**923,400**	**3,126,000**	**3.39**

[1] Data may not add to totals shown because of independent rounding.

while the value increased by 33.6% to $3.2 million. Canada remained the major source of imported construction sand and gravel with 74.6% of the total, followed by Antigua with 17.7%.

TECHNOLOGY

Between 1982 and 1984, the Transportation Research Board conducted a comprehensive study for the Federal Highway Administration (FHWA) on the extent to which expanded research and development could make major contributions toward improving the quality of U.S. highways and related structures. The Strategic Transportation Research Study concluded that a time-specific, concentrated, short-term, and result-oriented research program would be highly cost-effective.[6] In April 1987, the Strategic Highway Research Program (SHRP), a 5-year $150 million research program, was created and funded under the Surface Transportation and Uniform Relocation Assistance Act of 1987.[7] Under the provisions of the act, 0.25% of State-apportioned Federal highway aid was allocated to SHRP for highway research to solve key technical problems of common concern to State highway departments and other road transportation agencies. SHRP is administered as a unit of the National Research Council through a mutual agreement between the Council, the FHWA, and the American Association of State Highway and Transportation Officials (AASHTO). SHRP research areas of investigation were selected based on recommendations made by the Strategic Transportation Research Study and include: asphalts, concrete and structures, highway operations, and long-term pavement performance. These areas were selected as priority targets of investigation because short-term research could yield economically significant results that could be readily implemented.

The asphalt program includes both laboratory and field tests to determine how fundamental properties of asphaltic materials affect the service life of pavements. The information collected under this program will form the basis for recommendations for performance-based specifications for asphalt pavement materials. The concrete and structure program will develop improved concrete materials and construction processes, as well as better means of controlling corrosion in steel-reinforced concrete. The highway operations program includes research in both snow and ice control and in improved materials and equipment for highway maintenance. The long-term pavement performance program is focused on improvement of pavement design and maintenance methods. It includes collection and analysis of long-term performance data on different types of new and rehabilitated pavement structures and using different materials under different loading environments at approximately 1,300 inservice test sections in roadways throughout the United States and Canada. A significant number of contracts were awarded and research teams were assembled with the initial multiyear contract awards. To enhance creativity and innovation in the research contracts, SHRP is seeking alternative approaches to the objectives of the planned research through two special programs, Ideas Deserving Exploratory Analysis and Asphalt Independent Innovative Research.

The State highway agencies were instrumental in the development of SHRP, and their support continues.

TABLE 9

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS

(Thousand short tons

Geographic region	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:								
New England	9,158	46,788	156	1,187	534	1,934	2,805	14,065
Middle Atlantic	15,202	71,543	619	3,452	909	4,187	4,985	23,429
Midwest:								
East North Central	40,434	122,766	992	3,854	2,640	7,729	15,081	45,365
West North Central	18,164	54,296	345	1,199	1,050	2,956	9,449	21,907
South:								
South Atlantic	28,818	122,195	2,293	7,714	1,204	4,605	5,559	19,326
East South Central	10,022	31,940	313	1,524	338	1,080	3,199	15,558
West South Central	33,100	110,184	305	1,397	657	2,650	4,255	17,429
West:								
Mountain	17,097	66,407	541	2,358	1,436	5,465	11,687	42,812
Pacific	58,581	261,303	3,664	20,540	1,635	8,311	25,397	118,771
Total[2]	**230,600**	**887,400**	**9,200**	**43,200**	**10,400**	**38,900**	**82,400**	**318,700**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes sand and gravel used in road and other stabilization (cement and lime).
[2] Data may not add to totals shown because of independent rounding.

The States donated test sites for the pavement performance experiments and provided personnel and equipment to assist in tasks related to management of the test sites and traffic data collection. Twenty-five countries are also working with SHRP through its International Cooperation Program in a variety of ways, ranging from exchanging research information to running parallel or complementary research programs. The impact of SHRP on the highway industries is expected to be much greater than the findings and recommendations of the AASHTO road test conducted at Ottawa, IL, that have been the basis of pavement design since 1962.

The Third Automation Conference, cosponsored by the National Stone Association and the U.S. Bureau of Mines, was held on October 9-11 in Baltimore, MD. The conference, titled "Guidelines for the Successful Application of Automation in the Crushed Stone Industry," focused on relatively inexpensive methods to begin automating smaller pits and quarries. A recent survey conducted by Pit & Quarry Magazine indicated that only 40% of the companies producing less than 500,000 short tons per year plan to purchase new equipment in 1989, and less than 10% expect to buy computers or automation equipment.[8] The Director of the Bureau of Mines said in his keynote address, "The question is not whether to automate, but how much and when. . . . In times of high competition, automation technology may make the difference between a company surviving or not."[9] Seven areas of interest related to automating pit and quarry operations were covered in either general or concurrent sessions: quarry computerization and automation; system automation in the processing plant; plant design for effective automation; sensors and auxiliary equipment; energy management; materials loadout, including scale and dispatch order-entry systems; and automated sand classifier systems.

The recycling of old concrete and asphalt, used mostly in pavements, has been receiving increased attention in recent years. Recycling of concrete resulting from demolished buildings or old roads provides a means of disposing of large volumes of cumbersome waste and also is a limited source of aggregates. In some States, limited recycling especially in road construction is either encouraged or required by law. However, there are some negative aspects related to the concept of using recycled aggregates that should be taken into consideration. The problems often associated with the use of recycled concrete or reclaimed asphalt pavement were reviewed in a report published by the National Aggregates

IN THE UNITED STATES IN 1988, BY GEOGRAPHIC REGION AND MAJOR USE

and thousand dollars)

Road base and coverings[1]		Fill		Snow and ice control		Railroad ballast		Other uses		Total[2]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
7,043	24,494	6,015	13,086	1,792	5,976	28	178	30,082	94,705	57,614	202,413
9,242	33,463	5,138	12,191	1,710	6,605	16	54	34,207	135,565	72,027	290,490
23,296	66,427	15,209	31,927	909	2,274	178	602	81,943	247,113	180,681	528,057
18,866	41,019	6,037	11,722	578	1,497	49	101	36,016	88,027	90,555	222,723
2,495	7,931	6,758	12,955	W	W	W	W	34,930	117,146	82,187	292,308
3,089	6,754	564	919	W	W	W	W	20,671	60,938	38,216	118,810
5,647	19,345	4,460	8,189	12	37	—	—	33,164	113,611	81,598	272,842
23,096	62,948	3,871	7,866	395	1,440	69	326	56,444	187,678	114,635	377,300
47,196	159,993	14,560	35,854	441	1,766	284	1,549	54,090	212,969	205,848	821,055
140,000	**422,400**	**62,600**	**134,700**	**6,000**	**20,100**	**650**	**2,800**	**381,500**	**1,257,800**	**923,400**	**3,126,000**

Association.[10] The report stresses the fact that recycled aggregates should not be used solely for the sake of recycling, especially when the cost of using recycled materials will increase the price tag of the entire project. Sound crushed concrete can make good coarse aggregate, the report indicates, but the fines produced in crushing the concrete have a higher absorption, are more friable, and will require a higher amount of asphalt in asphaltic concrete and a higher amount of mixing water in portland cement. Reclaimed asphalt pavement materials may contain hardened, aged asphalt cement that will not perform in a satisfactory manner unless it is mixed with the proper blending agents. The report suggests using crushed concrete and reclaimed asphalt pavement materials for lower specification items such as fill or subbase rather than in high-quality pavement. The report also underlines the need for proper testing under engineering supervision in all construction projects using recycled materials as aggregates to insure that the technical specifications are met.

A computer-aided visual simulation system that accurately models topography, simulates landform changes, and quickly illustrates a mining project from any known viewpoint, both stationary and in motion, was developed by Design Workshop Inc. of Denver, CO.[11] The simulation system combines the three-dimensional simulation technology with image-processing computer techniques. The system involved transferring an image electronically to a computer database, and then "painting" on it to illustrate proposed changes. The technique involves overlaying site photos with the simulation to depict how the project will change the site. The computer-aided visual simulation system can be used to better plan, design, and review alternatives of proposed mining and reclamation projects.

Clarifying systems represent a cost-effective solution to some of the frustrating problems faced by many producers of aggregates and related mineral products.[12] Most clarification systems work by mixing wash water with a flocculent that causes the suspended solids to settle rapidly. These solids, also referred to as underflow, can then be dewatered and stockpiled and used as landfill or even as products. Some clarifier systems reduce the need for settling ponds dramatically, generally to just one pond, or eliminate them entirely. At the same time, clarifiers permit immediate reuse of wash water and help producers maintain compliance with increasingly stringent water and discharge effluent standards.

Vibrating screens are common sources of noise and dust in pit and quarry operations. Contributing to the problem

TABLE 10

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS

(Thousand short tons

State	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	4,123	11,938	170	711	W	W	1,203	7,369
Alaska	116	694	17	140	W	W	148	939
Arizona	3,914	14,819	W	W	W	W	1,914	9,663
Arkansas	3,631	12,211	W	W	90	253	329	1,170
California	47,607	220,272	3,425	19,360	1,355	7,177	19,822	96,830
Colorado	3,506	14,806	54	303	1,035	3,958	2,794	9,894
Connecticut	1,141	6,926	W	W	W	W	221	1,164
Delaware	520	1,902	W	W	W	W	W	W
Florida	4,854	17,052	441	1,427	W	W	381	1,761
Georgia	2,433	8,011	260	872	W	W	37	80
Hawaii	W	W	W	W	—	—	—	—
Idaho	933	3,186	42	228	W	W	532	1,428
Illinois	9,226	27,310	306	1,084	755	2,380	2,903	10,072
Indiana	7,441	20,227	188	783	542	1,315	2,355	6,355
Iowa	3,485	11,741	W	W	71	281	639	1,791
Kansas	2,536	5,730	48	126	46	95	965	2,664
Kentucky	417	1,223	38	250	18	38	118	275
Louisiana	2,452	8,349	W	W	W	W	700	4,090
Maine	1,211	6,781	—	—	316	633	344	2,121
Maryland	8,462	46,006	335	872	255	1,489	2,062	6,896
Massachusetts	4,202	21,306	68	567	W	W	611	2,401
Michigan	6,712	22,469	99	370	457	1,326	3,085	7,151
Minnesota	5,305	14,351	W	W	631	1,622	5,145	10,310
Mississippi	3,726	12,648	40	221	33	130	1,177	4,478
Missouri	4,493	15,375	78	229	197	654	1,139	2,300
Montana	658	2,567	W	W	—	—	955	2,348
Nebraska	1,480	3,912	60	153	94	271	738	1,956
Nevada	3,458	15,091	54	237	—	—	2,342	8,481
New Hampshire	1,571	6,184	71	471	W	W	1,067	4,930
New Jersey	3,719	18,301	160	828	73	383	485	2,468
New Mexico	1,357	5,085	156	548	W	W	577	1,472
New York	6,812	27,633	108	543	393	1,567	1,950	8,673
North Carolina	3,864	15,922	541	1,764	71	367	1,130	4,139
North Dakota	W	W	—	—	W	W	297	862
Ohio	9,465	31,799	263	1,061	526	1,655	5,692	19,369
Oklahoma	4,053	11,093	55	128	43	203	439	902
Oregon	3,484	13,019	79	384	W	W	2,830	11,108
Pennsylvania	4,672	25,608	351	2,081	442	2,237	2,550	12,287
Rhode Island	390	2,700	W	W	—	—	W	W

See footnotes at end of table.

IN THE UNITED STATES IN 1988, BY STATE AND MAJOR USE

and thousand dollars)

Road base and coverings[1]		Fill		Snow and ice control		Railroad ballast		Other and undistributed uses		Total[2]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
493	991	215	299	W	W	12	35	5,526	20,076	11,742	41,417
14,998	38,806	W	W	32	221	—	—	1,889	7,949	17,200	48,749
3,980	10,037	408	1,032	—	—	—	—	22,183	88,302	32,399	123,854
516	1,432	84	221	W	W	—	—	3,071	10,914	7,722	26,201
23,041	88,808	7,477	20,943	71	270	62	245	39,085	168,170	141,946	622,074
4,804	14,484	925	1,641	215	973	19	169	8,213	23,653	21,566	69,882
435	2,256	872	1,920	224	1,004	—	—	5,382	18,832	8,275	32,102
—	—	482	1,081	W	W	—	—	931	3,005	1,933	5,988
W	W	1,764	3,449	—	—	—	—	11,214	29,395	18,654	53,083
W	W	48	119	—	—	—	—	6,747	21,102	9,526	30,185
261	1,001	W	W	—	—	—	—	391	2,173	652	3,173
2,736	6,242	93	147	W	W	10	51	2,569	8,625	6,914	19,897
4,642	19,134	4,120	9,896	44	114	55	184	8,046	23,330	30,098	93,504
1,975	5,477	2,201	4,914	201	525	1	10	11,019	40,378	25,923	79,985
2,042	4,811	1,572	3,259	104	325	W	W	3,967	13,880	11,880	36,087
2,135	4,952	1,175	2,409	65	251	—	—	3,790	9,102	10,760	25,329
23	86	151	201	1	3	—	—	5,558	13,166	6,325	15,243
520	2,004	1,000	1,850	—	—	—	—	9,562	36,527	14,233	52,820
1,732	5,592	1,154	3,207	449	950	—	—	4,977	13,724	10,183	33,007
950	2,295	661	1,397	24	78	—	—	6,518	36,138	19,266	95,169
1,737	6,802	2,878	6,026	552	2,595	W	W	12,119	39,668	22,168	79,364
7,525	18,169	2,512	3,896	319	698	24	77	32,775	84,016	53,508	138,171
6,294	11,975	1,990	3,549	271	528	W	W	14,132	30,342	33,769	72,678
850	2,035	126	212	—	—	—	—	7,362	19,083	13,314	38,806
518	1,917	606	1,198	65	225	—	—	4,120	11,042	11,217	32,941
2,438	5,293	152	213	70	167	W	W	3,711	9,637	7,984	20,225
3,033	7,765	443	1,010	56	140	—	—	5,325	13,721	11,229	28,928
3,201	9,257	923	2,484	37	118	—	—	5,714	15,259	15,729	50,928
1,052	3,816	751	1,362	300	726	W	W	4,277	15,125	9,089	32,614
1,281	3,941	902	3,389	134	502	—	—	11,564	44,371	18,318	74,183
1,644	6,254	357	688	W	W	W	W	4,697	17,320	8,787	31,367
4,860	16,475	3,448	7,048	1,324	4,955	16	54	14,973	57,391	33,884	124,341
515	1,748	641	973	17	45	—	—	4,297	13,502	11,076	38,459
2,022	3,732	60	77	8	11	W	W	1,386	3,397	3,772	8,079
3,191	10,382	3,962	9,223	W	W	W	W	23,005	82,830	46,104	156,318
1,185	2,711	928	1,301	11	34	—	—	2,560	6,283	9,273	22,654
4,082	14,288	284	692	155	781	W	W	3,967	12,385	14,880	52,657
3,101	13,048	788	1,753	252	1,148	—	—	7,669	33,803	19,826	91,966
W	W	W	W	20	125	—	—	1,443	5,023	1,853	7,847

TABLE 10

CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS

(Thousand short tons

State	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
South Carolina	4,182	12,751	390	935	330	779	637	1,502
South Dakota	804	2,874	W	W	W	W	524	2,024
Tennessee	1,756	6,131	65	342	227	664	701	3,436
Texas	22,963	78,531	228	1,183	327	1,460	2,787	11,268
Utah	2,692	8,570	62	244	W	W	1,851	6,654
Vermont	642	2,891	W	W	92	413	358	1,706
Virginia	3,938	18,406	222	1,412	303	1,171	993	3,718
Washington	7,354	27,159	140	617	W	W	2,598	9,894
West Virginia	565	2,147	46	184	22	66	W	W
Wisconsin	7,590	20,961	W	W	359	1,053	1,046	2,418
Wyoming	579	2,283	W	W	11	19	721	2,872
Total [2]	**230,493**	**886,950**	**8,660**	**40,656**	**9,116**	**33,657**	**81,892**	**315,689**
Undistributed	83	472	570	2,570	1,287	5,259	525	2,973
U.S. total [2]	**230,600**	**887,400**	**9,200**	**43,200**	**10,400**	**38,900**	**82,400**	**318,700**

W Withheld to avoid disclosing company proprietary data, included by State in "Other and undistributed uses" column, and by use in "Undistributed" line. XX Not applicable.
[1] Includes sand and gravel used in road and other stabilization (cement and lime).
[2] Data may not add to totals shown because of independent rounding.

is the fact that screens are generally on elevated structures, which tends to make dust more visible and allows noise to travel farther. Enclosure and wet suppression may reduce these problems to some extent, but may not always be cost-effective. Enclosures not only are expensive to build and maintain but also complicate screen, crusher, and conveyor maintenance. Excess moisture resulting from wet suppression of dust can negatively affect screening operations by "blinding" screens. The use of urethane screening media significantly reduces both plant noise and blinding caused by water-mist dust control. Operating costs are also lower, based on the longer wear life of urethane screens and significantly fewer blinding problems.[13]

A prototype over-the-road haul truck dump trailer fitted with both rubber tires and a rail bogie undercarriage is being tested by the RoadRailer Co. of Hamburg, NY. The trailer can be mounted on the rail bogie for movement on the track and dismounted at destination for highway service, without the need of outside lift-on and lift-off equipment. The truck-rail system will allow quarries without a rail siding to load haul trucks in standard fashion and then haul them to the rail head for transfer to rail. At the destination, a highway move completes the delivery. Conversely, quarries with rail facilities could assemble a unit train of the dump trailers for direct rail move to consumer destinations. On arrival, highway tractors would complete the deliveries to specific locations without transloading the aggregates. The train units move at high speeds pulled by a single locomotive. On the highways, the loaded trailers are pulled by conventional tractors for pickup and delivery. The system eliminates flatcars, switch locomotives and crews, overhead cranes, and piggybackers. The truck-rail system will allow remote quarry locations to serve metropolitan markets with scheduled deliveries, moving as many as 75 trailers in a single rail haul.[14]

[1] Physical scientist, Branch of Industrial Minerals.
[2] World Health Organization, IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans—Silica and Silicates. V. 42, 1987, pp. 39-142.
[3] Federal Register. OSHA Hazard Communication Standard. V. 52, No. 163, Aug. 24, 1987, pp. 31852-31886.
[4] National Council on Public Works Improvement.
[5] Beeby, D. J. Aggregate Resources—California's Effort Under SMARA To Ensure Their Continued Availability. Min. Eng., v. 40, No. 1, Jan. 1988, pp. 42-45.

—Continued

IN THE UNITED STATES IN 1988, BY STATE AND MAJOR USE

and thousand dollars)

Road base and coverings[1]		Fill		Snow and ice control		Railroad ballast		Other and undistributed uses		Total[2]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
413	2,065	664	966	W	W	W	W	914	1,753	7,529	20,751
2,823	5,867	191	219	9	17	—	—	3,579	7,682	7,929	18,681
1,723	3,643	72	207	W	W	W	W	2,292	8,920	6,836	23,343
3,426	13,198	2,448	4,818	—	—	—	—	18,191	60,709	50,370	171,167
3,037	7,782	931	1,480	28	42	W	W	9,241	25,025	17,843	49,796
1,960	5,527	323	498	247	577	W	W	2,425	5,867	6,047	17,478
498	1,571	2,476	4,915	72	246	—	—	4,049	11,136	12,551	42,573
4,813	17,090	6,679	13,904	183	494	W	W	9,404	25,245	31,170	94,402
W	W	22	56	—	—	—	—	998	3,647	1,653	6,099
5,963	13,265	2,414	3,998	223	555	W	W	7,452	17,831	25,048	60,080
1,255	3,598	81	180	30	109	W	W	735	2,289	3,413	11,351
139,723	**421,621**	**62,455**	**134,320**	**5,812**	**19,547**	**198**	**824**	**381,546**	**1,257,754**	**923,400**	**3,126,000**
247	753	156	389	162	539	440	2,025	XX	XX	XX	XX
140,000	**422,400**	**62,600**	**134,700**	**6,000**	**20,100**	**650**	**2,800**	**XX**	**XX**	**923,400**	**3,126,000**

[6]National Research Council. Strategic Highway Research Program—1988 Program Annual Report. Oct. 31, 1988, pp. 1-32.

[7]Grayson, W. J. Impact of the Strategic Highway Research Program on the Crushed Stone Industry. Stone Rev., v. 4, No. 2, Apr. 1988, pp. 8-12.

[8]Drake, B. Mastering Technologies and Budgets. Pit & Quarry, v. 81, No. 6, Dec. 1988, p. 20.

[9]Ary, T S. The Question is Not Whether To Automate, But How Much and When. Stone Rev., v. 4, No. 6, Dec. 1988, pp. 20-21.

[10]Meininger, R. C. National Aggregates Association Technical Information Letter. No. 395, p. 7.

[11]Culbertson, K., L. Adams, and A. Bauer. Using Computers in Reclamation. Rock Prod., v. 91, No. 7, July 1988, pp. 66-69.

[12]Michard, D. Special Report: Clarifiers. Rock Prod., v. 91, No. 8, Aug. 1988, pp. 56-59.

[13]Drake, B. Screening Out Noise, Dust Problems. Pit & Quarry, v. 80, No. 11, May 1988, pp. 24-26.

[14]Rukavina, M. New Idea Combines Truck and Long-Haul Rail Delivery. Rock Prod., v. 91, No. 12, p. 16.

TABLE 11

NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS[1] AND PROCESSING PLANTS IN THE UNITED STATES IN 1988, BY STATE

State	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Alabama	30	6	2	5	12	55
Alaska	5	6	1	6	2	20
Arizona	64	33	13	4	—	114
Arkansas	40	11	2	6	4	63
California	173	51	16	10	8	258
Colorado	41	118	17	22	12	210
Connecticut	33	12	6	6	2	59
Delaware	5	—	—	1	2	8
Florida	26	3	—	4	14	47
Georgia	17	2	1	5	23	48
Hawaii	2	2	—	3	—	7
Idaho	39	33	1	14	2	89
Illinois	64	32	17	16	26	155
Indiana	71	26	13	6	17	133
Iowa	87	56	9	12	31	195
Kansas	42	27	4	11	49	133
Kentucky	6	12	2	—	3	23
Louisiana	31	36	1	6	22	96
Maine	31	69	2	18	—	120
Maryland	26	20	3	24	3	76
Massachusetts	54	42	6	8	—	110
Michigan	84	160	9	22	7	282
Minnesota	76	151	13	20	5	265
Mississippi	33	36	3	11	16	99
Missouri	26	38	2	2	21	89
Montana	25	64	4	4	—	97
Nebraska	27	62	4	4	81	178
Nevada	22	36	8	5	2	73
New Hampshire	20	17	5	2	—	44
New Jersey	34	15	3	7	8	67
New Mexico	31	49	9	3	1	93
New York	148	157	26	45	6	382
North Carolina	43	5	4	45	24	121
North Dakota	14	45	2	19	—	80
Ohio	122	21	12	41	20	216
Oklahoma	34	10	1	70	34	149
Oregon	46	23	1	14	5	89
Pennsylvania	64	30	10	12	10	126
Rhode Island	9	1	—	1	—	11
South Carolina	19	5	—	12	10	46

See footnote at end of table.

TABLE 11—Continued

NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS[1] AND PROCESSING PLANTS IN THE UNITED STATES IN 1988, BY STATE

State	Mining operations on land: Stationary	Portable	Stationary and portable	No plants or unspecified	Dredging operations	Total active operations
South Dakota	36	83	7	40	2	168
Tennessee	21	5	—	9	11	46
Texas	99	12	5	76	18	210
Utah	37	49	8	14	—	108
Vermont	18	38	2	18	1	77
Virginia	35	7	1	9	13	65
Washington	62	68	12	43	3	188
West Virginia	5	—	—	—	1	6
Wisconsin	52	144	21	18	2	237
Wyoming	15	32	2	6	1	56
Total	**2,144**	**1,960**	**290**	**759**	**534**	**5,687**

[1] An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

TABLE 12

TRANSPORTATION OF CONSTRUCTION SAND AND GRAVEL IN THE UNITED STATES IN 1988 TO SITE OF FIRST SALE OR USE

Method of shipment	Quantity (thousand short tons)	Percent of total
Truck	400,554	43
Rail	7,101	1
Waterway	22,208	3
Not shipped, used at site	20,718	2
Unspecified	472,782	51
Total	[1] **923,400**	**100**

[1] Data do not add to total shown because of independent rounding.

TABLE 13

U.S. EXPORTS OF CONSTRUCTION SAND AND GRAVEL IN 1988, BY COUNTRY

(Thousand tons and thousand dollars)

Country	Sand		Gravel	
	Quantity	F.a.s. value[1]	Quantity	F.a.s. value[1]
North America:				
Anguilla	3	12	1	9
Antigua	—	—	5	59
Bahamas	—	—	2	22
Bermuda	—	—	5	42
British Virgin Islands	—	—	7	134
Canada	361	2,324	358	1,465
Guadalupe	2	18	6	85
Martinique	—	—	2	12
Mexico	57	867	49	1,220
Netherlands Antilles	14	113	1	13
Other[2]	4	202	2	69
Total[3]	**441**	**3,537**	**437**	**3,131**
South America:				
Argentina	10	271	—	—
Brazil	2	101	1	7
Peru	2	82	—	—
Venezuela	2	75	—	—
Other[2]	([4])	82	([4])	27
Total[3]	**16**	**612**	**2**	**35**
Europe:				
Austria	7	4	—	—
France	2	4	—	—
Germany, Federal Republic of	18	361	—	—
Greece	—	—	3	14
Iceland	2	3	—	—
Netherlands	2	147	—	—
Sweden	2	60	—	—
United Kingdom	1	136	4	79
Yugoslavia	2	36	—	—
Other[2]	2	332	([4])	19
Total[3]	**37**	**1,084**	**7**	**112**
Asia:				
Japan	3	923	1	77
Korea, Republic of	3	475	5	58
Singapore	—	—	7	83
Other[2]	1	362	([4])	73
Total[3]	**8**	**1,760**	**13**	**291**
Oceania	1	38	—	—
Middle East and Africa	([4])	446	1	4
Grand total[3]	**506**	**7,476**	**459**	**3,572**

[1] Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.
[2] Includes Angola, Colombia, Jamaica, Kuwait, Panama, Spain, Taiwan, Trinidad and Tobago, and Turks and Caicos Islands.
[3] Data may not add to totals shown because of independent rounding.
[4] Less than 1/2 unit.

TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF CONSTRUCTION SAND AND GRAVEL, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1987		1988	
	Quantity	C.i.f. value[1]	Quantity	C.i.f. value[1]
Antigua	41	267	62	433
Australia	2	470	3	493
Bahamas	13	78	2	14
Barbados	—	—	6	36
British Virgin Islands	3	59	10	188
Canada	198	965	262	1,215
Costa Rica	19	87	—	—
Taiwan	2	33	(2)	41
Other	5	408	6	742
Total	**283**	**2,367**	**351**	**[3]3,163**

[1] Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

INDUSTRIAL SAND AND GRAVEL

By Wallace P. Bolen[1]

Production of industrial sand and gravel in 1988 increased to 28.5 million short tons, about a 2% increase over that of 1987, but remained 15% below the record-high production level of 1979. The production increase was due in part to the addition of new operations in California and Tennessee.

Imports of industrial sand and gravel decreased about 59% in quantity, but the associated value increased 79%. Exports of industrial sand and gravel increased about 40% in quantity with a slight increase in average value per ton. Domestic apparent consumption of industrial sand and gravel in 1988 was 27.5 million tons.

DOMESTIC DATA COVERAGE

Domestic production data for industrial sand and gravel are developed by the Bureau of Mines from voluntary surveys of U.S. producers. Of the 171 industrial sand and gravel operations surveyed, 158, or 92%, reported to the Bureau of Mines. Their combined production represented about 99% of the U.S. total published in table 1. The nonrespondents' production was estimated using employment data. Of the 171 operations, 166, or 97%, were active and 5 were idle.

LEGISLATION AND GOVERNMENT PROGRAMS

The Occupational Safety and Health Administration (OSHA) again extended a partial stay, to July 21, 1989, on its revised asbestos standards for the nonasbestiform varieties of tremolite, anthophyllite, and actinolite minerals. The agency wanted to review additional information and collect more data on the feasibility of regulating the minerals. The existing asbestos standard remained in effect throughout the extension of the stay. Implementation of the revised OSHA regulations could have significant impact on the industrial sand and gravel industry. The changes could increase materials costs and possibly disrupt supplies in some areas.

OSHA was reviewing other standards on air contaminants and expected to release a final decision in 1989. The regulations, governing the amount of employee exposure to airborne contaminants, were being reviewed to determine if standards needed to be changed. More stringent regulations for respirable silica may cause a decline in use should the cost of meeting standards be prohibitive.

DOMESTIC PRODUCTION

The Midwest (East and West North Central regions) continued to lead the Nation in production with about 42% of the 28.5 million tons produced in the United States, followed by the South (South Atlantic, East and West South Central regions) with about 34%, and the West (Pacific and Mountain regions) with 14%. Compared with 1987 production, the output of industrial sand and gravel increased 19% in the West and 5% in the Midwest, but decreased 9% in the Northeast (Middle Atlantic and New England regions) and 5% in the South.

Based on the 1987 census population estimate, 1988 U.S. per capita industrial sand and gravel production was 0.12 ton. Per capita production by major geographic region was 0.20 ton in the Midwest, followed by the South with 0.12 ton, the West with 0.08 ton, and the Northeast 0.05 ton.

The five leading States in the production of industrial sand and gravel, in descending order of volume, were Illinois, Michigan, California, New Jersey, and Texas. Their combined production represented 47% of the national

TABLE 1

SALIENT U.S. INDUSTRIAL SAND AND GRAVEL STATISTICS[1]

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
Sold or used:					
Sand:					
Quantity	28,680	29,070	26,940	27,380	27,207
Value	$370,370	$370,730	$354,460	$357,660	$376,202
Gravel:					
Quantity	705	357	484	631	1,272
Value	$6,844	$3,340	$4,853	$6,424	$11,796
Total industrial:[2]					
Quantity	29,380	29,430	27,420	28,010	28,480
Value	$377,200	$374,070	$359,300	$364,100	$388,000
Exports:					
Quantity	1,193	866	849	758	1,060
Value	$27,656	$22,580	$20,363	$21,253	$30,843
Imports for consumption:					
Quantity	26	81	88	104	43
Value	$926	$1,513	$1,014	$1,071	$1,918

[1] Puerto Rico excluded from all industrial sand and gravel statistics.
[2] Data may not add to totals shown because of independent rounding.

total. Of the major producing States, significant increases were recorded in California, 9%, Michigan, 9%, and Texas, 8%, while production decreased significantly in New Jersey, 12%.

The Bureau of Mines canvassed 93 producers of industrial sand and gravel with 166 active operations. About 74% of the industrial sand and gravel was produced by 46 operations, each with an annual production of more than 200,000 tons. The 10 leading producers of industrial sand and gravel were, in descending order of tonnage, Unimin Corp., U.S. Silica Co., Fairmount Minerals Ltd., The Morie Co. Inc., Manley Bros. of Indiana, Badger Mining Corp., Construction Aggregates Corp., Oglebay Norton Co., Owens-Illinois Inc., and Simplot Industries Inc. Their combined production, from 59 operations, represented 71% of the U.S. total.

Corona Industrial Sand Co. completed its first full year of production after starting operations in September 1987, near Corona, CA. Glass sand is the major product produced, but other products include stucco, blast, golf course, and specialty sands. The firm exemplifies a continuing trend towards the application of advanced technology in the silica industry. A computer system monitored and adjusted the flow of materials through the mill; also utilized is an energy-dispersive X-ray spectrometer to maintain the quality of products.

Short Mountain Silica Co., Mooresburg, TN, began operations in April 1988, with production intended for the flat and container glass industries. Short Mountain plans to diversify into other markets, possibly including sales in the construction sand sector.

Unimin Corp., New Caanan, CT, purchased Silica Products Co., of Guion, AR, a major producer of foundry sands. The acquisition extended Unimin's network of plants in the United States to 16 industrial sand operations located in 13 states.

Best Silica Sand Co., Chardon, OH, ceased operations in May and announced the closing of its pit in Geauga County. The pit produced sand mainly for the foundry industry.

Cyprus Minerals, Denver, CO, acquired Inspiration Consolidated Copper Co., of Claypool, AZ, which produces silica ore for use in metal smelting.

The Morie Co., Millville, NJ, acquired and combined the Cumberland County, NJ, operations of Owen-Illinois Inc. of Toledo, OH, and GF Pettinos Inc. of Ardmore, PA. Both operations produced sands for the foundry and blasting industries.

A.F. Gelhar Co. Inc. of Berlin, WI, closed its Winnebago County operation but continued to produce foundry sands in Waupaca and Green Lake Counties.

Fairmount Minerals Ltd. discontinued operations at Serena, IL. Fairmount, with operations in Illinois and Ohio, remains a major producer of silica sands for a wide variety of uses.

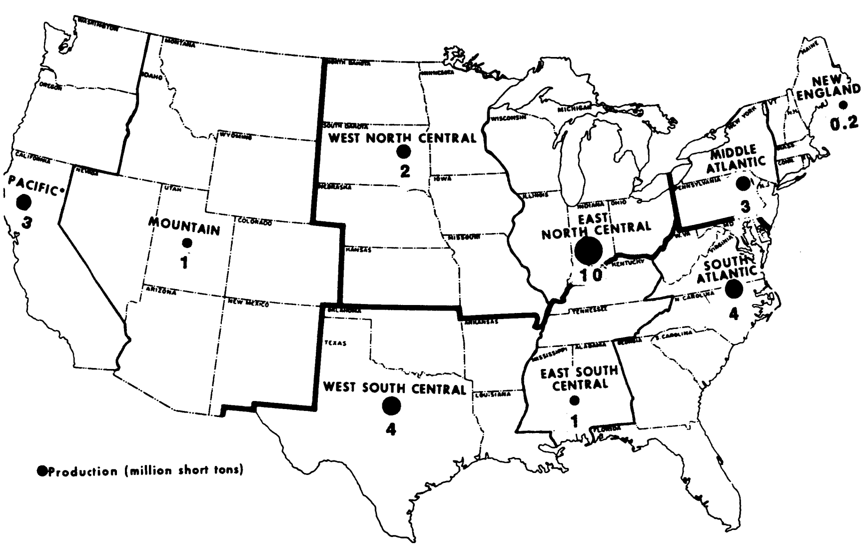
CONSUMPTION AND USES

Sand and gravel production reported by producers to the Bureau of Mines is actually material used by the companies or sold to their customers. Stockpiled material is not reported until it is consumed or sold.

Of the 28.5 million tons of industrial sand and gravel sold or used, 43% was consumed as glassmaking sand, and 27% as foundry sand. Other important uses were abrasive sand, 7%, and hydraulic fracturing (frac) sand, 5%. Because some producers did not report a breakdown by end use, their total production as well as the estimated production for nonrespondents was included in "Other uses, unspecified," which represent about 3% of the U.S. total. On the regional level, most of the glassmaking sand was produced in the South, 39%, followed by the Midwest with 28%, and the West with 19%.

FIGURE 1

PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 1988, BY GEOGRAPHIC REGION



Most of the foundry sand was produced in the Midwest, 76%, and the South, 16%. Of the important but smaller volume uses, most of the frac sand was produced in the Midwest, 68%, and most of the abrasive sand was produced in the South, 44%, and the Midwest, 23%.

Northeast

Cumberland County, NJ, was the largest source for the glass, foundry, and blast sand markets in the region. Unimin, U.S. Silica, Morie, and Whibco Inc., which all operated plants in the county, were among the largest producers of sand for these markets. U.S. Silica's plant in Huntingdon County, PA, also produced significant amounts of sand for the glass and foundry markets. New Jersey Pulverizing Co.'s plant in Ocean County, NJ, produced a major percentage of the abrasive blast sand.

Midwest

Unimin's plants in LaSalle and Ogle Counties, IL, and LeSueur County, MN, were among the leaders in producing sand for the glass, foundry, frac sand, and blasting markets. Fairmount Minerals, operating plants in Geauga County, OH, and La Salle County, IL, was a major producer for the glass and blasting markets. U.S. Silica's plant in La Salle County, IL, and Badger Mining's plant in Jackson County, WI, were large producers for the glass and frac sand markets, respectively. Construction Aggregates Corp., in Ottawa County, MI, and Manley Brothers of Indiana, in Van Buren County, MI, were major producers of foundry sand.

South

Unimin and U.S. Silica Co. were two of the largest producers of sand for the glass and foundry markets. Unimin's major plants were in Frederick County, VA, Richmond County, NC, and Izard County, AR. U.S. Silica's major operations were located in Bullock County, AL, and Johnston County, OK. Morie's Tuscaloosa County, AL, plant was a large producer of foundry sand. Pioneer Concrete of Texas Inc., Southern Silica of Louisiana, and Specialty Sand Co. produced the bulk of the blasting sand, while W. R. Bonsal Co. Inc. and B. V. Hedrick Sand and Gravel produced the majority of the industrial gravel used in the processing of silicon and ferrosilicon. The companies produced the blast sands in Texas, and the gravel was mined in Anson County, NC.

West

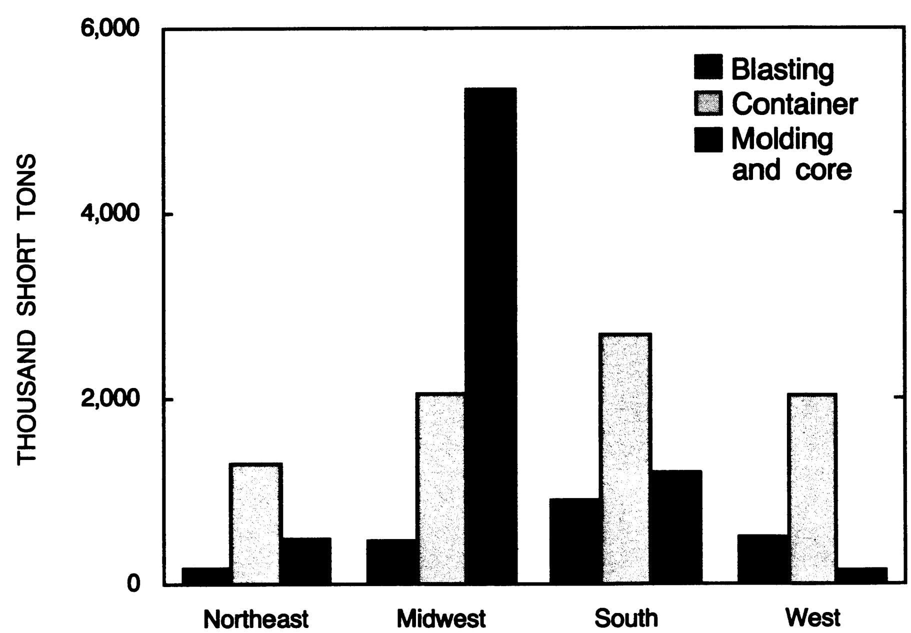
Owens-Illinois, Simplot Industries, and Unimin were the three largest producers of glass sand in the region, with major operations in Amador County, CA, Clark County, NV, and Contra Costa County, CA, respectively. Corona Industrial Sand and Monterey Sand Co. Inc., located in Riverside County and Monterey County, CA, respectively, supplied the majority of sand for the sand blasting industry.

TRANSPORTATION

Of the total industrial sand and gravel produced, 56% was transported by truck from the plant to the site of first sale or use, down from 63% in 1987; 34% was transported by rail, unchanged from 1987; 4% by water, up from 3% in 1987: and 6% not transported, up from 0% in 1987. Because most of the producers did not report shipping distances or cost per ton per mile, no transportation cost data were available.

FIGURE 2

SAND USED IN SELECTED END USES, 1988



PRICES

The average value, f.o.b. plant, of U.S. industrial sand and gravel increased nearly 5% to $13.62 per ton. Average unit values for industrial sand and industrial gravel were $13.83 and $9.27 per ton, respectively. Nationally, industrial sand used as fillers for rubber, paint, and putty, etc., had the highest value per ton, $70.11, followed by silica sand used in ceramics, $32.99, fiberglass (ground), $27.23, scouring cleansers, $25.09, and silica flour, $24.94.

The average value per ton of industrial sand and gravel was highest in the West major geographic region, $16.15, followed by the Northeast, $14.72, the South, $14.06, and the Midwest, $12.18. Higher production and transportation costs in the West and the predominance of the lower value foundry sand in the Midwest are reflected in these values. Average value per ton of container glass sand varied markedly: $16.48 in the West, $12.91 in the Northeast, $11.79 in the South, and $8.71 in the Midwest. Tighter supplies and higher production and transportation costs in the West and Northeast increased the cost of sand and gravel in these regions.

FOREIGN TRADE

Exports

Exports of industrial sand increased 40% to 1,060,000 tons and the value increased 45% to $30.8 million. Of this, 74% went to Canada, 6% to Mexico, 7% to several Asian countries, and 5% to several European countries.

Imports

Imports for consumption for industrial sand decreased 59% to 43,000 tons valued at $1.9 million. Of this, 84% came from Antigua and 5% came from the British Virgin Islands. Small amounts of specially prepared silica sand from Australia, France, and the Federal Republic of Germany, sold for very high values per ton.

TECHNOLOGY

The glass and foundry industries still dominate silica sand usage in terms of tonnage, but sand producers continue to explore and develop other markets. Glass and ceramic spheres have been developed for use as fillers and have proved to have many advantages over other filler material. Large variation in diameter and density of the spheres makes them adaptable to many different filler applications.[2] Research continued on developing processes for making glass into ceramic superconductors. The material is said to be stronger than conventionally processed material and the glass-ceramic process may prove to be a more efficient way to form a variety of shapes.[3] Uses for silica as fillers for adhesives and sealants and for fused silica in high-energy-laser optics, among others, continue to provide new markets for silica sand.

The Environmental Protection Agency (EPA), issued regulations for underground storage tanks (UST) for petroleum products and other materials. As many as 1.5 million tanks may have to be replaced or repaired. One of the approved materials for UST is fiberglass. As the process of repair and replacement continues over the next decade, fiberglass tank usage should provide additional markets for silica.[4]

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Harben, P. Glass and Ceramic Spheres—Myriad Names in a Growing Market. Ind. Min. (London), No. 248, May 1988, pp. 53–57.

[3] Ceramic Industry (Solon, OH). Glass-Ceramic Route Shows Promise. V. 131, No. 7, Dec. 1988, p. 14.

[4] U.S. Environmental Protection Agency. Office of Underground Storage Tanks. Must For UST's. EPA/530/UST-88/008, Sept. 1988.

TABLE 2

INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC REGION

Geographic region	1987 Quantity (thousand short tons)	1987 Percent of total	1987 Value (thousands)	1987 Percent of total	1988 Quantity (thousand short tons)	1988 Percent of total	1988 Value (thousands)	1988 Percent of total
Northeast:								
New England	161	1	$3,921	1	159	1	$4,254	1
Middle Atlantic	2,830	10	38,155	10	2,579	9	36,052	9
Midwest:								
East North Central	9,931	35	105,815	29	10,447	37	124,020	32
West North Central	1,516	5	20,263	6	1,595	5	22,701	6
South:								
South Atlantic	5,545	20	75,505	21	4,414	15	65,770	17
East South Central	1,098	4	10,719	3	1,380	5	14,688	4
West South Central	3,545	13	49,065	13	3,885	14	55,595	14
West:								
Mountain	847	3	13,980	4	1,272	4	17,607	5
Pacific	2,535	9	46,658	13	2,748	10	47,311	12
Total[1]	**28,010**	**100**	**364,100**	**100**	**28,480**	**100**	**388,000**	**100**

[1] Data may not add to totals shown because of independent rounding.

TABLE 3

INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1987		1988	
	Quantity	Value	Quantity	Value
Alabama	580	5,025	871	8,507
Arizona	W	W	119	3,045
Arkansas	505	5,147	669	6,784
California	2,241	41,472	2,444	42,078
Colorado	W	W	W	W
Connecticut	W	W	W	W
Florida	1,884	19,713	636	6,928
Georgia	W	W	W	W
Idaho	W	W	483	5,089
Illinois	4,346	45,547	4,328	56,142
Indiana	230	1,357	362	1,829
Kansas	127	1,400	W	W
Kentucky	W	W	—	—
Louisiana	289	3,997	318	4,786
Maryland	W	W	W	W
Massachusetts	56	922	W	W
Michigan	2,792	22,451	3,045	27,150
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	622	7,786	744	9,876
Montana	W	W	W	W
Nebraska	W	W	W	W
Nevada	578	W	602	W
New Jersey	2,112	27,872	1,860	25,437
New York	58	651	53	625
North Carolina	1,184	15,329	1,246	15,953
North Dakota	W	W	—	—
Ohio	1,249	21,292	1,361	23,441
Oklahoma	1,243	17,078	1,268	17,381
Pennsylvania	W	W	W	W
Rhode Island	W	W	W	W
South Carolina	844	15,188	859	15,271
Tennessee	W	W	W	W
Texas	1,509	22,843	1,631	26,645
Utah	6	111	3	60
Virginia	W	W	W	W
Washington	294	5,186	W	W
West Virginia	W	W	W	W
Wisconsin	1,314	15,168	1,351	15,458
Other	3,945	68,545	4,228	75,513
Total [1]	**28,010**	**364,100**	**28,480**	**388,000**

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Data may not add to totals shown because of independent rounding.

TABLE 4

INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 1988, BY SIZE OF OPERATION

Size range	Number of operations	Percent of total	(thousand short tons)	Percent of total
Less than 25,000	36	21.7	366	1.3
25,000 to 49,999	26	15.7	1,000	3.5
50,000 to 99,999	30	18.1	2,239	7.9
100,000 to 199,999	28	16.9	3,885	13.6
200,000 to 299,999	13	7.8	3,206	11.3
300,000 to 399,999	10	6.0	3,382	11.9
400,000 to 499,999	5	3.0	2,289	8.0
500,000 to 599,999	7	4.2	3,699	13.0
600,000 to 699,999	6	3.6	3,881	13.6
700,000 and over	5	3.0	4,533	15.9
Total	**166**	**100.0**	**28,480**	**100.0**

TABLE 5

NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 1988, BY GEOGRAPHIC REGION

Geographic region	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Northeast:						
New England	4	—	—	1	—	5
Middle Atlantic	8	—	2	2	4	16
Midwest:						
East North Central	36	—	2	—	3	41
West North Central	7	—	—	—	3	10
South:						
South Atlantic	16	1	—	4	6	27
East South Central	10	—	—	1	3	14
West South Central	15	—	—	2	11	28
West:						
Mountain	10	1	—	—	—	11
Pacific	11	—	—	1	2	14
Total	**117**	**2**	**4**	**11**	**32**	**166**

TABLE 6

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS, BY MAJOR USE

Major use	Northeast			Midwest			South			West			U.S. total[1]		
	(Quantity thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton
1988															
Sand:															
Glassmaking:															
Containers	1,292	$16,679	$12.91	2,061	$17,959	$8.71	2,676	$31,563	$11.79	2,041	$33,643	$16.48	8,069	$99,844	$12.37
Flat (plate and window)	W	W	13.55	769	8,968	11.66	1,255	14,533	11.58	W	W	14.85	2,351	28,136	11.97
Specialty	W	W	14.37	294	4,536	15.43	W	W	14.07	8	169	21.13	644	9,569	14.86
Fiberglass (unground)	W	W	9.60	206	1,925	9.34	270	2,904	10.76	W	W	16.34	651	7,116	10.93
Fiberglass (ground)	—	—	—	92	1,714	18.63	W	W	29.76	W	W	20.67	426	11,600	27.23
Foundry:															
Molding and core	480	W	W	5,339	54,161	10.14	1,204	12,286	10.20	145	W	W	7,168	75,575	10.54
Molding and core facing (ground)	([2])	W	18.00	W	W	10.00	W	W	56.00	W	W	W	6	246	41.00
Refractory	W	W	9.25	431	3,643	8.45	—	—	—	W	W	15.00	436	3,695	8.47
Metallurgical:															
Silicon carbide	—	—	—	W	W	5.03	—	—	—	—	—	—	W	W	5.03
Flux for metal smelting	—	—	—	W	W	8.86	W	W	4.20	84	2,340	27.86	117	2,609	22.30
Abrasives:															
Blasting	173	3,374	19.50	472	8,463	17.93	903	17,875	19.80	512	8,224	16.06	2,060	37,936	18.42
Scouring cleansers (ground)	W	W	45.00	W	W	23.53	W	W	34.00	W	W	65.00	53	1,330	25.09
Chemicals (ground and unground)	W	W	13.02	W	W	12.59	288	4,848	16.83	44	741	16.84	655	9,692	14.80
Fillers (ground):															
Rubber, paints, putty, etc.	26	1,027	39.50	W	W	66.74	59	5,452	92.41	W	W	37.09	142	9,956	70.11
Silica flour	W	W	21.40	55	1,451	26.38	W	W	22.26	—	—	—	83	2,070	24.94
Ceramic (ground):															
Pottery, brick, tile, etc.	W	W	36.94	156	5,396	34.59	103	2,983	28.96	W	W	66.25	280	9,236	32.99
Filtration	79	2,178	27.57	36	660	18.33	269	3,629	13.49	22	859	39.05	407	7,326	18.00
Traction (engine)	43	330	7.67	154	1,286	8.35	74	634	8.57	34	441	12.97	305	2,690	8.82
Coal washing	—	—	—	—	—	—	W	W	9.00	—	—	—	W	W	9.00
Roofing granules and fillers	W	W	30.69	194	4,829	24.89	238	3,840	16.13	W	W	20.26	575	12,452	21.66

See footnotes at end of table.

TABLE 6—Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS, BY MAJOR USE

Major use	Northeast			Midwest			South			West			U.S. total[1]		
	(Quantity thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton
Hydraulic fracturing	W	W	—	878	$18,827	$21.44	400	$8,317	$20.79	W	W	$26.29	1,299	$27,697	$21.32
Other uses, specified	625	$16,616	$26.59	604	9,486	15.71	679	14,204	20.92	632	$13,907	22.00	XX	XX	XX
Other uses, unspecified[3]	19	97	5.11	127	1,409	11.09	596	6,648	11.15	67	1,150	17.16	809	9,304	11.50
Total[1] or average	**2,738**	**40,301**	**14.72**	**11,866**	**144,711**	**12.20**	**9,013**	**129,717**	**14.39**	**3,590**	**61,473**	**17.12**	**27,207**	**376,202**	**13.83**
Gravel:															
Metallurgical:															
Silicon, ferrosilicon	—	—	—	W	W	11.67	W	W	10.01	—	—	—	695	7,223	10.39
Filtration	([2])	5	28.08	W	W	8.20	W	W	4.00	—	—	—	25	126	5.04
Nonmetallurgical flux	—	—	—	—	—	—	W	W	7.98	430	$3,445	$8.01	W	W	8.00
Other uses	—	—	—	10	102	10.20	1	14	14.00	—	—	—	W	W	9.67
Total[1] or average	**([2])**	**5**	**—**	**175**	**2,010**	**11.49**	**667**	**6,336**	**9.50**	**430**	**3,445**	**8.01**	**1,272**	**11,796**	**9.27**
Grand total[1] or average	**2,738**	**40,306**	**14.72**	**12,042**	**146,721**	**12.18**	**9,680**	**136,053**	**14.06**	**4,020**	**64,918**	**16.15**	**28,480**	**388,000**	**13.62**

W Withheld to avoid disclosing company proprietary data; included with "Other uses, specified"; also included in "U.S. Total" by use. XX Not Applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.
[3] Mostly estimated total production plus other uses (small quantities) as reported by producers.

TABLE 7

TRANSPORTATION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 1988 TO SITE OF FIRST SALE OR USE

Method of shipment	Quantity (thousand short tons)	Percent of total
Truck	16,056	56
Rail	9,828	34
Waterway	1,011	4
Not transported	1,585	6
Total	**28,480**	**100**

TABLE 8

U.S. EXPORTS OF INDUSTRIAL SAND, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1987		1988	
	Quantity	F.a.s. value[1]	Quantity	F.a.s. value[1]
North America:				
Bahamas	1	18	6	58
Canada	600	8,638	790	11,260
Costa Rica	([2])	7	—	—
Dominican Republic	2	96	3	125
Leeward and Windward Islands	3	35	—	—
Mexico	50	1,388	67	2,284
Netherlands Antilles	8	174	19	170
Panama	8	273	5	86
Other	3	262	4	206
Total [3]	**676**	**10,890**	**893**	**14,189**
South America:				
Argentina	2	340	([2])	51
Chile	1	372	2	450
Colombia	1	174	1	105
Ecuador	([2])	97	7	176
Peru	1	135	14	747
Venezuela	6	341	3	296
Other	([2])	217	1	152
Total [3]	**11**	**1,675**	**29**	**1,977**
Europe:				
Belgium	17	1,176	15	974
Finland	2	41	2	48
France	([2])	198	1	222
Germany, Federal Republic of	8	874	8	1,006
Italy	8	531	6	654
Netherlands	6	1,722	12	4,737
United Kingdom	9	334	12	579
Other	2	646	2	424
Total [3]	**52**	**5,522**	**57**	**8,643**
Asia:				
Indonesia	([2])	8	6	662
Japan	6	770	9	1,407
Korea, Republic of	1	328	6	424
Malaysia	—	—	15	298
Singapore	5	888	19	1,514
Taiwan	1	157	10	493
Other	([2])	209	7	373
Total [3]	**13**	**2,361**	**71**	**5,172**

See footnotes at end of table.

TABLE 8—Continued

U.S. EXPORTS OF INDUSTRIAL SAND, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1987 Quantity	1987 F.a.s. value[1]	1988 Quantity	1988 F.a.s. value[1]
Middle East and Africa:				
Saudi Arabia	([2])	7	([2])	16
South Africa, Republic of	3	344	5	259
United Arab Emirates	1	48	2	123
Other	1	152	2	191
Total [3]	**5**	**551**	**9**	**588**
Oceania	1	253	1	274
Grand total[3]	**758**	**21,253**	**1,060**	**30,843**

[1] Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1987 Quantity	1987 C.i.f. value[1]	1988 Quantity	1988 C.i.f. value[1]
Antigua	54	134	36	264
Australia	18	407	([2])	874
Bahamas	19	30	—	—
Canada	6	51	1	47
Germany, Federal Republic of	6	365	([2])	556
Japan	—	—	([2])	2
United Kingdom	([2])	38	([2])	27
Other	1	45	5	147
Total[3]	**104**	**1,071**	**43**	**1,918**

[1] Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

SILICON

By Joseph Gambogi[1]

Demand for silicon ferroalloys and silicon metal overall increased compared with that of 1987 owing to increased production of aluminum, iron and steel, and silicon-base chemicals. Strong demand, limited imports from elsewhere in the world, and a relatively weak U.S. dollar combined to help revitalize the domestic ferrosilicon industry. In response to increases in demand, prices for silicon-base alloys rose significantly in 1988.

DOMESTIC DATA COVERAGE

Domestic production data for the silicon commodity are developed by the Bureau of Mines by means of monthly and annual voluntary domestic surveys. Typical of these surveys is the monthly "Silicon Alloys" survey. Of the 17 canvassed operations, 16 responded, representing 100% of the total production shown in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

On August 23, 1988, Congress enacted the Omnibus Trade and Competitiveness Act (Public Law 100-418) to enhance the competitiveness of the Nation's industries and to improve the management of the U.S. trade strategy. The act included provisions for modifying U.S. customs laws and tariff schedules. Subtitle B of the law required that all tariff schedules after January 1, 1989, conform to the internationally established Harmonized system. Consequently, U.S. customs import and export categories for silicon-base alloys were scheduled for revision.

In 1988, the United States-Canada Free Trade Agreement was passed by legislatures in both countries in an effort to reduce trade barriers between them. Part of the agreement was scheduled to take effect in the following year and was to eliminate duties on ferrosilicon products.

DOMESTIC PRODUCTION

Production and shipments of silicon-containing ferroalloys and metal overall showed significant increases compared with those of 1987. Overall ferrosilicon production increased more than 35%, while production of standard 75% (56% to 95%) grade increased more than 85%. Production of silicon metal increased by about 10%, while that of miscellaneous alloys, which consisted mostly of magnesium ferrosilicon, increased by more than 5%. Shipments during 1988 showed increases similar to those of production. Stocks of silicon-containing materials rose 15% overall. Estimated ferrous scrap consumption by the domestic silicon ferroalloys industry to produce silicon ferroalloys was 300,000 tons in 1988.

In conjunction with the demand by the steel industry, silicon demand by the chemical and aluminum industries persuaded domestic producers of silicon products to rekindle idle furnaces. By the end of 1988, the domestic producers were operating at close to full capacity.

Dow Corning Corp. restarted its silicon metal furnace at its facility in Springfield, OR. The furnace had been shut down in 1987 after a lining failure.[2]

Elkem Metals Co., Pittsburgh, PA, restarted a 5,000 kilovolt-ampere (kV•A) furnace at its Ashtabula, OH, facility doubling its ferrosilicon production level there.[3] However, in January, the same facility was forced to suspend production of 50% ferrosilicon and foundry alloys owing to a power failure at a local powerplant. Full production resumed about 1 month later.[4]

TABLE 1

PRODUCTION, SHIPMENTS, AND STOCKS OF SILVERY PIG IRON, FERROSILICON, AND SILICON METAL IN THE UNITED STATES IN 1988

(Short tons, gross weight, unless otherwise specified)

Material	Silicon content (percent) Range	Silicon content (percent) Typical	Producers' stocks Dec 31, 1987[r]	Gross production	Net shipments	Producers' stocks Dec 31, 1988
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon	25-55	48	39,559	402,543	319,892	47,691
Do.	56-95	76	16,853	88,465	85,979	14,150
Silicon metal (excluding semiconductor grades	96-99	98	5,238	164,974	162,283	7,243
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	—	12,067	77,762	69,582	15,663

[r] Revised. W Withheld to avoid disclosing company proprietary data.

Globe Metallurgical Inc. brought back on-line four furnaces at its Beverly, OH, plant. Three of the furnaces were used for the production of ferrosilicon and ferrosilicon-base alloys and one for the production of silicon metal. The increase at Beverly brought the plant to 100% capacity utilization for the first time since 1981.[5] In 1988, Globe was recognized by the U.S. Department of Commerce for performance under Globe's quality efficiency and cost program and was presented with the Malcolm Baldridge National Quality Award.[6]

Northwest Alloys Inc., a subsidiary of Aluminum Co. of America (Alcoa), restarted a 27-megawatt furnace in Addy, WA, in April to produce 75% ferrosilicon. Production of 75% ferrosilicon at Addy was reported to be captive, since the company used ferrosilicon to produce magnesium, which, in turn was used by the parent, Alcoa. The furnace, which had been idle for 2 years, was capable of producing about 50,000 short tons of 75% ferrosilicon annually, which was sufficient to satisfy the company's demand.[7]

In April, Ohio Ferro-Alloys Corp. (OFA) restarted an idle 20-megawatt silicon metal furnace at its Montgomery, AL, plant. Restarting the furnace brought the plant to its full capacity.[8] After spending almost 2 years under protection of chapter 11 of the U.S. Bankruptcy Code, OFA's reorganization plan was approved by a U.S. Bankruptcy Court. The company also changed its name to Simetco Inc., reflecting its only business, silicon metal production.[9]

Silicon Metaltech Inc. completed its purchase of the M. A. Hanna Co.'s silicon metal plant in Rock Island, WA, spending $16 million on the plant and quartz mining operations in Canada.[10]

The U.S. Trade Representative's office considered the domestic silicon industry's request for an end to duty-free imports of certain silicon products. The request was filed by the Ferroalloys Association in an attempt to end exemption of the 5.3% duty on imports of silicon metal in the 99.0%- to 99.7%-pure category from two countries, Argentina and Yugoslavia. Both of these countries were considered by the industry to be "longtime" producers of silicon metal. A decision was still pending at the yearend.[11]

Late in 1988, Union Carbide Corp. filed an antitrust suit against seven Japanese companies. The suit alleged that the companies colluded with the Japanese Government to expand domestic production of polysilicon and prevent foreign polysilicon sales in Japan. Union Carbide claimed that the companies created a cartel for the purpose of catapulting Japan past the United States to the top in world polysilicon production.[12]

CONSUMPTION AND USES

Apparent consumption (demand) of silicon-containing ferroalloys and silicon metal increased 15% compared with that of 1987. The increase reflected higher production levels in the aluminum, iron and steel, and silicon-based chemical industries. Consumption of silicon metal increased more than 20%, while ferrosilicon applications increased 13%. The aluminum industry used silicon metal in the production of wrought and cast products. Ferrosilicon was used as a deoxidizing and alloying agent in the production of steel. Ferrosilicon and miscellaneous silicon alloys used in the production of iron and steel accounted for about two-

TABLE 2

PRODUCERS OF SILICON ALLOYS AND/OR SILICON METAL IN THE UNITED STATES IN 1988

Producer	Plant location	Product
Aluminum Co. of America, Northwest Alloys Inc.	Addy, WA	FeSi and Si.
American Alloys Inc.[1]	New Haven, WV	FeSi.
Applied Industrial Minerals Corp.	Bridgeport, AL	Do.
Do.	Kimball, TN	Do.
Dow Corning Corp.	Springfield, OR	Si.
Elkem Metals Co.	Alloy, WV	FeSi and Si.
Do.	Ashtabula, OH	FeSi.
Do.	Marietta, OH	Do.
Globe Metallurgical Inc.	Beverly, OH	FeSi and Si.
Do.	Selma, AL	Si.
Keokuk Ferro-Sil Inc.[1]	Keokuk, IA	FeSi and silvery pig iron.
Reactive Metals & Alloys Corp.	West Pittsburgh, PA	FeSi.
Reynolds Metals Co.	Sheffield, AL	Si.
Silicon Metaltech Inc.[2]	Wenatchee, WA	FeSi and Si.
Simetco Inc.[3]	Montgomery, AL	Si.
SKW Alloys Inc.	Calvert City, KY	FeSi.
Do.	Niagara Falls, NY	FeSi and Si.

[1] Formerly Foote Mineral Co., Ferroalloy Div.
[2] Formerly M. A. Hanna Co., Silicon Div.
[3] Formerly Ohio Ferro-Alloys Corp.

thirds of all the silicon materials consumed, based on silicon content. Metallurgical-grade silicon metal produced by tonnage methods was used as the basic raw material in the manufacturing of many chemical products and intermediates such as silicones and silanes. Silanes were used in the production of high-purity silicon for semiconductor devices and solar cells (photovoltaic cells). The Bureau of Mines did not collect data on electronic grades of silicon, which were relatively low in quantity but high in unit value.

PRICES

Published prices for silicon-containing materials increased in 1988. The increases were largely attributed to increases in demand by the steel, aluminum, and chemical industries. Prices of domestically produced products increased significantly. The published price for domestic 75% ferrosilicon rose by almost 20% by midyear and then remained unchanged at 56 cents per pound of contained silicon for the remainder of the year. The average price for domestic 50% grade ferrosilicon also increased by almost 20%, showing only three price changes over the year. Producer prices for silicon metal increased 10% overall.

Published prices for imported silicon alloys generally showed significant increases in 1988. Prices for imported 50% grade ferrosilicon increased 17% overall, with most of the rise occurring in the early and later portions of the year. By far the most significant price hikes were seen for imported 75% ferrosilicon. Prices for this grade climbed steadily throughout the year, finishing at 66 to 69 cents per pound, about 40% higher than at the beginning of the year. The price of imported silicon metal reached a midyear high of 71 cents per pound, but by yearend fell to 68 cents, for an overall increase of 10%.

FOREIGN TRADE

Exports of ferrosilicon increased more than 90% compared with those of the previous year. Three-fourths of the exported material was shipped to Canada and Japan. Ferrosilicon was shipped to a total of 27 countries. Silicon metal exports increased more than 10%, although the value increased by more than 70%. Nearly 60% of the silicon metal exported was shipped to Japan, with the remainder distributed among 41 other countries.

Imports for consumption of ferrosilicon were unchanged with respect to those of 1987. Imports of silicon metal increased nearly 70%. Silicon metal imports in the category of 96% to 99% silicon increased dramatically by more than four times owing largely to increased shipments from Argentina, Canada, China, Norway, and Sweden.

TABLE 3

U.S. EXPORTS OF FERROSILICON AND SILICON METAL

Year	Quantity (short tons)	Value (thousands)
FERROSILICON		
1984	29,364	$21,135
1985	12,969	12,671
1986	11,331	8,306
1987	15,049	11,647
1988	28,912	25,379
SILICON METAL		
1984	4,420	88,543
1985	2,120	61,647
1986	5,378	65,157
1987	9,247	106,213
1988	10,304	184,205

Source: Bureau of the Census.

WORLD REVIEW

Demand for silicon-containing ferroalloys and silicon metal increased compared with that of the preceding year, owing to the health of the steel, aluminum, and chemical industries. Increased demand coupled with sharply rising prices for ferrosilicon and silicon metal persuaded producers throughout the world to restart existing facilities and make plans for future expansion. Although several new operations came on line in 1988 to help meet the strong demand, some producers were forced to close operations owing to high energy costs.

Australia

Barrack Silicon Pty. Ltd. made plans for a new silicon metal plant in Bunbury, Western Australia. Scheduled for completion late in 1989, the plant was to include two 18-megawatt furnaces producing 27,000 short tons per year (tpy) of silicon. Plant feed was to be supplied domestically by Barrack's Moora Quarry.[13]

Belgium

Applied Industrial Materials Corp., Deerfield, IL, made plans to invest $20 million in a carbon-silica composite plant in Antwerp. The plant was designed to produce a proprietary carbon-silica product in the form of briquets. The product was intended for use as a raw material in the production of silicon metal. Scheduled for startup late in 1989, the initial production rate of the plant was expected to be 110,000 tpy.[14]

Brazil

Brazilian output of silicon alloys and metal rose significantly in 1988. Total production was 417,052 short tons, up 28% from the previous year, owing largely to increases in output of 75% grade ferrosilicon and silicon metal, 15% and 98%, respectively.[15] Power rationing, which had affected the ferroalloy producer Eletrosiderúrgica Brasileira S.A. in 1987, ended in 1988. At midyear, Inonibrás Inoculantes e Ferroligãs Nipo-

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY

Grade and country	1987 Quantity (short tons) Gross weight	1987 Quantity (short tons) Silicon content	1987 Value (thousands)	1988 Quantity (short tons) Gross weight	1988 Quantity (short tons) Silicon content	1988 Value (thousands)
Ferrosilicon:						
Over 8% but not over 30% silicon:						
Brazil	3,527	575	$1,080	1,727	465	$596
Canada	51	15	9	1,416	231	188
China	22	6	8	19	5	30
Japan	2	1	2	—	—	—
Norway	—	—	—	2,868	717	401
South Africa, Republic of	73	11	33	—	—	—
United Kingdom	—	—	—	81	19	141
Total[1]	**3,675**	**607**	**1,132**	**6,111**	**1,437**	**1,356**
Over 30% but not over 60% silicon, with over 2% magnesium:						
Brazil	5,577	2,523	2,908	3,952	1,815	2,893
Canada	495	266	145	830	411	316
China	—	—	—	39	12	56
France	76	36	80	80	43	87
Germany, Federal Republic of	608	331	1,859	563	306	1,812
Italy	60	27	46	60	27	49
Japan	109	48	202	127	55	235
Mexico	22	10	15	—	—	—
Spain	—	—	—	155	70	62
U.S.S.R.	—	—	—	6,392	3,180	2,782
United Kingdom	18	10	30	44	21	37
Total[1]	**6,965**	**3,252**	**5,286**	**12,239**	**5,940**	**8,330**
Over 30% but not over 60% silicon, not elsewhere classified:						
Argentina	1,683	943	832	—	—	—
Belgium	—	—	—	38	23	44
Brazil	14,778	7,494	6,894	20,370	10,453	12,369
Canada	7,541	3,660	2,304	3,969	2,061	1,194
Egypt	—	—	—	5,362	2,404	1,855
France	2,379	1,326	1,794	2,636	1,397	2,498
Germany, Federal Republic of	105	59	141	359	185	546
Japan	188	92	308	184	83	342
Spain	1,068	615	1,045	219	128	241
U.S.S.R.	31,003	14,887	9,137	20,200	10,026	8,160
Venezuela	—	—	—	3,210	1,525	1,225
Total[1]	**58,747**	**29,076**	**22,456**	**56,549**	**28,285**	**28,474**
Over 60% but not over 80% silicon, with over 3% calcium:						
Argentina	1,317	820	1,235	2,163	1,310	2,225
Belgium	—	—	—	38	23	45
Brazil	8,260	5,326	6,294	10,484	6,942	10,571
Canada	273	208	153	20	13	39
France	1,606	990	1,450	2,251	1,399	2,554
Germany, Federal Republic of	150	99	124	56	39	130
Italy	663	405	540	990	605	1,136

See footnote at end of table.

TABLE 4—Continued

U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY

Grade and country	1987 Quantity (short tons) Gross weight	1987 Quantity (short tons) Silicon content	1987 Value (thousands)	1988 Quantity (short tons) Gross weight	1988 Quantity (short tons) Silicon content	1988 Value (thousands)
Netherlands	19	13	$15	—	—	—
Spain	148	90	139	133	83	$151
Venezuela	2,756	2,067	1,316	1,735	1,170	536
Total [1]	**15,191**	**10,019**	**11,267**	**17,870**	**11,583**	**17,386**
Over 60% but not over 80% silicon, not elsewhere classified:						
Argentina	10,552	8,069	4,897	10,767	8,133	6,940
Belgium-Luxembourg	666	503	311	—	—	—
Brazil	44,289	33,083	20,246	41,211	30,919	29,913
Canada	17,689	13,438	8,846	17,856	13,571	12,680
Chile	—	—	—	154	116	106
China	2,872	2,163	1,294	111	82	43
Dominican Republic	3	2	18	—	—	—
France	242	175	722	148	102	255
Germany, Federal Republic of	703	500	1,916	607	450	1,997
Iceland	7,320	5,367	3,440	12,655	9,421	11,200
Italy	132	87	123	4	3	10
Netherlands	—	—	—	30	24	46
Norway	33,783	25,793	15,089	16,071	11,954	12,502
Philippines	20	15	11	119	90	91
South Africa, Republic of	817	613	411	1,935	1,482	1,330
Spain	52	39	37	—	—	—
United Kingdom	1,113	835	502	—	—	—
Venezuela	23,584	17,525	9,682	34,108	25,394	24,108
Yugoslavia	2,018	1,550	864	1,516	1,174	944
Total [1]	**145,855**	**109,755**	**68,410**	**137,291**	**102,916**	**102,164**
Over 90% but not over 96% silicon:						
Brazil	154	145	135	62	60	60
Canada	2	2	3	3	3	5
Mexico	—	—	—	772	733	287
Norway	70	67	62	—	—	—
Total [1]	**226**	**214**	**200**	**838**	**796**	**353**
Total ferrosilicon [1]	**230,658**	**152,923**	**108,749**	**230,897**	**150,957**	**158,063**
Silicon metal:						
Over 96% but not over 99% silicon:						
Argentina	—		—	1,099		1,052
Australia	—		—	910		804
Brazil	—		—	692		793
Canada	1,901		1,816	3,723		4,096
China	—		—	1,433		1,497
France	32	NA	41	—	NA	—
Hong Kong	—		—	555		643
Norway	451		388	3,885		4,960
South Africa, Republic of	—		—	834		807
Sweden	—		—	1,504		1,914
United Kingdom	278		339	451		630
Total [1]	**2,662**		**2,584**	**15,087**		**17,197**

See footnote at end of table.

TABLE 4—Continued

U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY

Grade and country	1987 Quantity (short tons) Gross weight	1987 Quantity (short tons) Silicon content	1987 Value (thousands)	1988 Quantity (short tons) Gross weight	1988 Quantity (short tons) Silicon content	1988 Value (thousands)
Over 99% but not over 99.7% silicon:						
Argentina	6,235	6,180	$5,880	8,553	8,481	$8,673
Australia	—	—	—	198	196	167
Brazil	4,807	4,765	4,527	12,242	12,130	14,596
Canada	9,836	9,754	10,632	8,688	8,610	10,228
China	1,331	1,319	1,209	7,887	7,798	8,136
France	512	509	510	215	213	263
Germany, Federal Republic of	([2])	([2])	4	—	—	—
Hong Kong	—	—	—	304	301	322
Japan	55	55	48	—	—	—
Norway	180	179	208	27	27	53
South Africa, Republic of	2,738	2,713	2,469	4,901	4,855	4,730
Spain	19	18	21	218	216	242
Sweden	1,794	1,776	1,830	1	1	17
Switzerland	—	—	—	165	163	142
United Kingdom	—	—	—	244	243	386
Venezuela	—	—	—	22	22	23
Yugoslavia	5,941	5,876	5,621	2,275	2,260	2,374
Total[1]	**33,448**	**33,144**	**32,960**	**45,941**	**45,516**	**50,353**
Over 99.7% silicon:						
Argentina	—		—	135		1,416
Belgium-Luxembourg	3		54	—		—
Brazil	—		—	17		691
Canada	2		4	20		57
China	2		36	98		815
Denmark	([2])		97	1		206
France	7		1,036	5		1,188
Germany, Federal Republic of	694		27,685	572		22,844
Hong Kong	([2])	NA	3	1	NA	41
Italy	55		7,624	92		10,780
Japan	55		2,168	74		2,171
Korea, Republic of	([2])		6	7		935
Malaysia	([2])		11	([2])		11
Sweden	([2])		14	([2])		7
Switzerland	([2])		4	—		—
Taiwan	1		10	—		—
U.S.S.R.	([2])		2	—		—
United Kingdom	—		—	([2])		6
Total[1]	**820**	**NA**	**38,754**	**1,022**	**NA**	**41,168**
Total silicon metal[1]	**36,930**	**XX**	**74,298**	**62,050**	**XX**	**108,717**

NA Not available. XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Source: Bureau of the Census.

Brasileiros S.A. brought a furnace on-line capable of producing 13,000 tpy of ferrosilicon. Cia. Paulista de Ferro-Ligas made plans to put into operation two 18,000-kV•A furnaces capable of producing 44,000 short tons annually.[16] Ferro Ligas Assofun S.A. made plans to complete construction of one 7,500-kV•A furnace toward the end of 1989.[17] Camargo Correa Metals S.A. started silicon metal production with one of two planned 18,000-kV•A electric furnaces. The plant's power needs were met by hydroelectric power available from the Amazon River. The two additional furnaces, which were scheduled for 1989, were to give the plant a total capacity of 35,000 tpy.[18]

Canada

Strong market conditions prompted Timminco Metals to restart an idle ferrosilicon furnace at its Beauharnois, Quebec, plant. The furnace capacity was reported to be 19.2 megawatts, suitable for producing 50% or 75% ferrosilicon.[19] Dow Corning and the Manitoba Energy Authority began a study to evaluate a new process that produce silicon metal from Lake Winnipeg area sands. If successful, a commercial plant producing up to 15,000 short tons per year of silicon metal was to be in operation by 1994.[20]

China

The Government of China imposed a ban on exports of ferrosilicon from three of its northern Provinces. The Provinces, Jilin, Liaoning, and Heilongjian, formed the heart of China's steel industry.[21] In September, a 40% export tax was levied by the Chinese Government on export shipments of ferrosilicon based upon the f.o.b. contract price in U.S. dollars.[22]

France

Pechiney Électrométallurgie completed a switch from the production of ferrosilicon to silicomanganese at its Dunkirk operation.[23]

Japan

Owing to high energy costs, Toyo Denka Kogyo Co. Ltd. closed its 19,200 tpy ferrosilicon plant in Kochi. The move left Japan with only three domestic producers of ferrosilicon: Japan Metals & Chemicals Co. Ltd. (28,000 tpy), Yahagi Iron Co. Ltd. (30,000 tpy), and Yakushima Denko Co. Ltd. (9,000 tpy).[24] In July, the Japanese domestic ferrosilicon industry became subject to an industry restructuring law administered by the Ministry of International Trade and Industry. Under the law, producers could be given financial and tax assistance for scrapping their existing facilities. The law was to incorporate low-interest loans to enable ferrosilicon producers to move into new industries.[25]

Norway

Elkem A/S signed a technical and marketing agreement with C.V.G. Ferrosilicio de Venezuela C.A. to allow Elkem to market 55,000 tpy of ferrosilicon in 1991.[26] Elkem also signed a letter of intent with Corporación Venezolana de Guyana (CVG) to explore the development of a silicon metal project. Under the terms of the agreement, CVG was to own a 20% stake in the project.[27] Fesil KS signed a letter of intent with Norsk Jern Holding A/S to develop a new ferrosilicon plant at Mo I Rana. The project was to involve converting two idle pig iron furnaces to ferrosilicon production. The new capacity was expected to yield 77,000 tpy of ferrosilicon.[28]

Philippines

Late in 1988, Maria Christina Chemical Industry, made plans for reactivating an idle 27,000-kV•A. furnace capable of producing both carbide and ferrosilicon.[29]

Portugal

Italmagnesio S.A. Industria e Comercio planned a joint venture with a group of former plant employees to reactivate an idle ferroalloy plant near Coimbra. The plan included four silicon metal furnaces, each producing 14,000 tpy. The first of these furnaces was to come on-line in mid-1990. Plans were also made for 25,000 tpy of silicon carbide capacity beginning late in 1990.[30]

Spain

The Spanish ferroalloy industry switched its Mataproqueras ferrosilicon plant to processing nonferrous scrap.[31] General Electric Co. made plans to spend $1.7 billion over 15 years on a new plastics and silicone plant to be built in Cartagena. Initial production of the plant was to be silicone polymers.[32]

Sweden

Owing to the Swedish state power board's policy decision to increase power price rates by 33% to 55% over 3 years, KemaNord Industrikemi AB shut down an 11,000-tpy silicon furnace. The move left KemaNord with 15,000 tpy of remaining silicon metal capacity.[33]

Venezuela

The Brazilian ferroalloy group Rima Electrometalurgia S.A. signed an agreement with CVG in March to set up a silicon metal plant within 2 to 3 years. The plant was to consist of two furnaces producing 13,000 tpy. The project, named Guayasil, was to be capable of producing chemical-grade silicon metal. When completed, the plant was to derive its electrical power from CVG's Guri Dam. Raw materials for the plant were to be obtained locally. In September, a letter of intent was signed by CVG and Italmagnesio S.A. concerning a project called Central de Ferroaleaciones de Venezuela CA (Cefeca). Cefeca included plans for numerous plants and related service companies that were to come into operation by 1997. Among these plans was a silicon metal plant with 53,000 short tons of capacity and a scheduled startup in 1993. The Cefeca project also called for acquiring capacity to

TABLE 5

WORLD PRODUCTION CAPACITY FOR SILICON-CONTAINING FERROALLOYS AND SILICON METAL IN 1988

(Thousand short tons, contained silicon)

Country	Capacity
Argentina	68
Australia	34
Brazil	348
Bulgaria	([1])
Canada	100
Chile	([1])
China	375
Colombia	([1])
Czechoslovakia	([1])
Egypt	50
France	170
German Democratic Republic	([1])
Germany, Federal Republic of	54
Hungary	([1])
Iceland	54
India	55
Italy	90
Japan	90
Korea, North	([1])
Korea, Republic of	18
Mexico	18
Norway	438
Peru	([1])
Philippines	25
Poland	([1])
Portugal	13
Romania	([1])
South Africa, Republic of	113
Spain	83
Sweden	131
Switzerland	([1])
Taiwan	30
United States	521
U.S.S.R.	650
Uruguay	([1])
Venezuela	50
Yugoslavia	135
Zimbabwe	6
Other	281
Total	**4,000**

[1] Included in other.

produce 42,000 tpy of 75% ferrosilicon by 1994 and 26,000 tpy of silicon carbide by 1992.[34]

TECHNOLOGY

In 1988, applications of silicon-base products continued to grow. Silicon was used in the electronics, photovoltaic, chemicals, and metals industries. Advanced materials, such as metal matrix composites (MMC's) and ceramic matrix composites (CMC's), were becoming an important part of the silicon industry.

Silicon continued to dominate the semiconductor manufacturing industry. Although new materials were being studied as alternatives to silicon, none were as economical and reliable. Among these materials were silicon carbide-base semiconductors, which can operate at higher temperatures than those made with ordinary silicon. Gallium arsenide semiconductors have been proven to be five times faster than those based on silicon, but were cost prohibitive for most applications and failed to break out of specialized markets for defense and telecommunications.

Compared with standard materials, MMC's have higher operating-temperature limits and greater strength, stiffness, abrasion resistance, and durability. Over the past 10 years an estimated $400 million has been spent on research in these materials.[35] The drawback of MMC's had been high cost. However, some recent low-performance MMC's offered prices and performance that were comparable to those of traditional materials. Composites consisting of silicon carbide particles within an aluminum matrix have proven their viability as engineering materials. Material consisting of 20% by volume silicon carbide resulted in 200% of the stiffness and 150% of the fatigue resistance of normal aluminum. Although a composite, the material was still workable by normal metal-forming processes. Several manufacturers have produced this basic material in a variety of end products, including turbine engine blades, boat beams, wire, and sporting equipment. Alcan Smelters and Chemicals Co. Ltd., a subsidiary of Alcan Aluminium Ltd., announced plans in 1988 to construct a plant that would produce 12,500 short tons annually of a silicon carbide particulate reinforced aluminum by 1990.

CMC's, which included those based on silicon carbide and silicon nitride, had begun to succeed in several applications because of their superior high-temperature strength, along with their heat and wear resistance. These materials were used with success in cutting tools, thermal barrier coatings, and engine components. The major difficulty with these materials was the inherent brittle nature of ceramics.

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[1] Physical scientist, Branch of Ferrous Metals.

[2] American Metal Market. V. 96, No. 170, Aug. 30, 1988, p. 1.

[3] ———. V. 96, No. 3, Jan. 6, 1988, p. 2.

[4] ———. V. 96, No. 37, Feb. 24, 1988, pp. 1, 8.

[5] ———. V. 96, No. 4, Jan. 7, 1988, p. 1.

[6] ———. V. 96, No. 222, Nov. 14, 1988, p. 4.

[7] ———. V. 96, No. 74, Apr. 15, 1988, p. 2.

[8] ———. V. 96, No. 80, Apr. 25, 1988, p. 2.

[9] ———. V. 96, No. 229, Nov. 23, 1988, p. 9.

[10] ———. V. 96, No. 173, Sept. 2, 1988, p. 16.

[11] Metals Week. V. 59, No. 46, Nov. 21, 1988, p. 8.

[12] Wall Street Journal. Oct. 5, 1988, p. B4.

[13] The Tex Report. V. 20, No. 4780, Oct. 11, 1988, p. 12.

[14] Metal Bulletin (London). No. 7285, May 16, 1988, p. 13.

[15] ———. No. 7378, Apr. 24, 1989, p. 17.

[16] Metal Bulletin Monthly. No. 213, Sept. 1988, pp. 31-33.

[17] The Tex Report. V. 20, No. 4803, Nov. 14, 1988, p. 2.

[18] ———. V. 20, No. 4767, Sept. 20, 1988, p. 7.

[19] Metal Bulletin (London). No. 7293, June 16, 1988, p. 21.

[20] American Metal Market. V. 96, No. 246, Dec. 20, 1988, p. 16.

[21] The Tex Report. V. 20, No. 4669, Apr. 27, 1988, p. 13.

[22] Metal Bulletin (London). No. 7323, Oct. 3, 1988, p. 19.

[23] Metals Week. V. 59, No. 3, Jan. 18, 1988, p. 3.

[24] ———. V. 59, No. 7, Feb. 15, 1988, p. 1.

[25] Japan Metal Bulletin. V. 5114, July 14, 1988, pp. 2-3.

[26] Page 21 of work cited in footnote 22.

[27] The Tex Report. V. 20, No. 4779, Oct. 7, 1988, p. 3.

[28] Metal Bulletin (London). No. 7330, Oct. 27, 1988, p. 11.

[29] The Tex Report. V. 20, No. 4764, Sept. 14, 1988, p. 11.

[30] ———. V. 20, No. 4784, Oct. 17, 1988, p. 8, 9.

[31] Page 15 of work cited in footnote 14.

[32] American Metal Market. V. 96, No. 205, Oct. 19, 1988, p. 4.

[33] Metal Bulletin (London). No. 7302, July 18, 1988, p. 16.

[34] Metal Bulletin Monthly (London). No. 220, Apr. 1989, pp. 26–29.

[35] Journal of Metals. V. 40, No. 11, Nov. 1988, pp. 46–48.

SILVER

By Robert G. Reese Jr.[1]

Domestic silver production increased to the highest level since 1942, reflecting capacity expansions and increased output at existing mines, production from new mines, and the reopening of some mines. World mine output of silver was unchanged, despite a 16-million-ounce drop in Peruvian production, which was partly offset by the increase in U.S. production.[2]

DOMESTIC DATA COVERAGE

Domestic mine production data for silver are developed by the Bureau of Mines from four separate voluntary surveys of U.S. operations. Typical of these surveys is the lode mine production survey of copper, gold, lead, silver, and zinc. Of the 157 silver-producing lode mines to which a survey form was sent, 155 responded.

LEGISLATION AND GOVERNMENT PROGRAMS

On February 25, the President signed Executive Order 12626 consolidating management of the National Defense Stockpile (NDS) within the U.S. Department of Defense (DOD). Prior to issuance of the Executive Order, responsibility for the NDS was divided among the General Services Administration, the Federal Emergency Management Agency, and Defense.

The Treasury and Postal Service appropriations bill enacted as Public Law 100-440, required the U.S. Department of the Treasury to sell 7.5 million ounces of silver from its stocks over a 3-year period. Sales of 2.5 million ounces was to occur in each of fiscal years 1989-91. The Secretary of the Treasury was authorized to reduce the quantity of silver sold, if it was determined that the sale would severely disrupt the domestic silver market. The Conference Committee report on Public Law 100-440 contained language to the effect that Treasury sales in a declining market would be considered severely disruptive. The President signed Public Law 100-440 September 22, and the remainder of 1988 was used to develop criteria for governing the silver sales.

On October 3, the President signed Public Law 100-467, the Dwight David Eisenhower Commemorative Coin Act of 1988, which authorized the U.S. Mint to produce up to 4 million silver coins in 1990 to honor the centennial of the birth of President Eisenhower. Each coin was to weigh 26.73 grams, consist of an alloy of 90% silver, 10% copper, be legal tender, and have a face value of $1.00. The

TABLE 1

SALIENT SILVER STATISTICS

		1984	1985	1986	1987	1988
United States:						
Mine production	thousand troy ounces	44,592	39,433	34,524	[r]39,897	53,416
Value	thousands	$362,976	$242,205	$188,846	[r]$279,675	$349,339
Percentage derived from:						
Precious metals ores		80	70	63	W	W
Base metal ores		20	30	37	W	W
Placers		(1)	(1)	(1)	(1)	(1)
Refinery production:						
Domestic and foreign ores and concentrates	thousand troy ounces	59,331	53,808	42,413	[r]45,480	47,402
Secondary (old scrap)	do.	27,842	27,830	24,494	26,034	27,397
Exports:						
Refined	do.	10,340	12,611	10,109	11,240	14,269
Other	do.	14,107	12,145	15,005	15,853	17,833
Imports for consumption:						
Refined	do.	93,546	137,398	125,365	67,959	72,662
Other	do.	21,420	15,203	19,525	13,867	15,976
Stocks, Dec. 31:						
Industry	do.	21,217	18,467	17,671	[r]15,125	15,380
Futures exchanges	do.	137,631	173,144	162,089	169,731	188,470
Apparent demand, refined[2]	do.	170,379	206,425	182,163	128,233	133,192
Coinage	do.	2,665	362	7,535	15,074	8,828
Price, average per troy ounce[3]		$8.14	$6.14	$5.47	$7.01	$6.54
Employment[4]		2,600	3,000	2,200	1,800	2,300
World:						
Mine production	thousand troy ounces	[r]420,065	[r]424,416	419,433	[p]443,050	[e]443,330
Consumption:[5]						
Industry and the arts	do.	353,300	357,200	[r]394,700	[r]409,600	431,500
Coinage	do.	8,700	12,700	26,000	[r]31,000	30,100

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Less than 1/2 unit.
[2]Defined as refinery production from primary materials plus refinery production from old scrap plus net imports of bullion. Represents not only the quantity of silver required by the domestic fabricating industry, some of which may be placed in stocks, but also the quantity of silver demanded by U.S. investors.
[3]Handy & Harman.
[4]Mine Safety and Health Administration.
[5]Market economy countries only. Source: Handy & Harman.

silver for the coins was to be obtained from the NDS. Coin sales were authorized to begin January 1, 1990.

DOMESTIC PRODUCTION

Silver was produced from precious metal ores at 93 lode mines, while 49 lode mines produced silver as a byproduct of the processing of copper, lead, and zinc ores. In 1988, 15 mines each produced more than 1 million ounces of silver; their aggregated production equaled 74% of total domestic production. Silver was also produced at 10 placer operations. U.S. silver production in 1988, 53.4 million ounces, was the largest quantity produced in any year since 1942, when 55.9 million ounces were produced.

AMAX Inc. reacquired 15.2 million shares of its stock from Chevron Corp. in May. The acquisition, equivalent to 15.5% of AMAX's outstanding shares, ended the 13-year association of the two companies.

In June, Echo Bay Mines Ltd., Silver King Mines Inc., and Pacific Silver Corp. formed the Alta Bay joint venture. Echo Bay contributed its Sunnyside Mine in Colorado, its Illipah Mine in Nevada, and its Easy Junior and Pan exploration properties in Nevada to the joint venture. Echo Bay also paid Silver King and Pacific Silver $17.5 million. Silver King and Pacific Silver contributed their Robinson Mine, and their Golden Butte development property, both in Nevada. Echo Bay had a 40% interest in the joint venture, while Silver King and Pacific Silver, through their affiliate Alta Gold Co., had the remaining 60%. Alta Gold was the operator of the joint venture properties.

Arizona

In July, Inspiration Resources Co. sold the Arizona assets of its Inspiration Consolidated Copper Co. subsidiary to Cyprus Minerals Co. Included in the sale were several open pits collectively referred to as the Inspiration Mine, two concentrators, a smelter, a refinery, and a rod mill. The sale price was $126 million in cash plus the assumption of certain liabilities. Inspiration used a portion of the proceeds from the sale to reduce its debt. Cyprus renamed the operation Cyprus Miami. Cyprus' Bagdad, Sierrita, and Twin Buttes Mines were expected to provide most of the copper concentrates for the smelter.

Cyprus leased the Twin Buttes copper-silver mine from Park Corp. The lease, signed in March, was for 15 years, and mining resumed in June. The mine, on care and maintenance since late 1985, was adjacent to the Sierrita Mine. Ore from Twin Buttes was processed at the Sierrita mill.

Echo Bay began production at the Congress Mine in March. The underground operation produced a silver-bearing high-silica ore that was trucked directly to a smelter for use as a flux. An abandoned mine adjacent to Congress was purchased by Echo Bay in 1988 for its potential to increase the Congress Mine's reserves.

Colorado

Cobb Resources Corp. and its joint-venture partner Boulder Gold Inc. placed the London Mine in production on May 1. Prior to commercial production, the partners acquired a 200-ton-per-day flotation mill for use at the mine. Expansion of the mill to a capacity of 300 tons per day was being considered.

In November, the Alta Bay venture and Washington Mining Co. entered into a joint venture. Alta Bay contributed the Sunnyside Mine, which it had acquired from Echo Bay in June, while Washington Mining contributed its net smelter return royalty from the Sunnyside Mine. Alta Bay's interest in the venture was 67% and Washington Mining's interest was 33%. Washington Mining became the operator of the Sunnyside Mine on January 1, 1989.

Idaho

The Bunker Hill Mine was reopened by its owner, Bunker Limited Partnership. Although historically a lead-silver mine, it initially was to produce from a zinc ore zone near the main shaft. Employment was expected to reach 200 by yearend 1989. When the mine closed in 1981, it employed more than 2,000 workers.

At the Sunshine Mine, members of the United Steelworkers of America (USWA) ratified a new 3-year labor agreement with Sunshine Mining Co. in May. The new agreement contained a flexible wage scale that would fluctuate proportionately with the price of silver, as well as provisions guaranteeing employees a percentage of the profits generated by the mine and shares of Sunshine's common stock as a portion of their wages. Corporate officials believed that the new USWA contract, combined with a similar contract negotiated with the mine's International Brotherhood of Electrical Workers local in 1987, would allow the mine to continue operating during periods of low silver prices.

The Yellow Pine Mine, owned by Hecla Mining Co., was officially opened in late June, and the first doré was poured in late July. The oxidized ore was processed by Pioneer Metals Corp. at its nearby Stibnite mill under an agreement reached by Hecla and Pioneer in late 1987. Production in 1988 was lower than expected, according to Hecla, owing primarily to a disagreement with Pioneer that eventually led to the termination of the processing agreement. Yellow Pine was Hecla's first heap-leach operation, and the company reportedly was considering several options for processing the ore. Hecla officials reported that it was unlikely that any gold or silver would be produced at Yellow Pine in 1989.

Nevada

Capacity at American Barrick Resources Corp.'s Goldstrike Mine was increased through the construction of a 9-million-ton-per-year crushing and agglomerating plant and the construction of a new 4,500-ton-per-day carbon-in-leach mill. The crushing and agglomerating plant began operating in May, while the new mill began operations in August. To supply the expansions, additional mining equipment was purchased, and new leach pads were constructed to handle the low-grade output from the crushing and agglomerating plant.

The Gooseberry Mine, which had been closed since late 1985, was reopened, producing gold and silver by milling the ore and using flotation. Construction of a leach pad to reprocess the mine's tailings was completed in late 1988.

Ore reserves at the Illipah Mine were mined out in late 1988. Heap leaching continued throughout the year and was expected to be completed in mid-1989.

Several projects were completed at Nevada Goldfields Corp.'s Kingston Mine. Silver recoveries were improved by lengthening the ore treatment period through the installation of two additional leach tanks in the mill's carbon-in-leach circuit, and by finer screening of the ore. Haulage costs were reduced following the completion of an underground ore transfer system that eliminated 1.4 miles of truck haulage. The transfer system consisted of a 600-foot ore pass from the face level to the canyon-floor level, and a conveyor system to move the ore from the base of the chute to an outside loadout facility. Power costs were reduced by connecting the mine and mill electrical systems to the local utility system, eliminating the company-owned diesel generators.

At its McCoy-Cove Mine, Echo Bay Mines began mining operations at the Cove deposit in February. The McCoy-Cove Mine consisted of two deposits located approximately 1 mile apart and operated by Echo Bay as a single unit. Ore was mined from both deposits using conventional open pit methods and then heap leached. Some of the higher grade ore produced at the Cove pit was also heap leached, while some was stored and the remainder was trucked 160 miles to Echo Bay's mill at its Manhattan Mine. Construction of a 7,500-ton-per-day mill at McCoy-Cove to treat the mine's sulfide ore was begun during the year, and was expected to be operational in 1989. Echo Bay also began driving ramps at both deposits to test the deeper mineralization.

FMC Gold Co. expanded operations at its Paradise Peak Mine. Heap leaching was begun to complement the existing 4,000-ton-per-day mill and resulted in the production of an additional 10,000 ounces of gold and almost 100,000 ounces of silver. Notable about the heap-leach system was the use of a drip system to apply leachant to the heap. Use of the drip system combined with a cover of crushed rock on the heap was expected to reduce solution losses through evaporation and to allow year-round processing.

In February, Coeur d'Alene Mines Corp. assumed full operation of the Rochester Mine, replacing Morrison-Knudsen Co., the contract mining company that had been the mine's operator. In March, Coeur acquired the remaining 52% interest in Royal Apex Silver Inc. giving it full ownership of Rochester.

Corona Corp.'s Santa Fe open pit, heap-leach mine began commercial production in November. The mine was unusual when compared with most heap-leach operations owing to its high silver-to-gold ratio. The mine was expected to produce 55,000 ounces of gold and 195,000 ounces of silver in 1989.

AMAX Gold Inc. expanded its mill capacity to 1,500 tons per day and its heap-leach capacity to 5 million tons per year at the Sleeper Mine. The capacity expansions followed delineation of additional gold-silver reserves at Sleeper.

Nerco Inc. acquired Silver King Mines' 50% interest in the Taylor Mine near midyear. The acquisition gave Nerco total ownership of the mine. Taylor, which had been maintained on a caretaker basis since January 1985, was not reopened in 1988.

Construction was begun on the Wood Gulch Mine in June, and the first gold and silver was poured in November. Wood Gulch, a small open pit, heap-leach operation, was owned by Homestake Mining Co.

U.S. Gold Corp. began construction of its White Pine Mine in June. The mine, a conventional open pit, heap-leach operation, produced its first gold-silver doré in mid-October. White Pine consisted of several small deposits, and during the year ore was mined from four pits.

Utah

Mining ceased at Hecla's Escalante Mine on December 30 owing to exhaustion of the known ore body. Efforts to locate additional reserves were reportedly unsuccessful. The mine's 750-ton-per-day mill was expected to continue operating until late 1990, processing stockpiled ore.

At the Mercur Mine, a pressure-oxidation autoclave was started in February. The new facility allowed American Barrick to begin treating the mine's refractory sulfide ore. Prior to the autoclave's construction the refractory sulfide ore was stockpiled. The autoclave had a designed capacity of 750 tons per day.

Other States

Cactus Gold Mines Co. began commercial production at its Shumake Mine in December. The mine, located in California, was expected to produce about 40,000 gold-equivalent ounces of gold and silver.

ASARCO Incorporated reported that construction at its West Fork Mine in Missouri was completed. The lead-silver-zinc operation, had been operating on a limited basis since its opening in 1985. Production reached full capacity in August following completion of a ventilation shaft.

The Black Pine Mine in Montana was closed in February.

In South Carolina, the first gold was poured at the Ridgeway Mine on December 6. Commercial production was expected to begin in January 1989. Processing at Ridgeway consisted of a carbon-in-pulp vat-leaching system to produce a gold-silver dore. The mine was a joint venture of BP America Inc. (52%) and Galactic Resources Ltd. (48%).

At the Gilt Edge Mine in South Dakota, a heap-leach facility was completed and production began in October. Operations were suspended in late October when Brohm Mining Corp., the mine's operator, discovered that the leach pad was leaking excessively. Fortunately, the mine's backup systems were able to contain the leaks. Brohm discovered that the leaks were occurring at the seams in the leach pad. The remainder of 1988 was spent repairing the pad by applying a sealant to the seams, followed by spraying a second sealant over each section of the pad. Brohm expected to have the pad fully operational by the spring of 1989.

Bond International Gold Inc. began production at the Richmond Hill gold-silver mine in South Dakota. The mine was an open pit, heap-leach operation.

CONSUMPTION AND USES

The Bureau of Mines has discontinued publication of reported data on silver consumption by end use, owing to the low response rate by industry to the Bureau's canvass.

Apparent U.S. demand for silver in 1988, calculated as refinery production from primary materials and from old scrap plus net imports of refined bullion, was 133.2 million ounces. Apparent demand included silver absorbed by investors, the quantity of which was unknown, as well as silver required by the domestic fabricating industry.

Available data indicate that photographic materials accounted for approximately one-half of the silver used for industrial purposes. Electrical and electronic products such as batteries, contacts, and conductors apparently accounted for much of the remaining silver consumed industrially.

STOCKS

Total accountable stocks at yearend 1988 increased by 11.6 million ounces over the previous year owing primarily to an increase in the quantity of silver held by the futures exchanges. The quantity of silver held in the NDS continued to decline as the U.S. Mint drew down the silver for coinage. As reported to the Bureau of Mines, refiner, fabricator, and dealer stocks, remained essentially unchanged, possibly owing in part to the declining silver price and to uncertainty concerning the U.S. inflation rate.

PRICES

The domestic silver price as quoted by Handy & Harman remained in a relatively narrow range throughout 1988. The price began the year at $6.52 per ounce and was $6.08 at yearend. The most significant price movement occurred from late May through July when the price rose from $6.58 on May 28 to $7.99 on July 21 before dropping to less than $7.00 by the end of the month. Factors that analysts believed to have affected the silver price during the year included investor concerns about a potential increase in the U.S. inflation rate, increasing U.S. interest rates, U.S. trade deficits, the value of the U.S. dollar in terms of certain foreign currencies, and the crude oil market.

As with the domestic price, the London spot price was quoted within a relatively narrow range throughout the year. The U.S. dollar equivalent of the London spot price, as published in Metals Week, began 1988 at $6.64, and ended the year at its lowest point, $6.05. The high price for the year, $7.82, occurred on July 20. The average for 1988 was $6.53.

The amount of silver represented by the futures contracts traded on the Commodity Exchange Inc. (COMEX) decreased slightly in 1988 to 23.3 billion ounces. At the Chicago Board of Trade (CBT), the quantity of silver corresponding to the futures trading volume declined from 597 million ounces to 502 million ounces in 1988. Silver futures trading volume on the Mid-America Commodity Exchange (Mid-AM), at 11 million ounces, remained essentially unchanged from the previous year.

Near mid-April, the CBT received permission from the Commodity Futures Trading Commission (CFTC) to trade options on its 5,000-ounce silver futures contract. Each option entitled the holder to either buy or sell one CBT futures contract representing 5,000 ounces of silver at a given price for a specified period. Trading procedures were essentially identical to those for the existing options on CBT's 1,000-ounce silver futures contract.

The Chicago Mercantile Exchange (CME) received permission from the CFTC to begin trading a 5,000-ounce silver futures contract near the end of June. The terms and conditions of the contract were reportedly similar to the terms and conditions of the futures contracts traded on COMEX, the CBT, and Mid-Am. Although the CME received permission to trade the contract, trading was not started during the year, reportedly owing to the poor performance of CME's 100-ounce gold futures contract.

FOREIGN TRADE

U.S. silver exports increased in 1988 for the fourth consecutive year, reaching their highest level since 1980, when 80.9 million ounces of silver were exported. The lower domestic silver price and the continued weakness of the U.S.

dollar in terms of many foreign currencies both helped make domestic silver more competitive worldwide.

As in 1987, Japan, France, and the United Kingdom recorded the largest increases in receipts of U.S. silver exports, totaling more than 4 million ounces. The largest decrease in U.S. silver exports was in shipments of refined bullion to Canada—more than 1 million ounces.

Although U.S. silver imports for consumption increased by more than 8% in 1988, they remained 26% lower than the average annual imports in the years 1980–87. U.S. imports from Canada and the United Kingdom increased by nearly 15 million ounces and 3 million ounces, respectively, while imports from Peru, Mexico, Belgium-Luxembourg, and Chile fell collectively by about 12 million ounces.

WORLD CAPACITY

The data in table 13 were rated production capacity in mines as of December 31, 1988. Rated capacity was defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

WORLD REVIEW

A sizable decline in Peruvian mine production of silver, owing to strikes and economic problems, was offset by increased production in the United States and other countries, leaving world output essentially unchanged. In those countries where production grew, the flow of byproduct silver from gold and base metal mines contributed substantially to the increases. Worldwide, gold continued to be the primary metals exploration target, and as in the United States, most new gold discoveries had some byproduct silver. Oceania and countries bordering the Pacific Ocean continued to be the most active exploration areas.

Total consumption of silver in market economy countries, as estimated by Handy & Harman, was 461.6 million ounces, an increase of 21 million ounces over the revised figure for 1987. Of the total, an estimated 431.5 million ounces was used in industrial applications, an increase of 21.9 million ounces over the 1987 level. The quantity of silver used for coinage decreased from 31 million ounces in 1987 to 30.1 million ounces in 1988.[3]

The total silver required by all market economy countries, including the United States, for industrial use, coinage, and bullion stocks, exceeded primary production in these countries by 104.6 million ounces. The shortfall was met with silver obtained from the following sources, according to Handy & Harman: old scrap, 81.3 million ounces; outflow from stock held in India, 14.5 million ounces; demonetized coin, 2 million ounces; withdrawals from private stocks, 1.8 million ounces; and net imports from centrally planned economy countries, 6.9 million ounces. U.S. and foreign Government-held silver stocks had a net increase of 1.9 million ounces.

Canada

Workers at the Dome Mine in Ontario agreed to a new 2-year contract in mid-April. The new contract provided for average wage increases of 5% and 4.2% in the first and second years respectively. Production at Dome declined owing to an accident, which temporarily closed the main production shaft. The shaft was repaired and reopened in early 1989.

At the Kiena Mine in Quebec, hourly employees decided to become union members. In December, the Provincial government approved the application by Metallurgistes-unis-d'Amerique to represent Placer Dome's employees at Kiena. Prior to 1988, the mine had been nonunion. Negotiations on the first contract covering the workers was expected to begin in 1989.

Lornex Mining Corp. Ltd. was dissolved near yearend by its major shareholders. The decision by Rio Algom Ltd. and Teck Corp. reportedly acknowledged that Lornex, with no direct operating interests, served only as a holding company, and that Lornex's dissolution would simplify Rio Algom's and Teck's corporate structures. At the time of the agreement, Rio Algom held 69.1% and Teck 23.5% of Lornex's common shares. The remaining 7.4% was publicly held. Rio Algom and Teck had proposed dissolving Lornex and splitting its assets on a pro rata basis between them. Other shareholders had the option of exchanging their shares for cash or stock in Rio Algom. The proposal was the subject of litigation by at least one of the minority shareholders; however, the Supreme Court of Ontario dismissed the suit. Lornex's major asset was its 45% holding in the Highland Valley Copper Co.

Highland Valley Copper announced in February plans to move its recently acquired Highmont mill approximately 6 miles to a site adjacent to its Lornex mill. Estimated cost of the move was $70 million. By yearend, all of major components had been moved to the new site and were expected to be operational in the second quarter of 1989. Capacity of the Highmont mill exceeded 39,000 tons per day, while that of the Lornex mill was nearly 90,000 tons per day.

In July, Corona Corp. was formed by the amalgamation of Royex Gold Mining Corp., International Corona Resources Ltd., Lacana Mining Corp., Mascot Gold Mines Ltd., and Galveston Resources Ltd., five interrelated companies. The merger was viewed as a means of simplifying the corporate structure as well as providing other financial benefits. Corona produced gold and silver from operations throughout North America.

The Royal Canadian Mint began sales of its new Maple Leaf silver bullion coin. The coin contained 1 ounce of 99.99%-pure silver and had a face value of Canadian $5.00.

Other Countries

Cía. Minera Ojos del Salado S.A., a small Chilean copper-gold-silver producer that operates two mines and a mill, completed its mill expansion project in July. Mill capacity was increased about 80% to 1,900 tons per day.

The Waihi Mine, located on New Zealand's North Island, began production in July. The open pit produced gold and silver from a deposit near the Martha Hill Mine, a former gold-silver operation. AMAX Gold had a 28.35% interest in the Waihi Mine.

TECHNOLOGY

Silver-related research and development was extensive in 1988. A sample of the reported work included the development of several silver alloys for use in electrical contacts, investigations into the antibacterial effect of silver in some medical applications, and applications for various silver catalysts.

These and numerous other reports on silver-related research were summarized by the staff of the Silver Institute in its New Silver Technology publication.[4]

[1] Physical scientist, Branch of Nonferrous Metals.

[2] Ounce as used throughout this chapter refers to the troy ounce.

[3] Handy & Harman. The Silver Market, 1988. 73d Annual Report. 26 pp.

[4] Silver Institute. New Silver Technology: Silver Summaries From the Current World Literature monthly publication; available from the Silver Institute, 1206 16th St. NW., Washington, DC 20036.

TABLE 2

MINE PRODUCTION OF RECOVERABLE SILVER IN THE UNITED STATES, BY STATE

(Troy ounces)

State	1984	1985	1986	1987	1988
Alaska	W	W	W	r15,812	20,589
Arizona	4,246,616	4,885,310	4,506,197	r3,661,277	4,888,951
California	W	115,478	155,176	121,817	481,376
Colorado	2,199,888	548,696	644,574	860,562	854,413
Idaho	18,869,186	18,827,948	11,206,851	W	10,934,631
Michigan	—	W	W	W	W
Missouri	1,401,070	1,635,301	1,459,185	1,180,584	1,460,271
Montana	5,652,847	4,009,979	4,773,264	r5,937,155	6,186,074
Nevada	6,477,032	4,946,523	6,408,783	r12,186,692	19,535,223
Oregon	W	—	—	W	W
South Carolina	—	W	W	W	W
South Dakota	50,036	63,156	W	W	84,398
Other[1]	5,694,996	4,400,582	5,369,866	15,932,642	8,969,751
Total	**44,591,671**	**39,432,973**	**34,523,896**	**r39,896,541**	**53,415,677**

r Revised. W Withheld to avoid disclosing company proprietary data.

[1] Includes Illinois, New Mexico, New York, Tennessee, Utah, Washington, and data indicated by symbol W.

TABLE 3

MINE PRODUCTION OF RECOVERABLE SILVER IN THE UNITED STATES, BY MONTH

(Thousand troy ounces)

Month	1984	1985	1986	1987[r]	1988
January	3,774	3,429	3,703	3,178	3,733
February	3,897	3,049	3,257	3,114	3,662
March	4,202	3,389	3,282	3,372	4,227
April	4,027	3,211	3,183	3,325	4,065
May	3,892	3,355	2,879	3,184	4,155
June	3,780	3,234	2,778	3,249	4,562
July	3,576	3,238	2,704	3,542	4,558
August	3,719	3,359	2,611	3,427	4,871
September	3,245	2,922	2,623	3,490	4,887
October	3,662	3,847	2,635	3,374	5,048
November	3,323	3,122	2,372	3,223	4,829
December	3,495	3,278	2,497	3,419	4,819
Total	**44,592**	**39,433**	**34,524**	**39,897**	**53,416**

[r] Revised.

TABLE 4

TWENTY-FIVE LEADING SILVER-PRODUCING MINES IN THE UNITED STATES IN 1988, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of silver
1	Rochester	Pershing, NV	Coeur Rochester Inc.	Silver ore.
2	Paradise Peak	Nye, NV	FMC Gold Co.	Gold ore.
3	Trinity	Pershing, NV	United States Borax & Chemical Corp.	Silver ore.
4	Troy	Lincoln, MT	ASARCO Incorporated	Silver-copper ore.
5	Candelaria	Mineral, NV	Nerco Metals Inc.	Silver ore.
6	Galena	Shoshone, ID	ASARCO Incorporated	Do.
7	Bingham Canyon	Salt Lake, UT	BP Minerals America Inc.	Copper ore.
8	Sunshine	Shoshone, ID	Sunshine Mining Co.	Silver ore.
9	Coeur	do.	ASARCO Incorporated	Do.
10	Escalante	Iron, UT	Hecla Mining Co.	Do.
11	Lucky Friday	Shoshone, ID	do.	Lead-zinc ore.
12	DeLamar	Owyhee, ID	Nerco DeLamar Co.	Gold-silver ore.
13	Tyrone	Grant, NM	Phelps Dodge Corp.	Copper ore.
14	Mission Complex[1]	Pima, AZ	ASARCO Incorporated	Do.
15	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Gold ore.
16	Sierrita	Pima, AZ	Cyprus Sierrita Corp.	Copper ore.
17	Pinos Altos	Grant, NM	Cyprus Pinos Altos Corp.	Do.
18	White Pine	Ontonagon, MI	Copper Range Co.	Do.
19	McCoy and Cove	Lander, NV	Echo Bay Mining Co.	Gold ore.
20	Morenci	Greenlee, AZ	Phelps Dodge Corp.	Copper ore.
21	Fortitude and Surprise	Lander, NV	Battle Mountain Gold Co.	Gold ore.
22	Continental	Silver Bow, MT	Montana Resources Inc.	Copper ore.
23	Bagdad	Yavapai, AZ	Cyprus Bagdad Copper Co.	Do.
24	Chino	Grant, NM	Phelps Dodge Corp.	Do.
25	San Manuel	Pinal, AZ	Magma Copper Co.	Do.

[1] Includes Eisenhower, Mission, and Pima Mines

TABLE 5

SILVER PRODUCED IN THE UNITED STATES, BY STATE, TYPE OF MINE, AND CLASS OF ORE

Year and State	Placer (troy ounces of silver)	Lode					
		Gold ore		Gold-silver ore		Silver ore	
		Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
1984	1,503	24,581,032	1,333,227	1,587,850	2,890,407	7,804,144	31,328,954
1985	6,434	26,888,194	1,647,506	1,043,854	2,039,797	4,302,681	24,012,856
1986	6,490	42,914,649	3,858,979	869,099	1,809,687	5,555,677	15,835,513
1987[r]	22,788	68,391,909	7,118,307	W	W	8,757,526	13,885,053
1988:							
Alaska	W	W	W	—	—	—	—
Arizona	5	W	W	—	—	—	—
California	W	11,908,840	477,412	—	—	—	—
Colorado	—	W	W	W	W	—	—
Idaho	—	2,013,143	168,488	W	W	W	W
Illinois	—	—	—	—	—	—	—
Michigan	—	W	W	—	—	—	—
Missouri	—	—	—	—	—	—	—
Montana	—	17,719,323	1,534,851	—	—	W	W
Nevada	W	76,495,064	6,792,551	W	W	9,732,733	12,293,560
New Mexico	—	W	W	—	—	W	W
New York	—	—	—	—	—	—	—
Oregon	W	—	—	—	—	—	—
South Carolina	—	W	W	—	—	—	—
South Dakota	—	W	W	—	—	—	—
Tennessee	—	—	—	—	—	—	—
Utah	—	W	W	22,611	157,733	W	W
Washington	—	W	W	—	—	—	—
Total	**12,144**	**119,392,165**	**10,341,252**	**W**	**W**	**10,552,980**	**21,663,796**
Percent of total silver	**([1])**	**XX**	**19**	**XX**	**W**	**XX**	**41**

See footnotes at end of table.

TABLE 5—Continued

SILVER PRODUCED IN THE UNITED STATES, BY STATE, TYPE OF MINE, AND CLASS OF ORE

Year and State	Lode				Total	
	Copper ore		Other[2 3]			
	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
1984	[4]166,255,710	[4]6,526,427	21,573,113	2,511,153	221,801,849	44,591,671
1985	154,658,676	9,659,224	12,313,173	2,067,156	199,206,578	39,432,973
1986	[4]146,673,936	[4]11,104,036	6,045,883	1,909,191	202,059,244	34,523,896
1987[r]	222,043,186	15,330,720	W	W	308,375,589	39,896,541
1988:						
Alaska	—	—	—	—	W	20,589
Arizona	152,531,057	4,765,636	W	W	152,811,381	4,888,951
California	—	—	W	W	W	481,376
Colorado	—	—	W	W	W	854,413
Idaho	—	—	W	W	3,500,049	10,934,631
Illinois	—	—	—	W	—	W
Michigan	W	W	—	—	W	W
Missouri	—	—	6,584,947	1,460,271	6,584,947	1,460,271
Montana	W	W	916	4,885	37,848,993	6,186,074
Nevada	W	W	W	W	86,253,913	19,535,223
New Mexico	W	W	W	W	W	W
New York	—	—	W	W	W	W
Oregon	—	—	—	—	—	W
South Carolina	—	—	—	—	W	W
South Dakota	—	—	W	W	2,951,747	84,398
Tennessee	—	—	W	W	W	W
Utah	W	W	—	—	W	W
Washington	—	—	W	W	W	W
Total	**244,984,913**	**15,596,669**	**W**	**W**	**386,215,704**	**53,415,677**
Percent of total silver	**XX**	**29**	**XX**	**W**	**XX**	**100**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1] Less than 1/2 unit.
[2] Includes lead, zinc, copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores.
[3] Includes silver recovered from tungsten and fluorspar ores.
[4] Includes copper-zinc ore and silver recovered from copper-zinc ore.

TABLE 6

SILVER PRODUCED IN THE UNITED STATES BY CYANIDATION[1]

Year	Leaching in vats, tanks, and closed containers[2 3]		Leaching in open heaps or dumps[4]	
	Ore treated (short tons)	Silver recovered (troy ounces)	Ore treated (short tons)	Silver recovered (troy ounces)
1984	11,172,695	7,752,063	18,222,366	2,986,172
1985	15,421,903	6,819,904	14,875,363	2,701,360
1986	19,269,750	7,504,350	27,620,640	3,641,741
1987[r]	25,220,966	8,991,240	49,886,488	8,175,841
1988	29,325,281	9,696,407	95,758,367	14,668,317

[r] Revised.
[1] May include small quantities recovered by leaching with thiourea, by bioextraction, and by proprietary processes.
[2] Including autoclaves.
[3] May include small quantities recovered by gravity methods.
[4] May include tailings and waste ore dumps.

TABLE 7

LODE SILVER PRODUCED IN THE UNITED STATES, BY STATE

Year and State	Amalgamation: Ore treated (short tons)	Amalgamation: Silver recovered (troy ounces)	Cyanidation: Ore treated (short tons)	Cyanidation: Silver recovered (troy ounces)	Smelting of concentrates: Ore concentrated (short tons)	Smelting of concentrates: Concentrates smelted (short tons)	Smelting of concentrates: Silver recovered (troy ounces)	Smelting of ore: Ore smelted (short tons)	Smelting of ore: Silver recovered (troy ounces)	Total ore processed[1] (short tons)	Total silver recovered (troy ounces)
1984	—	—	29,395,061	10,738,235	192,253,620	4,108,133	33,373,850	153,168	478,083	221,801,849	44,590,168
1985	—	—	30,297,266	9,521,264	168,650,998	4,523,641	29,313,819	258,314	591,456	199,206,578	39,426,539
1986	752,421	10,396	46,890,390	11,146,091	154,212,790	3,904,999	23,065,267	203,643	295,652	202,059,244	34,517,406
1987[r]	W	W	75,107,454	17,167,081	233,080,321	4,916,134	22,368,539	W	W	308,405,119	39,873,753
1988:											
Alaska	—	—	W	W	—	—	—	—	—	W	W
Arizona	—	—	W	9,243	152,590,317	2,561,736	4,766,500	W	113,203	152,811,381	4,888,946
California	W	W	11,908,536	476,033	W	W	W	W	W	W	[2]481,376
Colorado	W	W	W	W	W	W	W	W	W	W	854,413
Idaho	—	—	W	W	W	W	W	—	—	3,500,049	10,934,631
Illinois	—	—	—	—	—	—	W	—	—	—	W
Michigan	—	—	W	W	W	W	W	—	—	W	W
Missouri	—	—	—	—	6,584,947	605,389	1,460,271	—	—	6,584,947	1,460,271
Montana	—	—	W	332,721	24,127,131	276,550	5,790,356	W	62,997	37,848,993	6,186,074
Nevada	—	—	85,924,817	19,356,171	W	W	W	W	W	86,253,913	[2]19,535,223
New Mexico	—	—	38,000	7,000	W	W	W	W	W	W	W
New York	—	—	—	—	W	W	W	—	—	W	W
South Carolina	—	—	W	W	—	—	—	—	—	W	W
South Dakota	—	—	W	W	—	—	—	W	W	2,951,747	84,398
Tennessee	—	—	—	—	W	W	W	—	—	W	W
Utah	—	—	W	W	W	W	W	22,611	157,733	W	W
Washington	—	—	W	W	W	W	W	W	W	W	W
Total	**1,667**	**3,689**	**125,083,648**	**24,364,724**	**260,866,722**	**5,443,973**	**28,422,745**	**263,667**	**612,375**	**386,215,704**	**53,403,823**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes old tailings and some non-silver-bearing ores not separable, in amounts ranging from 0.04% to 0.12% of the totals for the years listed. Excludes fluorspar, molybdenum, and tungsten ores from which silver was recovered as a byproduct and excludes ores leached for recovery of copper.

[2] Includes some placer production to avoid disclosing company proprietary data.

TABLE 8

U.S. REFINERY PRODUCTION OF SILVER

(Thousand troy ounces)

Raw material	1984	1985	1986	1987	1988
Concentrates and ores:					
Domestic and foreign	59,331	53,808	42,413	[r]45,480	47,402
Old scrap	27,842	27,830	24,494	26,034	27,397
New scrap	42,091	44,643	46,563	42,319	48,426
Total	**129,264**	**126,281**	**113,470**	**[r][1]113,834**	**123,225**

[r] Revised.

[1] Data do not add to total shown because of independent rounding.

TABLE 9

YEAREND STOCKS OF SILVER IN THE UNITED STATES

(Thousand troy ounces)

	1984	1985	1986	1987	1988
Industry	21,217	18,467	17,671	[r]15,125	15,380
Futures exchanges	137,631	173,144	162,089	169,731	188,470
Department of the Treasury	31,889	32,621	33,819	39,517	38,613
Department of Defense	342	460	2,500	2,400	2,600
National Defense Stockpile	137,500	137,500	127,306	113,082	106,421

[r] Revised.

TABLE 10

U.S. SILVER PRICES

(Dollars per troy ounce)

Period	Low		High		Average
	Price	Date	Price	Date	
1984	6.26	Dec. 20	10.04	Mar. 5	8.14
1985	5.57	Mar. 12	6.74	Mar. 27	6.14
1986	4.87	May 20	6.20	Jan. 27	5.47
1987	5.36	Jan. 7	10.20	Apr. 27	7.01
1988:					
January	6.50	Jan. 29	7.00	Jan. 6	6.73
February	6.12	Feb. 29	6.58	Feb. 2	6.32
March	6.16	Mar. 3	6.73	Mar. 29	6.41
April	6.37	Apr. 26	6.83	Apr. 4	6.48
May	6.34	May 4	6.76	May 23	6.54
June	6.63	June 29	7.37	June 7	7.04
July	6.76	July 6	7.99	July 21	7.15
August	6.52	Aug. 30 and 31	6.91	Aug. 5	6.71
September	6.11	Sept. 30	6.62	Sept. 1	6.36
October	6.16	Oct. 5	6.40	Oct. 17	6.28
November	6.01	Nov. 21	6.47	Nov. 10	6.29
December	6.01	Dec. 29	6.21	Dec. 7	6.11
Average and date	6.01	Nov. 21 and Dec. 29	7.99	July 21	6.54

Source: Handy & Harman daily quotation.

TABLE 11

U.S. EXPORTS OF SILVER, BY COUNTRY

(Thousand troy ounces and thousand dollars)

Year and country	Ores and concentrates		Wastes and scrap		Doré and precipitates		Refined bullion		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1984	1,048	8,335	12,059	102,452	1,001	9,178	10,340	86,339	24,447	206,306
1985	270	1,651	10,325	67,884	1,550	9,551	12,611	81,746	24,756	160,832
1986	284	1,630	12,913	72,729	1,805	11,436	10,109	56,785	25,114	142,581
1987	15	150	13,675	96,738	2,163	16,294	11,240	79,123	27,093	192,305
1988:										
Belgium	3	24	1,593	10,380	8	60	131	843	1,734	11,307
Brazil	—	—	5	30	47	265	1,103	7,175	1,155	7,470
Canada	492	630	1,073	6,988	150	871	1,073	6,897	2,788	15,386
France	—	—	7,011	46,198	87	520	157	1,222	7,255	47,941
Germany, Federal Republic of	—	—	264	1,638	116	781	480	3,123	860	5,542
Hong Kong	—	—	—	—	—	—	20	129	20	129
Japan	—	—	1,257	8,320	436	2,578	6,030	39,269	7,722	50,167
Korea, Republic of	—	—	3	19	6	41	166	1,049	175	1,109
Luxembourg	—	—	—	—	—	—	14	78	14	78
Mexico	—	—	19	103	—	—	10	68	29	172
Sweden	—	—	1,002	6,230	1	3	—	—	1,002	6,234
Switzerland	—	—	5	29	106	627	70	464	180	1,120
Taiwan	—	—	23	129	415	2,752	84	548	523	3,429
United Kingdom	322	758	3,027	19,703	338	2,216	4,894	32,906	8,582	55,583
Venezuela	—	—	—	—	—	—	16	121	16	121
Other	1	4	5	30	19	129	21	136	45	297
Total[1]	**818**	**1,416**	**15,287**	**99,797**	**1,728**	**10,844**	**14,269**	**94,029**	**32,102**	**206,086**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF SILVER, BY COUNTRY

(Thousand troy ounces and thousand dollars)

Year and country	Ores and concentrates[1]		Wastes and scrap		Doré and precipitates		Refined bullion		Total[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1984	13,018	105,587	903	7,871	7,499	64,901	93,546	784,838	114,966	963,198
1985	3,533	20,180	1,771	10,854	9,900	65,364	137,398	855,550	152,601	951,947
1986	5,516	30,926	1,867	10,372	12,141	68,590	125,365	688,296	144,890	798,183
1987	2,681	18,019	3,404	22,514	7,781	53,858	67,959	460,235	81,826	554,627
1988:										
Australia	—	—	—	—	129	833	253	1,581	382	2,415
Canada	288	1,828	1,253	8,915	2,454	16,448	31,361	212,115	35,357	239,306
Chile	405	2,087	12	77	3,491	23,004	211	1,343	4,119	26,511
Dominican Republic	—	—	2	10	1,051	6,582	78	489	1,131	7,080
Ecuador	—	—	30	143	49	300	317	1,992	396	2,434
Germany, Federal Republic of	—	—	—	—	20	174	25	193	45	367
Japan	432	2,629	2	23	2	24	—	—	436	2,676
Malaysia	—	—	21	109	—	—	630	4,093	651	4,202
Mexico	1,511	10,482	40	273	552	4,315	37,470	239,068	39,574	254,139
Panama	—	—	207	1,333	4	27	11	66	222	1,426
Peru	196	1,050	319	1,779	27	165	1,391	9,079	1,933	12,073
South Africa, Republic of	225	1,364	—	—	—	—	—	—	225	1,364
U.S.S.R	—	—	—	—	56	686	—	—	56	686
United Kingdom	3,063	15,772	—	—	15	106	21	151	3,100	16,031
Venezuela	—	—	—	—	—	—	40	236	40	238
Yugoslavia	—	—	—	—	—	—	754	4,978	754	4,978
Other	31	296	56	332	29	177	98	797	215	1,599
Total[2]	**6,151**	**35,508**	**1,944**	**12,995**	**7,881**	**52,840**	**72,662**	**476,181**	**88,638**	**577,524**

[1] Includes silver content of base metal ores, concentrates, and matte imported for refining.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 13

WORLD ANNUAL SILVER PRODUCTION CAPACITY, DECEMBER 31, 1988

(Million troy ounces)

	Rated capacity[1]
North America:	
Canada	44
Mexico	80
United States	60
Other	6
Total	**190**
South America:	
Chile	17
Peru	66
Other	11
Total	**94**
Europe:	
Poland	27
Spain	10
U.S.S.R.	50
Other	33
Total	**120**
Africa	21
Asia:	
Japan	12
Other	18
Total	**30**
Oceania:	
Australia	38
Other	2
Total	**40**
World total	**495**

[1] Includes capacity at operating plants as well as at plants on standby basis.

TABLE 14

SILVER: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Thousand troy ounces)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Algeria[e]	120	120	120	120	120
Argentina	1,984	2,170	2,134	1,917	[3]2,832
Australia	31,260	34,914	32,882	35,986	35,848
Bolivia	4,560	3,580	3,058	4,565	[3]7,459
Brazil[e 4]	[3]829	1,013	1,490	1,610	1,900
Bulgaria[e]	930	930	910	910	910
Burma	455	568	527	839	[3]311
Canada	42,655	38,484	34,979	44,207	[3]44,094
Chile	15,766	16,633	16,078	16,068	[e]16,700
China[e]	2,500	2,500	3,000	3,000	3,500
Colombia[5]	130	153	187	160	[3]211
Costa Rica[e]	2	2	2	2	2
Czechoslovakia	1,029	[e]1,000	[e]1,000	[r e]1,100	1,100
Dominican Republic	[r]1,222	[r]1,610	1,318	1,148	[3]1,273
Ecuador[e]	2	2	2	2	2
El Salvador	22	—	—	—	—
Fiji	15	14	17	27	[3]32
Finland	1,101	998	1,193	1,421	1,010
France	770	849	832	810	800
German Democratic Republic	1,290	1,320	1,320	[e]1,200	1,200
Germany, Federal Republic of	1,225	1,090	884	1,736	1,600
Ghana[e]	14	14	14	[r]16	18
Greece	1,832	1,630	1,726	1,668	1,700
Greenland	334	[e]300	385	418	418
Honduras	2,697	2,765	1,745	747	[3]795
India[5]	862	816	1,048	1,220	[3]1,429
Indonesia	[r]1,247	[r]1,232	1,498	1,623	[3]1,876
Ireland	279	276	262	231	[3]292
Italy[5 6]	1,554	2,301	1,813	2,668	2,600
Japan	10,403	10,915	11,294	9,035	[3]8,085
Korea, North[e]	1,600	1,600	1,600	1,600	1,600
Korea, Republic of	3,759	3,990	5,034	6,502	[3]7,051
Malaysia	470	522	452	507	335
Mexico	75,340	73,167	75,200	77,643	[3]75,841
Morocco	2,410	2,733	1,566	[e]1,410	[3]4,197
Namibia	3,255	3,404	3,472	2,411	[3]2,186
Nicaragua	[e]50	30	[e]25	29	25
Papua New Guinea	1,427	1,483	1,787	1,963	2,264
Peru	53,080	58,230	61,916	66,052	[3]49,885
Philippines	1,574	1,685	1,688	1,684	[3]1,662
Poland	23,920	26,717	26,653	[e]26,500	26,500
Portugal	22	[r]20	17	24	22
Romania[e]	810	810	800	750	725

See footnotes at end of table.

TABLE 14—Continued

SILVER: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Thousand troy ounces)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Solomon Islands	—	—	—	—	([3] [7])
South Africa, Republic of	6,997	6,700	7,145	6,691	[3]5,759
Spain	[r]9,311	[r]11,797	10,513	11,253	10,000
Sweden	7,676	7,442	7,555	6,912	6,800
Taiwan	364	366	406	315	[3]268
Tunisia	[e]85	26	50	[e]50	50
Turkey[e]	220	[3]225	220	[r]284	514
U.S.S.R.[e 5]	47,400	47,900	48,200	48,200	48,000
United States	44,592	39,433	34,524	39,790	[3]53,416
Yugoslavia[5]	4,051	5,015	5,690	[e]4,850	4,850
Zaire	1,225	1,516	[e]1,500	[e]1,400	1,400
Zambia	795	607	861	961	900
Zimbabwe	893	799	841	815	[3]706
Total	**[r]420,065**	**[r]424,416**	**419,433**	**443,050**	**443,073**

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Recoverable content of ores and concentrates produced unless otherwise specified. Table includes data available through June 27, 1989.

[2] In addition to the countries listed, Botswana produces silver and Austria and Thailand may produce silver, but information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

[4] Of total production, the following quantities, in thousand troy ounces are identified as placer silver (the balance being silver content of other ores and concentrates): 1984—250 (estimated); 1985—434 (estimated); 1986—640 (estimated); 1987—650 (estimated); and 1988—700 (estimated).

[5] Smelter and/or refinery production.

[6] Includes production from imported ores.

[7] Less than 1/2 unit.

SLAG—IRON AND STEEL

By Judith F. Owens[1]

The predominant slag issue during 1988 was whether iron and steel slags should be regulated as solid wastes. The Nation's top two iron and steel slag States, Indiana and Ohio, both passed legislation that exempted slags from regulation as solid wastes. The Environmental Protection Agency (EPA), on the other hand, proposed that blast furnace slag be considered a solid waste. This issue continued past yearend.

Combined iron and steel slag sales were essentially unchanged from those of 1987. A slight decrease in sales and use of expanded and granulated blast furnace slag was offset by a significant increase in sales of steel slag. Air-cooled blast furnace slag continued to comprise the largest portion of total blast furnace slags sold or used and remained unchanged from 1987.

The construction industry continued to be the major user of iron and steel slag products. Air-cooled blast furnace slag was primarily used for road base, concrete aggregate, fill, and asphaltic concrete aggregate. Expanded and granulated blast furnace slags were still primarily used for lightweight concrete aggregate, cement production, and soil conditioning. Steel slag was typically used as road base, fill, and asphaltic concrete aggregate. The average unit value of the combined blast furnace slags increased slightly from that of 1987, whereas the average unit value of steel slag remained essentially unchanged from the prior year's level.

DOMESTIC DATA COVERAGE

Sales, use, and transportation data for iron and steel slag are developed by the Bureau of Mines from a voluntary survey of U.S. processors. Of the 91 operations canvassed, 91 responded, representing 100% of the total sales or use data shown in table 1. Three respondents reported their operations as idle and two reported their plants as closed.

LEGISLATION AND GOVERNMENT PROGRAMS

On October 20, 1988, EPA proposed its reinterpretation of the Bevill exclusion of special mineral processing wastes under the Resource Conservation and Recovery Act (RCRA).[2] Section 3001(b)(3)(A)(ii) of RCRA excludes "solid waste from the extraction, beneficiation, and processing of ores and minerals" from regulation as hazardous waste under Subtitle C of RCRA, pending completion of certain studies by EPA. The agency proposed that iron-blast-furnace slag be retained within the Bevill exclusion and be studied in a report to the Congress and subjected to subsequent regulatory determination pursuant to section 3001 of RCRA.

Blast furnace slag was chosen for the "special waste" exclusion under the Bevill amendment because it met all of the following EPA criteria:

1. It was generated in an operation that removed or concentrated a substance having commercial value from an ore or mineral, or from a beneficiated ore or mineral, and was uniquely associated with that operation.
2. It was generated at an annual nationwide rate of more than 2 million metric tons per year or it was generated at an average rate of more than 50,000 metric tons per facility per year.

The Bureau of Mines gave a written response during the public comment period stating that blast furnace slag should not be classified as a solid waste by EPA. The Bureau's position was that the slag, which is predominately consumed by the U.S. construction industry, is a valued byproduct from the blast furnace.

Indiana stated in its revised Solid Waste Article (329 Indiana Annotated Code 2) that iron and steel slags were exempt from regulation under the solid-waste management program that went into effect September 1, 1988. The State ruled that through the "legitimate use of iron and steelmaking slags . . ., including the use as a base for road building. . ." that they were not subject to the provisions of the Solid Waste Article. It did state, however, that slags could not be used for "land reclamation" unless "approved by the commissioner as a legitimate use that does not pose a threat to health and environment." Indiana was the Nation's top consumer of iron and steel slags in 1988.

The Ohio State legislature passed House Bill 592 pertaining to the State's solid-waste regulatory program. The definition of solid waste specifically excluded ". . . slag and other substances that are not harmful or inimical to public health." The solid-waste management program went into effect June 24, 1988. Ohio was the Nation's second-highest consumer of iron and steel slags in 1988.

DOMESTIC PRODUCTION

Domestic iron and steel slag production, which is not reported to the Bureau of Mines, apparently increased owing to an increase in U.S. iron and steel production. However, sales and consumption of iron and steel slag, as reported by processors, when combined remained essentially unchanged from those of 1987. Steel slag consumption apparently reflected the increased steel slag production. Sales of slag products generally reflect demand from the construction industry. According to the U.S. Department of Commerce, total new construction in 1988 was 4% below the 1987 level.[3] Private nonresidential construction remained at the prior year's level. New highway construction increased 8% over that of 1987. Selected maintenance and repair of the Nation's existing highways increased only 4% from that of 1987.

Blast furnace slag sold or used remained essentially unchanged from that of 1987, totaling 15.9 million short tons valued at $102 million. Approximately 65% of this, in decreasing order, was consumed in Indiana, Ohio, Pennsylvania, and Michigan.

Of all the iron and steel slag products sold, 89% traveled by truck with an average marketing range of 27 miles; 4% traveled by waterway with an average range of 558 miles; and 5% traveled by rail with an average range of 160 miles. The remaining 2% was used at the plant where it was processed.

Heckett Co., a division of the Harsco Corp. and based in Butler, PA, was awarded two contracts from foreign mills in 1988.[4] The contracts called for such services as slag handling and sales, scrap recovery and pit cleaning. The mills are the Courtice Steel in Cambridge, Ontario, and Cía Siderúrgica de Guadalajara in Guadalajara, Mexico. Heckett is a major processor of slags in the United States, and is also the world's leading steel mill service contractor.

CONSUMPTION AND USES

Iron and steel slags were consumed mainly by the construction industry as substitutes for natural aggregates and other construction materials. Historically, iron and steel slags have been used in place of other materials because of their lower costs, their superior performance for many applications, or shortages of natural aggregates.

Practically all of the blast furnace slag products are eventually utilized. Of the air-cooled blast furnace slag sold or used in 1988, 57% was used as road base, 12% as concrete aggregate, 10% as fill, and 7% as asphaltic concrete aggregate. The remaining 14% was used in railroad ballast, mineral wool, concrete products, glass manufacture, sewage treatment, roofing (built-up and shingles), soil conditioning, and other miscellaneous uses. Expanded blast furnace slag was used as a lightweight concrete aggregate. Granulated blast furnace slag was mainly utilized in cement manufacture. Potential growth area for the use of blast furnace slag may occur in the area of low-level-radioactive hazardous-waste containment and soil stabilization.

Based on raw steel production, an estimated 2.0 million tons of steel slag was recycled to blast furnaces in 1988. However, the bulk of steel slag produced was used in aggregate applications. Steel slag processed and sold primarily as road base constituted 46%; as fill, 25%; and as asphaltic concrete aggregate, 11%. The remaining 18% was used for railroad ballast, ice control, soil conditioning, and miscellaneous uses. A major growth area for steel slag usage would appear to be as both the coarse and fine aggregate in asphaltic concrete.

PRICES

The average price, f.o.b. plant, for all blast furnace slag sold increased slightly from that of 1987 to $6.39 per ton. The price of air-cooled iron slag increased 7% to $4.87 per ton. Granulated and expanded slag price information was withheld to avoid disclosing company proprietary data. The unit value of steel slag remained essentially unchanged from that of 1987 at $3.16 per ton.

FOREIGN TRADE

U.S. foreign trade data for iron and

TABLE 1

IRON AND STEEL SLAGS SOLD OR USED[1] IN THE UNITED STATES

(Thousand short tons and thousand dollars)

Year	Blast furnace slag: Air-cooled		Granulated		Expanded		Total iron slag[2]		Steel slag		Total slag[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1984	15,325	66,289	(3)	(3)	1,452	19,142	16,776	85,432	5,287	17,327	22,063	102,758
1985	13,363	62,588	(3)	(3)	1,742	24,290	15,106	86,878	5,972	17,472	21,078	104,351
1986	13,501	58,899	(3)	(3)	1,879	33,851	15,380	92,750	5,689	17,883	21,068	110,633
1987[r]	14,447	65,943	(3)	(3)	1,774	33,750	16,221	99,693	5,013	15,787	21,234	115,480
1988	14,242	69,415	(3)	(3)	1,658	32,139	15,900	101,554	5,714	18,058	21,614	119,614

[r] Revised.
[1] Value based on selling price at plant.
[2] Data may not add to totals shown because of independent rounding.
[3] Included with "Expanded" to avoid disclosing company proprietary data.

steel slag cannot be determined because slag was classified in categories with other materials and cannot be separated. U.S. exports of slag were classified under the headings "Metal Bearing Ores and Metal Bearing Materials" or "Waste and Scrap Not Specifically Provided For."

Imports for 1988 were classified under the heading "Basic Slag-Fertilizer Materials." However, the imports were actually blast furnace slag. Statistics developed by the U.S. Department of Commerce, Bureau of the Census, indicated 170,508 tons of slag valued at $1,513,869 were imported into the country during 1988. The breakdown was as follows: 134,132 tons from Canada valued at $1,236,669 and 36,376 tons from Japan valued at $277,200. The Canadian imports primarily entered through Detroit, MI, and Cleveland, OH. The Japanese imports entered through Los Angeles, CA, reportedly destined for a major U.S. cement producer.

WORLD REVIEW

Estimated world production of blast furnace slag and steel slag was 80.1 million tons and 85.8 million tons, respectively. These estimates were based on iron and steel production estimates for 1988. Reported production of iron and steel slag by country was incomplete owing to late reporting, incompleteness of data, and lack of reporting by some countries. Some countries did not report slag production because slag was considered a waste product rather than as a resource.

Australia

Products based on blast furnace slag cement are covered under Australian standards as Type SA.[5] Granulated blast furnace slag is used as an extender in cement at replacement levels up to 20% to 40% in some areas of Australia. In Western Australia, slag cement has 25% of the entire cement market. In the past, the granulated slag was supplied by a local blast furnace that has since shut down. During 1988, granulated slag was shipped in from New South Wales. In northwestern Western Australia, projects that required low heat generation during curing have utilized high slag blends for large concrete pours. These slag blends contained up to 65% granulated slag. Demand has grown in the past several years for a lighter-colored masonry cement. A slag-based product called Mortar Mix has been marketed in Western Australia to meet this demand.

Canada

Forty-thousand tons of slag from Hamilton, Ontario, was used for the construction of the Scotia Plaza Office Tower in Toronto.[6] Slag was the most utilized aggregate, following sand and stone, during the construction of this $450 million, 69-story building. Slag cement, semi-lightweight slag concrete, and slag blocks were all used. Advantages from the use of slag included: reduced shrinkage cracking in the concrete, reduced design weight from the floor system, and easier handling of the lightweight concrete blocks.

Japan

Nippon Kokan K.K. added a new $125 million granulated blast furnace slag treatment facility at its Fukuyama Works.[7] The new operation will be able to grind 360,000 tons of granulated slag per year into a fine powder, which will then be sold to concrete and cement manufacturers such as Nihon Cement Co. Ltd. The facility included a 50-ton-per-hour grinding mill, a 1,320 pound-per-hour classifier, and a 5,000-ton shipping silo. This new operation brings to five the number of granulated slag treatment facilities in Japan.

Osaka Cement Co. Ltd. placed an order with Ishikawajima-Harima Heavy Industries Co. Ltd. to manufacture a vertical mill to pulverize blast furnace slag at its Osaka Works.[8] Osaka Cement placed the order for the mill to meet increased demands for granulated slag powder.

U.S.S.R.

The Karagandsk metallurgical combine generated 3.2 million tons per year of blast furnace slag.[9] Basically, the slag was granulated at a capacity of 2.1 million tons per year through the use of two hydraulic channels. The moisture content of the granulated slags was between 15% and 20%. The standard practice was to dehydrate these slags before shipping by standing them in warehouse stockpiles for 5 hours or more. The granulated slags were moved around the warehouse with clamshell cranes in order to facilitate their dehydration. When the slag was finally shipped to the consumers, the moisture content was usually around 6% to 9%.

United Kingdom

Castle Cement planned to invest in new equipment at its Coatbridge Works near Glasgow, Scotland, to increase production of ground-granulated blast furnace slag.[10] Anticipating a surge in cement demand from the Scottish construction industry, Castle planned to invest $8.9 million in a new grinding mill.[11] Castle processed 65,000 tons of granulated slag per year and marketed it under the product name GX5. The granulated slag originated from British Steel Corp.'s Ravenscraig Works.

Ground-granulated blast furnace slag was utilized during the construction of the new thermal oxide reprocessing plant at the Sellafield Nuclear Plant in Cambria, England.[12] Two 90-meter concrete storage ponds were constructed that in the future will hold spent fuel and fuel rods. The 1.5-meter-thick concrete pond walls were built in vertical sections and poured in single lifts. Since low-heat generation during curing was required, the concrete contained cement composed of 60% ground-granulated blast furnace slag.

Blast furnace slag was also utilized in the construction of a reinforced concrete lock at the Port Solent site, Paulsgrove Lake, near Portsmouth, England.[13] Almost three-fourths of the concrete's cement mix was ground-granulated blast furnace slag.

TECHNOLOGY

Results of an evaluation of 18 different bituminous test sections on a major Canadian freeway were presented at the annual conference of the U.S. Transportation Research Board.[14] The study was undertaken to determine which coarse and fine aggregates exhibited superior frictional properties under high-speed and heavy traffic conditions. The coarse aggregates tested were steel slag, blast furnace slag, and traprock. The fine aggregates consisted of screenings from limestone, blast furnace slag, traprock, and steel slag. Natural sand, asbestos and limestone filler were also included as fine aggregates. Between 1974 and 1985, the test sections were periodically monitored and laboratory tested in order to gather information on: pavement performance, surface friction characteristics, and material properties. The study concluded that the bituminous mixes that performed best under high-speed, heavy traffic contained steel slag or traprock as either the coarse and fine aggregates.

Preliminary test results on the ability of granulated blast furnace slag to contain a low-level radioactive waste within a cement-based grout were presented at Spectrum '88 in Pasco, WA.[15] The waste in question resulted from the treatment of an aqueous effluent from uranium recovery and equipment decontamination operations at the Portsmouth Gaseous Diffusion Plant in Ohio. Radionuclide technetium (^{99}Tc) is the mobile and biologically active species of concern that was contained within this waste. Cement-based grouts in the past have been successful in sequestering wastes when the species of concern were relatively insoluble in the high pH of the pore water. However, they were not as successful in containing species such as technetium and nitrates which are readily soluble in pore water. The purpose of this research was to determine specific grout formulas that would effectively contain the ^{99}Tc. Experiments were conducted on cement-based grouts that contained: Type I-II LA Portland cement, ASTM Class F flyash, and blast furnace slag. Preliminary test results confirmed that the technetium and, to a lesser degree the nitrates, were retained at a higher rate due to the addition of blast furnace slag. The authors concluded that the principal mechanism of improved retention was a direct result of the redox potential of the blast furnace slag.

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[1] Physical scientist, Branch of Ferrous Metals.

[2] Federal Register. Environmental Protection Agency. Mining Waste Exclusion; Notice of Proposed Rulemaking. V. 53, No. 203, Oct. 20, 1988, pp. 41288–41300.

[3] U.S. Department of Commerce. Construction Review. V. 34, No. 6, Nov.–Dec. 1988, pp. 4–5.

[4] American Metal Market. V. 96, No. 134, July 12, 1988, p. 3.

[5] World Cement. V. 19, No. 8, Aug. 1988, pp. 327–329.

[6] National Slag Association. Another Slag Success Story. MF 188-3, 1988, 2 pp.

[7] 33 Metal Producing. V. 26, No. 12, Dec. 1988, p. 9.

[8] World Cement. V. 19, No. 9, Sept. 1988, p. 365.

[9] Kuznetsov, A. I. Investigation of the Process of Freezing up of Granulated Slags. Metallurg (Metallurgist) (Moscow). No. 7, July 1988, p. 41.

[10] World Cement. V. 19, No. 10, Oct. 1988, p. 413.

[11] Value has been converted from pounds sterling (£) to U.S. dollars at the rate of £1.00=US$1.78, the average rate during 1988.

[12] Construction News. Sellafield Civils Nears Completion, 1988.

[13] Concrete. Sept. 1988, pp. 38–39.

[14] Tam, K. K., R. Raciborski, and D. F. Lynch. 11 Years Performance of 18 Bituminous Test Sections on a Major Urban Freeway. Transportation Research Board preprint 88-0379, 1988, 32 pp.

[15] Gilliam, T. M. Performance Testing of Blast Furnace Slag for Immobilization of Technetium in Grout. Pres. at Spectrum '88, Pasco, WA, Sept. 1988, 3 pp.; available from Martin Marietta Energy Systems, Oak Ridge, TN (Dep. Energy contract DE-AC05-840R21400).

TABLE 2

BLAST FURNACE SLAGS SOLD OR USED[1] IN THE UNITED STATES, BY REGION AND STATE

(Thousand short tons and thousand dollars)

Region and State	1987[r]				1988			
	Air-cooled, screened and unscreened		Total, all types		Air-cooled, screened and unscreened		Total, all types	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
North Central:								
Illinois, Indiana, Michigan	5,322	17,246	W	W	W	W	W	W
Ohio	2,291	15,717	W	W	2,324	W	W	W
Total	**7,613**	**32,963**	**8,282**	**37,674**	**W**	**W**	**8,466**	**42,507**
Middle Atlantic:								
Maryland, New York, West Virginia	W	W	W	W	1,319	7,107	W	W
Pennsylvania	2,724	13,604	W	W	2,220	13,000	W	W
Total	**W**	**W**	**5,174**	**50,028**	**3,539**	**20,107**	**W**	**W**
West:								
Colorado, Texas, Utah	W	W	W	W	W	W	W	W
South:								
Alabama and Kentucky	W	W	W	W	W	W	W	W
Pacific:								
California	843	2,978	843	2,978	591	2,303	591	2,303
Grand total[2]	**14,447**	**65,943**	**16,221**	**99,693**	**14,242**	**69,415**	**15,900**	**101,554**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total" and "Grand total."
[1] Value based on selling price at plant.
[2] Data may not add to totals shown because of independent rounding.

TABLE 3

LOCATIONS AND PROCESSING METHODS OF IRON SLAG AND SOURCES OF STEEL SLAG[1] IN 1988

State, city and company	Processing method of iron slag: Aircooled	Processing method of iron slag: Expanded	Processing method of iron slag: Granulated	Steel slag	Sources of steel slag: Open hearth	Sources of steel slag: Basic oxygen process	Sources of steel slag: Electric
Alabama:							
Alabama City:							
Vulcan Materials Co.	1	—	—	1	—	1	—
Fairfield:							
Vulcan Materials Co.	2	—	—	2	—	2	—
Total	**3**	**—**	**—**	**3**	**—**	**3**	**—**
Arkansas:							
Fort Smith:							
International Mill Service Co.	—	—	—	1	—	—	1
California:							
Emeryville:							
Heckett Co.	—	—	—	1	—	—	1
Fontana:							
Heckett Co.	1	—	—	—	—	—	—
Total	**1**	**—**	**—**	**2**	**—**	**—**	**2**
Colorado:							
Pueblo:							
Fountain Sand and Gravel Co.	2	—	—	—	—	—	—
International Mill Service Co.	—	—	—	1	—	1	—
Total	**2**	**—**	**—**	**1**	**—**	**1**	**—**
Florida:							
Tampa:							
International Mill Service Co.	—	—	—	1	—	—	1
Georgia:							
Atlanta:							
International Mill Service Co.	—	—	—	1	—	—	1
Cartersville:							
International Mill Service Co.	—	—	—	1	—	—	1
Total	**—**	**—**	**—**	**3**	**—**	**—**	**3**
Illinois:							
Alton:							
International Mill Service Co.	—	—	—	1	—	—	1
Chicago:							
Heckett Co.	1	1	—	—	—	—	—
Granite City:							
International Mill Service Co.	—	—	—	1	—	1	—
St. Louis Slag Products Co. Inc.	1	—	—	—	—	—	—
Sterling:							
Heckett Co.	—	—	—	1	—	—	1
Total	**2**	**1**	**—**	**3**	**—**	**1**	**2**
Indiana:							
Burns Harbor:							
The Levy Co. Inc.	2	1	—	1	—	1	—

See footnote at end of table.

TABLE 3—Continued

LOCATIONS AND PROCESSING METHODS OF IRON SLAG AND SOURCES OF STEEL SLAG[1] IN 1988

State, city and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Aircooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
East Chicago:							
The Levy Co. Inc.	1	—	—	—	—	—	—
Gary:							
International Mill Service Co.	—	—	—	2	—	2	—
Indiana Harbor:							
Heckett Co.	—	—	—	1	—	1	—
Total	**3**	**1**	**1**	**4**	**—**	**4**	**—**
Kentucky:							
Ashland:							
Heckett Co.	1	—	—	1	—	1	—
Coalton:							
Heckett Co.	—	—	—	1	—	—	1
Owensboro:							
Heckett Co.	—	—	—	1	—	—	1
Total	**1**	**—**	**—**	**3**	**—**	**1**	**2**
Louisiana:							
Laplace:							
International Mill Service Co.	—	—	—	1	—	—	1
Maryland:							
Baltimore:							
International Mill Service Co.	—	—	—	1	—	—	1
Maryland Slag Co.	1	—	—	—	—	—	—
Sparrows Point:							
Blue Circle Atlantic	—	—	1	—	—	—	—
C. J. Langenfelder & Sons Inc.	—	—	—	1	1	—	—
Total	**1**	**—**	**1**	**3**	**1**	**—**	**2**
Michigan:							
Detroit:							
Edward C. Levy Co.	2	1	—	3	—	2	1
Monroe:							
International Mill Service Co.	—	—	—	1	—	—	1
Total	**2**	**1**	**—**	**4**	**—**	**2**	**2**
Minnesota:							
Newport:							
International Mill Service Co.	—	—	—	1	—	—	1
Mississippi:							
Jackson:							
Heckett Co.	—	—	—	1	—	—	1
Missouri:							
Kansas City:							
International Mill Service Co.	—	—	—	1	—	—	1

See footnote at end of table.

TABLE 3—Continued

LOCATIONS AND PROCESSING METHODS OF IRON SLAG AND SOURCES OF STEEL SLAG[1] IN 1988

State, city and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Aircooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
New Jersey:							
Perth Amboy:							
International Mill Service Co.	—	—	—	1	—	—	1
Riverton:							
International Mill Service Co.	—	—	—	1	—	—	1
Total	**—**	**—**	**—**	**5**	**—**	**—**	**5**
New York:							
Buffalo:							
Buffalo Crushed Stone Inc.	1	—	—	—	—	—	—
North Carolina:							
Charlotte:							
Heckett Co.	—	—	—	1	—	—	1
Ohio:							
Canton:							
Heckett Co.	—	—	—	1	—	—	1
Cleveland:							
Standard Slag Co.	1	—	—	—	—	—	—
Do.	1	—	—	—	—	—	—
Stein Inc.	—	—	—	2	—	1	1
Lorain:							
Fritz Enterprises Inc.	1	—	—	—	—	—	—
Stein Inc.	—	—	—	1	—	1	—
Lordstown:							
Standard Slag Co.	—	—	1	—	—	—	—
Mansfield:							
Heckett Co.	—	—	—	1	—	—	1
Marion:							
International Mill Service Co.	—	—	—	1	—	—	1
Middletown:							
American Aggregates Corp.	1	—	—	—	—	—	—
International Mill Service Co.	—	—	—	1	—	1	—
Mingo Junction:							
International Mill Service Co.	—	—	—	1	—	1	—
Standard Slag Co.	1	—	—	—	—	—	—
New Miami:							
American Aggregates Corp.	1	—	—	—	—	—	—
Warren:							
Heckett Co.	—	—	—	2	—	1	1
Standard Slag Co.	1	—	—	—	—	—	—
Total	**8**	**—**	**1**	**11**	**—**	**5**	**6**
Oklahoma:							
Sand Springs:							
International Mill Service Co.	—	—	—	1	—	—	1

See footnote at end of table.

TABLE 3—Continued

LOCATIONS AND PROCESSING METHODS OF IRON SLAG AND SOURCES OF STEEL SLAG[1] IN 1988

State, city and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Aircooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
Pennsylvania:							
Bala-Cynwyd:							
Warner Co.	1	1	—	—	—	—	—
Beaver Falls:							
International Mill Service Co.	—	—	—	1	—	—	1
Bethlehem:							
Waylite Corp.	1	1	—	2	—	1	1
Burgettstown:							
Duquesne Slag Products Co.	—	—	1	1	—	1	—
International Mill Service Co.	—	—	—	1	—	—	1
Butler:							
Heckett Co.	—	—	—	1	—	—	1
Coatesville:							
International Mill Service Co.	—	—	—	1	—	—	1
Fairless Hills:							
Heckett Co.	—	—	—	1	1	—	—
Johnstown:							
Heckett Co.	—	—	—	1	—	—	1
Lebanon:							
Sheridan Corp.	1	—	—	—	—	—	—
Midland:							
International Mill Service Co.	—	—	—	1	—	—	1
Monessen:							
Duquesne Slag Products Co.	—	—	—	1	—	1	—
Natrona Heights:							
Heckett Co.	—	—	—	1	—	—	1
Patton:							
International Mill Service Co.	—	—	—	1	—	1	—
Penn Hills:							
Gascola Slag Co.	—	—	—	1	1	—	—
Riddlesburg:							
New Enterprise Stone & Lime Co. Inc.	1	—	—	—	—	—	—
Steelton:							
Hempt Bros. Inc.	—	—	—	1	—	—	—
West Aliquippa:							
Duquesne Slag Products Co.	1	—	—	1	1	1	1
West Mifflin:							
Duquesne Slag Products Co.	2	—	—	1	—	1	—
Wheatland:							
Dunbar Slag Co. Inc.	1	—	—	1	1	1	—
Total	**8**	**2**	**1**	**21**	**4**	**7**	**10**

See footnote at end of table.

TABLE 3—Continued

LOCATIONS AND PROCESSING METHODS OF IRON SLAG AND SOURCES OF STEEL SLAG[1] IN 1988

State, city and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Aircooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
South Carolina:							
Georgetown:							
Heckett Co.	—	—	—	1	—	—	1
Tennessee:							
Jackson:							
International Mill Service Co.	—	—	—	1	—	—	1
Texas:							
Beaumont:							
International Mill Service Co.	—	—	—	1	—	—	1
El Paso:							
International Mill Service Co.	—	—	—	1	—	—	1
Jewett:							
International Mill Service Co.	—	—	—	1	—	—	1
Longview:							
International Mill Service Co.	—	—	—	1	—	—	1
Midlothian:							
International Mill Service Co.	—	—	—	1	—	—	1
Total	**—**	**—**	**—**	**7**	**—**	**—**	**7**
Utah:							
Plymouth:							
International Mill Service Co.	—	—	—	1	—	—	1
Provo:							
Heckett Co.	1	—	—	1	1	—	—
Total	**1**	**—**	**—**	**2**	**1**	**—**	**1**
Washington:							
Kent:							
Heckett Co.	—	—	—	1	—	—	1
Seattle:							
Heckett Co.	—	—	—	1	—	—	1
Total	**—**	**—**	**—**	**2**	**—**	**—**	**2**
West Virginia:							
Weirton:							
International Mill Service Co.	—	—	—	1	—	1	—
Standard Slag Co.	1	—	—	—	—	—	—
Total	**1**	**—**	**—**	**1**	**—**	**1**	**—**
Grand total	**33**	**5**	**3**	**75**	**6**	**25**	**44**

[1] Number indicates the existence of an active and/or idle plant shown by processing method or furnace source; previous years showed the number of active processing lines for some plants.

TABLE 4

SHIPMENTS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 1988, BY METHOD OF TRANSPORTATION

Method of transportation	Quantity (thousand short tons)
Truck	19,204
Waterway	801
Rail	1,119
Not transported (used at plant site)	490
Total	**21,614**

TABLE 5

AIR-COOLED BLAST FURNACE SLAG SOLD OR USED[1] IN THE UNITED STATES, BY USE

(Thousand short tons and thousand dollars)

Use	1987[r]		1988	
	Quantity	Value	Quantity	Value
Asphaltic concrete aggregate	1,223	6,872	1,042	6,511
Concrete aggregate	1,717	8,759	1,752	9,325
Concrete products	323	1,951	383	2,505
Fill	1,449	4,518	1,410	4,643
Glass manufacture	W	W	115	W
Mineral wool	644	3,605	542	3,830
Railroad ballast	698	3,137	W	W
Road base	7,715	32,045	8,095	36,858
Roofing, built-up and shingles	87	839	70	689
Sewage treatment	W	W	W	W
Soil conditioning	W	W	W	W
Other[2]	590	4,215	834	5,052
Total[3]	**14,447**	**65,943**	**14,242**	**69,415**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Value based on selling price at plant.
[2] Includes snow and ice control, miscellaneous uses, and data indicated by symbol W.
[3] Data may not add to totals shown because of independent rounding.

TABLE 6

GRANULATED AND EXPANDED BLAST FURNACE SLAGS SOLD OR USED[1] IN THE UNITED STATES, BY USE

(Thousand short tons and thousand dollars)

Uses	1987[r]				1988			
	Granulated		Expanded		Granulated		Expanded	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Cement manufacture	(2)	(2)	—	—	(2)	(2)	—	—
Fill	(2)	(2)	—	—	—	—	—	—
Lightweight concrete aggregate	—	—	W	W	—	—	W	W
Road base	(2)	(2)	—	—	(2)	(2)	—	—
Soil conditioning	(2)	(2)	—	—	(2)	(2)	—	—
Other[3]	(2)	(2)	1,774	33,750	(2)	(2)	1,658	32,139
Total	**(2)**	**(2)**	**1,774**	**33,750**	**(2)**	**(2)**	**1,658**	**32,139**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Value based on selling price at plant.
[2] Included with "Expanded" to avoid disclosing company proprietary data.
[3] Includes miscellaneous uses and data indicated by symbol W.

TABLE 7

STEEL SLAG SOLD OR USED[1] IN THE UNITED STATES, BY USE

(Thousand short tons and thousand dollars)

	1987[r]		1988	
	Quantity	Value	Quantity	Value
Asphaltic concrete aggregate	721	3,347	654	2,976
Fill	1,093	2,964	1,451	4,039
Railroad ballast	164	513	W	W
Road base	2,328	7,057	2,630	7,647
Other[2]	872	2,419	980	3,398
Total[3]	**5,013**	**15,787**	**5,714**	**18,058**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Includes some tonnages returned to furnace for charge material. Value based on selling price at plant.
[2] Includes snow and ice control, miscellaneous uses, and data indicated by symbol W.
[3] Data may not add to totals shown because of independent rounding.

TABLE 8

AVERAGE VALUE AT THE PLANT FOR IRON AND STEEL SLAGS SOLD OR USED IN THE UNITED STATES

(Dollars per short ton)

Year	Blast furnace slag: Air-cooled	Blast furnace slag: Granulated	Blast furnace slag: Expanded	Blast furnace slag: Total iron slag	Steel slag	Total slag
1983	4.12	W	9.67	4.78	3.01	4.31
1984	4.33	W	11.49	5.09	3.28	4.66
1985	4.68	W	11.00	5.75	2.93	4.95
1986	4.36	W	12.57	6.03	3.14	5.25
1987[r]	4.56	W	W	6.15	3.15	5.42
1988	4.87	W	W	6.39	3.16	5.48

[r] Revised. W Withheld to avoid disclosing company proprietary data.

TABLE 9

AVERAGE SELLING PRICE AND RANGE OF SELLING PRICES AT THE PLANT FOR IRON AND STEEL SLAGS IN THE UNITED STATES IN 1988, BY USE

(Dollars per short ton)

Use	Blast furnace slag: Air-cooled: Average	Air-cooled: Range	Granulated: Average	Granulated: Range	Expanded: Average	Expanded: Range	Steel slag: Average	Steel slag: Range
Asphaltic concrete aggregate	6.25	2.44–10.29	—	—	—	—	4.55	3.73–5.64
Cement manufacture	W	W	W	W	—	—	—	—
Concrete aggregate	5.32	3.33–10.29	—	—	—	—	—	—
Concrete products	6.54	5.09–10.29	—	—	—	—	—	—
Fill	3.29	1.67– 6.78	—	—	—	—	2.78	1.30–5.50
Glass manufacture	W	W	—	—	—	—	—	—
Lightweight concrete aggregate	—	—	—	—	W	W	—	—
Mineral wool	7.07	4.63–10.25	—	—	—	—	—	—
Railroad ballast	5.27	4.63– 7.00	—	—	—	—	2.44	1.00–4.65
Road base	4.55	1.92–10.29	W	W	—	—	2.91	1.00–6.24
Roofing, built-up and shingles	9.87	5.09–12.56	—	—	—	—	—	—
Sewage treatment	W	W	—	—	—	—	—	—
Soil conditioning	W	W	W	W	—	—	—	—
Other	4.66	3.82– 6.86	—	—	W	W	3.62	2.00–8.50

W Withheld to avoid disclosing company proprietary data; withheld data for air-cooled blast-furnace and steel slags included with "Other."

SODA ASH AND SODIUM SULFATE

By Dennis S. Kostick[1]

Domestic soda ash production and consumption increased about 8% following several years of low growth. Export sales were also strong, primarily to Asia and South America. These increases were attributed to a rise in domestic and foreign demand for consumer products that use soda ash, and a cyclic opportunity to sell soda ash to certain crossover markets that traditionally use caustic soda, such as pulp and paper, chemicals, and alumina refining.

Production of natural and synthetic sodium sulfate continued to decline, although consumption began to increase in the fourth quarter of the year because of improvements in the economic conditions of major consumers, such as the pulp and paper and detergent industries.

DOMESTIC DATA COVERAGE

Domestic production data for soda ash and natural sodium sulfate are developed by the Bureau of Mines from monthly, quarterly, and annual voluntary surveys of U.S. operations. Of the seven soda ash operations and four natural sodium sulfate operations to which a survey request was sent, all responded, representing 100% of the total production data shown in table 1.

DOMESTIC PRODUCTION

Soda Ash

The U.S. soda ash industry produced 9.6 million short tons of soda ash, of which about 81,000 tons was in the form of soda liquors and mine water converted to soda ash equivalent. Although these sodium carbonate-bearing liquors historically were discharged as process waste solutions, sales of these and other soda liquors have increased because of growing demand for them by powerplants for neutralizing process water. The liquors provide a growing market for soda ash producers and additional revenue.

The soda ash produced in the refinery and the additional soda ash equivalent within the liquors do not seriously influence capacity utilization calculations because a nominal amount of purge liquors are incorporated into the design capacity of each plant. With this understanding, the Wyoming and California soda ash industry operated at a combined 92% of total nameplate capacity in 1988, up 8% compared with that of 1987.

The nameplate capacity of the soda ash industry was reduced by 150,000 tons in January with the closure of the soda ash portion of Kerr-McGee Chemical Corp.'s Westend facility in California. Tenneco Minerals Co. added some additional capacity through improvements in production efficiency. FMC Corp. expanded its value-added soda product line by acquiring Riverside Products Corp.'s sodium bicarbonate plant in Cartersville, GA, which has an annual capacity of 30,000 tons. FMC also announced it will construct a 60,000-ton-per-year sodium bicarbonate plant at its Green River, WY, soda ash facility by mid-1990.

Some Wyoming soda ash producers strived to reduce mining costs by implementing continuous belt and mobile track conveyor systems to transport trona underground more effectively. This new haulage system will replace ore-carrying shuttle cars, reduce the mine workforce, and increase the quantity of ore mined per shift. Companies were also considering eliminating conventional mining but retaining other mining methods sometime in the foreseeable future in order to further reduce labor, safety, and other operating costs so that producers can maintain a competitive price for soda ash, espe-

TABLE 1

SALIENT SODA ASH AND SODIUM SULFATE STATISTICS

(Thousand short tons and thousand dollars)

	Soda ash		Sodium sulfate[1]	
	1987	1988	1987	1988
United States:				
Production	[2]8,891	[2]9,632	[r]813	788
Value	$593,685	$644,973	[r] [3]$70,503	[3]$62,119
Exports	[4]2,224	[4]2,467	122	85
Value	[4]$253,200	[4]$286,945	$10,554	$8,737
Imports for consumption	150	133	138	150
Value	$18,334	$15,999	$10,363	$11,943
Stocks, Dec. 31: Producers'[5]	259	256	55	59
Consumption:				
Apparent	6,853	7,301	838	849
Reported	6,724	7,159	NA	NA
World: Production	[p]33,330	[e]34,258	[p]5,101	[e]5,080

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Includes natural and synthetic. Total production data for sodium sulfate obtained from the Bureau of the Census.
[2]Includes soda liquors and mine water converted to soda ash equivalent; 69,963 tons in 1987, and 80,871 tons in 1988.
[3]The value for synthetic sodium sulfate is based upon the average value for natural sodium sulfate.
[4]Export data were adjusted by the Bureau of Mines to reconcile data discrepancies among the Bureau of the Census, the American Natural Soda Ash Corp. and Statistics Canada.
[5]Natural only.

cially in certain export markets.

Sodium Sulfate

The natural sodium sulfate industry operated at 91% of total nameplate capacity, which excludes Ozark-Mahoning Co.'s idle Brownfield, TX, facility. This operating rate was a significant improvement compared with that of previous years.

About 85,000 tons of synthetic sodium sulfate capacity was almost lost when Avtex Fibers Inc. announced plans to close its Front Royal, VA, rayon fiber mill due to economic and environmental problems. Because the plant manufactured special carbonized rayon fabric for the U.S. Department of Defense and for the National Aeronautics and Space Administration, the Federal Government and private contractors agreed to provide the necessary financial assistance to avert the closure. However, certain soap and detergent manufacturers that purchased Avtex's sodium sulfate were alarmed at the potential disruption in supply and began importing sodium sulfate from Mexico.

Courtaulds North America increased its byproduct saltcake recovery by 40% by installing a new double-effect evaporator, which also produced a more pure product than before. The high-grade material was suitable for detergent and textile use.

CONSUMPTION AND USES

Apparent consumption of soda ash in the United States increased 7% because of greater demand for soda ash for use in flat glass, chemicals, pulp and paper, and alumina refining. Some detergent manufacturers began reformulating their products to remove sodium tripolyphosphate as a builder and substitute tetrasodium pyrophosphate because of environmental concerns in many States. This action resulted in additional soda ash and sodium sulfate consumption.

The total chloralkali industry operating capacity has been reduced by 15% since 1982 in order to maximize efficiency and productivity within the industry and to boost capacity utilization rates, which averaged 98% in 1988. Despite rising chlorine production, chlorine demand declined after midyear because of ethylene shortages for vinyl chloride monomer manufacture, efforts to reduce dioxins made from pulp bleaching with chlorine, and efforts to replace chlorine-base chlorofluorocarbon chemicals that contribute to upper atmosphere ozone depletion. These events started a chain reaction that affected the domestic supply and demand for coproduct caustic soda. The resultant shortage caused the price to increase rapidly, thereby forcing certain customers to convert to substitutive soda ash because of its greater availability and affordable prices. Although 1.3 tons of soda ash must be used to have the same

TABLE 2

PRODUCERS OF SODA ASH AND NATURAL SODIUM SULFATE IN 1988

Product and company	Plant nameplate capacity (thousand short tons)	Plant location	Source of sodium
Soda ash natural:			
FMC Wyoming Corp.	2,850	Green River, WY	Underground trona.
General Chemical (Soda Ash) Partners[1]	2,200	do.	Do.
Kerr-McGee Chemical Corp., Argus plant	1,300	Trona, CA	Dry lake brine.
Stauffer Chemical Co. of Wyoming[2]	1,960	Green River, WY	Underground trona.
Tenneco Minerals Co.	1,075	do.	Do.
T. G. Soda Ash Inc.[3]	1,100	Granger, WY	Do.
Total	**10,485**		
Sodium sulfate, natural:			
Great Salt Lake Minerals & Chemicals Corp.	50	Ogden, UT	Salt lake brine.
Kerr-McGee Chemical Corp., Westend plant	240	Trona, CA	Dry lake brine.
Ozark-Mahoning Co.[4]	150	Seagraves, TX	Do.
Total	**440**		

[1] A joint venture between General Chemical Corp. and Australian Consolidated Industries International, which owns 49% of the soda ash operation.
[2] Owned by Stauffer Chemical Co. of Rhône-Poulenc S.A.
[3] Owned by Texasgulf Inc. of Société Nationale Elf Aquitaine. Acquired permits to operate at 1.3 million tons of capacity.
[4] Ozark's Brownfield plant was placed on standby in Sept. 1987; not included in industry capacity.

Note.—Tables 10 and 11 contain additional industry capacity information.

TABLE 3

SYNTHETIC AND NATURAL SODIUM SULFATE[1] PRODUCED IN THE UNITED STATES

(Thousand short tons and thousand dollars)

Year	Synthetic and natural[2] (quantity)			Natural	
	Lower purity[3] (99% or Less)	High purity	Total[4]	Quantity	Value
1984	426	475	901	435	40,125
1985	375	436	811	389	35,860
1986	r362	r479	r841	396	34,102
1987	r344	r470	r813	382	33,086
1988	342	446	788	398	31,377

r Revised.
1 All quantities converted to 100% Na_2SO_4 basis.
2 Current Industrial Reports, Inorganic Chemicals, Bureau of the Census. Revisions for 1986 and 1987 from 1987 Annual, MA28A(87)-1, Nov. 1988, p. 16.
3 Includes Glauber's salt.
4 Data may not add to totals shown because of independent rounding.

TABLE 4

REPORTED CONSUMPTION OF SODA ASH IN THE UNITED STATES, BY END USE

(Short tons)

SIC	End use	1987	1988
32	Glass:		
3221	Container	2,322,195	2,345,991
3211	Flat	904,970	939,006
3296	Fiber	274,870	271,469
3229	Other	182,755	180,294
	Total	**3,684,790**	**3,736,760**
281	Chemicals	1,364,206	1,593,070
284	Soaps and detergents	754,392	791,342
26	Pulp and paper	69,447	122,352
2899	Water treatment[1]	78,890	121,105
	Flue gas desulfurization	201,611	220,054
	Distributors	384,752	411,646
	Other	186,397	162,542
	Imports[2]	150,105	132,950
	Total domestic consumption	**6,724,485**	**7,158,871**
	Exports[3]	2,341,571	2,662,472
	Total industry sales	**8,915,951**	**9,821,343**
	Total production	**8,890,746**	**9,632,031**

1 Includes 69,963 tons in 1987 and 80,871 tons in 1988 of soda ash equivalent from soda liquors, purge liquors, and mine water, sold to powerplants for water treatment.
2 Data are from the Bureau of the Census. Actual imports of light and dense soda ash, as reported by the producer-importer, are proprietary data but have been distributed into appropriate end-use categories and included in "Total domestic consumption."
3 As reported by U.S. producers. Includes 198,631 tons exported to Canada in 1988. Export totals may differ from totals reported by other sources of trade data because of varying plant-to-port transit times and the quantity of carryover inventories.

chemical effect as 1.0 ton of caustic soda, several customers began switching to bulk, dry soda ash in the third quarter of 1988. The substitution for soda ash was particularly strong in the pulp and paper, chemical, and alumina refining industries.

The total effect of the caustic soda crossover was between 150,000 tons to 200,000 tons of additional soda ash consumed. The trend was strong and total substitution could reach 300,000 tons in 1989, depending on the demand for chlorine-base products.

The shortage of ethylene that decreased chlorine demand also reduced polyethylene terephthalate (PET) resin production. This decrease in PET supply caused the price of PET containers to rise, allowing glass containers to compete in certain container markets. Increasing public awareness of the long-term environmental effects of plastics disposal led to discussions of plastics recycling that also affected sales of PET products. Some increases in long-necked glass container manufacture stimulated additional soda ash and sodium sulfate consumption. Although glass container statistics showed a decrease in total shipments, raw material usage increased for cullet manufacture by the glass container industry because the price of purchased cullet was expensive in certain States.

The flat glass and fiber glass sector, in which soda ash and sodium sulfate were used, also experienced some growth.

In 1987, the Bureau of Mines and the U.S. soda ash industry developed a comprehensive end-use survey to report soda ash consumption on a quarterly basis. These reported sales by U.S. producers replace estimated consumption data based on previous consumption patterns and best estimates provided by industry analysts. The survey data are categorized by major industrial sectors of soda ash consumption, however, some overlap among categories may exist. For example, some customers may use soda ash for multiple purposes that may or may not be indicated in the data despite efforts to identify downstream applications. Soda ash sold to distributors has been included in the appropriate primary end use when possible.

Differences between reported consumption and apparent consumption, and the export data reported by Bureau of the Census and the industry are attributed to dissimilar reporting periods, inventory fluctuations, and delays in product transit to port.

STOCKS

Soda Ash

Yearend inventories of dense soda ash in plant silos, warehouses, terminals, and on teamtracks amounted to 256,000 tons. Producers report that when total inventories fall below about 200,000 tons, a potential supply problem could exist.

Sodium Sulfate

Inventories of natural sodium sulfate increased slightly to 59,000 tons.

PRICES

Soda Ash

An attempted price increase of $4 per ton in mid-1987 was not fully supported by the industry. In May 1988, however, a $10 per ton increase in the list price was announced, raising the price to $93 and $123 per ton, f.o.b. Wyoming and California, respectively. This was followed in October by a $6 per ton rise in the offlist price. Despite these major price movements, the average annual value of bulk, natural soda ash, f.o.b. Green River, WY, and Searles Valley, CA, was $66.96 per ton in 1988, which was only 18 cents more than the previous year's average value. The latest value was somewhat less than expected but was attributed to certain factors. Although production and sales of soda ash were strong in the last quarter of the year, a few long-term contracts for low-priced soda ash were still in effect throughout 1988, which depressed the average annual value. Furthermore, the tight soda ash supply forced some customers to purchase low-quality, low-price material. Although the average value increased slightly, most producers improved their economic position by reducing mining and other operating costs.

TABLE 5

SODA ASH AND SODIUM SULFATE YEAREND PRICES

		1987	1988
Sodium carbonate (soda ash):			
Light, paper bags, carlots, works	per ton	$150.00	$150.00
Light, bulk, carlots, works,	do.	123.00	123.00
Dense, paper bags, carlots, works	do.	131.00	141.00
Dense, bulk, carlots, works	do.	83.00	93.00
Sodium sulfate (100% Na_2SO_4):			
Technical detergent, rayon grade, bags, carlots	do.	$ 90.00 – 96.00	$ 90.00 – 96.00
Sodium sulfate, bulk, carlots, works[1]	do.	113.00 – 114.00	113.00 – 114.00
Domestic salt cake, bulk, works[1]	do.	65.00 – 98.00	65.00 – 98.00
National Formulary (NF XII), drums	per pound	.235	.235

[1] East of Mississippi River.

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 232, No. 28, Dec. 28, 1987, p. 35; and v. 235, No. 1, Jan. 2, 1989, p. 33.

Sodium Sulfate

Prices remained stagnant for natural and synthetic sodium sulfate despite minor improvements in demand. List prices were about $55 per ton for saltcake and about $100 per ton for the synthetic material. Prices for natural sodium sulfate are generally tied to the price of synthetic sodium sulfate, which is sold at any price in order to dispose of it because it is a byproduct. The average annual value of bulk, natural product, f.o.b. mine or plant, was $78.81 per ton.

FOREIGN TRADE

Soda Ash

Some Bureau of the Census export data were adjusted to correct for erroneous information. In July, 33,069 tons was shipped to China, not Bulgaria. The United States fulfilled an export commitment to China on behalf of Bulgaria. In May, 1,193 tons was inadvertently reported as an export to the U.S.S.R. This shipment was not included in the total.

The quantity of soda ash exported to Canada was also questionable. Census data and Statistics Canada data differ and both are under-reported, according to industry sources. The six U.S. soda ash producers reported to the Bureau of Mines that 198,631 tons was exported to Canada, compared with 123,254 tons reported by the Census Bureau and 99,404 tons reported by Statistics Canada.

China remained as the largest importer of U.S. soda ash, representing 25% of total exports when Hong Kong and Taiwan are included. According to the Bureau of the Census, the major countries that imported U.S. soda ash, in decreasing order, were China, Japan, the Republic of South Africa, Venezuela, Brazil, the Republic of Korea, and Hong Kong, which in combination represented 63% of total exports.

TABLE 6

U.S. EXPORTS OF SODIUM CARBONATE AND SODIUM SULFATE

(Thousand short tons and thousand dollars)

Year	Sodium carbonate[1]		Sodium sulfate	
	Quantity	Value[2]	Quantity	Value[2]
1985	1,747	173,937	119	11,899
1986	2,049	241,238	111	10,183
1987	2,224	253,200	122	10,554
1988	2,467	286,945	85	8,737

[1] Adjusted by the Bureau of Mines to account for discrepancies in data.
[2] F.a.s. value at U.S. port.

Source: Bureau of the Census.

WORLD CAPACITY

The data in tables 10 and 11 are rated capacities for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Soda Ash

Natural soda ash mine capacity assumes two daily mine shifts and one daily maintenance shift per 5-day work week. Considerations were made for operations that mine underground trona, surface sodium salts, and sodium carbonate-bearing brines. Natural and synthetic soda ash refining capacities are based on 360 working days per year with scheduled short-term maintenance periods once or twice per year, depending on the physical characteristics of the plant.

The U.S. soda ash industry rated capacity was derived by averaging each producer's third and fourth highest months of output during the past year. These months were used because the first- and second-highest months were not realistic for sustained production rates. The range between each producer's third- and fourth-highest months were close and probably more indicative of what each plant can effectively sustain on a monthly basis, given favorable market conditions. The calculated averages were aggregated and annualized. Individual rated capacities may or not be synonymous with plant nameplate capacities.

Sodium Sulfate

Mine capacity for natural sodium sulfate is derived from available company data on ore throughput to the refinery. The ore refers to mined crystalline sodium sulfate or harvested thermal precipitate, and sodium sulfate-bearing brines. Refinery capacity for natural sodium sulfate pertains to the total amount of anhydrous sodium sulfate that the plant is capable of processing from the ore. Synthetic, or byproduct, sodium sulfate-refining capacity is dependent on the production capabilities of the primary industry and the sodium sulfate recovery rates. The footnotes in table 11 list the various primary industries associated with synthetic sodium sulfate.

WORLD REVIEW

Botswana

The Government of Botswana and African Explosives and Chemicals Industries (AECI) signed an agreement to build a soda ash and salt facility at Sua Pan in northeastern Botswana. The project will be owned and operated by Soda Ash Botswana Ltd., which is owned by AECI, 26.5%, Anglo American Corp. and DeBeers Consolidated Mines Ltd., 25.5%, and the Botswana Government, 48%. Anglo American has a 38% share in AECI. The operation is scheduled to produce 330,000 tons of soda ash and 660,000 tons of salt annually beginning in January 1991. Forty wells will provide brine to several solar evaporation ponds in which the salt will be recovered. Sodium carbonate-rich liquor will be fed to a carbonation system for conversion to soda ash.[2]

The project will employ 600 people and cost $390 million, of which AECI will provide 35%. Another 27% will come from South African credits, 18.5% from South African bank loans, 8% from West German and Japanese trade credits, 5.5% from Botswana bank loans, and the remainder yet to be financed.[3]

Botswana, which belongs to the Southern African Customs Union (SACU), has an agreement with the Republic of South Africa to protect the project by means of a 10% ad valorem tariff on imports from outside the SACU. Most of the soda ash will be consumed in the Republic of South Africa with some material exported to Zambia and Zimbabwe.

China

Development began on a natural soda deposit in the Wulan Buh desert area in Inner Mongolia. The project will produce 200,000 tons per year of soda ash. An alkali deposit with a surface area of 5 square miles reportedly was discovered in Tongbai, Henan,

TABLE 7

REGIONAL DISTRIBUTION OF U.S. SODA ASH EXPORTS, BY CUSTOMS DISTRICTS IN 1988

(Short tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total
Atlantic:										
Baltimore, MD	—	—	—	—	32	—	—	—	—	32
Charleston, SC	—	16	—	—	108	—	—	—	—	124
Miami, FL	—	51	41	208	11	—	—	—	—	311
New York, NY	—	1	116	8	117	1	—	267	1	511
Philadelphia, PA	—	1	13	—	—	—	—	—	—	14
Gulf:										
Houston, TX	—	45	3,056	20	—	11	8	—	—	3,140
Mobile, AL	—	29	—	—	—	—	—	—	109	138
New Orleans, LA	—	—	25	20	—	—	—	—	—	45
Port Arthur, TX	—	2,184	349,096	14,896	5,392	6,460	104,014	—	—	482,042
Tampa, FL	—	—	—	—	—	—	—	—	—	43
Pacific:										
Anchorage, AK	3,020	—	—	—	—	—	—	—	—	3,020
Los Angeles, CA	—	20,194	106,573	—	27,944	4	9,923	477,153	18	641,809
San Diego, CA	881	—	—	—	—	—	—	—	—	881
San Francisco, CA	—	—	—	—	—	—	—	1,043	—	1,043
Seattle, WA	7,495	—	—	—	—	—	—	11	—	7,506
Portland, OR	—	—	3,872	—	59,684	—	68,343	812,444	91,611	1,035,954
North Central:										
Detroit, MI	63,470	—	—	—	78	—	—	—	—	63,548
Great Falls, MT	36,240	—	—	—	—	—	—	—	—	36,240
Pembina, ND	12,544	—	—	—	—	—	—	—	—	12,544
Northeast:										
Buffalo, NY	118	—	—	—	—	—	—	—	—	118
Ogdensburg, NY	69	—	—	26	—	—	—	—	—	95
St. Albans, VT	298	—	—	—	6	—	—	—	—	304
Southwest:										
El Paso, TX	74	—	—	—	—	—	—	—	—	74
Laredo, TX	85,020	—	—	—	—	—	—	—	—	85,020
Puerto Rico	—	—	—	—	351	—	—	—	—	351
Total[1]	**209,229**	**22,521**	**462,792**	**15,178**	**93,723**	**6,476**	**182,288**	**1,290,918**	**91,739**	**2,374,907**
Adjusted total[2]	**[3]284,606**	**[4]22,564**	**462,792**	**15,178**	**[5]105,980**	**6,476**	**182,288**	**[6]1,295,328**	**91,739**	**2,466,951**

[1] Bureau of the Census.
[2] Adjusted by the Bureau of Mines to reconcile discrepancies in export data reported by the Bureau of the Census, Statistics Canada, Journal of Commerce Port Import/Export Reporting Service (PIERS), and U.S. soda ash producers, as noted in table 4.
[3] Includes additional 75,377 tons of soda ash exported to Canada, as reported by U.S. producers in table 4; not included in Bureau of the Census data.
[4] Adjusted to include 43 tons exported to Honduras in July through Tampa, FL, customs district.
[5] Adjusted to include 12,257 tons exported to Belgium in March and September through Los Angeles, CA, customs district.
[6] Adjusted to include 4,410 tons exported to Singapore in September and December through Portland, OR, customs district.

with proven reserves of 132 million tons, or three times the total amount previously known to exist in China. This deposit could be an extension of the one discovered several years ago.[4]

China was aggressively pursuing several major-scale activities. The two synthetic soda ash plants in Lianyungang and Shandong, each with an annual capacity of 660,000 tons, were scheduled to begin production by the end of 1989. The Hebei Tangshan soda ash plant, with the same capacity, will be operable in early 1990. A total expansion of about 600,000 tons soon was to be completed in Dalian, Hubei, Qingdao, Tianjin, and Zigong. Some improvements in production efficiency that will increase operational capacity also were planned for 20 small plants in Chengdu, Hefei, Taiyuan, and Zhengzhou. In addition, the Government authorized construction of 23 new soda ash plants in Chongqing, Fushan, Kunshan, Lianyungang, Nanbao, Shouguang, Yanan, Yibing, and Zhangjiakou, with a total of 2.4 million tons of annual capacity. Discussions were also underway regarding the proposed financing from Canadian sources of soda ash projects in Guangong and Xinjiang, with planned capacities of 198,000 tons and 88,000 tons, respectively.

India

A 440,000-ton-per-year synthetic soda ash plant was commissioned at Sutrapada in the Junagedh District. The facility was built for $100 million, and uses local salt and limestone resources for feedstock.[5]

Saudi Arabia

International Chemical Industries and Trading Co. Ltd. announced plans to build a 100,000-ton-per-year soda ash facility in Jubail. The plant will use caustic soda and natural gas as raw materials. Most of the soda ash will be used for domestic consumption.[6]

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[1] Physical scientist, Branch of Industrial Minerals.

[2] European Chemical News. AECI, Botswana Soda Ash Deal. V. 51, No. 1351, Nov. 28, 1988, p. 26.

[3] Chemical Week. Soda Ash for Southern Africa. V. 143, No. 22, Nov. 30, 1988, p. 13.

[4] European Chemical News. Saudi Soda Ash. V. 51, No. 1346, Oct. 24, 1988, p. 28.

[5] ———. In Brief. V. 50, No. 1322, May 2, 1988, p. 13.

[6] Foreign Broadcast Information Service. Large Alkali Deposit Found in Henan. FBIS-CH1-88-097, May 19, 1988, p. 57.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF SODIUM SULFATE

(Thousand short tons and thousand dollars)

Year	Crude (salt cake)[1]		Anhydrous		Total[1]	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2 3]
1985	40	2,549	155	11,943	195	14,492
1986	32	1,885	156	11,944	188	13,829
1987	37	2,189	101	8,173	138	10,363
1988	30	1,921	120	10,021	150	11,943

[1] Includes Glauber's salt as follows: 1985—none; 1986—38 tons ($9,175); 1987—666 tons ($38,318); and 1988—604 tons ($16,963).
[2] C.i.f. value at U.S. port.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF SODIUM CARBONATE

	1987		1988	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Sodium carbonate, calcined	149,603	$18,211	132,339	$15,868
Sodium carbonate, hydrated and sesquicarbonate	500	123	609	132
Total	**150,103**	**18,334**	**132,948**	**[2]15,999**

[1] C.i.f. value at U.S. port.
[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 10

WORLD SODA ASH ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons)

	Natural	Synthetic	Total
North America:			
Canada	—	450	450
Mexico	275	220	495
United States	10,200	—	10,200
Total	**10,475**	**670**	**11,145**
South America:			
Brazil	—	220	220
Colombia	—	120	120
Total	**—**	**340**	**340**
Europe, Western:			
Austria	—	220	220
Belgium	—	440	440
France	—	1,700	1,700
Germany, Federal Republic of	—	1,800	1,800
Italy	—	775	775
Netherlands	—	420	420
Portugal	—	140	140
Spain	—	810	810
Turkey	—	365	365
United Kingdom	—	1,100	1,100
Total	**—**	**7,770**	**7,770**
Europe, Eastern:			
Albania[e]	—	30	30
Bulgaria	—	1,200	1,200
Czechoslovakia	—	150	150
German Democratic Republic	—	990	990
Poland	—	1,100	1,100
Romania	—	1,015	1,015
U.S.S.R.	NA	5,570	5,570
Yugoslavia	—	225	225
Total	**—**	**10,280**	**10,280**
Africa:			
Chad	NA	—	NA
Egypt	—	45	45
Kenya	330	—	330
Sudan	NA	—	NA
Total	**330**	**45**	**375**
Asia:			
China	NA	2,855	2,855
India	—	1,200	1,200
Iran	—	66	66
Japan	—	1,540	1,540
Korea, Republic of	—	350	350

See footnotes at end of table.

TABLE 10—Continued

WORLD SODA ASH ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons)

	Natural	Synthetic	Total
Pakistan	—	145	145
Taiwan	—	160	160
Total	**—**	**6,316**	**6,316**
Oceania: Australia	—	385	385
Total	**—**	**385**	**385**
World total	**10,805**	**25,806**	**36,611**

[e] Estimated. NA Not available.
[1] From natural sources of trona and sodium carbonate-bearing brines and from the manufacture by the Solvay, ammonium chloride, and caustic carbonation processes.

TABLE 11

WORLD SODIUM SULFATE ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1988

(Thousand short tons)

	Natural	Synthetic	Total
North America:			
Canada	538	28	566
Mexico	510	5	515
United States	510	539	1,049
Total	**1,558**	**572**	**2,130**
South America:			
Argentina	18	NA	18
Brazil	—	10	10
Chile[e]	70	—	70
Total	**88**	**10**	**98**
Europe, Western:			
Austria[e]	—	130	130
Belgium[e]	—	[2]350	[2]350
Finland[e]	—	39	39
France	—	180	180
Germany, Federal Republic of	—	220	220
Greece[e]	—	8	8
Italy	—	140	140
Netherlands[e]	24	17	41
Portugal	—	65	65
Spain[e]	615	100	715
Sweden	—	138	138
Turkey	160	33	193
United Kingdom	—	60	60
Total	**799**	**1,480**	**2,279**
Europe, Eastern:			
German Democratic Republic	—	165	165
Hungary[e]	—	10	10
U.S.S.R.[e]	704	176	880
Yugoslavia	—	45	45
Total	**704**	**396**	**1,100**
Asia:			
China	55	NA	55
Iran[e]	20	—	20
Japan	—	300	300
Pakistan	—	1	1
Total	**75**	**301**	**376**
Africa:			
Egypt	50	—	50
South Africa, Republic of	5	—	5
Total	**55**	**—**	**55**
World total	**3,279**	**2,759**	**6,038**

[e] Estimated. NA Not available.

[1] Includes capacity at operating plants as well as at plants on standby basis. Production capacities of sodium sulfate are based on processing of solid minerals or sodium sulfate-bearing brines. Synthetic (byproduct) sodium sulfate capacities can fluctuate depending on the production capabilities of the primary industry (e.g., ascorbic acid, boric acid, cellulose, chromium chemicals, lithium carbonate, pharmaceuticals, rayon, resorcinol, and silica pigments) and the sulfate recovery rates.

[2] The Tessenderloo hydrochloric acid plant reportedly has 1 million tons of byproduct sodium sulfate capacity, most of which is diverted to potassium sulfate production. About 300,000 tons of sodium sulfate routinely can be recovered.

TABLE 12

SODIUM CARBONATE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country	1984	1985	1986	1987[p]	1988[e]
Albania[e]	33,100	34,200	35,300	34,000	33,100
Australia[e]	330,000	330,000	330,000	330,000	330,000
Austria[e]	165,000	165,000	165,000	165,000	160,000
Belgium	451,224	492,164	530,934	493,804	490,000
Brazil[e]	210,000	210,000	220,000	231,000	248,000
Bulgaria	1,336,292	1,142,695	1,162,070	1,179,679	1,210,000
Canada[e]	400,000	385,000	385,000	[r]360,000	360,000
China[e]	2,070,000	2,220,000	2,310,000	2,610,000	2,855,000
Colombia	142,683	124,791	124,473	128,820	138,000
Czechoslovakia	111,711	123,459	124,561	[e]121,000	121,000
Denmark[2]	139	126	129	[e]130	130
Egypt	53,072	54,132	[e]55,000	4,409	4,400
France[e]	[r]1,500,000	[r]1,500,000	[r]1,375,000	[r]1,400,000	1,400,000
German Democratic Republic	981,056	974,442	975,544	984,363	981,000
Germany, Federal Republic of	1,503,551	1,556,462	1,589,531	1,596,145	1,540,000
Greece[e]	1,100	1,100	1,100	1,100	1,100
India	915,869	896,839	962,978	1,068,800	1,058,000
Italy[e]	[r]680,000	[r]680,000	[r]650,000	[r]675,000	675,000
Japan	1,142,140	1,165,254	1,125,292	1,210,849	[3]1,193,935
Kenya[4]	249,177	251,062	261,964	252,043	250,000
Korea, Republic of	273,292	276,559	291,245	318,016	309,000
Mexico[5]	[r]466,286	[r]504,205	[e]500,000	[r] [e]475,000	430,000
Netherlands[e]	440,000	420,000	420,000	420,000	420,000
Pakistan	131,376	130,169	144,286	147,051	154,000
Poland	1,011,921	1,035,069	1,061,525	1,025,148	[3]1,003,102
Portugal[e]	165,000	165,000	170,000	180,000	180,000
Romania	1,005,307	921,531	[e]940,000	[e]950,000	950,000
Spain[e]	610,000	610,000	580,000	610,000	620,000
Switzerland[e]	49,000	50,000	48,000	25,000	—
Taiwan	118,179	123,479	147,002	140,359	138,000
Turkey[e]	220,000	331,000	[r]365,000	[3]414,468	[3]417,775
U.S.S.R.[6]	5,639,418	5,418,956	5,546,824	5,565,563	5,620,000
United Kingdom[e]	1,100,000	1,100,000	1,100,000	1,100,000	1,100,000
United States[7]	8,511,359	8,511,055	8,438,192	8,890,746	[3]9,632,031
Yugoslavia	207,555	220,053	229,245	222,158	[3]235,774
Total	**[r]32,224,807**	**[r]31,123,802**	**32,365,195**	**33,329,651**	**34,258,347**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through May 3, 1989. Synthetic unless otherwise specified.
[2] Production for sale only; excludes output consumed by producers.
[3] Reported figure.
[4] Natural only.
[5] Includes natural and synthetic. In 1988, Mexico reportedly produced 140,000 tons of natural soda ash.
[6] Excludes potash for 1985-87.
[7] Includes natural and synthetic for 1984-86, natural only thereafter.

TABLE 13

SODIUM SULFATE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Natural:					
Argentina	36	[r]23	35	30	18
Canada	427	403	[e]409	[r e]377	342
Chile[3]	1	1	[e]1	[e]1	1
China[e 4]	10	10	15	20	30
Egypt	[r e]33	74	21	47	47
Iran[e]	13	13	[r]14	[r]14	14
Mexico[e 5]	456	[r]434	502	506	496
Netherlands[e]	20	20	20	24	24
South Africa, Republic of	1	([6])	1	([6])	([6 7])
Spain	405	530	497	[e]496	496
Turkey	92	120	161	[e]165	165
U.S.S.R.[e 8]	390	385	380	400	413
United States	435	389	396	382	[7]398
Total	**[r]2,319**	**[r]2,402**	**2,452**	**2,462**	**2,444**
Synthetic:					
Austria[e]	55	55	61	[r]120	130
Belgium[e]	276	287	292	287	281
Brazil[e]	10	10	10	10	10
Chile[9]	63	58	65	67	65
Finland[e]	39	39	39	39	39
France[e]	132	138	121	127	170
German Democratic Republic	181	190	200	197	130
Germany, Federal Republic of	141	153	180	181	185
Greece[e]	8	8	8	8	8
Hungary[e]	11	11	10	10	10
Italy[e]	88	88	83	88	140
Japan	307	305	279	281	287
Netherlands[e]	[r]17	[r]17	[r]17	[r]17	17
Pakistan[e]	1	1	1	1	1
Portugal[e]	55	55	57	61	60
Spain[e 10]	187	165	165	182	182
Sweden[e]	110	110	110	110	110
Turkey[e]	25	25	30	30	30
U.S.S.R.[e 8]	300	300	300	300	300
United Kingdom[e]	35	35	40	50	50
United States[11]	466	422	445	432	[7]390
Yugoslavia	46	45	44	41	41
Total	**[r]2,533**	**[r]2,517**	**2,557**	**2,639**	**2,636**
Grand total	**[r]4,852**	**[r]4,919**	**5,009**	**5,101**	**5,080**

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through May 5, 1989.

[2] In addition to the countries listed, China, Poland, Romania, and Switzerland are known to or are assumed to have produced synthetic sodium sulfate, and other unlisted countries may have produced this commodity, but production figures are not reported, and available information is inadequate to make reliable estimates of output levels.

[3] Natural mine output, excluding byproduct output from the nitrate industry, which is reported separately under "Synthetic" in this table.

[4] Byproduct sodium sulfate is known to be recovered but reliable data are unavailable; not included under "Synthetic."

[5] Series reflects output reported by Industrias Peñoles S.A. de C.V., Mexico's principal producer, plus an additional 33,000 short tons (estimated) by a smaller producer.

[6] Less than 1/2 unit.

[7] Reported figure.

[8] Conjectural estimates based on 1968 information on natural sodium sulfate and general economic conditions.

[9] Byproduct of nitrate industry.

[10] Quantities of synthetic sodium sulfate credited to Spain are reported in official sources in a way such as to indicate that they are in addition to the quantities reported as mined (reported in this table under "Natural"), but some duplication may exist.

[11] Derived approximate figures; data presented are the difference between reported total sodium sulfate production (natural and synthetic not differentiated) and reported natural sodium sulfate sold by producers (reported under "Natural" in this table).

CRUSHED STONE

By Valentin V. Tepordei[1]

A total of 1.25 billion short tons of crushed stone was estimated to have been produced in the United States in 1988, an increase of 4% over the 1987 total. This tonnage is the highest production ever recorded in the United States, and represents the fourth consecutive year of production of over 1 billion tons. About three-quarters of the crushed stone production continued to be limestone and dolomite, followed by granite, traprock, sandstone and quartzite, shell, marble, calcareous marl, volcanic cinder and scoria, and slate, in order of volume.

Foreign trade in crushed stone remained relatively minor. Exports increased 13.1% while imports decreased 6.6%. Ninety-three percent of the exported and 11% of the imported crushed stone was limestone. Apparent consumption of crushed stone was 1.25 billion tons.

DOMESTIC DATA COVERAGE

Domestic production data for crushed stone are developed by the Bureau of Mines from voluntary surveys of U.S. producers. Full surveys of crushed stone producers are conducted for odd-numbered years only. For even-numbered years, a preliminary survey, which collects production information on a sample basis, is used to generate only annual estimates at the State level. In addition, a new quarterly sample survey for crushed stone and sand and gravel was implemented by the Bureau of Mines in 1989, to provide for the first time production estimates by quarters for each State and the nine geographic regions for 1988. Both surveys canvass most of the large companies in each State accounting for up to 80% of the State's total tonnage. The production estimates for 1988 may be revised in the 1989 crushed stone chapter if additional information is furnished by producers at that time.

LEGISLATION AND GOVERNMENT PROGRAMS

On November 10, 1988, the U.S. Congress enacted the Technical Corrections and Miscellaneous Revenue Act of 1988, (Public Law 100-647) which includes a provision reinstating the diesel fuel tax exemption for all off-road users effective January 1, 1989. The bill also provides for a special one-time, interest-bearing refund of diesel taxes paid between March 31, 1988, and January 1, 1989.

On August 25, 1988, the Mine Safety and Health Administration (MSHA) published its final rules for Loading, Hauling & Dumping, and Machinery & Equipment that became effective October 24, 1988. One of the requirements of the new rules is that seat belts be installed and worn in quarry off-highway haulers.

Responding to requests made by the industry, the Occupational Safety and Health Administration (OSHA) has again extended a partial stay to July 21, 1989, for the new provisions of its revised asbestos standards for nonasbestiform varieties of tremolite, anthophyllite, and actinolite minerals originally published on June 20, 1986. The stay was issued to allow OSHA time to review or complete additional studies and to collect more data, including that on the feasibility of regulating these nonasbestiform minerals. The extension of the stay was needed because of the range of affected industries and the lack of mineralogic and exposure data in these industries. The former asbestos standard remains in effect for the extent of the stay.

The introduction of the revised OSHA regulations for airborne asbestos standards that include nonasbestiform varieties of tremolite, anthophyllite, and actinolite, is expected to have a significant impact on the aggregates and the construction industries. The consequences could include increased construction costs and disruption of the supply of aggregates.

The International Agency for Re-

TABLE 1

SALIENT U.S. CRUSHED STONE STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
Sold or used by producers:					
Quantity[1]	^{e}956,000	1,000,800	^{e}1,023,200	1,200,100	^{e}1,247,800
Value[1]	^{e}\$3,755,600	\$4,053,000	^{e}\$4,255,000	\$5,248,600	^{e}\$5,558,000
Exports (value)	\$23,970	\$29,347	\$36,957	\$26,063	\$30,413
Imports for consumption (value)[2]	[2]\$17,543	\$11,640	\$12,451	\$14,024	\$16,789

[e] Estimated.
[1] Does not include American Samoa, Guam, Puerto Rico, and the Virgin Islands.
[2] Excludes precipitated calcium carbonate.

search on Cancer (IARC) of the World Health Organization published in 1988 the "IARC Monographs on the Evaluation of the Carcinogenic Risk to Humans—Silica and Some Silicates." The document states that there is "sufficient evidence" that crystalline silica is carcinogenic to experimental animals, and "limited evidence" of its carcinogenicity to humans. Under IARC rules, the findings mean that all material safety data sheets for products containing 0.1% or more of crystalline silica must contain a cancer warning. Following the publication of this ruling, OSHA decided that "Information regarding the evidence of carcinogenicity must be included on required labels and material safety data sheets for crystalline silica, and for products containing crystalline silica, where employee exposure to crystalline silica may occur," as part of OSHA Hazard Communication Standard requirements. Although OSHA's standard does not directly regulate the aggregates industry, it does affect the industry customers. It may also serve as a model for State hazardous communication programs, as well as the one currently being developed by MSHA, which will directly regulate the aggregates industry.

The National Council on Public Works Improvement, which was created by the Public Works Improvement Act of 1984 (Public Law 98-501), submitted to the President and the U.S. Congress on February 24, 1988, its final report entitled "Fragile Foundations: A Report on America's Public Works." According to the report, America's public works are barely adequate to meet current needs and are insufficient to support economic growth. Transportation, water, and waste-disposal systems need an infusion of capital to meet the demands created by a growing economy, while solid- and hazardous-waste-disposal systems have serious and growing problems that require immediate action. The Council concludes in its report that the causes for the poor state of the nation's infrastructure are largely monetary. The Council recommends a national commitment, shared by all levels of government, the private sector, and the public, to vastly improve America's infrastructure. Such a commitment could require an increase of up to 100% in the amount of capital the Nation invests each year in new and existing public works.[2]

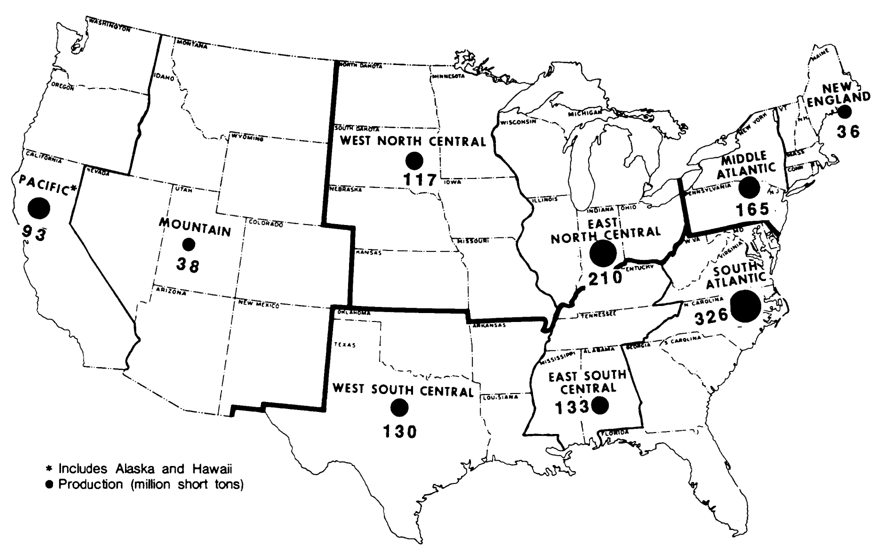
California's Surface Mining and Reclamation Act (SMARA), was passed in 1975. The main purpose of SMARA was to identify and protect mineral resources in areas of high land use and to ensure reclamation of mined lands. The act requires that aggregate resources be quantified and compared to forecasted demand in specific market regions. High-quality deposits are legally designated as "regionally significant." This designation ensures that such resources will be available in the future for aggregate production. While the effectiveness of SMARA classification program in resource protection is difficult to measure with certainty at this time due to the long-term nature of its goals, the aggregate classification reports have been well received. Government agencies, aggregate producing companies as well as other interested companies and individuals are now using the existing reports and requesting accelerated classification of other regions. The information provided by these reports has helped make better decisions regarding land use and long-range planning.[3]

DOMESTIC PRODUCTION

The production estimates indicate that in 1988 the output of crushed stone increased in all geographic regions except West North Central, West South Central, and the Mountain regions. The South Atlantic region continued to lead the Nation in the produc-

FIGURE 1

PRODUCTION OF CRUSHED STONE IN THE UNITED STATES IN 1988, BY GEOGRAPHIC REGION



tion of crushed stone with an estimated 327 million tons or 26.2% of the U.S. total, followed by the East North Central region with 210 million tons or 16.8%, and the Middle Atlantic region with 165 million tons or 13.2%.

A comparison of the reported 1987 and estimated 1988 production data indicates that the largest increases were recorded in the East North Central region, 7.3%; Middle Atlantic region, 7.1%; and the Pacific region, 5.9%. Production decreased 1.1% in the West North Central region and 0.6% in the Mountain region, and remained unchanged in the West South Central region. The estimated production by quarters for 1988, provided for the first time this year, indicates that most of the crushed stone in the United States was produced in the third quarter of 1988, followed by the second quarter and the fourth quarter.

Crushed stone was produced in every

TABLE 2

CRUSHED STONE[1] SOLD OR USED IN THE UNITED STATES, BY REGION

(Thousand short tons and thousand dollars)

Region	1987		1988[e]	
	Quantity	Value	Quantity	Value
Northeast:				
New England	34,500	$203,581	36,500	$214,000
Middle Atlantic	153,782	767,445	164,700	794,400
Midwest:				
East North Central	195,622	804,954	210,000	852,500
West North Central	118,759	431,975	117,400	455,100
South:				
South Atlantic	315,991	1,510,541	326,500	1,598,000
East South Central	126,245	556,353	132,600	583,000
West South Central	129,613	465,909	129,600	465,200
West:				
Mountain	38,121	147,323	37,900	144,600
Pacific	87,497	360,517	92,700	451,200
Total[2]	**1,200,100**	**5,248,600**	**1,247,800**	**5,558,000**

[e] Estimated.
[1] Includes volcanic cinder and scoria.
[2] Data may not add to totals shown because of independent rounding.

TABLE 3

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, IN 1988, BY QUARTER AND REGION

(Thousand short tons)

Region	Quantity					Percent coverage[2]	Number of Co.[3]
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total[1]		
Northeast:							
New England	3,500	11,200	11,800	10,000	36,500	45	27
Middle Atlantic	20,300	47,300	55,100	41,900	164,700	55	30
Midwest:							
East North Central	21,500	62,900	68,400	57,200	210,000	61	39
West North Central	18,000	34,600	36,800	28,000	117,400	42	36
South:							
South Atlantic	65,100	88,400	89,900	83,100	326,500	76	40
East South Central	23,100	36,000	39,000	34,500	132,600	58	14
West South Central	28,700	35,700	35,300	29,900	129,600	64	29
West:							
Mountain	4,300	12,400	11,200	10,000	37,900	28	21
Pacific	18,300	23,900	27,200	23,400	92,700	26	25
Total[1]	**202,700**	**352,400**	**374,700**	**318,100**	**1,247,800**	**XX**	**XX**

XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.
[2] Indicates the total amount of crushed stone reported by producers for the quarterly survey as percentage of the region total for each quarter and the year.
[3] Number of companies reporting for the quarterly survey.

State except Delaware. The 10 leading States in the estimated production of crushed stone, in order of volume, were Pennsylvania, Florida, Texas, Virginia, Illinois, Georgia, Tennessee, Missouri, Kentucky, and North Carolina. Their combined production represented 53% of the national total. Production increased in 25 States, including 7 of the top 10. The increases were significant in the following major producing States: Indiana, Kentucky, Illinois, California, and Virginia. The top two States, Pennsylvania and Florida, showed an increase of 7.6% and 5.3% respectively, in their production, and Texas, the third State in order of volume, showed a 2.8% decrease in production.

Acquisitions by foreign as well as domestic companies and mergers in the crushed stone industry continued in 1988. Colonial Sugar Refineries (CSR) Ltd. of Sydney, Australia, a major sugar and building-material producer, acquired Rinker Materials Corp. of West Palm Beach, FL. The acquisition included 3 quarries and a cement plant located in Dade County, as well as 100 concrete and concrete products operations throughout Florida. Earlier in the year, CSR Ltd. acquired another small crushed stone producer, Krome Aggregates of Miami, FL, that operated one stone quarry.

English China Clay (ECC) of Exeter, United Kingdom, the world's largest producer of kaolin, acquired the J.L. Shiely Co. of St. Paul, MN, and its wholly owned subsidiary, Cooley Gravel Co. of Denver, CO. Shiely and its subsidiary operate four quarries and sand and gravel pits supplying construction aggregates to the Minneapolis-St. Paul, MN, and Denver and Colorado Springs, CO, metropolitan areas. ECC also acquired Cyprus Minerals Co. of Denver, CO, and its calcium carbonate operations at Sylacauga, AL, and Cartersville, GA. Included in this acquisition were significant reserves in Vermont and California.

C. H. Beazer PLC, of Bath, United Kingdom, acquired Koppers Co., of Pittsburgh, PA, the second largest U.S. aggregates producer and its subsidiar-

TABLE 4

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

(Thousand short tons and thousand dollars)

State	1987		1988[e]	
	Quantity	Value	Quantity	Value
Alabama	30,018	$146,247	29,700	$140,100
Alaska	2,033	8,945	1,800	8,400
Arizona	7,712	33,999	7,400	33,000
Arkansas	15,234	63,847	17,100	70,100
California	44,315	186,504	49,100	275,000
Colorado	8,045	33,465	10,600	42,400
Connecticut	11,412	76,668	11,400	76,900
Florida[2]	78,992	350,537	83,200	374,400
Georgia	60,834	318,903	57,400	317,200
Hawaii	5,732	41,548	5,700	41,000
Idaho	3,852	15,346	3,400	13,100
Illinois	52,102	216,212	57,900	251,200
Indiana	31,067	106,770	36,600	130,000
Iowa	25,991	110,106	29,200	128,500
Kansas	19,319	69,628	17,300	72,700
Kentucky	43,330	173,222	50,700	207,900
Louisiana[3]	4,390	36,514	3,700	29,200
Maine	2,010	7,532	1,400	5,300
Maryland	30,136	151,579	32,700	167,000
Massachusetts	14,907	78,969	17,500	91,900
Michigan	37,909	109,514	38,800	120,300
Minnesota	8,995	29,246	8,300	28,200
Mississippi	1,492	9,621	1,500	9,000
Missouri	54,910	184,824	52,100	183,000
Montana	1,463	3,585	1,800	4,500
Nebraska	4,316	19,461	4,900	22,000
Nevada[4]	1,264	5,700	1,300	5,700
New Hampshire	2,479	10,386	2,400	9,800
New Jersey[5]	17,576	111,951	19,300	123,500
New Mexico	4,503	15,919	3,500	13,900
New York	38,103	188,694	39,900	193,500
North Carolina	48,847	237,181	50,500	250,000
North Dakota	W	W	W	W
Ohio	51,590	300,096	48,000	252,000
Oklahoma[4]	25,155	83,732	26,300	92,000
Oregon	20,663	73,902	22,200	77,600
Pennsylvania	97,213	458,676	104,600	470,700
Rhode Island	1,228	7,797	1,500	9,400
South Carolina[6]	24,278	105,387	23,500	105,800
South Dakota	5,070	18,515	5,500	20,600

See footnotes at end of table.

TABLE 4—Continued

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

(Thousand short tons and thousand dollars)

State	1987		1988[e]	
	Quantity	Value	Quantity	Value
Tennessee	51,406	227,263	52,200	235,000
Texas	84,347	276,477	82,000	271,300
Utah	7,989	23,606	7,300	20,600
Vermont[7]	2,159	20,400	2,000	18,000
Virginia	60,376	295,903	66,000	326,700
Washington	14,754	49,618	13,900	48,700
West Virginia	12,458	50,947	11,600	47,600
Wisconsin[8]	22,757	71,776	28,500	98,300
Wyoming	3,171	15,049	2,500	11,400
Other	2,230	16,831	2,100	13,700
Total U.S.[9]	**1,200,100**	**5,248,600**	**1,247,800**	**5,558,000**

[e]Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]To avoid disclosing company proprietary data, certain State totals do not include all kinds of stone produced within the State; the portion not shown has been included with "Other."
[2]Excludes marl.
[3]Excludes other stone.
[4]Excludes dolomite.
[5]Excludes limestone.
[6]Excludes shell.
[7]Excludes granite.
[8]Excludes traprock.
[9]Data may not add to totals shown because of independent rounding.

ies: Kaiser Sand and Gravel of Pleasanton, CA; Cherokee Crushed Stone of Pembroke Pines, FL; Davidson Minerals of Lithonia, GA; France Stone Co, of Toledo, OH; Hoosier Stone and Concrete of Salem, IN; Kentucky Stone of Louisville, KY; Eastern Rock Products of Utica, NY; General Crushed Stone of Easton, PA; Berry Materials of North Vernon, IN; and Stone Man Inc. of East Ridge, IN. The acquisition included a total of 80 stone quarries, and 24 sand and gravel operations in 13 States, as well as Koppers' chemical division. The newly formed organization will operate under the name of Beazer Materials and Services Inc. of Pittsburgh, PA, a member of The Beazer Group.

Vulcan Materials Co. of Birmingham, AL, acquired B. L. Anderson Co., of Cedar Rapids, IA. The purchase included 18 rock quarries and two dredging operations, all located in Iowa. The company will operate under the Vulcan name as a member of its Midwest division. Vulcan also purchased from Granite Construction Co. of Watsonville, CA, a stone quarry in Mississippi, and from Wilson County Rock Products of Lebanon, TN, a quarry operating in Tennessee.

Dravo Basic Materials Co. of Kenner, LA, acquired from Cyprus Minerals the Three Rivers Rock Co. limestone quarry in Kentucky and from Louisiana Limestone Aggregates Inc. six aggregates distribution facilities in Louisiana and Tennessee.

Pioneer Concrete of America of Bedford, TX, acquired Davison Sand & Gravel Co. of New Kensington, PA, a major sand and gravel producer in the Pittsburgh area, as well as G & S Towing Co., a towboat and barge company that supports Davison's four dredging operations.

Redland PLC of Groby, United Kingdom, announced in June that it had acquired Kopper's 50% interest in Western-Mobile Inc., a Koppers-Redland equal joint venture that was established in 1986. Western-Mobile supplies construction aggregates and ready-mix concrete in Colorado, New Mexico, Kansas, and Wyoming.

Cement-Roadstone Holdings PLC of Dublin, Ireland, announced that a newly formed corporation, Pike Holdings Inc., acquired Pike Industries Inc. of New England, which operates 4 quarries, 6 sand and gravel pits, and 30 asphalt plants in New Hampshire, Vermont, and Maine.

Evered Materials, of Guilford, United Kingdom, acquired Mid-State Construction & Materials Co. of Little Rock, AR, and its four crushed stone quarries operating in Arkansas.

Tarmac America of Herndon, VA, a subsidiary of Tarmac PLC of Wolverhampton, United Kingdom, purchased the outstanding 40% equity in the Tarmac-Lone Star Inc. joint venture that was formed in January 1987.

As a result of these acquisitions, the foreign ownership of crushed stone and sand and gravel companies increased significantly.

FOREIGN TRADE

Exports

Exports of crushed stone increased 13.1% to 3.6 million tons, while value increased 16.7%. About 93% of the exported crushed stone was limestone, of which more than 99% went to Canada.

Imports

Imports of crushed stone decreased 6.6% to 3.6 million tons, but increased in value by 19.7%. About 86% of this tonnage was classified as "other crushed stone," 83% of which came from Can-

TABLE 5

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, IN 1988, BY QUARTER AND STATE

(Thousand short tons)

State	Quantity					Percent coverage[2]	Number of Co.[3]
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total[1]		
Alabama	6,000	8,100	8,000	7,500	29,700	57	7
Alaska	—	—	—	—	1,800	—	—
Arizona	—	—	—	—	7,400	—	—
Arkansas	2,600	5,200	5,000	4,300	17,100	32	4
California	9,900	12,000	14,100	13,100	49,100	30	10
Colorado	700	3,500	3,200	3,300	10,600	54	5
Connecticut	1,600	3,300	3,300	3,200	11,400	43	7
Delaware	—	—	—	—	—	—	—
Florida	19,300	20,800	21,200	21,900	83,200	60	11
Georgia	12,200	16,700	15,300	13,200	57,400	91	6
Hawaii	—	—	—	—	5,700	—	—
Idaho	—	—	—	—	3,400	—	—
Illinois	6,200	16,900	18,400	16,300	57,900	61	9
Indiana	5,200	10,300	11,200	9,800	36,600	74	15
Iowa	3,000	7,900	10,400	7,900	29,200	35	5
Kansas	2,400	5,600	5,400	4,000	17,300	48	10
Kentucky	9,600	13,100	14,800	13,200	50,700	56	8
Louisiana	1,000	1,000	800	900	3,700	88	3
Maine	300	400	400	300	1,400	51	4
Maryland	5,800	8,500	9,300	9,200	32,700	90	9
Massachusetts	800	5,700	6,200	4,700	17,500	44	6
Michigan	1,700	12,500	13,000	11,600	38,800	53	6
Minnesota	900	3,100	2,700	1,600	8,300	44	6
Mississippi	—	—	—	—	1,500	—	—
Missouri	10,300	14,600	14,300	12,900	52,100	37	12
Montana	—	—	—	—	1,800	—	—
Nebraska	1,000	1,300	1,500	1,100	4,900	97	6
Nevada	300	300	300	300	1,300	68	4
New Hampshire	200	700	800	700	2,400	24	3
New Jersey	3,100	5,700	5,800	4,700	19,300	75	7
New Mexico	—	—	—	—	3,500	—	—
New York	2,000	11,800	14,800	11,300	39,900	53	7
North Carolina	8,800	13,600	15,100	12,900	50,500	94	8
North Dakota	—	—	—	—	W	—	—
Ohio	4,200	15,000	16,600	12,200	48,000	73	10
Oklahoma	5,200	7,500	7,500	6,100	26,300	66	10
Oregon	3,200	6,800	7,600	4,700	22,200	19	7
Pennsylvania	14,000	29,800	34,800	26,000	104,600	52	18
Rhode Island	100	500	500	400	1,500	70	4
South Carolina	5,000	6,500	6,100	5,900	23,500	80	7

See footnotes at end of table.

TABLE 5—Continued

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, IN 1988, BY QUARTER AND STATE

(Thousand short tons)

State	Quantity					Percent coverage[2]	Number of Co.[3]
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total[1]		
South Dakota	400	1,800	2,200	1,000	5,500	56	5
Tennessee	7,600	14,700	16,100	13,800	52,200	60	7
Texas	18,700	22,400	22,200	18,700	82,000	69	16
Utah	—	—	—	—	7,300	—	—
Vermont	200	600	600	600	2,000	72	3
Virginia	12,500	18,200	18,800	16,500	66,000	66	15
Washington	3,000	3,600	3,900	3,500	13,900	26	8
West Virginia	—	—	—	—	11,600	—	—
Wisconsin	4,100	8,200	8,900	7,400	28,500	34	7
Wyoming	200	1,400	700	300	2,500	26	4
Other[4]	9,500	13,000	12,700	10,900	2,100	XX	XX
Total [1]	**202,700**	**352,400**	**374,700**	**318,100**	**1,247,800**	**XX**	**XX**

W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

[2] Indicates the total amount of crushed stone reported by producers for the quarterly survey as percentage of the State total for each quarter and the year.

[3] Number of companies reporting for the quarterly survey.

[4] Due to a very low number of reporting companies in some States, no production estimates by quarters were generated for Alaska, Arizona, Hawaii, Idaho, Mississippi, Montana, New Mexico, North Dakota, Utah, and West Virginia. The limited amount of information available from these States used to generate production estimates by quarters is included in "Others."

ada and 12% from the United Kingdom. The significant decrease in the imports of crushed limestone is due in part to the fact that no "limestone for cement manufacturing" was reported this year to the U.S. Bureau of the Census.

Imports of calcium carbonate fines increased 36% to 358,000 tons and 30% in value to $2.0 million. Ninety-one percent of the natural aragonite came from the Bahamas and 5% from Taiwan, and most of the processed calcium carbonate was imported from France, 75%; Switzerland, 14%; and the United Kingdom, 6%.

Shipments of crushed stone from Scotland, United Kingdom, and from Nova Scotia, Canada, into the United States continued in 1988. The imported crushed stone, used mostly as construction aggregates, was distributed in North Carolina, South Carolina, Florida, Louisiana, and Texas. This trend is expected to continue and the volume of imports to increase.

WORLD REVIEW

Canada

The 1987 production of stone in Canada was 124.9 million tons, an increase of 16.1% over the 1986 total, valued at $583 million. About 98% of this output was crushed stone. The Province of Ontario continued to be the largest producer of stone, with 57.8 million tons valued at $273 million, followed by Quebec with 47.1 million tons valued at $213 million. The two provinces accounted for 84% of the total stone production. Preliminary estimates for 1988 stone production indicate a decrease of about 1% to 124 million tons, but an increase in value to $601 million. The Provinces of Ontario and Quebec continued to be the largest producers of stone with about 84% of the total output.

United Kingdom

The 1987 production of crushed stone in Great Britain was 164 million metric tons, of which 142 million tons was used for construction purposes, as reported by the British Aggregate Construction Materials Industries Association (BACMI). About 68% of this output was limestone and dolomite. South West was the largest producing region with 35.7 million tons, followed by East Midlands with 34.2 million tons, and Wales with 23.4 million tons. Preliminary estimates for 1988 made by BACMI indicate a 12% increase in the production of crushed stone for 1988.

Detailed site investigations begun in the first half of 1988 concerning the construction of the National Stone Center in Wirksworth, Derbyshire. The first stage of the project will consist in reclamation work on a 50-acre site that includes six individual quarries and the construction of the visitor and exhibition building. The aim of the project is

TABLE 6

U.S. EXPORTS OF CRUSHED STONE IN 1988, BY DESTINATION

(Short tons)

Destination	Quartzite	Limestone [1]	Other	Total
North America:				
Bahamas	—	7,204	2,264	9,468
Bermuda	—	4,966	—	4,966
Canada	1,059	3,361,092	101,983	3,464,134
Mexico	149	1,236	3,789	5,174
Other	164	1,366	3,630	5,160
Total	**1,372**	**3,375,864**	**111,666**	**3,488,902**
South America:				
Chile	—	593	22	615
Venezuela	52	335	1,047	1,434
Other	—	833	964	1,797
Total	**52**	**1,761**	**2,033**	**3,846**
Europe:				
France	570	—	2,073	2,643
Germany, Federal Republic of	34,365	—	198	34,563
Netherlands	77,663	—	—	77,663
United Kingdom	484	62	2,347	2,893
Other	351	150	15	516
Total	**113,433**	**212**	**4,633**	**118,278**
Asia:				
Japan	1,384	586	7,753	9,723
Korea, Republic of	7,211	161	170	7,542
Taiwan	1,365	715	904	2,984
Other	27	349	357	733
Total	**9,987**	**1,811**	**9,184**	**20,982**
Oceania	24	199	10,137	10,360
Middle East and Africa	—	5	22	27
Grand total	**124,868**	**3,379,852**	**137,675**	**3,642,395**
Total value thousands	**$8,786**	**$16,900**	**$4,727**	**$30,413**

[1] Includes ground limestone.

Source: U.S. Bureau of the Census.

to provide a center for the presentation of the geology, history, present operations, and future plans of the British stone and associated industries. When completed, the Center is expected to become a documentation and research center that will provide management and technical training, information, and promotion for the stone industry, and a place to organize technical conferences and seminars. The Center will have a library and will be producing publications related to all aspects of the industry. Funding of the Center is expected to come as grants from government-supported organizations as well as stone-producing companies, equipment manufacturers, and scientific and environmental organizations. The first stage of the Center was to open in mid-1989.[4]

TECHNOLOGY

Between 1982 and 1984, the Transportation Research Board conducted a comprehensive study for the Federal Highway Administration (FHWA) on the extent to which expanded research and development could make major contributions toward improving the quality of U.S. highways and related structures. The Strategic Transportation Research Study concluded that a time-specific, concentrated, short-term, and result-oriented research program would be highly cost effective. In April 1987, the Strategic Highway Research Program (SHRP), a 5-year, $150 million research program was created and funded under the Surface Transportation and Uniform Relocation Assistance Act of 1987. Under the provisions of the act, 0.25% of State-apportioned Federal highway aid is allocated to SHRP for highway research to solve key technical problems of common concern to State highway departments and other road transportation agencies. SHRP is administered as a unit of the National Research Council through a mutual agreement between the Council, the FHWA, and the American Association of State Highway and Transportation Officials (AASHTO). SHRP research areas of investigation were selected based on recommendations made by the Strategic Transportation Research Study, and include: asphalts, concrete and structures, highway operations, and long-term pavement performance. These areas were selected as priority targets of investigation because short-term research could yield economically significant results that could be readily implemented.

The asphalt program includes both laboratory and field tests on determining how fundamental properties of asphaltic materials affect the service life of pavements. The information collected under this program will form the basis for recommendations for performance-based

TABLE 7

U.S. IMPORTS OF CRUSHED STONE AND CALCIUM CARBONATE FINES, BY TYPE

(Thousand short tons and thousand dollars)

Type	1987		1988	
	Quantity	Customs value	Quantity	Customs value
Crushed stone and chips:				
Limestone[1]	1,330	4,775	358	1,404
Marble, breccia	3	333	2	166
Quartzite	67	1,234	100	1,686
Slate	1	66	7	167
Other	2,193	6,092	2,778	11,393
Total[2]	**3,595**	**12,500**	**3,244**	**14,815**
Calcium carbonate fines:[3]				
Natural aragonite[4]	257	856	352	1,074
Chalk, whiting	5	668	6	899
Total[2]	**263**	**1,524**	**358**	**1,973**
Grand total[2]	**3,858**	**14,024**	**3,602**	**16,789**

[1] Excludes limestone for cement manufacturing.
[2] Data may not add to totals shown because of independent rounding.
[3] Excludes precipitated calcium carbonate.
[4] Includes some chalk and other calcareous materials.

Source: U.S. Bureau of the Census.

specifications for asphalt pavement materials. The concrete and structure program will develop improved concrete materials and construction processes, as well as better means of controlling corrosion in steel-reinforced concrete. The highway operations program includes research in both snow and ice control, and in improved materials and equipment for highway maintenance. The long-term pavement performance program is focused on improvement of pavement design and maintenance methods. It includes collection and analysis of long-term performance data on different types of new and rehabilitated pavement structures, using different materials and under different loading environments at approximately 1,300 in-service test sections in roadways throughout the United States and Canada. A significant number of contracts were awarded and research teams were assembled with the initial multiyear contract awards. To enhance creativity and innovation in the research contracts, SHRP is seeking alternative approaches to the objectives of the planned research through two special programs, Ideas Deserving Exploratory Analysis, and Asphalt Independent Innovative Research.

The State highway agencies were instrumental in the development of SHRP, and their support continues. The States donated test sites for the pavement performance experiments and provided personnel and equipment to assist in tasks related to management of the test sites and traffic data collection. Twenty-five countries are also working with SHRP through its International Cooperation Program in a variety of ways, ranging from exchanging research information to running parallel or complementary research programs. The impact of SHRP on the highway industries is expected to be much greater than the findings and recommendations of the AASHTO road test conducted at Ottawa, IL, that have been the basis of pavement design since 1962.[5]

The Third Automation Conference cosponsored by the National Stone Association and the U.S. Bureau of Mines was held on October 9-11 in Baltimore, MD. The conference, entitled "Guidelines for the Successful Application of Automation in the Crushed Stone Industry," focused on relatively inexpensive methods to begin automating smaller pits and quarries. A survey conducted by Pit & Quarry Magazine indicates that only 40% of companies producing less than 500,000 short tons per year plan to purchase new equipment in 1989, and fewer than 10% expect to buy computers or automation equipment. The Director of the Bureau of Mines, said in his keynote address, "The question is not whether to automate, but how much and when. . . . In times of high competition, automation technology may make the difference between a company surviving or not." Seven areas of interest related to automating pit and quarry operations were covered in either general or concurrent sessions: quarry computerization and automation; system automation in the processing plant; plant design for effective automation; sensors and auxiliary equipment; energy management; materials loadout, including scale and dispatch order/entry systems; and automated sand-classifier systems.[6]

Dravo Lime Co. of Pittsburgh, PA, and the U.S. Department of Energy's Argonne National Laboratory have agreed to participate jointly in a process development program designed to demonstrate the commercial feasibility of Argonne's patented nitrogen oxide removal technology for wet flue gas desulfurization (FGD) systems. The new Argonox process involves the use of metal-chelate additives to remove nitrogen oxides (NO_x) from flue gases. Laboratory tests suggest that the process could remove more than 70% of the nitrogen oxides. The process offers greater simplicity and operability than systems which combine selective catalytic reduction of NO_x with separate

FGD processes. In the early 1970's, Dravo developed a proprietary scrubbing process that uses thiosorbic lime, a process that set an industry standard for removal of sulfur dioxide from powerplant emissions. The work will be performed both at Argonne's laboratories near Chicago and at Dravo's research center near Pittsburgh. The agreement also gives Dravo an option to obtain an exclusive license to the Argonox technology.[7]

The recycling of old concrete and asphalt used mostly in pavements has been receiving increased attention in recent years. Recycling of concrete resulting from demolished buildings or old roads provides a means of disposing of large volumes of cumbersome waste and also is a limited source of aggregates. In some States, limited recycling, especially in road construction, is either encouraged or required by law. However, there are some negative aspects, related to the concept of using recycled aggregates, that should be taken into consideration. The problems often associated with the use of recycled concrete or reclaimed asphalt pavement were reviewed in a report published by the National Aggregates Association. The report stresses the fact that recycled aggregates should not be used solely for the sake of recycling, especially when the costs of using recycled materials will increase the price tag of the entire project. Sound crushed concrete can make good coarse aggregate, the report indicates, but the fines produced have a higher absorption, are more friable, and will require a higher amount of asphalt in asphaltic concrete and a higher amount of mixing water in portland cement. Reclaimed asphalt pavement materials may contain hardened, aged asphalt cement that will not perform in a satisfactory manner unless it is mixed with the proper blending agents. The report suggests using crushed concrete and reclaimed asphalt pavement materials for lower specification items such as fill or subbase rather than in high-quality pavement. The report also underlines the need for proper testing under engineering supervision in all construction projects using recycled materials as aggregates to ensure that the technical specifications are met.[8]

A blasting guidance manual produced under contract for the Office of Surface Mining Reclamation and Enforcement (OSMRE) by Vibra-Tech Engineers, Inc., provides technical background and guidelines regarding OSMRE blasting regulations. Blast vibration control is an important part of any successful blasting program, particularly in view of the general growing intolerance of mining activities by the general public. The manual contains chapters covering: preblast surveys; basic principles of blast vibrations; control of adverse effects; damages; human subjective tolerance; causes of excessive adverse effects; vibration monitoring; instrumentation; compliance options; prediction and control methods; frequency considerations; and record keeping. The manual shows that compliance with the OSMRE guidelines could improve the efficiency of blasting operations, lower explosive costs, cut drilling costs, and improve profitability.[9]

The cost of reclamation has become an important factor in quarry economics. For some quarries, lower reclamation costs may turn a "no go" situation into a viable stone producing operation. Reclamation by blasting has several important advantages over the other three basic methods: backhaul and fill; combined backfill and blasting; and simultaneous stripping, production, and reclamation. It is the least expensive and most efficient method. Careful blast design is reported to be an essential part of the reclamation by blasting method.[10]

A computer-aided visual simulation system that accurately models topography, simulates landform changes, and quickly illustrates a mining project from any known viewpoint, both stationary and in motion, was developed by Design Workshop Inc. of Denver, CO. Combining the three-dimensional simulation technology with image processing computer techniques, the system involves transferring an image electronically to a computer database, and then "painting" on it to illustrate proposed changes. The technique involves overlaying site photos with the simulation to depict how the project will change the site. The computer-aided visual simulation system can be used to better plan, design, and review alternatives of proposed mining and reclamation projects.[11]

Clarifying systems represent a cost-effective solution to some of the frustrating problems faced by many producers of aggregates and related mineral products. Most clarification systems work by mixing wash water with a flocculent that causes the suspended solids to settle rapidly. These solids, also referred to as underflow, can then be dewatered and stockpiled and used as landfill or even as products. Some clarifier systems reduce the need for settling ponds dramatically, generally to one, or eliminate them. At the same time, clarifiers permit immediate reuse of wash water and help producers maintain compliance with increasingly stringent water and discharge effluent standards.[12]

Vibrating screens are common sources of noise and dust in pit and quarry operations. Contributing to the problem is the fact that screens are generally located on elevated structures, which tends to make dust more visible and allows noise to travel farther. Enclosure and wet suppression may reduce these problems to some extent, but may not always be cost effective. Enclosures not only are expensive to build and maintain but also complicate screen, crusher, and conveyor maintenance. Excess moisture resulting from wet suppression of dust can negatively affect screening operations by "blinding" screens. The use of urethane screening media significantly reduces both plant noise and blinding caused by water-mist dust control. Operating costs are also lower, based on longer wear life of urethane screens and significantly fewer blinding problems.[13]

A prototype over-the-road haul truck dump trailer fitted with both rubber tires and a rail bogie undercarriage is being tested by the RoadRailer Co. of Hamburg, NY. The trailer can be mounted on the rail bogie for movement on the track and dismounted at destination for highway service, without the need of outside lift-on/lift-off equipment. The truck-rail system will allow quarries without a rail siding to load haul trucks in typical fashion and then haul them to the railhead for transfer to rail. At the destination, a highway move completes the delivery. Conversely, quarries with rail facilities could assemble a unit train of the dump trailers for direct rail move to consumer destinations. On arrival, highway tractors would complete the deliveries to specific locations without transloading the aggregates. On the rails, the train units move at high speeds and are pulled by a single locomotive. On the highways, the loaded trailers are detached from the train and pulled by conventional tractors for pickup and delivery. The system eliminates flatcars, switch locomotives and crews, overhead cranes, and piggybackers. The truck-rail system will allow remote quarry locations to serve metropolitan markets with scheduled deliveries, moving as many as 75 trailers in a single rail haul.[14]

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DIMENSION STONE

By Harold A. Taylor, Jr.[1]

Production of dimension stone increased slightly to 1.19 million short tons valued at $196 million. More than one-half of the dimension stone produced was granite. Limestone, marble, sandstone, and slate were also produced.

Exports of dimension stone increased 57% in value to $32 million. The value of dimension stone imports for consumption increased 18% to $518 million, equivalent to 235% of the value of domestic production.

DOMESTIC DATA COVERAGE

Domestic production data for dimension stone are developed by the Bureau of Mines from voluntary surveys of U.S. producers of rough and finished dimension stone. The survey of dimension stone producers was not conducted in 1988, since it was an even-numbered year. The preliminary survey for 1988, which collected production information on a sample basis for the first 9 months only, was used to generate State annual preliminary estimates. Of the 442 dimension stone operations surveyed for 1987 and 1986, including those that were idle, 415, or 94%, responded, representing 96% of the estimated value shown in table 1. The final 1986 data are based on data from the 1987 survey, and updated 1986 preliminary data for nonrespondents were estimated using preliminary production reports, adjusted prior years production levels, and employment data.

DOMESTIC PRODUCTION

Dimension stone was produced by 185 companies at 271 quarries in 36 States. Leading States, in order of tonnage, were Indiana, Georgia, and Vermont, producing together, 41% of the Nation's total. Of the total production, 52% was granite, 28% was limestone, 10% was sandstone, 3% was slate, 2% was marble, and the remaining 5% was miscellaneous stone. Miscellaneous stone included argillite, schist, soapstone, and traprock (basalt). Leading producing companies in terms of tonnage were Cold Spring Granite Co., principally in California, Minnesota, South Dakota, and Texas; Rock of Ages Corp., in New Hampshire and Vermont; and Coggins Granite Industries Inc. in Georgia.

Granite

Dimension granite includes all coarse-grained igneous rocks. Production increased slightly to 630,000 tons and decreased slightly in value to $105.7 million. Granite was produced by 64 companies at 103 quarries in 22 States. Georgia continued to be the leading State, producing 28% of the U.S. total, followed by Vermont and New Hampshire. These three States together produced over 53% of the U.S. total. Cold Spring Granite, Rock of Ages, and Coggins Granite Industries were the leading producers and accounted for 31% of U.S. production.

The International Trade Administration of the U.S. Department of Commerce made a final positive determination of sales at less than fair value (dumping) and of countervailing duty (subsidization) on granite products from Spain. The dumping margins ranged from 1.78% to 2.19% for the responding firms and 1.93% for all other firms. The net subsidization found resulted in duty deposit rates of 3.54% for two responding firms, 0.00% for two firms, and 0.85% for all others.

The International Trade Administration, also made a final positive determination of sales at less than fair value and of countervailing duty on granite products from Italy. The dumping margins were 28.34% for Filli Guarda S.p.A. and a narrower range of 0.00% to 4.93% for all other responding firms; nonresponding firms were 4.98%. The net subsidization found was de minimis, resulting in duty deposit rates of 0.00%.

The International Trade Commission (ITC) made a unanimous final determination that the domestic granite products industry was not injured or threatened with injury because of imports of granite products from Italy and Spain that were subsidized and being dumped. This means that present duties on these items will remain unchanged. The ITC has also issued a final report with valuable statistical information on profit-loss, the consumption of granite by color, thickness, and by several groupings of tile and slab.[2]

Limestone

Dimension limestone includes bituminous, dolomitic, and siliceous limestones. Indiana, the leading State, produced 195,000 tons in 1988 compared with 183,609 tons in 1987 and 174,005

TABLE 1

SALIENT U.S. DIMENSION STONE STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
Sold or used by producers[1]	e1,141	1,104	r e1,067	r1,177	e1,189
Value[1]	e$161,912	$172,435	r e$166,717	$190,209	e$196,289
Exports (value)	$23,007	$13,835	$14,623	$20,470	$32,219
Imports for consumption (value)	$222,596	$291,246	$379,724	$439,278	$517,835

e Estimated. r Revised.
[1] Excludes Puerto Rico.

TABLE 2

DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	1986[r] [e]		1987		1988[e]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Arizona	W	W	W	W	W	$1
Arkansas	W	W	10,541	$629	10,541	629
California	31,271	$2,826	33,335	4,554	42,048	5,991
Colorado	2,250	316	3,000	133	3,450	143
Connecticut	17,500	1,643	18,140	1,646	19,718	1,914
Georgia	149,863	18,219	179,207	21,683	190,472	27,768
Illinois	W	W	W	W	1,175	129
Indiana	174,005	21,158	183,609	23,115	195,444	24,956
Iowa	9,665	483	W	W	W	588
Kansas	10,847	452	11,423	445	6,889	219
Maine	2,100	384	7,512	5,924	7,512	5,924
Maryland	19,614	1,154	22,843	1,516	20,729	1,515
Massachusetts	64,475	13,006	[r]69,936	[r]12,801	W	W
Minnesota	34,532	10,899	41,354	12,967	45,000	13,000
Missouri	W	W	3,212	454	3,644	547
New Hampshire	66,494	9,077	67,479	10,684	73,393	10,546
New Mexico	21,372	479	21,893	626	21,893	626
New York	13,640	3,109	38,553	5,822	30,751	4,333
North Carolina	67,594	5,649	32,669	5,128	31,977	5,026
Ohio	35,611	3,172	47,816	2,427	38,300	3,137
Oklahoma	7,060	602	8,311	861	7,746	785
Pennsylvania	49,350	8,953	60,118	10,177	59,022	9,584
South Carolina	4,253	440	2,319	312	353	37
South Dakota	52,545	17,184	50,718	18,209	43,297	16,472
Tennessee	4,109	651	3,360	573	3,942	567
Texas	54,908	10,549	75,426	10,030	66,354	8,310
Utah	W	W	2,004	[r]93	2,004	93
Vermont	94,528	26,079	103,923	30,074	105,000	30,500
Virginia	8,401	2,870	9,077	2,720	10,000	2,900
Washington	100	20	297	42	697	60
Wisconsin	40,460	3,551	36,903	3,697	49,900	6,200
Other[1]	30,251	3,793	32,228	2,865	98,082	13,789
Total[2]	**1,066,798**	**166,717**	**[r]1,177,206**	**[r]190,209**	**1,189,333**	**196,289**

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes data for Alabama, Idaho, Michigan, and Montana.
[2]Data may not add to totals shown because of independent rounding.

tons in 1986. Wisconsin, usually the second or third largest producer, totaled 31,584 tons valued at $1,297,000 in 1987 and 34,426 tons valued at $1,325,000 in 1986.

CONSUMPTION AND USES

Dimension stone was marketed over wide areas. Industry stockpiles were not monitored, and production during the year was assumed to equal consumption.

Consumption of domestic dimension stone increased slightly to 1.19 million tons valued at $196.3 million in 1988 compared with 1.18 million tons valued at $190.2 million (revised) in 1987 and

TABLE 3

DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE

State	1986r e Quantity (short tons)	1986r e Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)	1988e Quantity (short tons)	1988e Value (thousands)
California	17,264	$1,995	16,525	$3,410	20,856	$4,304
Connecticut	17,500	1,643	W	W	19,718	1,914
Georgia	136,478	8,710	166,108	11,054	176,568	11,750
Maine	2,100	384	7,512	5,924	7,512	5,924
Massachusetts	61,975	12,681	r67,436	r12,426	65,197	10,989
New Hampshire	66,494	9,077	67,479	10,684	73,393	10,546
North Carolina	63,577	4,587	28,526	4,786	27,948	4,689
Oklahoma	4,643	552	5,950	796	5,546	742
Pennsylvania	12,566	2,358	12,516	2,566	12,335	2,529
South Carolina	4,253	440	2,319	312	353	37
South Dakota	52,545	17,184	50,718	18,209	43,297	16,472
Texas	35,047	6,724	46,717	6,935	41,139	6,107
Vermont	73,041	13,659	83,660	15,400	84,525	15,559
Wisconsin	2,924	2,034	2,730	2,241	3,692	3,031
Other[1]	45,990	10,884	64,526	12,368	47,857	11,062
Total	**596,398**	**92,911**	**r622,722**	**r107,111**	**629,936**	**105,655**

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."

1 Includes Colorado, Maryland, Minnesota, Missouri, New York, Rhode Island, Virginia, and Washington.

1.07 million tons valued at $166.7 million in 1986.

Consumption of domestic granite increased to 630,000 tons valued at $105.7 million in 1988 compared with 622,700 tons valued at $107.1 million in 1987 and 596,400 tons valued at $92.9 million in 1986.

Domestic limestone consumption was 347,000 tons valued at $38.1 million in 1988 compared with 331,800 tons valued at $35.9 million (revised) in 1987 and 302,800 tons valued at $33.2 million in 1986.

Domestic marble consumption, including travertine, totaled 22,000 tons valued at $25.0 million in 1988 compared with 24,370 tons valued at $20.4 million in 1987 and 25,000 tons valued at $17.3 million in 1986.

Consumption of domestic slate totaled 39,600 tons valued at $15.9 million in 1988 compared with 39,700 tons valued at $16.4 million in 1987 and 36,600 tons valued at $15.0 million in 1986.

PRICES

The average price for dimension stone increased to $165 per ton, up slightly from $162 in 1987.

FOREIGN TRADE

Exports

Exports of dimension stone, about 40% of which was granite, increased 57% in value.

Imports

Imports for consumption of dimension stone increased 18% in value to $518 million, mostly because of increases in imports of polished slabs of marble and dressed granite. Imports of polished marble slabs, mostly from Italy, increased 12% to $201 million. Imports of dressed granite increased 21%. On a value basis, marble accounted for 52% of imports, followed by granite, 34%; travertine, 6%; and slate, 4%.

A review of foreign trade in the dimension stone industry covered the most recent statistics, provided news on the trade cases on Italian and Spanish granite, and concluded that the balance between exports and imports looked like it would improve. The latest statistics indicated no major change in domestic production, some increase in most major import categories, and striking increases in most export categories. The only two countries that could have sizable increases in their exports to the United States were Brazil and China. U.S. exporters, on the other hand, seem to have good markets awaiting them in Japan and certain northern European countries.[3]

TABLE 4

DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

Use	1986[r,e]		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Rough stone:				
Rough blocks for building and construction	229,764	$17,649	240,329	$19,919
Irregular-shaped stone[1]	101,940	3,745	148,888	5,193
Flagging	—	—	2,700	165
Monumental	188,550	22,018	225,492	26,214
Other[2]	21,765	1,454	20,221	1,837
Dressed stone:				
Ashlars and partially squared pieces	193,559	41,166	210,034	45,729
Slabs and blocks for building and construction	62,095	15,028	52,671	18,101
Monumental	52,335	25,246	49,965	27,137
Curbing	141,041	21,723	129,294	23,339
Flagging	25,252	1,472	34,510	2,392
Flagging (slate)	7,695	1,639	9,086	1,785
Roofing slate	13,928	6,840	14,892	7,626
Structural and sanitary	5,533	2,984	5,636	3,200
Flooring slate	6,214	2,583	7,077	2,963
Other[3]	17,127	3,171	[r]26,411	[r]4,610
Total[4]	**1,066,798**	**166,717**	**[r]1,177,206**	**[r]190,209**

[e]Estimated. [r]Revised.
[1]Includes rubble.
[2]Includes unspecified uses.
[3]Includes a minor amount of slate used for billiard tabletops, miscellaneous, and unspecified uses.
[4]Data may not add to totals shown because of independent rounding.

WORLD REVIEW

Some production of dimension stone occurred in most countries of the world. As usual, Italy produced about one-half of the world's total. Other significant producers were Brazil, China, Finland, India, Norway, Portugal, Spain, Sweden, Turkey, and the United States.

China

A description of the Chinese dimension stone industry appeared in a Western stone publication this year.[4] A listing of the properties of some of the stones appeared in another Western stone publication.[5] These are the most complete descriptions to appear to date. According to the former source, China produced 17.6 million cubic feet per year of rough granite block and 0.7 million cubic feet of rough marble block. Chinese exports of both stones combined totaled about 330,000 tons. Using these numbers for granite, Chinese production was apparently about three times U.S. production, perhaps 30% to 40% more than Italian production, and approximately twice Spanish production. For marble, Chinese production would appear to be almost one-half Spanish production and 10% to 15% of Italian production.

The article indicated that the Chinese dimension stone industry was rapidly expanding. Reliable estimates have suggested that there were more than 200 stone finishing production lines recently installed in new or renovated plants. Almost $200 million had been invested already, and the process was still continuing. In 1984, there were 40 to 50 plants with a total capacity of 70,500 cubic feet per year assuming an average thickness per piece of 10 centimeters.

Equipment for the stone finishing lines was acquired by direct purchase, installation by joint ventures, or as part of compensation trade packages. All of the equipment will have to be paid for by exporting stone to world markets. Foreign stone buyers will have to be assured of consistent quality and reliable delivery before any large-scale exporting success will occur.

The equipment is mostly Italian, and all of the major machinery manufacturers are well represented. The West German firm Carl Meyer GmbH & Co. also equipped a number of large plants. The Chinese are producing some of the diamond tools used in these modern plants, but otherwise are mostly represented in the plants by non-state-of-the-art equipment.

Current capacities are known for some plants. The Shanghai Marble Factory has a capacity of 1.6 million square feet per year, as does the Yiexian Marble Factory in Shandong. The Lasenco S.A.-associated plant in Fuzhou has a capacity of 3.1 million square feet per year. An older plant in Beijing has a capacity of 750,000 square feet per year. Yixing City in Jiangsu Province was planning to build an 860,000-square-foot-per-year capacity plant.

The publication on technical properties of Chinese marbles not only covered color, texture, and pattern, but also described the appearance of a number of individual stones and the principal minerals each contains. Guidelines for compressive strength, bending strength, and shear strength and the related fastness coefficient were provided. Color was discussed in detail, and colors were classified by the bright-

TABLE 5

DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

Use	1986[r e] Quantity (short tons)	1986[r e] Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Rough stone:				
Rough blocks for building and construction	86,314	$8,037	85,052	$8,621
Irregular-shaped stone[1]	27,347	1,039	27,767	1,108
Flagging	—	—	2,700	165
Monumental	184,149	21,836	220,084	26,003
Other[2]	12,765	444	8,891	383
Dressed stone:				
Ashlars and partially squared pieces	89,132	19,561	106,132	25,275
Slabs and blocks for building and construction	18,417	1,246	11,308	1,405
Flagging	845	45	2,633	468
Monumental	40,395	19,064	37,813	20,311
Curbing	134,555	21,509	119,543	23,082
Other[3]	2,479	130	[r]799	[r]290
Total	**596,398**	**92,911**	**[r]622,722**	**[r]107,111**

[e] Estimated. [r] Revised.
[1] Includes rubble.
[2] Includes rough stone used for flagging and unspecified uses.
[3] Includes flagging and unspecified uses.

TABLE 6

DIMENSION LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

Use	1986[r e] Quantity (short tons)	1986[r e] Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Rough stone:				
Rough blocks for building and construction	131,674	$8,703	137,837	$9,964
Irregular-shaped stone[1]	40,744	640	70,082	1,266
Other[2]	7,889	958	10,623	1,300
Dressed stone:				
Ashlars and partially squared pieces	66,491	13,416	57,030	11,562
Slabs and blocks for building and construction	38,459	8,338	[r]36,036	[r]10,526
Monumental	3,077	397	3,061	264
Curbing	935	56	1,295	68
Flagging	11,721	327	12,735	434
Other[3]	1,758	335	3,112	493
Total[4]	**302,748**	**33,170**	**[r]331,811**	**[r]35,878**

[e] Estimated. [r] Revised.
[1] Includes rubble.
[2] Includes monumental and unspecified uses.
[3] Includes unspecified uses.
[4] Data may not add to totals shown because of independent rounding.

ness and (color) saturation coefficient. Patterns and finishes were also classified into different groupings.

Portugal

The marble industry, centered around Estremoz, recently modernized its equipment and has been growing rapidly. Most quarries in the area were small and apparently opened very recently. Diamond wire saws were fairly universal in the quarrys, although most had clearly been installed very recently, perhaps only a few months ago.

Spain

Spain is a major producer of dimension stone. In 1986 Spain produced 418,000 tons of rough granite block suitable for polishing; 129,000 tons of granite paving setts, curbing, and retaining wall stone; and 304,000 tons of granite building stone for unpolished uses, such as chimneys and church fronts. Spain produced 386,000 tons of roofing slate in the same year. In 1986 Spain produced 716,000 tons of limestone for building purposes, of which 499,000 tons was limestone for uses such as church fronts. Dimension marble production totaled 606,000 tons for all types in 1986.

The Spanish granite industry is quite widespread geographically. Of the total Spanish granite production, roughly 40% is Rosa Porrinho (also known as Spanish Pink) quarried east of Vigo around the town of Porrinho, 25% is granite quarried near Madrid, 20% is granite quarried in Galicia other than Rosa Porrinho, 15% is granite quarried in the Zafra-Badajoz area, and the balance is granite quarried elsewhere. With the exception of some Rosa Porrinho quarries and some gray granite quarries near Quintana, the granite quarries observed were new, small, and very near the surface. With the exception of some finishing plants in the Porrinho and Quintana areas, the granite finishing plants were also very new. In general, land for expansion of quarries and plants appeared to be avail-

TABLE 7

DIMENSION MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

Use	1986[r] [e] Quantity (short tons)	1986[r] [e] Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Rough stone:				
Rough blocks for building and construction	3,860	$613	3,571	$734
Irregular-shaped stone[1]	4,572	255	4,752	350
Monumental	41	1	—	—
Dressed stone:				
Slabs and blocks for building and construction	4,673	5,415	4,706	6,143
Monumental[2]	11,885	11,039	11,342	13,187
Total[3]	**25,031**	**17,321**	**24,371**	**20,413**

[e] Estimated. [r] Revised.
[1] Includes rubble and a minor amount of rough stone used for monumental purposes.
[2] Includes stone used in dressed ashlars and partially squared pieces, and a small amount used in flagging, and unspecified uses.
[3] Data may not add to totals shown because of independent rounding.

TABLE 8

DIMENSION SANDSTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

Use	1986[r] [e] Quantity (short tons)	1986[r] [e] Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Rough stone:				
Rough blocks for building and construction	7,754	$292	11,705	$501
Irregular-shaped stone[1]	22,846	1,449	32,485	1,527
Other[2]	2,096	80	1,846	95
Dressed stone:				
Ashlars and partially squared pieces	27,407	2,411	36,869	1,637
Slabs and blocks for building and construction	546	29	621	27
Flagging	3,376	313	6,695	505
Other[3]	14,099	1,872	26,065	3,007
Total[4]	**78,124**	**6,446**	**116,286**	**7,298**

[e] Estimated. [r] Revised.
[1] Includes rubble.
[2] Includes monumental and unspecified uses.
[3] Includes curbing and unspecified uses.
[4] Data may not add to totals shown because of independent rounding.

able. Industry executives indicated that while production had grown very rapidly, domestic consumption of granite had been growing even more rapidly. Domestic consumption was expected to continue its rapid expansion at least until 1992, when Spain will host the Olympics and have a world's fair.

The Spanish roofing slate industry was running at full capacity and was not bringing on-stream any major new capacity. Around 15% of production was used domestically, and all the rest was exported. The product was gray-black and comes in a number of different sizes, such as 20 by 20 centimeters, 30 by 30 centimeters, and 20 by 30 centimeters. These sizes can be 2½, 4, and 5 millimeters thick. The largest firms used the latest equipment in their open pit quarries such as automatic handheld feather-wedgers and self-propelled circular diamond saws. The finishing plants were well-mechanized to save labor. The smaller firms were believed to be much less up to date.

TECHNOLOGY

An automatic channel burner had come into commercial use at a few quarries. It had the advantages of reducing costs, making a more even cut, wasting less granite, and of not requiring the constant presence of an operator. The automatic channel burner will cut 15 square feet per hour rather than the 8 to 10 square feet per hour obtained with a handheld model. It only costs $1.25 per square foot to cut with the automatic compared to $1.80 to $2.00 per square foot for the handheld model. The automatic channel burner resembles a handheld burner held vertically in a frame attaching it to an electric motor and drive assembly that moves the whole unit slowly down a track. The unit is controlled by a computer that is part of the unit. It is programmed to deal with problems such as intrusions and faults, but will shut itself off if it encounters a nonroutine problem.

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[1] Physical scientist, Branch of Industrial Minerals.

[2] U.S. International Trade Commission. Certain Granite From Italy and Spain. USITC Publication 2110, Aug. 1988, 159 pp.

[3] Taylor, H. A., Jr. The United States Dimension Stone Industry and International Markets. Dimensional Stone, v. 4, No. 6, Sept. 1988, pp. 42-47, 56.

[4] Stone Industries. Investing in China's Stone. V. 23, No. 10, Dec. 1988, pp. 23-29.

[5] Guang-Sheng, F., and Y. Shao-de. Chinese Natural Marble, A Study of Technical Properties. Ind. Miner. (London), No. 253, Oct. 1988, pp. 65-71.

TABLE 9

DIMENSION SLATE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

Use	1986[r e]		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Flagging (slate)	7,695	$1,639	9,086	$1,785
Roofing (slate)	13,928	6,840	14,892	7,626
Structural and sanitary	5,533	2,984	5,636	3,200
Flooring slate	6,214	2,583	7,077	2,963
Other[1]	3,204	920	2,990	873
Total[2]	**36,574**	**14,966**	**39,681**	**16,446**

[e] Estimated. [r] Revised.
[1] Includes a minor amount of slate used for billiard tabletops, blackboards, and unspecified uses.
[2] Data may not add to totals shown because of independent rounding.

TABLE 10

U.S. EXPORTS OF DIMENSION STONE

(Thousand short tons and thousand dollars)

Name	1987		1988		Major destination in 1988 (percent)[1]
	Quantity	Value	Quantity	Value	
Granite articles	NA	2,608	NA	6,236	Canada 49%.
Granite, rough	54.2	7,800	92.2	12,458	Japan 51%.
Limestone, dressed, for building or monumental	2.4	257	8.4	390	United Kingdom 65%.
Limestone articles	18.0	1,000	13.2	463	Canada 74%.
Marble, breccia, and onyx, rough or squared	20.9	514	25.1	399	Canada 62%.
Marble, breccia, and onyx articles	NA	2,694	NA	4,126	Japan 30%.
Slate building articles	NA	213	NA	1,121	Jamaica 72%.
Slate building articles, other	NA	905	NA	912	Canada 26%.
Stone, rough, for building or monumental	19.0	2,280	17.9	2,501	Canada 56%.
Stone, other, including alabaster or jet	NA	2,199	NA	3,613	Canada 22%.
Total	**NA**	**20,470**	**NA**	**32,219**	

NA Not available.
[1] By value.

Source: Bureau of the Census.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF DIMENSION GRANITE, BY COUNTRY

(Thousand cubic feet and thousand dollars)

Country	Rough[1]		Dressed[1]		Other n.s.p.f. undecorated[2] (value)
	Quantity	Value	Quantity	Value	
1986	2,699	6,707	9,635	142,185	8,642
1987:					
Brazil	575	152	315	3,294	199
Canada	5,329	5,125	249	12,621	507
China	5	15	7	273	78
India	9	165	120	2,446	26
Italy	37	587	4,626	89,655	4,606
Japan	—	—	15	188	64
Portugal	593	1,224	20	977	54
Saudi Arabia	1	11	19	303	—
South Africa, Republic of	80	2,435	1	44	—
Spain	1	3	355	10,527	76
Other	703	923	335	7,267	468
Total[3]	**7,333**	**10,641**	**6,063**	**127,594**	**6,078**
1988:					
Brazil	4	83	289	3,891	351
Canada	4,491	5,790	233	15,876	690
China	([4])	1	69	1,312	172
India	9	271	351	4,374	166
Italy	23	253	4,020	103,521	5,147
Japan	—	—	21	252	69
Portugal	246	881	76	936	27
Saudi Arabia	11	155	19	346	—
South Africa, Republic of	91	2,495	([4])	20	37
Spain	26	60	496	14,416	252
Other	36	311	402	9,481	1,679
Total[3]	**4,937**	**10,299**	**5,974**	**154,425**	**8,591**

[1] Does not include nonmanufactured, nonmonumental granite.
[2] Quantity not reported. Excludes granite n.s.p.f. decorated.
[3] Data may not add to totals shown because of independent rounding.
[4] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF MAJOR CATEGORIES OF DIMENSION MARBLE, TRAVERTINE, AND OTHER CALCAREOUS STONES, BY COUNTRY

Country	Marble, breccia, or onyx, polished slabs		Marble, breccia, or onyx other n.s.p.f.[1] [2]	Travertine dressed[3]	
	Quantity (thousand square feet)	Value (thousands)	Value (thousands)	Quantity (short tons)	Value (thousands)
1986	74,069	$123,637	$47,728	173,812	$15,496
1987:					
China	345	686	595	—	—
France	1,307	6,657	464	59	23
Germany, Federal Republic of	320	597	866	—	—
Greece	3,569	9,155	1,042	55	66
Italy	53,338	120,692	29,686	104,508	14,285
Mexico	1,894	3,201	2,567	776	364
Pakistan	26	8	528	—	—
Phillipines	365	763	315	—	—
Portugal	3,240	7,513	1,278	—	—
Spain	15,925	20,161	2,868	1,437	127
Taiwan	4,382	4,813	9,407	—	—
Other	1,934	4,783	3,493	165	261
Total[4]	**86,645**	**179,030**	**53,109**	**107,000**	**15,128**
1988:					
China	856	2,042	1,207	—	—
France	1,163	4,587	559	35	5
Germany, Federal Republic of	268	1,193	875	—	—
Greece	4,376	14,591	1,369	40	42
Italy	39,933	125,285	33,274	140,374	18,501
Mexico	2,408	4,303	3,601	4,961	292
Pakistan	15	37	769	—	—
Phillipines	706	904	308	—	—
Portugal	3,904	8,464	991	—	—
Spain	11,908	24,863	2,952	46	46
Taiwan	2,432	6,405	10,599	18	30
Other	3,091	8,641	4,201	328	79
Total	**71,060**	**201,315**	**60,705**	**145,802**	**18,995**

[1] Excludes certain special kinds of rough marble, breccia, or onyx.
[2] Quantity not reported.
[3] Suitable for use as monumental, paving, or building stone. Excludes travertine articles.
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF OTHER DIMENSION STONE, BY TYPE

Type		1987 Quantity	1987 Value (thousands)	1988 Quantity	1988 Value (thousands)	Major source in 1988 (percent)[1]
Granite, n.s.p.f., decorated		—	$1,344	—	$1,663	Italy 38%.
Limestone, dressed, hewn	short tons	25,545	6,184	10,191	6,229	France 75%.
Marble and breccia, rough	cubic feet	86,538	840	138,599	1,067	Taiwan 38%.
Marble, breccia, onyx, slab and tiles, unpolished	square feet	1,441,111	4,428	1,405,651	5,127	Italy 61%.
Slate, roofing	do.	4,053,425	1,863	6,320,978	2,949	Spain 60%.
Slate, other, n.s.p.f		—	13,404	—	15,585	Italy 70%.
Travertine articles, undecorated		—	8,250	—	7,798	Italy 94%.
Travertine articles, decorated		—	1,573	—	3,012	Italy 90%.
Stone, unmanufactured	short tons	[r]6,457	658	12,850	727	Mexico 42%.
Stone, dressed, building	do.	24,589	2,094	35,432	2,690	Mexico 44%.
Stone, other n.s.p.f., undecorated		—	2,574	—	4,155	Philippines 35%.
Stone, other n.s.p.f., decorated		—	4,486	—	5,604	Philippines 31%.

[r] Revised.
[1] By value.

Source: Bureau of the Census.

SULFUR

By David E. Morse[1]

The United States retained its position as the world's foremost producer and consumer of sulfur and sulfuric acid. Production from U.S. Frasch mines remained low despite a surge in demand, which required a stock drawdown of 1.1 million tons. Two Frasch mines were reactivated and Frasch mining companies acquired leases to 14 blocks in the Gulf of Mexico from the U.S. Department of the Interior.

Production of recovered elemental sulfur, a nondiscretionary byproduct of petroleum refining and natural gas processing, continued to increase, setting a record high. Recovered elemental sulfur shipments to domestic consumers were greater than Frasch shipments and recovered sulfur exports, primarily from California where sulfur supplies exceed local demands, were higher than Frasch sulfur exports.

Byproduct sulfuric acid from the Nation's nonferrous smelters and roasters, essentially mandated by laws concerning sulfur dioxide (SO_2) emissions, supplied a significant quantity of sulfuric acid to the domestic merchant acid market. Marketing sulfuric acid continued to be a problem for many producers because smelters were located near western copper mines and far from large sulfuric acid markets.

Total world production of sulfur in all forms increased over that of 1987; mined sulfur output, however, was static. Recovered elemental production increased in Asia, Eastern Europe, and North America and was slightly less in Western Europe because of declining production from gas plants. Nearly two-thirds of the world's elemental sulfur production came from recovered sources; the quantity of sulfur supplied from these sources was dependent on the world demand for fuels and petroleum products, not on the demand for sulfur.

World consumption increased, especially in the fertilizer sector. Consumption for other industrial uses continued to be pressured by environmental constraints placed on either uses of the products or effluents from the processes. World trade of elemental sulfur increased, by more than 2 million metric tons. World stocks of elemental sulfur were reduced by an estimated 1.7 million tons and contributed to a surplus and low prices in the international marketplace.

DOMESTIC DATA COVERAGE

Domestic production data for sulfur are developed by the Bureau of Mines from four separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Elemental Sulfur" sur-

TABLE 1

SALIENT SULFUR STATISTICS

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Production:					
Frasch	4,193	5,011	4,043	3,202	3,174
Recovered[1]	5,214	5,313	5,816	6,161	6,444
Other forms	1,245	1,285	1,228	1,176	1,128
Total	**10,652**	**11,609**	**11,087**	**10,539**	**10,746**
Shipments:					
Frasch	5,001	4,678	4,108	3,610	4,341
Recovered[1]	5,210	5,266	5,798	6,180	6,470
Other forms	1,245	1,285	1,228	1,176	1,128
Total	**11,456**	**11,229**	**11,134**	**10,966**	**11,939**
Exports, elemental[2]	1,334	1,365	1,895	1,242	1,223
Imports, elemental	2,557	2,104	1,347	1,599	1,996
Consumption, all forms	12,679	11,968	10,586	11,323	12,712
Stocks, Dec. 31: Producer, Frasch and recovered	2,419	2,799	2,748	2,316	1,112
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	$546,106	$573,570	$508,512	$386,834	$430,814
Recovered[1]	416,878	485,084	533,752	492,136	498,368
Other forms	121,692	123,937	105,639	90,707	88,181
Total	**1,084,676**	**1,182,591**	**1,147,903**	**969,677**	**1,017,363**
Exports, elemental[3]	$156,067	$189,248	$251,664	$139,431	$131,863
Imports, elemental[4]	$200,189	$199,240	$142,220	$152,096	$185,864
Price, elemental, dollars per metric ton, f.o.b. mine or plant	$94.31	$106.46	$105.22	$89.78	$85.95
World: Production, all forms (including pyrites)	[r]52,499	[r]54,662	54,655	[p]56,940	[e]58,398

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Includes Puerto Rico and the Virgin Islands.
[2]Includes exports from the Virgin Islands to foreign countries.
[3]Includes value of exports from the Virgin Islands to foreign countries.
[4]Declared customs valuation.

vey. Of the 180 operations to which a survey request was sent, 179 responded, representing 99.98% of the total production shown in tables 1 and 2. The production of the nonrespondent was estimated using prior production history adjusted to reflect trends in output of its primary product.

DOMESTIC PRODUCTION

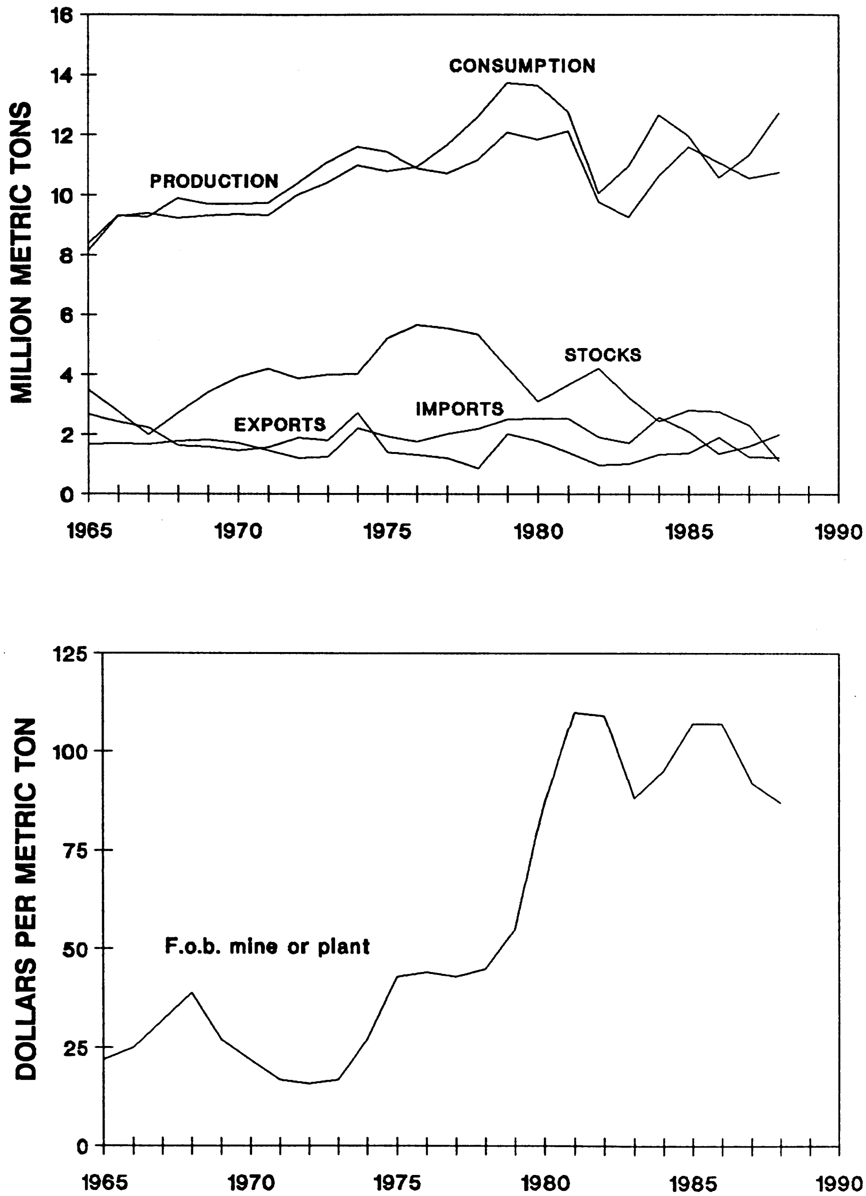
Sulfur is one of the few elements that occurs in the native, or elemental, state. It also occurs combined with iron and base metals as sulfide minerals, and with the alkali metals and alkali earths as sulfate minerals. In coal and petroleum, sulfur is found in a variety of complex organic compounds, and in natural gas as hydrogen sulfide (H_2S) gas. Commercial production of sulfur in the United States is accomplished by a variety of methods dictated by the source of sulfur.

Frasch

Native sulfur associated with the caprock of salt domes and in sedimentary deposits is mined by the Frasch hot water method, in which the native sulfur is melted underground and brought to the surface by compressed air. In January 1988, the United States had four Frasch mines operating in Texas and Louisiana. Mines in Louisiana were Freeport Minerals Co., at Garden Island Bay on the Mississippi River Delta, and Grand Isle, 7 miles offshore in the Gulf of Mexico. Mines in Texas were Pennzoil Sulphur Co., at Culberson, and Texasgulf Inc., at Boling Dome in Wharton County. Texasgulf's Comanche Creek facility in western Texas was brought back on-stream in December. Freeport completed rehabilitation of its Caminada Pass property, which had last produced sulfur in 1968, and began sulfur shipments in October. At yearend the Frasch mining industry was operating at about 70% of realizable capacity.

FIGURE 1

TRENDS IN THE SULFUR INDUSTRY IN THE UNITED STATES



The U.S. Department of the Interior held a sulfur-salt lease sale in February, the first sale in over 20 years. Bids were placed on 14 blocks, and leases for all were approved. In December, Freeport McMoRan Resource Partners announced a major sulfur find on one of the newly acquired leases. The company reported a geologic reserve of 50 million tons on block Main Pass 299 located 17 miles from the mouth of the Mississippi River offshore in the Gulf of Mexico. The announcement was based on the results of five exploratory holes. The company planned additional drilling to fully delineate the deposit in 1989.

Frasch sulfur output decreased 28,000 tons from the quantity produced in 1987. Total shipments to domestic and overseas consumers increased, however, by more than 700,000 tons. Frasch sulfur accounted for 30% of domestic production in 1988, the same as in 1987. Approximately 89% of Frasch sulfur shipments was for domestic consumption, and 11% for export. The total value of Frasch sulfur shipments increased by nearly $44 million.

Recovered

Production of recovered elemental sulfur, a nondiscretionary byproduct from petroleum refining, natural gas processing, and coking plants, accounted for 60% of the total domestic output of sulfur in all forms, compared with 59% in 1987. Both production and shipments reached alltime high levels of more than 6.44 million tons, owing to record production from the Nation's petroleum refineries. Recovered elemental sulfur was produced by 55 companies at 155 plants in 26 States, 1 plant in Puerto Rico, and 1 plant in the U.S. Virgin Islands. Most of these plants were of relatively small size, with only 17 reporting an annual production exceeding 100,000 tons. By source, 61% was produced at 84 refineries or satellite plants treating refinery gases and 3 coking plants. The rest was produced by 29 companies at 69 natural gas treatment plants. The five largest recovered-sulfur producers in 1988 were Chevron U.S.A. Inc., Exxon Co. U.S.A., Shell Oil Co., Standard Oil Co. (Indiana), and Texaco Inc. These companies' 60 plants accounted for 62% of recovered elemental sulfur output during the year.

Mobil Exploration and Producing, U.S. Inc. brought on-stream in April the Mary Ann sour gas field in Mobile Bay, AL. The field is at the lower end of Mobile Bay and the gas processing plant is on a 40-acre site 4 miles east of Coden, AL. The gas plant was designed to process 80 million cubic feet per day of sour gas containing 7.5% hydrogen sulfide (H_2S) and 4.5% carbon dioxide and to recover 230 tons per day of liquid sulfur. From initial lease purchase of Alabama State Blocks 76, 77, 95, and 96 in October 1969 to production required nearly 20 years. The Mary Ann Field, is astride the main shipping channel to Mobile, adjacent to historical and recreational sites, and in commercial fishing waters. Extensive environmental permitting was required for both exploration and development.

Byproduct Sulfuric Acid

Byproduct sulfuric acid at copper,

TABLE 2

PRODUCTION OF SULFUR AND SULFUR-CONTAINING RAW MATERIALS IN THE UNITED STATES

(Thousand metric tons)

	1987		1988	
	Gross weight	Sulfur content	Gross weight	Sulfur content
Frasch sulfur	3,202	3,202	3,174	3,174
Recovered sulfur[1]	6,161	6,161	6,444	6,444
Byproduct sulfuric acid (100% basis) produced at copper, lead, molybdenum, and zinc plants	3,069	1,003	3,443	1,125
Other forms[2]	445	173	7	3
Total	**XX**	**10,539**	**XX**	**10,746**

XX Not applicable.
[1] Includes Puerto Rico and the Virgin Islands.
[2] Includes hydrogen sulfide, liquid sulfur dioxide, and pyrites.

TABLE 3

SULFUR PRODUCED AND SHIPPED FROM FRASCH MINES IN THE UNITED STATES

(Thousand metric tons and thousand dollars)

Year	Production			Shipments	
	Texas	Louisiana	Total[1]	Quantity	Value[2]
1984	2,257	1,937	4,193	5,001	546,106
1985	2,940	2,071	5,011	4,678	573,570
1986	2,463	1,579	4,043	4,108	508,512
1987	1,833	1,369	3,202	3,610	386,834
1988	1,991	1,183	3,174	4,341	430,814

[1] Data may not add to totals shown because of independent rounding.
[2] F.o.b. mine.

TABLE 4

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES[1]

(Thousand metric tons and thousand dollars)

Year	Production			Shipments	
	Natural gas plants	Petroleum refineries[2]	Total	Quantity	Value[3]
1984	2,407	2,807	5,214	5,210	416,878
1985	2,373	2,940	5,313	5,266	485,084
1986	2,246	3,570	5,816	5,798	533,752
1987	2,536	3,624	[4]6,161	6,180	492,136
1988	2,501	3,943	6,444	6,470	498,368

[1] Includes Puerto Rico and the Virgin Islands.
[2] Includes a small quantity from coking operations.
[3] F.o.b. plant.
[4] Data do not add to total shown because of independent rounding.

TABLE 5

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE

(Thousand metric tons and thousand dollars)

State	1987			1988		
	Production	Shipments		Production	Shipments	
		Quantity	Value		Quantity	Value
Alabama	319	319	30,629	375	372	33,634
California	656	670	39,764	697	696	42,852
Florida	72	72	W	68	68	W
Illinois	255	256	26,034	258	258	22,367
Louisiana	538	536	51,074	569	571	53,198
Michigan and Minnesota	152	152	12,648	170	170	13,544
Mississippi	778	780	70,379	764	773	67,266
New Mexico	46	46	2,870	44	44	2,797
North Dakota	126	127	8,000	115	115	7,178
Ohio	42	43	3,915	48	48	4,296
Pennsylvania	59	58	4,417	61	62	5,457
Texas	1,516	1,532	134,232	1,654	1,653	137,635
Wyoming	1,010	1,015	46,629	991	982	44,461
Other[1]	591	576	61,548	627	660	63,684
Total[2]	**6,161**	**6,180**	**492,136**	**6,444**	**6,470**	**498,368**

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Includes Arkansas, Colorado, Delaware, Indiana, Kansas, Kentucky, Montana, New Jersey, Utah, Virginia, Washington, Wisconsin, Puerto Rico, the Virgin Islands, and data indicated by symbol W.
[2] Data may not add to totals shown because of independent rounding.

lead, molybdenum, and zinc roasters and smelters amounted to 10% of the total domestic production of sulfur in all forms. Seven acid plants operated in conjunction with copper smelters, and eight were accessories to lead, molybdenum, and zinc smelting and roasting operations. The five largest acid plants accounted for 71% of the output, and production in five States was 88% of the total. The five largest producers of byproduct sulfuric acid were ASARCO Incorporated, Inspiration Consolidated Copper Co., Kennecott, Magma Copper Co., and Phelps Dodge Corp. Their eight plants produced 86% of the 1988 total.

Magma dedicated a new $150 million flash furnace at its San Manuel, AZ, copper smelter in October. The new furnace and associated sulfuric acid plant replaced three older reverberatory units that had been in use since 1956, and it nearly doubled sulfuric acid capacity.

Pyrites, Hydrogen Sulfide, and Sulfur Dioxide

The total sulfur contained in these products was less than that of 1987 and did not constitute a significant portion of total domestic production. The leading producers were Chevron, Magma, and Phelps Dodge. Tennessee Chemical Co., a long-time pyrites producer that terminated pyrites mining operations in 1987, burned purchased sulfur for sulfuric acid production at its Copper Hill, TN, and Augusta, GA, facilities.

CONSUMPTION AND USES

Domestic consumption of sulfur in all forms increased 12% in 1988. In 1988, 84% of the sulfur was obtained from domestic sources, compared with 86% in 1987. The sources of supply were domestic recovered elemental sulfur, 45%; domestic Frasch sulfur, 30%; and combined domestic byproduct sulfuric acid, pyrites, hydrogen sulfide, and sulfur dioxide, 9%. The remaining

TABLE 6

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT

(Thousand metric tons)

District and source	1987		1988	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	253	246	279	283
Natural gas	72	72	68	68
Total [1]	**325**	**319**	**347**	**351**
PAD 2:				
Petroleum and coke	602	603	640	641
Natural gas	128	128	114	115
Total [1]	**730**	**731**	**755**	**756**
PAD 3: [2]				
Petroleum	1,961	1,966	2,151	2,181
Natural gas	1,336	1,339	1,339	1,338
Total [1]	**3,298**	**3,306**	**3,491**	**3,520**
PAD 4 and 5:				
Petroleum	806	818	871	872
Natural gas	999	1,004	978	969
Total [1]	**1,806**	**1,823**	**1,849**	**1,841**
Grand total [1]	**6,161**	**6,180**	**6,444**	**6,470**

[1] Data may not add to totals shown because of independent rounding.
[2] Includes Puerto Rico and the Virgin Islands.

TABLE 7

BYPRODUCT SULFURIC ACID [1] PRODUCED IN THE UNITED STATES

(Thousand metric tons, sulfur content, and thousand dollars)

Year	Copper plants [2]	Zinc plants [3]	Lead and molybdenum plants [3]	Total	Value
1984	736	145	81	962	59,098
1985	729	141	87	957	56,299
1986	755	124	40	919	54,164
1987	831	134	38	1,003	61,996
1988	946	136	43	1,125	87,820

[1] Includes acid from foreign materials.
[2] Excludes acid made from pyrites concentrates.
[3] Excludes acid made from native sulfur.

16% was supplied by imports of Frasch and recovered elemental sulfur.

The Bureau of Mines collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities. Shipments by end use of elemental sulfur were reported by 61 companies, and shipments of sulfuric acid were reported by 56 companies. Shipments of both elemental sulfur and sulfuric acid were reported by 9 companies.

The largest sulfur end use, sulfuric acid, represented 90% of shipments for domestic consumption. Some identified end uses were tabulated in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipment by end use were also tabulated as "Unidentified." Although there is no supporting data, it could be reasonably assumed that a significant portion of the sulfur in the "unidentified" category could have been shipped to sulfuric acid producers or exported. The difference between exports reported in the canvass and exports of 1.2 million tons reported by the Bureau of the Census may have been caused by differences in accounting between company records and compilations of Census, or by sales to other parties that exported sulfur and were not included in the Bureau of Mines canvass.

In 1988, sulfuric acid retained its position, both domestically and worldwide, as the most universally used mineral acid and the largest volume inorganic chemical in terms of the quantity produced and consumed. U.S. shipments of 100% sulfuric acid increased by more than 3.8 million tons in 1988 because demand for the production of phosphatic fertilizers, the largest single end use of sulfuric acid, increased 11%. Shipments of sulfuric acid for petroleum refining and other petroleum and coal products, the second largest end use, decreased slightly from those of 1987. Demand for sulfuric acid in copper ore leaching was more than 1.4 million tons because high-purity copper could be produced through solvent extraction-

TABLE 8

PYRITES, HYDROGEN SULFIDE, AND SULFUR DIOXIDE SOLD OR USED IN THE UNITED STATES

(Thousand metric tons, sulfur content, and thousand dollars)

Year	Pyrites	Hydrogen sulfide	Sulfur dioxide	Total	Value
1984	W	W	45	283	62,594
1985	W	W	43	328	67,638
1986	W	W	W	309	51,475
1987	W	W	W	173	28,711
1988	W	W	W	3	361

W Withheld to avoid disclosing company proprietary data; included in "Total."

electrowinning (SX–EW) operations at a significantly lower cost than that by conventional smelting methods.

According to the 1988 canvass reports, company receipt of spent or contaminated sulfuric acid for reclaiming totaled 2.9 million tons. The largest source of this spent acid continued to be the petroleum refining industry, which accounted for 57% of the total returned. The petroleum refining industry was a net user of 709,000 tons of sulfuric acid. About 900,000 tons of spent acid was reclaimed from plastic and synthetic materials producers. The remaining reclaimed acid was from manufacturers of soaps and detergents, steel, industrial organic chemicals, other chemical products, storage batteries, explosives, agricultural chemicals, and some unidentified sources. The largest use of sulfur in all forms, for agricultural purposes, increased from 8.2 million tons in 1987 to 9.0 million tons.

STOCKS

Yearend inventories held by Frasch and recovered elemental sulfur producers decreased 52% from those of 1987 to the lowest level in over 70 years. Combined yearend stocks amounted to approximately a 1.2-month supply compared with a 2.8-month supply in 1987, based on domestic and export demands for Frasch and recovered sulfur.

PRICES

The posted price for liquid sulfur ex-terminal Tampa, FL, began the year at $127.50 to $128 per long ton, increased to $132 per long ton in July, and was raised to $138 in October. Spot prices and contract prices for sulfur, f.o.b. Vancouver, British Columbia, Canada, were $90 to $100 per metric ton during the first half of the year; Vancouver spot prices were increased to $97 to $106 per ton in the third quarter. Fourth quarter spot prices from Vancouver recovered slightly by yearend and remained above $100 per ton. The Vancouver first half contract prices of $90 to $93 per ton were increased to $100 to $104 late in the third quarter.

On the basis of total shipments and value reported to the Bureau of Mines, the average value of shipments of Frasch sulfur, f.o.b. mine, for domestic consumption and exports combined decreased from $89.78 to $85.95 per ton. The average value, f.o.b. plant, for shipments of recovered elemental sulfur varied widely by geographic region: lowest in the Rocky Mountain States, higher on the west coast, somewhat higher in the midcontinent, and near the values for Frasch sulfur in the East and South. Although reported values for recovered elemental sulfur were generally lower throughout the Nation, the disproportionately low average value for Wyoming distorted the average calculation for all recovered elemental sulfur shipments.

FOREIGN TRADE

Exports of elemental sulfur from the United States, including the U.S. Virgin Islands, decreased slightly in quantity and 5% in value. According to the Bureau of the Census, exports from the west coast were 533,000 tons or 44% of total U.S. exports.

The United States was a net importer of sulfur with imports exceeding exports by more than 770,000 tons in 1988. Frasch sulfur from Mexico and recovered elemental sulfur from Canada, both delivered to U.S. terminals and consumers in the liquid phase, continued to furnish nearly all U.S. sulfur import requirements. Total elemental sulfur imports increased 25% in quantity; imports by rail from Canada increased 20%, while waterborne shipments from Mexico were 36% higher. An estimated 480,000 tons of sulfur shipped to the west coast of Mexico from Canada and the United States was exchanged for Mexican sulfur delivered to Florida and U.S. east coast ports.

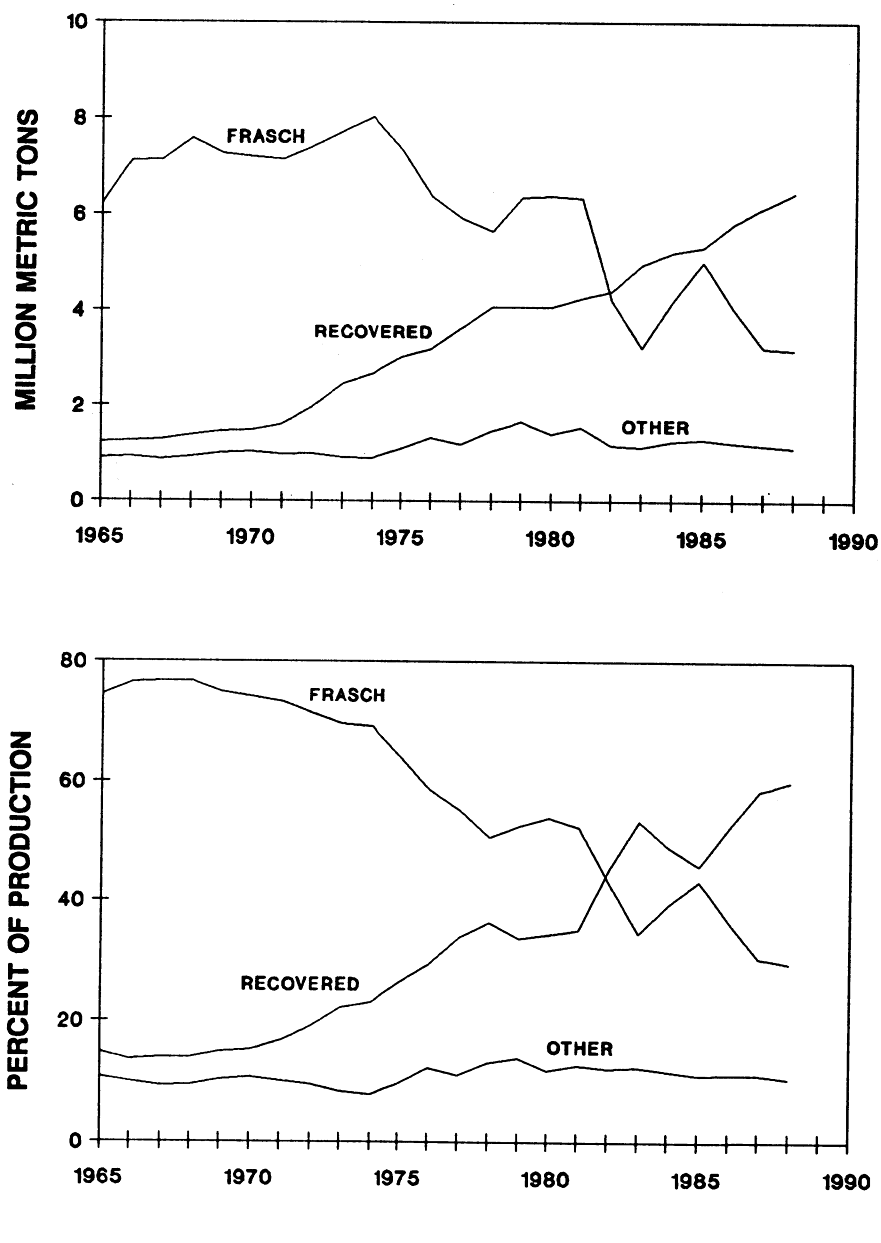
The United States also had significant trade in sulfuric acid. Sulfuric acid exports increased by 50% from those of 1987. Imports, which were significantly greater than exports, were mostly from Canada and increased 25% from the quantity reported in 1987; the value of imported sulfuric acid, however, increased by more than 38%.

WORLD CAPACITY

The data in table 20 are rated capacity for Frasch mines, elemental sulfur mining facilities and attendant benefi-

FIGURE 2

TRENDS IN THE PRODUCTION OF SULFUR IN THE UNITED STATES



ciation plants, pyrites mines and plants, and sulfur/sulfuric acid recovery units associated with petroleum refineries, natural gas processing plants, metal smelting operations, electric powerplants, and coke ovens as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the facility, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with a minimum of capital expenditure. Rated capacity is not equivalent to engineering (design) capacity of installed equipment.

Frasch mines operate continuously and capacity is related to the quantity of superheated water that can be injected into the associated sulfur deposit. The nature of Frasch mining makes capacity quite variable over time and depends on the number of "steaming wells," water injection rates, water losses from the formation, location of wells within the deposit, and length of time that the deposit has been worked. The rated capacity or realizable capacity of a Frasch mine generally decreases as the deposit becomes depleted.

Petroleum refineries, large expensive and complex processing facilities designed to produce a spectrum of fuels and petrochemical products, operate continuously. Sulfur recovery units make up only a small segment of these facilities, but because sulfur recovery is mandated by environmental considerations, the installed sulfur recovery capacity at petroleum refineries generally exceeds the expected sulfur production. To ensure that the loss of a sulfur recovery unit does not require the shutdown of the entire refinery, multiple sulfur recovery units, each capable of servicing the petroleum refinery, are

TABLE 9

CONSUMPTION OF SULFUR[1] IN THE UNITED STATES

(Thousand metric tons)

	1984	1985	1986	1987	1988
Frasch:					
Shipments	5,001	4,678	4,108	3,610	4,341
Imports	722	724	726	793	1,079
Exports	911	986	1,250	465	464
Total	**4,812**	**4,416**	**3,584**	**3,938**	**4,956**
Recovered:					
Shipments[2]	5,210	5,266	5,798	6,180	6,470
Imports	1,835	1,380	621	806	917
Exports	423	379	645	777	759
Total	**6,622**	**6,267**	**5,774**	**6,209**	**6,628**
Pyrites, shipments	W	W	W	W	W
Byproduct sulfuric acid, shipments	962	957	919	1,003	1,125
Other forms, shipments[3]	283	328	309	173	3
Total, all forms	**12,679**	**11,968**	**10,586**	**11,323**	**12,712**

W Withheld to avoid disclosing company proprietary data; included with "Other forms, shipments."
[1] Crude sulfur or sulfur content.
[2] Includes Puerto Rico and the Virgin Islands.
[3] Includes consumption of hydrogen sulfide, liquid sulfur dioxide, and data indicated by symbol W.

TABLE 10

ELEMENTAL SULFUR SOLD OR USED IN THE UNITED STATES, BY END USE

(Thousand metric tons)

SIC	End use	1987	1988
20	Food and kindred products	W	W
26,261	Pulp and paper products	32	8
282,2822	Synthetic rubber, and other plastic products	W	W
287	Agricultural chemicals	541	460
28,286	Other chemical products, and industrial organic chemicals	55	144
284	Soaps and detergents	26	8
29,291	Petroleum refining and petroleum and coal products	180	172
281	Other industrial inorganic chemicals	80	80
30	Rubber and miscellaneous plastic products	W	—
	Sulfuric acid:		
	Domestic sulfur	7,420	8,589
	Imported sulfur	1,493	1,756
	Total	**8,913**	**10,345**
	Unidentified	403	289
	Total domestic uses	**10,230**	**11,506**
	Exports	1,127	1,055
	Grand total	**11,357**	**12,561**

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."

installed. The quantity of sulfur recovered by domestic petroleum refineries in the United States during 1988 was equal to 44% of the installed engineering capacity. Rated capacity for petroleum refineries is assumed to be 50% of installed engineering capacity.

Natural gas processing plants may be installed to service gasfields and/or oilfields that contain significant quantities of associated gas. Gas plants are designed to accommodate the natural gas from a specific field that may contain in addition to methane, which is sold as pipeline gas, varying amounts of nitrogen, carbon dioxide, helium, condensable hydrocarbon liquids, and poisonous hydrogen sulfide. The poisonous nature of hydrogen sulfide makes its removal from pipeline gas imperative. Sulfur removal and recovery plants in natural gas facilities vary in size from small units rated at 5 to 10 tons per day to multiple-train plants capable of recovering thousands of tons per day. In general, sulfur recovery rates from gasfields approximate installed engineering capacity, based on 340- to 345-days-per-year operation of all units, in the first 7 years of operation. In succeeding years, sulfur recovery declines steadily because the gas apparently becomes "sweeter" over time and because gas flow rates drop as the field is depleted. Rated capacity for gas processing plants is based on the age of the plant and its recent production history.

Rated capacity for plants operating in conjunction with metal smelters, powerplants, and coking operations is assumed to approximate engineering capacity. Where information on design capacity is unknown, rated capacity was estimated to be equal to the greatest output recorded by a plant or country in the past 5 years. World rated sulfur annual production capacity is significantly lower than the installed world engineering capacity of approximately 92 million tons.

WORLD REVIEW

World sulfur production, consumption, and trade all increased; international prices for elemental sulfur firmed and recovered somewhat from 1987 levels. International prices in the $90 to $100 range, f.o.b. from Canada and Persian Gulf countries, effectively restricted U.S. Frasch exporters from many of their traditional markets; Frasch sulfur exports remained at the lowest levels since the early 1950's when U.S. Government controls were in place.

Stocks of sulfur worldwide were reduced by nearly 1.7 million tons. Stock levels were reduced by 2.1 million tons in Canada, and more than 1 million tons in the United States. Producers' stocks increased in Iran, Iraq, Saudi Arabia, and the U.S.S.R. Worldwide consumers' stocks increased by an estimated 1.1 million tons.

TABLE 11

SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE

(Thousand metric tons of 100% H_2SO_4)

SIC	End use	1987	1988
102	Copper ores	1,046	1,491
1094	Uranium and vanadium ores	85	103
10	Other ores	52	67
261	Pulpmills	740	826
26	Other paper products	62	31
285, 2816	Inorganic pigments and paints and allied products	360	373
281	Other inorganic chemicals	899	959
282, 2822	Synthetic rubber and other plastic materials and synthetics	773	1,035
2823	Cellulosic fibers, including rayon	140	136
283	Drugs	90	73
284	Soaps and detergents	246	299
286	Industrial organic chemicals	1,178	1,092
2873	Nitrogenous fertilizers	201	243
2874	Phosphatic fertilizers	23,116	25,711
2879	Pesticides	([1])	18
287	Other agricultural chemicals	108	161
2892	Explosives	150	134
2899	Water-treating compounds	301	353
28	Other chemical products	140	155
29, 291	Petroleum refining and other petroleum and coal products	2,427	2,403
30	Rubber and miscellaneous plastic products	12	W
331	Steel pickling	206	226
333	Nonferrous metals	93	49
33	Other primary metals	24	25
3691	Storage batteries (acid)	124	155
	Unidentified	1,316	1,528
	Total domestic	**33,889**	**37,646**
	Exports	44	86
	Grand total	**33,933**	**37,732**

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
[1] Included with "Other agricultural chemicals."

Canada

Shipments of sulfur in all forms were about 9.0 million tons, or 2.1 million tons greater than production. Elemental sulfur exports increased in quantity by about 740,000 tons to nearly 7.4 million tons; exports from Vancouver, British Columbia, increased 11% to 6.46 million tons, and Canada remained the world's largest exporting country.

Noranda Inc. began construction of a 350,000-ton-per-year sulfuric acid plant at its Horne copper smelter in Rouyn-Noranda, Quebec. The acid plant was to reduce SO_2 emissions from the smelter by more than 50%; commissioning was set for mid-1989.

Chile

In July, Mitsubishi Heavy Industries Ltd. of Japan completed construction of a 600,000-ton-per-year sulfuric acid plant designed to recover exhaust gases from the Chuquicamata copper smelter. Corporación Nacional del Cobra de Chile contracted for the acid plant in 1986 to service its new flash smelter, designed by Outokumpu Oy of Finland. Most of the acid plant's output was to be used to treat Chuquicamata's oxide zone copper ore in a heap leach, SX-EW system that was scheduled to recover 80,000 tons per year of copper by 1990. The acid plant's design included oversized components because its 2,700-meter altitude increases the gas volume to be processed by 40%, compared to sea level. In addition, because Chile is in a severe earthquake zone, the design incorporated special components to mitigate any earthquake-related stresses.

Iraq

Sulfur exports continued to be routed overland through neighboring nations despite a cease-fire in the war with Iran. Production was increased at

TABLE 12

SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE

(Thousand metric tons, sulfur content)

SIC	End Use	Elemental sulfur[1]		Sulfuric acid (sulfur equivalent)		Total	
		1987	1988	1987	1988	1987	1988
102	Copper ores	—	—	342	487	342	487
1094	Uranium and vanadium ores	—	—	28	34	28	34
10	Other ores	—	—	17	22	17	22
20	Food and kindred products	W	W	—	—	W	W
26, 261	Pulpmills and paper products	32	8	262	280	294	288
28, 285, 286, 2816	Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products	[2]55	[2]144	118	122	173	266
281	Other inorganic chemicals	80	80	294	313	374	393
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	253	339	253	339
2823	Cellulosic fibers, including rayon	—	—	46	44	46	44
283	Drugs	—	—	29	24	29	24
284	Soaps and detergents	26	8	80	98	106	106
286	Industrial organic chemicals	—	—	385	357	385	357
2873	Nitrogenous fertilizers	—	—	66	79	66	79
2874	Phosphatic fertilizers	—	—	7,556	8,404	7,556	8,404
2879	Pesticides	—	—	([3])	6	([3])	6
287	Other agricultural chemicals	541	460	35	53	576	513
2892	Explosives	—	—	49	44	49	44
2899	Water-treating compounds	—	—	98	115	98	115
28	Other chemical products	—	—	46	51	46	51
29, 291	Petroleum refining and other petroleum and coal products	180	172	793	786	973	958
30	Rubber and miscellaneous plastic products	W	—	4	W	4	W
331	Steel pickling	—	—	67	74	67	74
333	Nonferrous metals	—	—	31	16	31	16
33	Other primary metals	—	—	8	8	8	8
3691	Storage batteries (acid)	—	—	41	51	41	51
	Exported sulfuric acid	—	—	14	28	14	28
	Total identified	**914**	**872**	**10,662**	**11,835**	**11,576**	**12,707**
	Unidentified	403	289	430	499	833	788
	Grand total	**1,317**	**1,161**	**11,092**	**12,334**	**12,409**	**13,495**

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
[1] Does not include elemental sulfur used for production of sulfuric acid.
[2] No elemental sulfur was used in inorganic pigments and paints and allied products.
[3] Included with "Other agricultural chemicals."

the Misraq Mine and from the Kurkuk gas plant. Freeport McMoRan Inc. of the United States and the State Organization for Minerals agreed to establish a filtration plant, using Freeport technology, to treat production from the Misraq Mine that had a high bitumen content.

Mexico

Frasch sulfur production decreased slightly from 1987. Efforts continued to expand production from the newly commissioned Otapan Mine, and exploration for new resources continued. Sulfur imports from Canada and the U.S. west coast were nearly 480,000 tons, which did not appear in official Mexican trade statistics. Most of these imports occurred by means of exchange agreements for deliveries of Mexican Frasch sulfur to the United States.

Construction was completed on a 600,000-ton-per-year sulfuric acid plant at Mexicana de Cobre S.A.'s La Caridad copper smelter. Boliden Chem Trade of Zug, Switzerland, contracted to market the sulfuric acid output from the smelter.

Morocco

Morocco was the world's leading importer of elemental sulfur because of increasing consumption at its phosphate fertilizer facilities at Safi and Jorf Lasfar. Imports increased from 2.0 million to more than 2.9 million tons.

Poland

Sulfur exports of 3.9 million tons included more than 1.8 million tons to Eastern Europe and 1.06 million tons to Western Europe; most of the remainder was shipped to Brazil, Morocco, and Tunisia.

Saudi Arabia

Sulfur production from natural gas processing plants and oil refineries increased slightly. Exports increased substantially to 1.46 million tons from 760,000 tons in 1987. India received nearly 50% of Saudi sulfur exports.

U.S.S.R.

Production of elemental sulfur increased substantially because of increasing output from the Astrakhan natural gas processing plant. Output from this facility, which had four processing trains, was significantly less, however, than the design capacity of 2.7 million tons per year. Construction of the second phase to double the size of the Astrakhan facility was nearly completed during the year.

TECHNOLOGY

Freeport McMoRan Resource Partners was installing a circular-grate furnace in a pilot plant to process waste gypsum from its Uncle Sam, LA, phosphoric acid facility into sulfuric acid and synthetic road aggregate. The 35-ton-per-day pilot plant was to test the viability of the process. If successful, a full-scale plant would be built to reduce the environmental problems associated with waste-gypsum stacks on the "gumbo soils" of Louisiana. In addition, the plant would supply aggregates to the lower Mississippi River area, which relies on imported stone or dredged shell for aggregate material.

[1] Physical scientist, Branch of Industrial Minerals.

TABLE 13

SULFURIC ACID FROM SMELTERS SOLD OR USED IN THE UNITED STATES, BY END USE

(Thousand metric tons of 100% H_2SO_4)

SIC	Use	1987	1988
102	Copper ores	1,039	1,200
1094	Uranium and vanadium ores	70	82
10	Other ores	29	W
26,261	Pulp mills and other paper products	123	81
2816	Inorganic pigments	W	W
281	Other inorganic chemicals	128	130
2823	Cellulosic fibers	W	—
283, 284	Drugs and soaps and detergents	W	W
2873	Nitrogenous fertilizers	W	W
2874	Phosphatic fertilizers	750	689
287	Other agricultural chemicals	37	34
2899	Water-treating compounds	118	191
28	Other chemical products	W	58
29,291	Petroleum refining and other petroleum and coal products	W	W
331	Steel pickling	23	W
33,333	Nonferrous metals and other primary metals	20	35
3691	Storage batteries (acid)	31	47
	Unidentified	913	993
	Total domestic	**3,281**	**3,540**
	Exports	W	W
	Total	**3,281**	**3,540**

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."

FIGURE 3

TRENDS IN THE CONSUMPTION OF SULFUR IN THE UNITED STATES

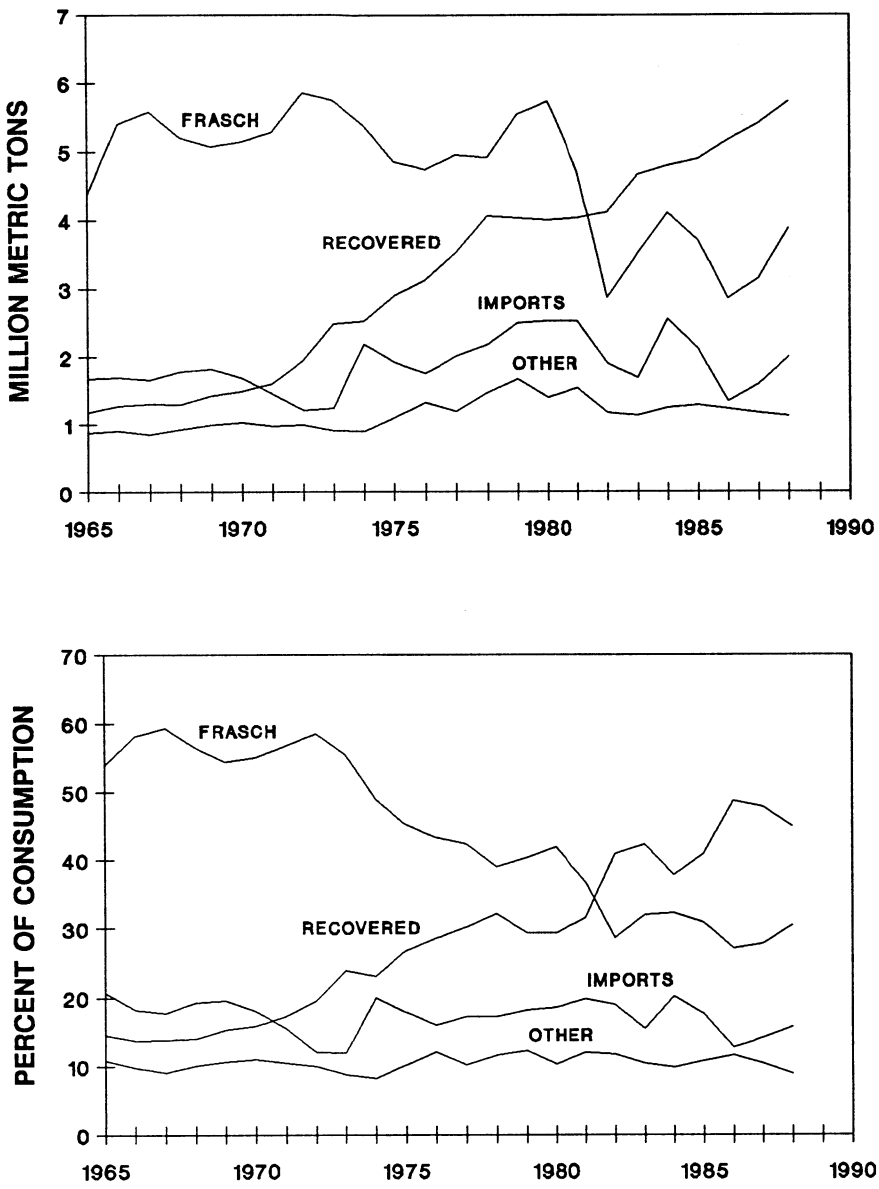
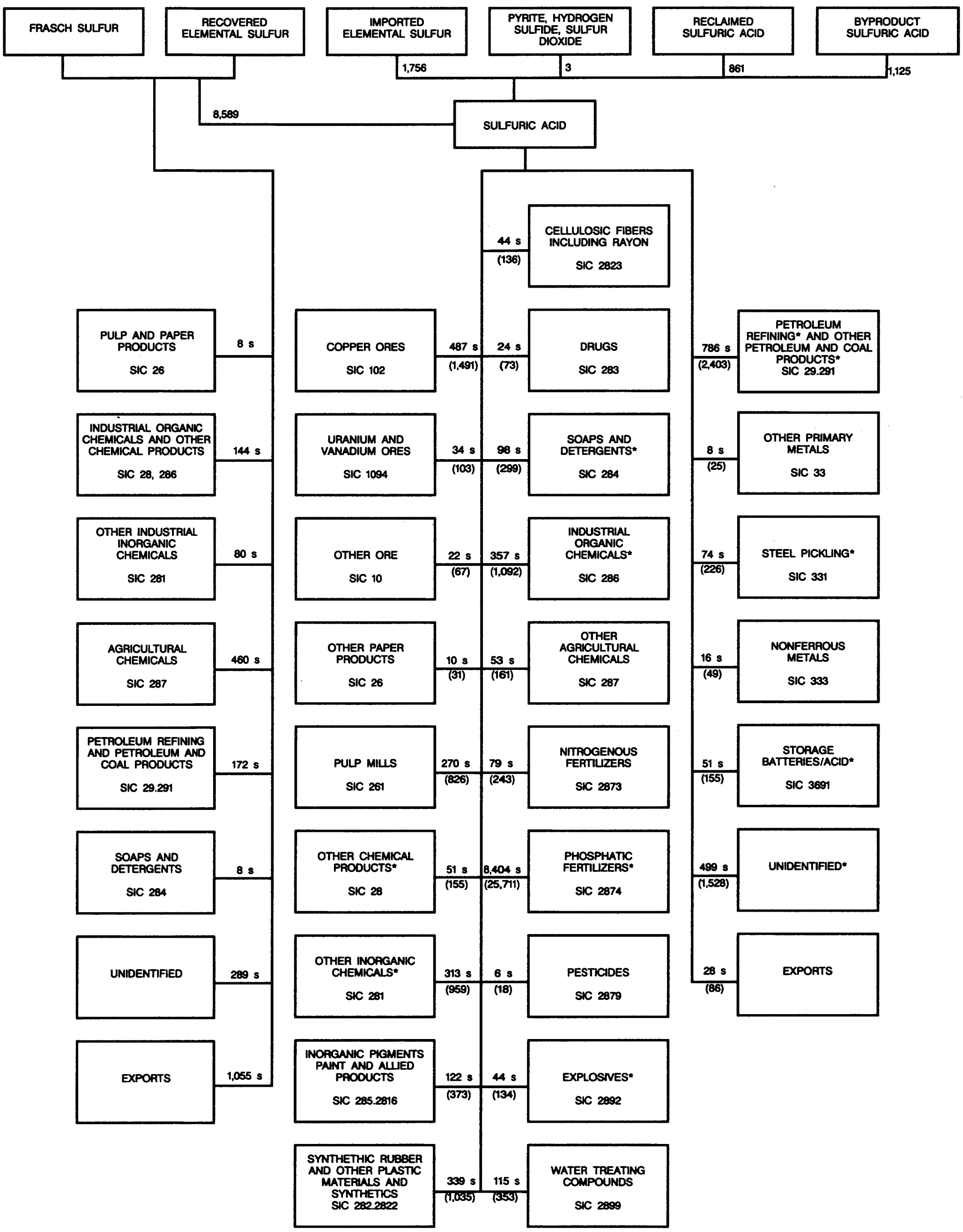


FIGURE 4

SULFUR-SULFURIC ACID SUPPLY AND END-USE RELATIONSHIP IN 1988



#s – SULFUR CONTENT THOUSAND METRIC TONS
(#) – 100% SULFURIC ACID THOUSAND METRIC TONS
★ – SOURCES OF SPENT ACID FOR RECLAIMING

TABLE 14

YEAREND SULFUR STOCKS OF U.S. PRODUCERS

(Thousand metric tons)

Year	Frasch	Recovered	Total
1984	2,264	155	2,419
1985	2,598	201	2,799
1986	2,532	216	2,748
1987	2,122	194	2,316
1988	954	158	1,112

TABLE 15

REPORTED SALES VALUES OF SHIPMENTS OF SULFUR, F.O.B. MINE OR PLANT

(Dollars per metric ton)

Year	Frasch	Recovered	Average
1984	109.20	80.02	94.31
1985	122.62	92.11	106.46
1986	123.79	92.06	105.22
1987	107.15	79.63	89.78
1988	99.24	77.03	85.95

TABLE 16

U.S. EXPORTS[1] OF ELEMENTAL SULFUR, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1987		1988	
	Quantity	Value	Quantity	Value
Argentina	13	1,850	8	932
Australia	12	1,862	12	1,949
Belgium-Luxembourg	217	26,801	300	36,067
Brazil	258	31,532	262	29,137
Canada	15	1,386	33	2,499
Colombia	21	2,255	36	3,343
France	25	2,574	([2])	5
India	85	8,409	39	3,738
Indonesia	24	2,332	59	5,572
Korea, Republic of	14	2,498	21	4,958
Mexico	222	20,798	211	18,820
Morocco	108	10,449	40	3,640
Netherlands	3	173	29	1,352
Nigeria	4	188	6	537
Philippines	1	243	11	1,066
Romania	21	2,110	—	—
Senegal	48	5,127	66	6,603
South Africa, Republic of	26	2,575	([2])	6
Taiwan	23	2,402	22	2,213
Tunisia	64	6,948	21	1,990
Turkey	18	2,064	—	—
Other	[r]19	[r]4,852	48	7,442
Total[3]	**1,242**	**139,431**	**1,223**	**131,863**

[r] Revised.
[1] Includes exports from the Virgin Islands.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 17

U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY

Country	1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	771	$49	5,464	$295
Canada	27,695	943	22,336	857
Chile	9,867	488	28,215	1,586
Costa Rico	1,557	86	1,853	68
Dominican Republic	263	44	607	50
Ecuador	5,044	220	3,375	203
Egypt	1,493	67	75	3
Israel	324	148	2,258	144
Japan	19	22	1,957	67
Korea, Republic of	1,973	991	6,402	1,235
Mexico	16,497	692	27,204	1,663
Netherlands	168	7	1,996	100
Netherlands Antilles	8,966	371	4,291	271
Pakistan	—	—	1,926	64
Panama	2,920	128	4,683	245
Saudi Arabia	1,380	71	5,657	223
Taiwan	3,380	350	4,525	269
Trinidad and Tobago	803	34	1,511	50
United Kingdom	3,194	108	6,516	215
Venezuela	6,368	375	10,513	431
Other	[r]5,272	[r]650	5,870	441
Total	**97,954**	**5,844**	**147,234**	**[1]8,479**

[r] Revised.
[1] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 18

U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1987		1988	
	Quantity	Value[1]	Quantity	Value[1]
Canada	764	52,048	913	58,835
Mexico	793	94,444	1,079	124,878
Venezuela	41	4,897	—	—
Other[2]	1	708	4	2,151
Total	**1,599**	**[3]152,096**	**1,996**	**185,864**

[1] Declared customs valuation.
[2] Includes Belgium, Chile, the Federal Republic of Germany, Japan, and Switzerland in 1987; and France, Gabon, the Federal Republic of Germany, Japan and the Netherlands in 1988.
[3] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 19

U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY

Country	1987 Quantity (metric tons)	1987 Value[1] (thousands)	1988 Quantity (metric tons)	1988 Value[1] (thousands)
Argentina	—	—	2,112	$22
Belgium	12	$42	2	7
Canada	715,008	22,284	807,232	27,429
France	49	155	21	40
Italy	9,444	479	21,110	947
Japan	30,634	916	50,107	1,634
Korea, Republic of	—	—	41	32
Mexico	—	—	47,261	1,906
Spain	5,112	281	14,393	1,237
Sweden	2,281	348	(2)	6
Switzerland	3,600	171	16,452	747
Taiwan	47	68	6	13
Other	r22	r17	2	32
Total[3]	**766,210**	**24,760**	**958,739**	**34,052**

r Revised.
1 Declared c.i.f. valuation.
2 Less than 1/2 unit.
3 Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 20

WORLD SULFUR ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988 RATED CAPACITY, SULFUR IN ALL FORMS[1]

(Thousand metric tons, sulfur content)

North America:	
United States	13,000
Canada	8,000
Total	**21,000**
Latin America:	
Brazil	500
Chile	440
Mexico	2,975
Other	675
Total	**4,590**
Europe:	
Belgium	400
Finland	620
France	2,000
Germany, Federal Republic of	2,451
Italy	760
Netherlands	350
Poland	5,350
Spain	1,550
Sweden	544
Turkey	613
United Kingdom	500
U.S.S.R.	12,500
Yugoslavia	750
Other	1,724
Total	**30,112**
Africa:	
South Africa, Republic of	1,000
Other	270
Total	**1,270**
Asia:	
China[e]	5,450
Iran	500
Iraq	1,600
Japan	4,100
Kuwait	500
Saudi Arabia	1,780
Other	1,400
Total	**15,330**
Oceania	300
World total	**72,602**

e Estimated.
1 Includes capacity at operating plants as well as plants on standby basis.

TABLE 21

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1]

(Thousand metric tons)

Country[2] and source[3]	1984	1985	1986	1987[p]	1988[e]
Algeria: Byproduct, natural gas and petroleum[e]	20	20	20	20	20
Australia:					
Byproduct:					
Metallurgy	[r]203	[r]190	174	194	200
Petroleum	13	12	10	9	9
Total	**[r]216**	**[r]202**	**184**	**203**	**209**
Austria:					
Byproduct:					
Metallurgy	10	11	11	10	11
Natural gas and petroleum	28	24	29	31	31
Gypsum	26	27	24	13	13
Total[4]	**65**	**62**	**64**	**54**	**55**
Bahamas: Byproduct, petroleum[e]	3	1	—	—	—
Bahrain: Byproduct, petroleum	52	[r]36	46	48	48
Belgium: Byproduct, all sources[e]	[r]245	[r]260	[r]300	[r]300	310
Bolivia: Native	2	3	5	9	5
Brazil:					
Frasch	4	4	6	6	6
Pyrites	89	91	92	77	105
Byproduct:					
Metallurgy	52	79	100	153	160
Petroleum	71	55	74	77	80
Total	**216**	**229**	**272**	**313**	**351**
Bulgaria:[e]					
Pyrites	75	65	80	80	70
Byproduct, all sources	62	53	62	65	60
Total	**137**	**118**	**142**	**145**	**130**
Canada:					
Byproduct:					
Metallurgy	875	822	758	723	820
Natural gas	5,260	[r]5,306	5,161	5,249	[5]5,402
Petroleum[e]	165	174	189	190	200
Tar sands	296	392	435	426	[5]485
Total[e]	**6,596**	**[r]6,694**	**6,543**	**[r]6,588**	**6,907**
Chile:					
Native:					
Refined	14	15	13	15	15
From caliche	40	64	44	22	22
Byproduct, metallurgy	[r]90	[r]100	100	130	170
Total	**[r]144**	**[r]179**	**157**	**167**	**207**

See footnotes at end of table.

TABLE 21—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1]

(Thousand metric tons)

Country[2] and source[3]	1984	1985	1986	1987[p]	1988[e]
China:[e]					
Native	200	300	300	300	300
Pyrites	2,100	2,200	2,500	[r]3,700	3,900
Byproduct, all sources	350	400	300	[r]500	550
Total	**2,650**	**2,900**	**3,100**	**[r]4,500**	**4,750**
Colombia:					
Native	36	41	36	41	45
Byproduct, petroleum	10	10	[e]10	[e]10	10
Total	**46**	**51**	**[e]46**	**[r][e]51**	**55**
Cuba: Byproduct, petroleum[e]	[r]5	[r]5	[r]5	[r]5	5
Cyprus:[6] Pyrites	10	31	25	41	40
Czechoslovakia:[e]					
Native	5	[5]6	6	6	6
Pyrites	60	[5]62	60	60	60
Byproduct, all sources	10	[5]12	10	11	11
Total	**75**	**[5]80**	**76**	**77**	**77**
Denmark: Byproduct, petroleum	11	7	13	18	19
Ecuador:[e]					
Native	5	4	4	5	5
Byproduct:					
Natural gas	5	5	5	5	5
Petroleum	5	5	5	5	5
Total	**15**	**14**	**14**	**15**	**15**
Egypt: Byproduct, natural gas and petroleum[e]	[r]4	[r]7	[r]7	[r]8	8
Finland:					
Pyrites	211	248	275	311	300
Byproduct:					
Metallurgy	265	257	[e]260	[e]220	240
Petroleum	45	45	42	[e]40	41
Total	**521**	**550**	**577**	**[e]571**	**581**
France:					
Byproduct:					
Natural gas	1,589	1,386	946	872	[5]762
Petroleum[e]	[5]163	160	180	200	200
Unspecified[e]	110	177	180	180	180
Total	**1,862**	**1,723**	**1,306**	**[e]1,252**	**1,142**
German Democratic Republic: Byproduct, all sources[e]	350	330	315	315	315
Germany, Federal Republic of:					
Byproduct:					
Metallurgy[e 7]	350	320	300	300	310
Natural gas	851	964	998	1,030	1,000

See footnotes at end of table.

TABLE 21—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1]

(Thousand metric tons)

Country[2] and source[3]	1984	1985	1986	1987[p]	1988[e]
Petroleum[e]	190	200	190	210	205
Unspecified[e]	[r]290	[r]285	[r]285	[r]285	280
Total[e]	**[r]1,681**	**[r]1,769**	**[r]1,773**	**[r]1,825**	**1,795**
Greece:[e]					
Pyrites	[5]78	78	66	70	72
Byproduct:					
Natural gas	120	130	130	130	130
Petroleum	5	5	5	5	5
Total	**203**	**213**	**201**	**205**	**207**
Hungary:[e]					
Pyrites	2	2	1	1	1
Byproduct, all sources	9	9	10	10	10
Total	**11**	**11**	**11**	**11**	**11**
India:					
Pyrites	18	7	8	12	10
Byproduct:					
Metallurgy[e]	115	120	120	120	125
Petroleum	[e]5	([8])	[e]1	—	1
Total[e]	**138**	**127**	**129**	**132**	**136**
Indonesia:[6] Native	5	4	5	4	4
Iran:[e]					
Native	30	30	30	30	30
Byproduct, natural gas and petroleum	130	150	250	300	300
Total	**160**	**180**	**280**	**330**	**330**
Iraq:[e]					
Frasch	500	500	600	[r]707	700
Byproduct, natural gas and petroleum	70	70	200	250	350
Total	**570**	**570**	**800**	**[5]957**	**1,050**
Israel: Byproduct, natural gas and petroleum	22	25	29	40	50
Italy:					
Native	8	1	—	—	—
Pyrites	192	280	309	[r e]330	320
Byproduct, all sources[e 9]	[r]350	[r]350	[r]385	[r]370	375
Total[e]	**[r]550**	**[r]631**	**[r]694**	**[r]700**	**695**
Japan:					
Pyrites	259	253	158	79	[5]70
Byproduct:					
Metallurgy	1,191	1,201	1,228	1,225	1,300
Petroleum	1,142	1,044	985	1,012	1,077
Total	**2,592**	**2,498**	**2,371**	**2,316**	**2,447**

See footnotes at end of table.

TABLE 21—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1]

(Thousand metric tons)

Country[2] and source[3]	1984	1985	1986	1987[p]	1988[e]
Korea, North:[e]					
Pyrites	200	200	200	200	200
Byproduct, metallurgy	30	30	30	30	30
Total	**230**	**230**	**230**	**230**	**230**
Korea, Republic of:[e]					
Pyrites	([5] [8])	—	—	—	—
Byproduct:					
Metallurgy	54	55	55	55	55
Petroleum	36	35	35	35	35
Total	**90**	**90**	**90**	**90**	**90**
Kuwait: Byproduct, natural gas and petroleum	237	238	[e]260	[r] [e]310	360
Libya: Byproduct, natural gas and petroleum[e]	14	14	14	14	14
Mexico:					
Frasch	1,364	1,551	1,588	1,806	[5]1,629
Byproduct:					
Metallurgy[e]	160	160	170	180	250
Natural gas and petroleum	461	469	462	498	514
Total[e]	**1,985**	**2,180**	**2,220**	**[r]2,484**	**2,393**
Namibia: Pyrites	104	108	134	74	75
Netherlands: Byproduct, petroleum[e]	245	250	250	245	245
Netherlands Antilles: Byproduct, petroleum[e]	[5]63	25	40	[r]60	60
New Zealand: Byproduct, all sources[e]	[5]1	1	1	1	1
Norway:					
Pyrites	203	193	181	179	170
Byproduct:					
Metallurgy	62	60	67	[e]80	80
Petroleum	8	10	[e]13	[e]15	10
Total	**273**	**263**	**261**	**[r] [e]274**	**260**
Oman: Pyrites[e]	31	31	31	30	30
Pakistan:					
Native	1	1	1	1	1
Byproduct, all sources[e]	26	26	26	26	26
Total[e]	**27**	**27**	**27**	**[r]27**	**27**
Peru:					
Native	([8])	([8])	([8])	([8])	([8])
Byproduct, all sources	64	68	[e]66	[e]66	66
Total	**64**	**68**	**[e]66**	**[e]66**	**66**
Philippines:					
Pyrites	39	108	113	158	160
Byproduct, metallurgy[e]	95	100	120	140	150
Total[e]	**134**	**208**	**233**	**298**	**310**

See footnotes at end of table.

TABLE 21—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1]

(Thousand metric tons)

Country[2] and source[3]	1984	1985	1986	1987[p]	1988[e]
Poland:[10]					
Frasch	4,485	[r]4,326	4,437	4,410	4,400
Native	505	657	550	694	500
Byproduct:[e]					
Metallurgy	170	170	170	170	150
Petroleum	30	30	30	30	20
Gypsum[e]	20	20	20	20	20
Total[e]	**5,210**	**[r]5,203**	**[r]5,207**	**[r]5,324**	**5,090**
Portugal:					
Pyrites	140	155	144	[e]140	142
Byproduct, all sources[e]	[5]4	5	5	5	5
Total[e]	**[5]144**	**160**	**149**	**145**	**147**
Qatar: Byproduct, natural gas	[r]12	37	49	53	55
Romania:[e]					
Pyrites	200	200	150	150	150
Byproduct, all sources	150	150	140	130	120
Total	**350**	**350**	**290**	**280**	**270**
Saudi Arabia: Byproduct, natural gas and petroleum	833	1,100	1,446	1,432	1,450
Singapore: Byproduct, petroleum[e]	[r]50	[r]50	[r]50	[r]50	50
South Africa, Republic of:					
Pyrites	464	562	499	468	470
Byproduct:					
Metallurgy	91	85	[e]108	105	110
Petroleum[e 11]	30	100	110	110	120
Total[e]	**585**	**747**	**717**	**[r]683**	**700**
Spain:					
Pyrites	1,094	1,231	1,195	960	1,100
Byproduct:[e]					
Coal (lignite) gasification	3	2	2	2	2
Metallurgy	[r]205	[r]215	[r]210	[r]225	230
Petroleum	9	7	8	8	8
Total[e]	**[r]1,311**	**[r]1,455**	**[r]1,415**	**[r]1,195**	**1,340**
Sweden:					
Pyrites	212	210	227	[e]220	224
Byproduct:					
Metallurgy	122	123	125	[e]125	124
Petroleum	26	23	49	[e]50	50
Total	**360**	**356**	**401**	**[e]395**	**398**

See footnotes at end of table.

TABLE 21—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1]

(Thousand metric tons)

Country[2] and source[3]	1984	1985	1986	1987[p]	1988[e]
Switzerland: Byproduct, petroleum	3	3	3	4	4
Syria: Byproduct, natural gas and petroleum[e]	35	35	35	40	40
Taiwan: Byproduct, all sources	29	43	63	89	86
Trinidad and Tobago: Byproduct, petroleum[e]	7	([5] [8])	5	[r]5	5
Turkey:					
Native	41	44	41	[e]40	[5]33
Pyrites	—	11	4	[e]30	40
Byproduct, all sources[e]	78	80	80	80	80
Total[e] [4]	**119**	**[r]135**	**[r]126**	**[r]150**	**153**
U.S.S.R.:[e]					
Frasch	[r]900	[r]960	[r]1,100	[r]1,100	1,100
Native	1,800	1,800	1,900	1,900	1,900
Pyrites	[r]2,650	[r]2,421	[r]2,090	[r]2,150	2,150
Byproduct:					
Metallurgy	1,700	1,700	1,700	1,650	1,700
Natural gas	1,850	[5]1,974	2,000	[r]2,850	3,400
Petroleum	[r]350	[r]350	[r]400	450	450
Total	**[r]9,250**	**[r]9,205**	**[r]9,190**	**[r]10,100**	**10,700**
United Arab Emirates: Abu Dhabi:[e]					
Byproduct:					
Natural gas	35	104	[r]104	[r]97	100
Petroleum	15	1	[r]11	[r]8	10
Total	**50**	**105**	**[r]115**	**[r]105**	**110**
United Kingdom:					
Byproduct:					
Metallurgy	71	69	70	64	67
Petroleum	75	80	105	[e]110	107
Spent oxides	1	—	—	—	—
Total[4]	**146**	**149**	**175**	**[e]174**	**174**
United States:					
Frasch	4,193	5,011	4,043	3,202	[5]3,174
Pyrites	W	W	W	W	W
Byproduct:					
Metallurgy	962	957	919	1,003	[5]1,125
Natural gas	2,407	2,373	2,246	2,536	[5]2,501
Petroleum	2,807	2,940	3,570	3,624	[5]3,943
Unspecified	283	328	309	173	[5]3
Total	**10,652**	**11,609**	**11,087**	**10,538**	**[5]10,746**
Uruguay: Byproduct, petroleum[e]	2	2	2	2	2
Venezuela: Byproduct, natural gas and petroleum	86	88	99	[r,e]125	125
Yugoslavia:					
Pyrites and pyrrhotite	[r]263	[r]221	327	264	258
Byproduct:[e]					
Metallurgy	160	170	175	175	170

See footnotes at end of table.

TABLE 21—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1]

(Thousand metric tons)

Country[2] and source[3]	1984	1985	1986	1987[p]	1988[e]
Petroleum	3	3	3	3	3
Total[e]	**[r]426**	**[r]394**	**[r]505**	**[r]442**	**431**
Zaire: Byproduct, metallurgy[e]	37	36	36	[r]37	38
Zambia:					
Pyrites	18	28	19	45	45
Byproduct, metallurgy[e]	[r]79	[r]79	[r]74	[r]74	74
Total[e]	**[r]97**	**[r]107**	**[r]93**	**[r]119**	**119**
Zimbabwe:[e]					
Pyrites	25	25	25	25	25
Byproduct, all sources	5	5	5	5	5
Total	**30**	**30**	**30**	**30**	**30**
Grand total[4]	**[r]52,499**	**[r]54,662**	**54,655**	**56,940**	**58,398**
Of which:					
Frasch	[r]11,446	[r]12,352	11,774	11,231	11,009
Native	[r]2,692	[r]2,970	2,935	3,067	2,866
Pyrites	[r]8,737	[r]9,021	8,913	9,854	10,187
Byproduct:					
Coal (lignite) gasification	3	2	2	2	2
Metallurgy	[r]7,149	[r]7,109	7,080	7,188	7,689
Natural gas	[r]12,129	[r]12,279	11,639	12,822	13,355
Natural gas and petroleum, undifferentiated	[r]1,940	[r]2,240	2,851	3,068	3,262
Petroleum	[r]5,644	[r]5,668	6,439	6,638	7,027
Spent oxides	1	—	—	—	—
Tar sands	296	392	435	426	485
Unspecified sources	[r]2,416	[r]2,582	2,542	2,611	2,483
Gypsum	46	47	44	33	33

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Byproduct: Unspecified sources."

[1] Table includes data available through May 31, 1989.

[2] In addition to the countries listed, a number of nations may produce limited quantities of either elemental sulfur or compounds (chiefly H_2S or SO_2) as a byproduct of petroleum, natural gas, and/or metallurgical operations, but output, if any, is not quantitatively reported, and no basis is available for the formulation of reliable estimates of output. Countries not listed in this table that may recover byproduct sulfur from oil refining include Albania, Bangladesh, Brunei, Burma, Costa Rica, Guatemala, Honduras, Jamaica, Malaysia, Nicaragua, Paraguay, and the People's Democratic Republic of Yemen. Albania and Burma may also produce byproduct sulfur from crude oil and natural gas extraction. No complete listing of other nations that may produce byproduct sulfur from metallurgical operations (including processing of coal for metallurgical use) can be compiled, but the total of such output is considered as small. Nations listed in the table that may have production from sources other than those listed are identified by individual footnotes.

[3] The term "source" reflects both the means of collecting sulfur and the type of raw material. Sources listed include the following: (1) Frasch recovery; (2) native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); (3) pyrites (whether or not the sulfur is recovered in the elemental form or as acid); (4) byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers; and (5) recovery from the processing of mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded because to include it would result in double counting. It should be noted that production of Frasch sulfur, other native sulfur, pyrites-derived sulfur, mined gypsum-derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw material; in contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides is credited to the nation where the recovery takes place, which in some instances is not the original source country of the crude product from which the sulfur is extracted.

[4] Data may not add to totals shown because of independent rounding.

[5] Reported figure.

[6] In addition, may produce limited quantities of byproduct sulfur from oil refining.

[7] Includes only the elemental sulfur equivalent of sulfuric acid produced as a byproduct from metallurgical furnaces; additional output may be included under "Byproduct: Unspecified sources."

[8] Less than 1/2 unit.

[9] Includes recovery from gypsum, if any.

[10] Official Polish sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

[11] Estimates for 1985–88 include byproduct production from synthetic fuels.

TALC AND PYROPHYLLITE

By Robert L. Virta[1]

Domestic production of talc and pyrophyllite increased 7% from that of 1987. Sales of crude and processed talc and pyrophyllite increased 5% in tonnage and 6% in value. Imports for consumption increased 66% in tonnage and 19% in value. Exports increased 32% in tonnage and 38% in value.

DOMESTIC DATA COVERAGE

Domestic production and sales data for talc and pyrophyllite are developed by the Bureau of Mines from a voluntary survey of U.S. mines and mills. Of the 52 mines and mills to which a survey request was sent, 32 responded, representing 62% of the U.S. production data shown in table 1. Production for the 20 nonrespondents was estimated using reported prior-year production levels adjusted by trends in employment and other guidelines.

LEGISLATION AND GOVERNMENT PROGRAMS

The Occupational Safety and Health Administration (OSHA) extended through July 21, 1989, an administrative stay on its 1986 regulation governing worker exposure to the nonasbestiform varieties of actinolite, anthophyllite, and tremolite. During the stay, OSHA continued to analyze the impact of using the asbestos standard to regulate the nonasbestiform varieties of the minerals. An exposure limit of 2 fibers per cubic centimeter will remain in effect during the stay.[2]

OSHA also proposed revisions to air contaminant standards. The proposed ruling establishes or modifies exposure limits for more than 300 substances, including soapstone and nonasbestiform talc. Permissible exposure limits of 6 and 3 milligrams per cubic meter were proposed for respirable and total soapstone dust, respectively. A permissible exposure limit of 2 milligrams per cubic meter was proposed for nonasbestiform talc.[3]

The Environmental Protection Agency (EPA) continued its review of the national emission standards for hazardous air pollutants. As part of this review, the EPA continued to collect data for a study of the asbestos and other mineral fiber content of mine emissions for producers of eight mineral commodities, including talc.

DOMESTIC PRODUCTION

Talc

U.S. mine production of crude talc increased 7% in tonnage and 1% in value. Talc and soapstone were produced at mines in 10 States. Mines that operated in Montana, New York, Texas, and Vermont accounted for 92% of domestic talc production. Montana led all States in the tonnage and value of talc produced. Montana Talc Co. applied for operating permits for a pro-

TABLE 1

SALIENT TALC AND PYROPHYLLITE STATISTICS

(Thousand short tons and thousand dollars)

	1984	1985	1986	1987	1988
United States:					
Mine production, crude:					
Talc	1,042	1,188	1,219	r1,190	1,269
Pyrophyllite	85	81	83	92	107
Total[1]	**1,127**	**1,269**	**1,302**	**r1,282**	**1,377**
Value:					
Talc	$21,755	$27,768	$29,687	r$27,265	$27,624
Pyrophyllite	1,412	1,420	1,540	1,607	1,820
Total	**23,167**	**29,188**	**31,227**	**r28,872**	**29,444**
Sold by producers, crude and processed:					
Talc	1,101	1,067	1,070	r1,075	1,123
Pyrophyllite	97	81	83	90	103
Total	**1,198**	**1,148**	**1,153**	**r1,165**	**1,226**
Value:					
Talc	$112,515	$114,542	$111,924	r$113,394	$119,460
Pyrophyllite	3,578	3,273	3,366	3,712	4,188
Total[1]	**116,093**	**117,815**	**115,290**	**r117,107**	**123,648**
Exports[2] (talc)	256	237	234	318	421
Value	$16,162	$14,282	$16,302	$21,040	$29,091
Imports for consumption[3] (talc)	45	47	52	53	88
Value	$9,156	$9,532	$8,715	$10,348	$12,268
Consumption, apparent[4]	1,009	1,079	1,120	r1,017	1,044
World: Production	r8,345	r8,443	8,251	p8,367	e8,432

e Estimated. p Preliminary. r Revised.
[1] Data may not add to total shown because of independent rounding.
[2] Excludes powders-talcum (in package), face, and compact.
[3] Excludes imported pyrophyllite.
[4] Production, plus imports, minus exports, plus adjustments in Government and industry stock changes.

posed mine about 12 miles southeast of Dillon, MT. The company planned to produce approximately 624,000 short tons of ore over an 8-year period.[4]

Cyprus Industrial Minerals Inc. completed its acquisition of Vermont Talc Co. The purchase of Vermont Talc included one mine in Windham, one mine near Troy, a mill in Chester, and a flotation mill in Johnson. Cyprus Industrial Minerals indicated that pharmaceutical-, paint-, paper-, and plastic-grade talc can be produced at the Johnson site and industrial-grade talc can be produced at the Chester site.[5]

The company also completed its acquisition of Windsor Minerals Inc., a major talc producing company in Vermont. Windsor Minerals owns several mines and two mills. The company produces cosmetic- and industrial-grade talc.[6]

Pyrophyllite

Pyrophyllite was produced by four companies operating six mines in California and North Carolina. Production increased 16% over that of 1987.

CONSUMPTION AND USES

Apparent domestic consumption of crude and processed talc and pyrophyllite increased 3%. Sales of talc and pyrophyllite increased 5% in tonnage and 6% in value.

End-use distribution of ground talc was ceramics, 34%; paint, 14%; paper, 13%; roofing, 11%; plastics, 10%; cosmetics, 5%; and insecticides, refractories, rubber, and other, 13%. The largest portion, 55%, of domestically produced ground pyrophyllite was used in ceramics; 14% in refractories, 7% in insecticides, and 24% in paint, plastics, roofing, rubber, and other.

PRICES

Talc prices varied depending on the quality and on the degree and method of processing. The average unit values of crude talc and crude pyrophyllite were $22 and $17 per ton, respectively. The average unit values of processed talc and processed pyrophyllite were $106 and $41 per ton, respectively. Unit values for imported crude and ground talc ranged from $66 per ton to $583 per ton. The average unit value for all imported talc was $140 per ton. Unit values for exported talc ranged from $25 per ton to $498 per ton and averaged $69 per ton.

Prices, quoted by the Engineering and Mining Journal, April 1988, per short ton of domestic ground talc, in carload lots, f.o.b. mine or mill, in-

TABLE 2

CRUDE TALC AND PYROPHYLLITE PRODUCED IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1987		1988	
	Quantity	Value	Quantity	Value
Georgia (talc)	20	286	26	260
Montana (talc)	r356	r11,334	378	11,309
Texas (talc)	255	4,380	261	4,466
Other[1]	r650	r12,872	712	13,409
Total	**r 2 1,282**	**r28,872**	**1,377**	**29,444**

r Revised.
[1] Includes Alabama, Arkansas, California, New York, North Carolina, Oregon, Vermont, and Virginia.
[2] Data do not add to total because of independent rounding.

TABLE 3

END USES FOR GROUND TALC AND PYROPHYLLITE

(Thousand short tons)

Use	1987			1988		
	Talc r	Pyrophyllite	Total r 1	Talc	Pyrophyllite	Total[1]
Ceramics	314	83	398	343	81	425
Cosmetics[2]	45	—	45	50	—	50
Insecticides	(3)	12	12	(3)	10	11
Paint	141	2	143	143	—	143
Paper	128	—	128	135	—	135
Plastics	88	1	89	100	4	103
Refractories	2	21	23	1	20	21
Roofing	104	1	105	106	1	106
Rubber	19	(3)	20	20	(3)	21
Other[4]	122	14	136	110	30	140
Total[1]	**963**	**135**	**1,099**	**1,008**	**147**	**1,154**

r Revised.
[1] Data may not add to totals shown because of independent rounding.
[2] Incomplete data. Some cosmetic talc known to be included in "Other."
[3] Less than 1/2 unit.
[4] Includes art sculpture, asphalt filler and coatings, crayons, floor tile, foundry facings, rice polishing, stucco, and other unspecified uses.

cluding containers, follows:

New Jersey:	
Mineral pulp, bags extra	$18.50-$20.50
Vermont:	
98% through 325 mesh, bulk	70.00
99.99% through 325 mesh, bags:	
Dry processed	147.00
Water beneficiated	213.00-228.00
New York:	
96% through 200 mesh	67.00- 75.00
98% to 99.25% through 325 mesh	83.00-100.00
100% through 325 mesh, fluid-energy ground	165.00
California:	
Standard	130.00
Fractionated	37.00- 71.00
Micronized	150.00-220.00
Cosmetic steatite	44.00- 65.00
Georgia:	
98% through 200 mesh	50.00
99% through 325 mesh	60.00
100% through 325 mesh, fluid-energy ground	100.00

Prices, quoted by the American Paint & Coatings Journal, December 26, 1988, in U.S. dollars per short ton for paint-grade talc in carload lots were as follows:

California:	
Bags, mill:	
White, Hegman No. 3-3½	$103.00
Hegman No. 4-5	129.00
Canada: Fine micron, Hegman No. 6	205.00
Montana: Ultrafine grind, Hegman No. 6	203.00
New York:	
Nonfibrous, bags, mill:	
98% through 325 mesh	80.00
99.6% through 325 mesh	95.00
Trace retained on 325 mesh	160.00

Approximate equivalents, in dollars per short ton, of price ranges quoted in Industrial Minerals (London), December 1988, for talc, c.i.f. main European ports, were as follows:

Norwegian:	
Ground (ex store)	$162-$180
Micronized (ex store)	207- 288
French, fine-ground	216- 342
Italian, cosmetic-grade	315
Chinese, normal (ex store):	
UK 200 mesh	254
UK 325 mesh	265
New York, paint, minimum 20-ton lot	175

FOREIGN TRADE

Talc exports increased 32% in tonnage and 38% in value. Mexico remained the largest importer of talc, followed by Canada, Belgium-Luxembourg, and Japan. Favorable exchange rates and slightly increased usage in Europe resulted in increased exports to Belgium. Exports to Mexico also increased in 1988.

Talc imports increased 64% in tonnage and 19% in value. Australia and Canada provided 77% of all talc imports.

WORLD CAPACITY

The data in table 6 are annual rated capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

WORLD REVIEW

The United States remained the world's largest talc producer, and Japan remained the largest pyrophyllite producer. China, Japan, and the United States accounted for 46% of the world's talc and pyrophyllite production.

Cyprus Industrial Minerals completed its acquisition of Distribuidora Malagueña de Talcos S.A. (DIMTASA). DIMTASA owned surface mines and a mill near Málaga, Spain. Cyprus Industrial Minerals will process high-value talc from Australia and the United States at the Málaga mill for the paint, paper, and plastics industries. The company will continue to sell talc from the Malaga mine to industrial markets in northern and southern Europe.[7]

TECHNOLOGY

In modernizing its mines in Italy, Talco e Grafite Val Chisone Co. increased production capabilities by changing from an overhand cut-and-fill method to an underhand horizontal slicing method with cemented backfill. To take advantage of the increased production capabilities, the company investigated electrically powered, rubber-tired loaders as replacements for compressed-air-powered rocker shovels and battery-powered trains as a means of improving the efficiency of ore loading and transport. The change from rocker shovels and trains to rubber-tired loaders resulted in greater safety for the miners, less dust because of the absence of compressed air exhaust, fewer loading maneuvers, lower noise levels, and a 32% reduction in the production cost per ton.[8]

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[1] Physical scientist, Branch of Industrial Minerals.

[2] Federal Register. Occupational Safety and Health Administration. Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite. V. 53, No. 139, July 20, 1988, pp. 27345-27346.

[3] ———. Occupational Safety and Health Administration. Air Contaminants. V. 53, No. 109, June 7, 1988, pp. 20960-21393.

[4] Montana (Butte) Standard. Talc Companies Apply for Permits Near Dillon. Jan. 23, 1988.

[5] Rutland Herald. Vermont Talc's Assets Are Sold. Apr. 22, 1988, p. 15.

[6] Cyprus Industrial Minerals News Bulletin. Cyprus Minerals Acquires U.S. and European Talc Properties. Sept. 8, 1988, p. 1.

[7] Work cited in footnote 6.

[8] Partrucco, M., A. Rostagnotto, and G. Longo. The Use of Rubber-Tired LHD's in Fontane Talc Mine, Italy. Min. Mag., June 1988, pp. 460-465.

TABLE 4

U.S. EXPORTS OF TALC[1]

(Thousand short tons and thousand dollars)

Year	Belgium-Luxembourg		Canada[2]		Japan		Mexico		Other[3]		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1984	11	722	76	5,265	22	1,518	107	3,696	40	4,961	256	16,162
1985	6	373	81	4,864	18	1,422	108	4,492	24	3,131	237	14,282
1986	15	1,273	59	4,411	22	1,707	112	4,464	27	4,447	[4]234	16,302
1987	30	2,482	61	5,000	26	2,405	149	5,614	52	5,538	318	[4]21,040
1988	61	8,017	68	5,079	39	4,549	204	6,150	49	5,296	421	29,091

[1] Excludes powders-talcum (in package), face, and compact.
[2] Probably includes shipments in transit through Canadian ports.
[3] Includes 43 countries in 1988.
[4] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF TALC, BY COUNTRY

Country	Crude and unground		Ground, washed, powdered, or pulverized		Cut and sawed		Talc n.s.p.f.	Total unmanufactured[1]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Value (thousands)	Quantity (short tons)	Value (thousands)
1986	10,086	$715	40,253	$5,951	1,634	$1,254	$795	51,973	$8,715
1987:									
Australia	1,450	87	—	—	—	—	—	1,450	87
Brazil	—	—	277	42	398	151	12	675	205
Canada	—	—	38,729	5,362	108	128	65	38,837	5,555
China	—	—	—	—	386	288	275	386	563
Italy	216	24	85	24	1,123	1,090	—	1,424	1,138
Korea, Republic of	—	—	917	252	34	19	—	951	271
Other[2]	8,438	805	777	431	288	341	952	9,503	2,529
Total[1]	**10,104**	**916**	**40,784**	**6,112**	**2,337**	**2,017**	**1,304**	**53,225**	**10,348**
1988:									
Australia	20,122	1,468	22	2	—	—	—	20,144	1,470
Brazil	—	—	543	88	204	59	36	747	184
Canada	402	36	46,305	6,384	110	149	40	46,817	6,609
China	9,126	599	—	—	768	435	342	9,894	1,376
Japan	694	95	811	330	19	24	66	1,524	515
Korea, Republic of	—	—	1,916	402	19	13	2	1,935	418
Other[2]	4,917	419	1,353	473	183	200	604	6,453	1,696
Total	**35,261**	**2,617**	**50,950**	**7,679**	**1,303**	**880**	**1,090**	**87,514**	**12,268**

[1] Data may not add to totals shown because of independent rounding.

[2] Includes 21 countries.

Source: Bureau of the Census.

TABLE 6

WORLD TALC AND PYROPHYLLITE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand short tons)

	Rated capacity[1]
North America:	
Canada	330
United States	1,500
Total	**1,830**
Latin America:	
Argentina	50
Brazil	500
Mexico	40
Other	40
Total	**630**
Europe:	
Austria	150
Finland	400
France	400
Italy	180
Norway	150
U.S.S.R.	600
Other	260
Total	**2,140**
Africa:	
Egypt	14
South Africa, Republic of	20
Other	1
Total	**35**
Asia:	
China	1,300
India	500
Iran	35
Japan	1,800
Korea, North	200
Korea, Republic of	1,100
Other	90
Total	**5,025**
Oceania:	
Australia	250
World total	**9,910**

[1] Includes capacities of operating plants as well as plants on standby basis.

TABLE 7

TALC AND PYROPHYLLITE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina (talc, steatite, pyrophyllite)	[r]25,104	[r]17,575	24,640	25,585	22,000
Australia (talc, chlorite, steatite, pyrophyllite)	205,867	153,652	207,294	209,196	210,000
Austria (unground talc)	147,722	144,903	146,959	143,255	143,000
Brazil (talc and pyrophyllite)[3]	455,637	426,647	416,736	440,924	441,000
Burma	100	141	62	24	28
Canada (shipments) (talc, pyrophyllite, soapstone)	138,891	139,993	135,584	155,000	155,000
Chile	465	1,432	2,488	1,080	990
China[e]	1,050,000	1,100,000	1,100,000	1,100,000	1,100,000
Colombia	7,479	9,492	9,935	13,147	13,200
Egypt	13,463	8,488	9,700	[r e]7,300	7,700
Finland	360,976	351,138	313,253	[e]364,000	364,000
France (ground talc)	322,315	342,705	347,189	[r e]362,440	364,000
Germany, Federal Republic of (marketable)	19,030	22,835	24,123	21,809	22,000
Greece (steatite)	1,887	1,901	[e]2,000	1,661	1,750
Hungary[e]	19,300	18,700	17,700	16,500	14,300
India (pyrophyllite and steatite)	460,473	422,111	436,520	453,239	452,000
Iran	39,022	33,951	[e]34,200	[e]34,200	34,200
Italy (talc and steatite)	157,329	142,875	166,676	166,138	170,900
Japan[4]	1,652,303	1,580,978	1,470,441	1,429,661	1,395,500
Korea, North[e]	185,000	185,000	185,000	185,000	185,000
Korea, Republic of (talc and pyrophyllite)	935,475	1,027,880	879,291	939,026	937,000
Mexico	9,811	32,959	26,787	19,256	22,000
Nepal[5]	8,372	6,630	9,678	3,901	4,400
Norway[e]	[6]124,561	110,000	110,000	110,000	110,000
Pakistan (pyrophyllite)	17,161	22,248	25,376	[e]27,500	27,500
Paraguay[e]	[6]165	132	132	132	132
Peru (talc and pyrophyllite)	10,183	551	10,040	9,370	8,800
Philippines	1,022	380	[e]1,100	([7])	—
Portugal	6,838	3,976	4,565	[e]4,400	4,400
Romania[e]	72,000	72,000	72,000	72,000	72,000
South Africa, Republic of[8]	15,886	15,925	14,602	12,646	[6]14,576
Spain (steatite)	[r]87,775	97,859	89,812	[e]88,000	93,700
Sweden	19,712	15,432	2,205	[e]2,200	2,200
Taiwan	20,591	19,357	23,757	24,363	22,000
Thailand (talc and pyrophyllite)	31,393	47,926	43,046	46,132	44,000
U.S.S.R.[e]	570,000	570,000	570,000	580,000	580,000
United Kingdom	[r]21,399	22,046	13,230	13,811	13,200
United States (talc and pyrophyllite)	1,127,421	1,268,750	1,302,179	[r]1,281,789	1,376,560
Uruguay[e]	[6]1,828	1,700	1,700	1,700	1,700
Zambia	405	[r e]2,200	293	284	290
Zimbabwe	314	482	879	569	550
Total	**[r]8,344,675**	**[r]8,442,950**	**8,251,172**	**8,367,238**	**8,431,576**

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 24, 1989.
[2]In addition to the countries listed, Czechoslovakia produces talc, but available information is inadequate to make reliable estimates of output levels.
[3]Total of beneficiated and salable direct shipping production of talc and pyrophyllite.
[4]Includes talc, pyrophyllite, and pyrophyllite clay.
[5]Data based on Nepalese fiscal year beginning mid-July of year stated.
[6]Reported figure.
[7]Revised to zero.
[8]Includes talc and wonderstone.

THORIUM

By James B. Hedrick[1]

Mine production of monazite, the principal source of thorium, decreased slightly in 1988. Associated Minerals (USA) Inc. was the only domestic monazite producer. Monazite produced in the United States was exported, and the thorium products used domestically were derived from imported materials, existing company stocks, and thorium nitrate released from the National Defense Stockpile (NDS). W. R. Grace & Co. and Rhône-Poulenc Inc., a subsidiary of Rhône-Poulenc S.A. of France, were the principal processors of thorium-containing ores in the United States. Rhône-Poulenc was the only producer of thorium-containing compounds.

Major nonenergy uses were in refractory applications, ceramics, and mantles for incandescent lanterns. The only energy use of thorium in the United States was in the high-temperature gas-cooled (HTGC) nuclear reactor at Fort St. Vrain, CO.

DOMESTIC DATA COVERAGE

Domestic mine production data for thorium-bearing monazite are developed by the Bureau of Mines from a voluntary survey of U.S. operations. This is the "Rare Earths and Thorium" survey. The one mine to which a survey form was sent responded, representing 100% of total production. Mine production data for thorium contained in monazite are withheld to avoid disclosing company proprietary data. Additional statistics on thorium were developed by surveying various processors and end users, and evaluating import-export reports.

LEGISLATION AND GOVERNMENT PROGRAMS

Public Law 99-661, the U.S. Department of Defense Authorization Act for Fiscal Year 1987, authorized the disposal from the NDS of 4,536 kilograms (10,000 pounds) of thorium nitrate; Public Law 100-180, the U.S. Department of Defense Authorization Act for Fiscal Years 1988 and 1989, extended the disposal authority of Public Law 99-661 to fiscal years 1988 and 1989. Public Law 100-180 authorized the President of the United States to change stockpile requirements for individual stockpiled items by amounts up to 10%, the changes to be effective on or after the first day of the next fiscal year. Changes greater than 10% would require congressional approval. In addition, Public Law 100-180 directed the President to designate a single Federal office to have responsibility for the NDS.

On February 25, 1988, the President signed Executive Order 12616, designating the Secretary of Defense to be the manager of the NDS.[2] The Office of the Secretary of Defense delegated operational management functions of the NDS to the Defense Logistics Agency. Previously, the NDS responsibilities were distributed among the U.S. Department of Defense, the Federal Emergency Management Agency, and the General Services Administration.

DOMESTIC PRODUCTION

Associated Minerals, a subsidiary of the Australian-owned firm Associated Minerals Consolidated Ltd., in turn a wholly owned subsidiary of Renison Goldfields Consolidated Ltd. (RGC) of Australia, was the only commercial minerals sands operation in the United States to produce thorium-containing monazite in 1988. The monazite was produced as a byproduct of minerals sands mined for titanium and zirconium minerals at Green Cove Springs, FL.

CONSUMPTION AND USES

Domestic thorium processors reported consumption of an estimated 63.6 metric tons of thorium oxide equivalent in 1988, an increase of 24 tons from the 1987 level. Nonenergy uses accounted for almost all of the total. The increase in consumption was primarily the result of increased demand for thorium oxide used in refrac-

TABLE 1

SALIENT U.S. REFINED THORIUM STATISTICS[1]

(Metric tons of ThO_2, unless otherwise specified)

	1984	1985	1986	1987	1988
Exports: Metal, waste and scrap	1.01	1.64	17.01	20.41	2.74
Imports: Compounds, gas mantles, metals	45.37	69.34	19.71	30.69	13.23
Shipments from Government stockpile excesses	—	2.17	—	—	3.06
Consumption, apparent nonenergy applications[e 2]	44.36	74.36	72.38	39.41	63.63
Prices, yearend, dollars per kilogram, ThO_2:[3]					
Nitrate, mantle-grade	$10.10	$10.10	$13.60	$10.10	$13.80
Oxide, 99% grade	$35.85	$35.85	$40.00	$41.00	$45.00

[e] Estimated.
[1] Some data through 1985 have been revised to reflect only refined products; excludes monazite concentrates with 1985.
[2] All domestically consumed thorium was derived from imported metals, alloys, and compounds; monazite containing 350 to 550 tons of thorium oxide has been imported annually but has not recently been used to produce thorium products.
[3] Rhône-Poulenc Inc.

TABLE 2

U.S. COMPANIES WITH THORIUM PROCESSING AND FABRICATING CAPACITY

Company	Plant location	Operations and products
Atomergic Chemetals Corp.	Plainview, NY	Produces oxide, fluoride, metal.
Bettis Atomic Power Laboratory.	West Mifflin, PA	Nuclear fuels; Government research and development.
Cerac Inc.	Milwaukee, WI	Produces ceramics.
Ceradyne Inc.	Santa Ana, CA	Produces advanced technical ceramics.
Chicago Magnesium Casting Corp.	Blue Island, IL	Magnesium-thorium alloys.
Coleman Co. Inc.	Wichita, KS	Produces thoriated mantles.
Controlled Castings Corp.	Plainview, NY	Magnesium-thorium alloys.
GA Technologies Inc.	San Diego, CA	Nuclear fuels.
W. R. Grace & Co., Davison Chemical Div.	Chattanooga, TN	Produces thorium compounds from monazite.
GTE Sylvania	Towanda, PA	Produces thoriated welding rods.
Hitchcock Industries Inc.	South Bloomington, MN	Magnesium-thorium alloys.
Phillips Elmet	Lewiston, ME	Produces thoriated welding rods.
Rhône-Poulenc Inc.	Freeport, TX	Produces thorium nitrate from an intermediate compound of monazite.
Spectrulite Consortium Inc.	Madison, IL	Magnesium-thorium alloys.
Teledyne Cast Products	Pomona, CA	Do.
Teledyne Wah Chang	Huntsville, AL	Produces thoriated welding rods.
Union Carbide Corp., Nuclear Div.	Oak Ridge, TN	Nuclear fuels; test quantities.
Wellman Dynamics Corp.	Creston, IA	Magnesium-thorium alloys.
Westinghouse Materials Co. of Ohio.[1]	Cincinnati, OH	Produces compounds and metals; manages DOE thorium stocks.

[1] Manager of U.S. Department of Energy stocks; formerly NLO Inc., prior to Jan. 1, 1986.

tory applications and ceramics. Domestic environmental concerns over the natural radioactivity of thorium continued to increase the industry handling, storage, and disposal costs, which were expected to continue to encourage the search for nonradioactive substitutes. The approximate distribution of thorium by end use, based on information supplied by producers, primary processors, and several consumers, was as follows: refractory applications, 71%; lamp mantles, 11%; ceramics, 8%; welding electrodes, 5%; aerospace alloys, 3%; and other applications, including lighting, 2%.

Almost all thorium used in metallurgical applications was alloyed with magnesium. Magnesium-thorium alloys used by the aerospace industry are lightweight and possess high-strength and excellent creep resistance at elevated temperatures, properties that are useful in aerospace applications. Small quantities of thorium were used in dispersion-hardened nickel alloys for high-strength, high-temperature applications.

Thorium oxide (thoria) had the highest melting point of all the oxides, 3,300° C, a property that contributed to its use in several refractory applications, including high-strength high-temperature ceramics, investment molds, crucibles, and research on heat-dissipative core-retention beds for nuclear reactors.

Thorium nitrate was used in the manufacture of mantles for incandescent "camping" lanterns and for oil lamps. Thorium nitrate was also used to produce thoriated tungsten welding electrodes. Thoriated tungsten welding electrodes were used to join stainless steels, nickel alloys, and other alloys that require a continuous and stable arc to achieve quality welds. The nitrate form was also used to produce thoriated tungsten elements used in the negative pole of magnetron tubes. Thorium was used because of its ability to emit electrons at relatively low temperatures when heated in a vacuum. Magnetron tubes were used to emit electrons at microwave frequencies to heat food in microwave ovens and in radar communication.

Thorium was used in other types of electron-emitting tubes, in bulbs to light airport runways, in special high-refractivity glass, in radiation detectors, in computer memory components, in catalysts, in photoconductive films, in target materials for X-ray tubes, and in fuel-cell elements.

In its only domestic energy application, thorium was used as a nuclear fuel in the thorium-232/uranium-233 fuel cycle in one domestic commercial reactor.

STOCKS

Government stocks of thorium nitrate in the NDS were 3,223,993 kilograms (1,541,810 kilograms of equivalent thorium oxide) on December 31, 1988, a decrease of 6,407 kilograms from the yearend 1987 inventory. The NDS goal at yearend was 272,155 kilograms of thorium nitrate (130,153 kilograms of equivalent thorium oxide); remaining stocks have been declared excess to goal.

The U.S. Department of Energy's inventory at yearend was 1,244,047 kilograms of thorium oxide equivalent contained in ore, metal, and various compounds, essentially unchanged from the yearend 1987 inventory.

PRICES

The average declared value of imported monazite increased during 1988 to $600 per ton, up $40 from the 1987 value. The price range of Australian monazite (minimum 55% rare-earth oxide including thoria, f.o.b.-f.i.d.),[3] as quoted in Australian dollars (A$),[4] increased from A$660–A$710 per ton at yearend 1987, to A$700–A$780 per ton by yearend 1988. Changes in the United States-Australian foreign exchange rate in 1988, resulting from the continued economic weakness of the U.S. dollar against Australian currency, caused the corresponding U.S. prices to be about $0.13 higher on the dollar. The U.S. price range, converted from Australian dollars, increased from US$477–US$513[5] in 1987 to US$598–US$666[6] in 1988.

Using the above price range for monazite concentrate and a thorium oxide content of 7%, the value of the thorium content of monazite was in the range of $8.54 to $9.52 per kilogram of equivalent thorium oxide.

Rhône-Poulenc quoted prices for thorium compounds per kilogram, net 30 days, f.o.b. Freeport, TX, or duty paid at point of entry, effective January 1, 1988, as follows: thorium oxide, 99% purity, $45.00; and 99.99% purity, $70.00. Rhône-Poulenc Canada quoted thorium nitrate of 99.5% purity (mantle-grade) at $13.87 per kilogram, net 30 days, f.o.b. Toronto, Canada.

Thorium alloy prices quoted by Magnesium Elektron at yearend 1988 were $45.32 per pound for thorium hardener (60% Mg-40% Th) in single drum quantities and $5.48 per pound for thorium-containing HZ-32 magnesium alloy ingot.

FOREIGN TRADE

Canada, France, and Panama were the destinations of U.S. exports classified as "thorium ore, including monazite," in 1988. Thorium products processed and manufactured in the United States in 1988 were derived mainly from imported materials, primarily thorium compounds and rare-earth concentrates that originated in France and Indonesia, and magnesium-thorium al-

TABLE 3

U.S. FOREIGN TRADE IN THORIUM AND THORIUM-BEARING MATERIALS

(Quantity in kilograms unless ctherwise specified)

	1986 Quantity	1986 Value	1987 Quantity	1987 Value	1988 Quantity	1988 Value	Principal destinations and sources, 1988
EXPORTS							
Thorium ore, monazite	581,854	$326,846	582,995	$427,838	e490,314	$310,384	France 468,702; Canada 18,649; Panama 2,963.
Metals[1]	14,949	954,604	17,961	402,370	2,406	54,271	France 1,678; United Kingdom 514; Italy 167; Canada 47.
IMPORTS							
Ore and concentrate:							
Thorium ore, monazite metric tons	2,960	1,105,996	1,121	627,312	1,924	1,154,498	Indonesia 1,144; Australia 382; Thailand 201; Malaysia 197.
ThO_2 content	211,700	XX	r89,680	XX	127,220	XX	
Compounds:							
Nitrate	21,534	283,841	34,670	653,986	15,900	221,322	France 14,401; Canada 1,499.
Oxide	7,084	166,334	11,625	346,218	4,101	158,933	Netherlands 2,061; France 1,866; United Kingdom 174.
Oxide equivalent, in gas mantles[e] [2]	1,668	495,797	1,824	606,344	862	284,673	India 618; Malta 117; other 127.
Other	658	187,119	656	250,355	663	213,677	United Kingdom 518; other 145.
Metals and alloys	60,062	NA	22,019	NA	15,167	NA	All from United Kingdom.
Unwrought, waste and scrap	—	—	1,149	37,999	77	2,550	All from Canada.

eEstimated. rRevised. NA Not available. XX Not applicable.

[1] Unwrought, wrought, waste and scrap.

[2] Based on the manufacture of 2,205 gas mantles per kilogram of thorium oxide.

Sources: Bureau of the Census and a producer.

loys from the United Kingdom.

WORLD CAPACITY

Thorium is produced as a byproduct during the extraction of the rare-earth elements, primarily from the rare-earth phosphate mineral, monazite. However, demand for thorium is minuscule compared to the amount generated from processing rare earths, and most thorium produced is discarded.

Processing facilities in Brazil, China, France, India, the U.S.S.R., the United Kingdom, and the United States separated thorium from monazite, but only a portion of the thorium separated was processed into thorium products. Total world output of separated thorium products was believed to be equivalent to about 400 tons of thorium oxide. Capacity data are withheld to avoid disclosing individual company data.

WORLD REVIEW

Australia

Wimmera Industrial Minerals (WIM), a subsidiary of CRA Limited, announced the commissioning of a 120-ton-per-day pilot plant at its mineral sands deposit near Horsham, Victoria. The deposit, designated WIM 150, contains reserves of 1 billion tons of sand grading in excess of 3% heavy minerals, including 600 thousand tons of thorium-bearing monazite.[7]

SX Holdings Ltd. announced plans to construct three processing facilities at Port Pirie, South Australia. The initial project will treat Chinese rare-earth concentrates using Chinese technology to produce experimental rare-earth fertilizers. A second plant is planned to recover rare earths and scandium from tailings from the Radium Hill Mine. The third facility planned was a rare earth and thorium separation plant scheduled to process 2,000 tons per year of thorium-bearing monazite. It was expected that most if not all of the thorium separated by SX Holdings will be discarded as residue.[8]

Mineral Deposits Ltd. reported plans to expand its mineral sands production to Queensland, primarily to meet strong demand for zircon and rutile. In addition to doubling its capacity to produce these minerals, an additional amount of thorium-containing monazite would be produced.[9]

Brazil

Production of monazite concentrates in 1986 was 3,618 tons: 197 tons from the State of Espirito Santo (a decrease from the 281 tons produced in 1985) and 3,421 tons from the State of Rio de Janeiro (a decrease from the 1985 production of 3,672 tons).

Measured reserves of monazite, located in the States of Bahia, Espirito Santo, Parana, and Rio de Janeiro, were 16,709 tons.[10] Estimated thorium oxide content based on these reserves is 1,086 tons.

Madagascar

The Government of Madagascar announced a joint-venture project to produce mineral sands, including monazite, in Madagascar. The Quebec Iron and Titanium Corp. of Canada, would reportedly commence mineral sands production in Madagascar in 1993.

Mozambique

Kenmar Resources PLC of Ireland and the Geological Survey of Yugoslavia, partners in a joint venture to recover mineral sands, delineated reserves at 28 million tons of ore grading 8% heavy minerals. Analysis of the heavy minerals indicated a monazite content of 1.3%. Commercial production was planned for late 1989.[11]

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Federal Register. National Defense Stockpile Manager. V. 53, No. 39, Feb. 29, 1988, p. 6114.

[3] Free on board/free into container depot.

[4] Metal Bulletin (London). Non-Ferrous Ores in Europe. Dec. 31, 1987, p. 29.

[5] Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of A$1.3841=US$1.00 based on yearend 1987 foreign exchange rates reported by the Wall St. J.

[6] Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of A$1.1710=US$1.00 based on yearend 1988 foreign exchange rates reported by the Wall St. J.

[7] CRA Limited Press Release. Wimmera Industrial Minerals Granted Development Lease. Dec. 8, 1988, 1 p.

[8] Industrial Minerals (London). SX Holdings RE Treatment Plant. No. 256, Jan. 1989, p. 11.

[9] ———. Mineral Deposits To Increase Minsands Production. No. 252, Sept. 1988, pp. 16–17.

[10] Anuário Mineral Brasileiro 1987. Monazita. Pp. 261–262.

[11] Industrial Minerals (London). Mozambique—Mineral Sands Venture. No. 244, Jan. 1988, pp. 9–10.

TABLE 4

MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Australia	16,260	18,735	14,822	12,813	13,500
Brazil	3,622	1,895	1,947	1,560	2,000
India[e]	4,000	4,000	4,000	4,000	4,000
Malaysia	4,980	5,808	5,959	2,908	3,900
Mozambique[e]	4	4	4	4	4
South Africa, Republic of[e]	1,000	1,000	1,000	1,200	1,200
Sri Lanka[e]	[3]147	200	200	200	200
Thailand	298	[r]663	1,609	458	500
United States	W	W	W	W	W
Zaire	2	—	7	97	100
Total	**[r]30,313**	**[r]32,305**	**29,548**	**23,240**	**25,404**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]Table includes data available through Apr. 27, 1989.
[2]In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and the U.S.S.R. may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.
[3]Reported figure.

TIN

By James F. Carlin, Jr.[1]

For the eighth consecutive year, there was a world excess of tin, but the excess narrowed considerably and was believed to be about 40,000 metric tons at yearend. Repercussions from the exhaustion of the International Tin Council (ITC) fund to support the tin price in late 1985 continued throughout 1988. Legal actions continued against the London Metal Exchange (LME) and the ITC, brought by the tin dealers and banks who had alleged monetary losses due to activities of the LME and ITC in late 1985. The price of tin remained in a fairly narrow band with a slightly rising trend. World tin mine and smelter output rose appreciably for the first time in recent years while producers strove to meet rising world demand. In the United States there was increased interest in detinning used tin cans, due to dwindling dumpsites and new detinning technology. Two major detinning facilities, each of which would primarily process used tin cans, were announced for a 1989 start. Two meetings were held in Geneva, Switzerland, under the auspices of the United Nations Conference on Trade and Development (UNCTAD) to explore the possibility of establishing an International Tin Study Group. Considerable progress was reported, but no final decision was made.

DOMESTIC DATA COVERAGE

Both U.S. mines voluntary furnished production data to the Bureau of Mines. The data on domestic production, which was negligible, was withheld to avoid disclosing company proprietary data.

LEGISLATION AND GOVERNMENT PROGRAMS

On February 25, 1988, the President

TABLE 1

SALIENT TIN STATISTICS

(Metric tons unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Production:					
Mine	W	W	W	W	W
Smelter	4,000	e3,000	3,213	13,905	11,467
Secondary	15,417	14,109	14,850	r16,159	e15,088
Exports[2]	1,429	1,478	1,547	1,318	1,209
Imports for consumption:					
Metal	41,224	33,830	35,768	41,150	43,493
Ore (tin content)	3,272	1,616	3,936	2,953	2,837
Consumption:					
Primary	37,201	36,524	r33,327	r35,620	37,008
Secondary	11,114	12,145	r10,197	8,599	8,065
Stocks, yearend, U.S. industry	9,679	12,359	13,857	14,641	14,972
Prices, average cents per pound:					
New York market	567.80	525.90	294.12	309.01	367.78
Metals Week composite	623.80	3595.95	3383.22	418.78	441.42
London	556.55	3556.26	NA	NA	NA
Kuala Lumpur[4]	564.95	3540.70	3272.26	303.45	319.86
World: Production:					
Mine	r188,183	r180,759	172,899	p177,205	e200,798
Smelter	r192,979	r193,703	181,381	p187,373	e204,340

eEstimated. pPreliminary. rRevised. NA Not available; the tin contract was suspended from London Metal Exchange trading on Mar. 12, 1986. W Withheld to avoid disclosing company proprietary data; U.S. mine production for 1984-88 was negligible.
[1] Reported figure.
[2] Exports (excluding reexports).
[3] Prices quoted for 10 months only.
[4] Beginning in 1985, Kuala Lumpur replaced Penang as the reference market.

signed Executive Order 12616, designating the Secretary of Defense to be the manager of the National Defense Stockpile (NDS).[2] The Office of the Secretary of Defense delegated management of the NDS to the Defense Logistics Agency. Previously, the NDS responsibilities were distributed among the Department of Defense, the Federal Emergency Management Agency, and the General Services Administration.

The Department of Defense sold 2,385 tons of tin in 1988, all of which represented payment for Defense's Ferroalloy Upgrading Program, which started April 11, 1984. At yearend, the NDS inventory was 174,269 tons; the stockpile goal was 42,674 tons.

Federal laws provided a depletion allowance of 22% for domestic operations and 14% for U.S. companies producing in other countries.

DOMESTIC PRODUCTION

Primary Tin

Mine Production.—One mine operating in Alaska produced tin concentrates. Total output amounted to only a small fraction of domestic tin requirements.

Smelter Production.—The only domestic tin smelter, TexTin Corp., in Texas City, TX, recovered tin primarily from imported and domestic concentrates, secondary tin-bearing materials, and its own stockpile of tin residues and slags. The smelter's main source of tin concentrate was Peru. The facility also produced a line of solder.

Secondary Tin

The United States was believed to be the world's largest producer of secondary tin. Tin metal recovered from tinplate scrap was the only type of secondary tin available as free tin; other secondary tin was available in scrap materials as an alloying ingredient. Secondary tin from recycled fabricated parts was an important source of material for the solder and the brass and bronze industries. The Steel Can Recycling Association in Pittsburgh, PA, funded and operated by five domestic tinplate producers, sought to advance the collection, preparation, and transportation of can scrap.

Generally, all domestic detinning operations treated only new factory-generated tinplate scrap, primarily from steel plant tin mills or can plants. Little or no old scrap, such as that from used tin cans, was detinned, primarily owing to technical difficulties in processing the cans. In recent years, new scrap preparation procedures were developed, especially a new shredding method, which permitted detinning of used tin cans. This development, combined with increased incentives for municipal recycling of trash due to lack of landfill space, set the stage for large-scale detinning of used tin cans. Proler International Corp. announced construction of a new detinning plant, with a 1989 startup, that would treat mostly used tin cans. Similarly, AMG Resources Corp. announced plans to build a new detinning facility near Princeton, NJ, with a 1989 starting date, devoted primarily to processing used tin cans. In future years, these developments should provide increased tonnages of secondary tin and augment the domestic supply of scrap steel, which has recently been in short supply.

CONSUMPTION AND USES

Primary tin consumption increased over that of 1987, mainly owing to gains in applications for solder, tinplate, and tin chemicals. Solder was the largest application for primary tin, followed closely by tinplate and then by tin chemicals. Tinplate continued to lose markets to aluminum in some container applications. Tinplated steel and tin-free steel accounted for 29% of the 113.3 billion metal cans shipped and aluminum accounted for 71%. In 1987, when steel accounted for 31% and aluminum for 69%, 109.2 billion metal cans were shipped.[3] Aluminum held an overwhelming segment of the beverage can market, while steel predominated in the food can and the general packaging markets.

PRICES

The price of tin metal, as published in Metals Week, remained in a narrow price band all year, with a slightly rising trend. Since tin trading on the LME was suspended in 1986, the price of tin has been largely determined by the only organized tin trading medium, the Kuala Lumpur Commodities Exchange (Malaysia), and by direct negotiation between suppliers, dealers, and users. LME officials held meetings to consider resumption of trading in tin contracts.

TABLE 2

TIN RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY FORM OF RECOVERY

(Metric tons unless otherwise specified)

Form of recovery	1987[r]	1988
Tin metal[1]	1,353	578
Bronze and brass[e 2]	10,245	9,778
Lead and tin alloys:		
Antimonial lead	623	902
Babbitt	77	112
Solder	3,765	3,619
Type metal	66	70
Other alloys[3]	30	29
Total	**4,561**	**4,732**
Tin content of chemical products	W	W
Grand total	**16,159**	**[e]15,088**
Value (thousands)[e 4]	$149,188	$146,831

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1] Includes tin metal recovered at detinning and other plants.
[2] Includes tin recovered from copper, lead, and tin-base scrap.
[3] Includes foil, terne metal, and cable lead.
[4] Based on Metals Week composite price.

TABLE 3

U.S. CONSUMPTION OF PRIMARY AND SECONDARY TIN

(Metric tons)

	1984	1985	1986[r]	1987[r]	1988
Stocks, Jan. 1[1]	8,063	8,430	9,336	9,876	10,217
Net receipts during year:					
Primary	38,813	38,006	35,475	38,451	38,854
Secondary	6,110	8,904	11,636	11,707	12,461
Scrap	6,791	7,471	6,346	6,635	6,707
Total receipts	**51,714**	**54,381**	**53,457**	**56,793**	**58,022**
Total available	**59,777**	**62,811**	**62,793**	**66,669**	**68,239**
Tin consumed in manufactured products:					
Primary	37,201	36,524	33,327	35,620	37,008
Secondary	11,114	12,145	10,197	8,599	8,065
Total	**48,315**	**48,669**	**43,524**	**44,219**	**45,073**
Intercompany transactions in scrap	317	214	354	512	630
Total processed	**48,632**	**48,883**	**43,878**	**44,731**	**45,703**
Stocks, Dec. 31 (total available less total processed)	11,145	13,928	18,915	21,938	22,536

[r] Revised.
[1] Includes tin in transit in the United States.

TABLE 4

TIN CONTENT OF TINPLATE PRODUCED IN THE UNITED STATES

Year	Tinplate waste (waste, strips, cobbles, etc., gross weight) (metric tons)	Tinplate (all forms) Gross weight (metric tons)	Tin content[1] (metric tons)	Tin per metric ton of plate (kilograms)
1984	151,540	2,409,399	8,659	3.6
1985	146,041	2,215,042	9,321	4.2
1986	120,186	2,068,246	8,660	4.2
1987	[r]141,842	[r]2,302,173	10,357	[r]4.5
1988	148,963	2,359,711	11,064	4.7

[r] Revised.
[1] Includes small tonnage of secondary tin and tin acquired in chemicals.

FOREIGN TRADE

Imports for consumption of tin concentrate remained about the same; but tin metal imports increased, reflecting stronger domestic demand. For many years, world tin-smelting capacity has exceeded tin mine capacity. Imports of tin metal increased, with Brazil remaining the major source by a wide margin, followed by China, Indonesia, and Malaysia.

There was a significant increase in imported tinplate scrap, due to the general scarcity of domestic steel scrap.

Imports of tin in all forms (ore and concentrate, metal, and waste and scrap) remained free of U.S. duty.

WORLD CAPACITY

The data in table 12 represent rated production capacity for mines and refineries on December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Tin mine and smelter capacities were estimated based on discussions with industry and Government officials, past and present production rates, and capacity data published in the recent past.

WORLD REVIEW

The Sixth International Tin Agreement, which commenced on July 1, 1982, and was extended until July 1989, was nominally in effect throughout 1988.

TABLE 5

U.S. CONSUMPTION OF TIN, BY FINISHED PRODUCT

(Metric tons of contained tin)

Product	1987[r]			1988		
	Primary	Secondary	Total	Primary	Secondary	Total
Alloys (Miscellaneous)[1]	W	W	W	W	W	W
Babbitt	850	210	1,060	709	207	916
Bar tin	703	W	703	557	—	557
Bronze and brass	1,835	1,724	3,559	1,890	2,044	3,934
Chemicals	W	W	W	W	W	W
Collapsible tubes and foil	W	W	W	W	W	W
Solder	10,959	4,312	15,271	11,078	4,210	15,288
Tinning	1,383	W	1,383	1,406	W	1,406
Tinplate[2]	10,357	W	10,357	11,064	W	11,064
Tin powder	W	W	W	W	W	W
Type metal	W	W	W	W	W	W
White metal[3]	1,183	W	1,183	1,131	W	1,131
Other	8,351	2,353	10,704	9,173	1,604	10,777
Total	**35,621**	**8,599**	**44,220**	**37,008**	**8,065**	**45,073**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Includes terne metal.
[2] Includes secondary pig tin and tin acquired in chemicals.
[3] Includes pewter, britannia metal, and jewelers' metal.

TABLE 6

U.S. INDUSTRY YEAREND TIN STOCKS

(Metric tons)

	1984	1985	1986	1987	1988
Plant raw materials:					
Pig tin:					
Virgin[1]	5,490	5,712	5,754	6,643	6,967
Secondary	1,562	2,342	3,021	2,333	1,435
In process[2]	1,124	1,342	1,377	1,289	1,056
Total	**8,176**	**9,396**	**10,152**	**10,265**	**9,458**
Additional pig tin:					
Jobbers-importers	802	1,642	1,272	1,890	3,387
Afloat to United States	701	1,321	2,433	2,486	2,127
Total	**1,503**	**2,963**	**3,705**	**4,376**	**5,514**
Grand total	**9,679**	**12,359**	**13,857**	**14,641**	**14,972**

[1] Includes tin in transit in the United States.
[2] Data represent scrap only, tin content.

Funds to pay the minimal ITC staff were exhausted, and the ITC statistical publications ceased. The United States was not a member of the agreement.

Legal actions continued on behalf of tin dealers and banks that had lost money, allegedly owing to activities of the LME and the ITC in late 1985, when the ITC exhausted borrowed funds to support the tin price. A movement was started to try to reach out-of-court settlements on the protracted litigation.

The Association of Tin Producing Countries (ATPC), comprising seven major producer nations—Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand, and Zaire—completed its fourth year. Two major tin-producing countries, Brazil and China, continued to decline ATPC membership, although each occasionally cooperated in some ATPC goals. ATPC viewed itself as being complementary to, and supportive of, the activities of the ITC, and the organization continued to persuade its member countries to restrain tin production and exports until a world supply-demand equilibrium was achieved. Industry sources estimated the world tin surplus at about 40,000 tons at yearend 1988.

During April 11-15 and November 21-December 2, 1988, meetings were held in Geneva, Switzerland, under the auspices of the UNCTAD to explore the possibility of establishing an International Tin Study Group. These meetings, at which the United States was represented, made considerable progress, but such important questions as the work content and goals of the group, base location, and budget allocations were left undecided.

Australia

The Renison Bell Mine in Tasmania, owned by Renison Consolidated Goldfields Ltd., remained Australia's largest tin mine, accounting for about 90% of the country's tin mine output. Numerous small tin mines remained closed owing to the relatively low tin price.

TABLE 7

MONTHLY COMPOSITE PRICE OF STRAITS TIN FOR DELIVERY IN NEW YORK

(Cents per pound)

Monthly	1987 High	1987 Low	1987 Average	1988 High	1988 Low	1988 Average
January	421.82	414.43	418.49	430.88	422.00	426.59
February	422.11	411.89	417.15	424.00	417.48	419.50
March	420.25	409.11	414.01	425.78	422.22	424.07
April	421.17	414.85	418.30	424.62	421.02	422.95
May	423.66	419.43	421.79	432.63	421.42	425.00
June	418.54	408.97	414.49	442.50	434.07	439.84
July	410.52	396.99	403.09	452.53	438.42	446.11
August	421.11	403.35	411.48	465.54	452.43	457.70
September	421.87	418.93	420.73	471.85	455.38	463.05
October	431.49	416.21	424.80	461.54	448.89	454.32
November	438.92	427.37	433.28	460.34	454.05	457.67
December	431.29	425.06	427.77	465.51	458.28	460.24
Average	**XX**	**XX**	**418.78**	**XX**	**XX**	**441.42**

XX Not applicable.

Source: Metals Week.

Renison Bell was the world's largest hard-rock underground tin mine and a relatively low-cost producer with substantial high-grade reserves. Renison operated at its full capacity of 850,000 tons of tin ore throughput. The entire tin concentrate output from Renison was believed to have been toll-smelted in Malaysia. Renison continued its program of direct sales of refined tin to large U.S. user firms from its affiliate office in Green Cove Springs, FL.

Greenbushes Ltd. continued to mine tin and tantalum near Perth. Tailings retreatment started up in mid-1988. In response to improving tantalum prices, overall throughput of all ore types increased to 2.1 million tons; however, tin output fell to 290 tons due to lower tin grades.

Oakridge Ltd. recovered 70 tons of tin-in-concentrate at its alluvial tin operation in North Queensland.

The tin mining operations of Great Northern Mining Corp. Ltd. remained closed, although exploration for tin accelerated.

Tin production resumed briefly at Ardlethan in central New South Wales, when Republic Resources NL commenced retreating tailings purchased from Ardlethan Tin Ltd.

Improved tantalum prices permitted resumption of mining at the Wodgina tailings dumps in the Pilbara area of Western Australia by Goldrim Mining Australia Ltd. The mixed concentrate was dressed in Perth for sale as separate tin and tantalite concentrates.

An announcement was made that the Anchor underground tin mine at Lottah, Tasmania, would commence production in 1989. Owned by Spectrum Resources Ltd. of New Zealand, the mine was expected to produce about 500 tons annually of tin-in-concentrate.

Tin smelting and refining operations in Sydney closed at midyear when Tolltreck Metal Products Ltd. rationalized its metal operations and sold two oper-

TABLE 8

U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF MISCELLANEOUS TIN, TIN MANUFACTURES, AND TIN COMPOUNDS

Year	Miscellaneous tin and tin manufactures: Imports: Tinfoil, tin powder, flitters, metallics, tin and manufactures, n.s.p.f.: Value (thousands)	Imports: Dross, skimmings, scrap, residues, tin alloys, n.s.p.f.: Quantity (metric tons)	Imports: Dross, skimmings, scrap, residues, tin alloys, n.s.p.f.: Value (thousands)	Exports: Tin scrap and other tin-bearing material, except tinplate scrap: Value (thousands)	Tin compounds: Imports: Quantity (metric tons)	Tin compounds: Imports: Value (thousands)
1986	$1,280	1,121	$1,899	$19,843	860	$5,165
1987	1,854	2,270	9,241	13,549	838	5,162
1988	1,013	1,542	6,054	21,832	838	5,439

Source: Bureau of the Census.

ating divisions. Tolltreck had experienced a dwindling supply of tin concentrates since purchasing the operation from Associated Tin Smelters Ltd. in mid-1986.

Bolivia

The tin industry generally experienced its first year of positive trends following several years of downsizing. The Huanuni tin mine, owned by the state-controlled Corpación Minera de Bolivia (COMIBOL), restarted production after being closed for 2 years. The Colquiri tin mine, also owned by COMIBOL, was undergoing rehabilitation, costing $3.8 million that included a new concentration plant, for a 1989 restart. The Poopo tin mine, formed by grouping together several small mines around the Poopo area and the tin concentrating plant in Machacamarca, restarted.

The Caracoles, Chorolque, and Viloco tin mines, closed in 1986, reopened. An extensive exploration program was carried out to increase ore reserves at Viloco. The Colavi tin mine was leased to mining cooperatives. The former ENAF tin smelter of Vinto, near Oruro, operated as an autonomous subsidiary of COMIBOL.

COMIBOL rented some of its tin mines to mining cooperatives formed chiefly by former workers of the company. The lease period was usually 5 to 10 years, and the rent was at least 1% of net minerals production annually.

The Catavi-Siglo tin mine, the largest underground tin mine in the world, was exhausted of economically minable tin ore reserves, although it has considerable amounts of tin ore at the surface in mill and mine dumps. The mine was rented to four mining cooperatives.

Brazil

Brazil was not a member of the ATPC, but agreed to cooperate with its guidelines and restrict its exports of tin. Brazil emerged in 1988 as the world's largest tin producer, a ranking long held by Malaysia. Tin mine and smelter production was mostly owned by private enterprise, both domestic and foreign. Brazilian tin mines generally were considered to be the lowest cost tin mines in the world.

The major producer, Paranapanema S.A. Mineração, Indústria e Construção accounted for more than one-half of Brazil's total tin output, operating at least seven tin mines. The Pitinga Mine, northeast of Manaus in Amazonas State, was the firm's largest mine. Pitinga reserves were reportedly 230,000 tons of contained tin in high-grade ore. In addition to cassiterite, other valuable minerals such as columbite-tantalite and zirconite were reportedly present but not currently mined. Near yearend, the National Department of Mineral Production, a Federal regulatory agency, awarded Paranapanema the right to buy the entire tin ore output from the Ariquemes Mine in the western Amazon region. Ariquemes produced about 10,000 tons of tin-in-concentrate annually and was worked by about 15,000 itinerant prospectors.

Brascan Recursos Naturais S.A. (BRN), jointly owned by Brascan Ltd. and B.P. Mineração, was Brazil's second leading tin producer. It operated several mines, all in the territory of Rondônia. BRN's tin concentrates were shipped to its Cesbra smelter for refining.

Rhodia, the Brazilian subsidiary of Rhône-Poulenc S.A. of France, with the recent acquisition of the Mineração, São Francisco de Assis tin mine, ranked as Brazil's third largest tin producer.

Empresas Brumadinhos S.A., the fourth largest tin producer, operated alluvial tin mines in Rondônia. Brumadinhos transported all its tin concentrates to the tin smelter of Bera do Brasil S.A., near São Paulo. Bera was 70% owned by Brumadinhos and 30% by Paul Bergsoe and Son A/S of Denmark.

Prospectors moved back into the Surcucus cassiterite deposit area of the remote territory of Roraima. This area had been closed to mining activity in 1976, when it was made into a reserve for the Yanomani and Maiongoni Indians. Some believe this area has the largest tin reserves in Brazil, and the tin ore can be easily extracted since it lies close to the surface.

TABLE 9

U.S. EXPORTS AND IMPORTS FOR CONSUMPTION OF TIN, TINPLATE, AND TERNEPLATE IN VARIOUS FORMS; EXPORTS OF INGOTS, PIGS, BARS; IMPORTS OF TINPLATE SCRAP

Year	Ingots, pigs, bars		Tinplate and terneplate				Tinplate scrap	
	Exports		Exports[1]		Imports		Imports	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	1,547	$9,742	219,074	$91,793	344,973	$199,484	2,375	$242
1987	1,318	9,456	209,526	106,156	329,783	193,110	2,543	380
1988	1,209	9,838	297,629	295,002	299,287	185,319	19,513	1,930

[1] Tinplate circles, strips, and cobbles are included with exports of tinplate and terneplate.

Source: Bureau of the Census.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF TIN, BY COUNTRY

Country	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Concentrates (tin content):				
Bolivia	732	$1,755	923	$2,313
Peru	2,165	7,596	1,914	5,600
Zaire	56	158	—	—
Total	**2,953**	**9,509**	**2,837**	**7,913**
Metal:[1]				
Austria	60	389	—	—
Australia	1,406	9,596	1,342	9,460
Belgium-Luxembourg[2]	302	2,005	—	—
Bolivia	3,476	10,579	3,926	27,643
Brazil	13,089	87,306	16,213	114,411
British Indian Ocean Territory	20	136	—	—
Burma	20	119	—	—
Canada	43	197	101	758
Chile	39	118	238	1,771
China	8,044	52,152	6,223	34,838
Denmark	90	609	—	—
France	40	267	—	—
Germany, Federal Republic of	([3])	4	1	7
Greece	3	3	—	—
Hong Kong	714	4,227	98	754
India	220	1,432	100	706
Indonesia	4,001	27,339	5,334	38,147
Japan	60	394	70	480
Korea, Republic of	1	5	—	—
Malaysia	4,959	32,499	5,317	36,786
Mexico	727	5,018	583	4,125
Netherlands	379	2,555	—	—
Nigeria	79	527	41	286
Poland	—	—	98	684
Seychelles	20	41	—	—
Singapore	743	5,036	1,342	9,954
Somalia	122	799	—	—
Switzerland	490	3,234	379	3,015
Thailand	1,460	9,452	670	8,466
Turkey	—	—	20	129
United Arab Emirates	40	257	40	266
United Kingdom	467	3,178	1,354	10,304
Zimbabwe	35	226	—	—
Total[4]	**41,150**	**259,699**	**43,493**	**302,991**

[1] Bars, blocks, pigs, or granulated.
[2] For 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

The State-owned Cia. Siderúrgica Nacional (CSN) announced a $79 million expansion of its tinplate production at its plant in Southern Rio de Janeiro State. CSN said the increased output, to 1 million metric tons of tinplate annually, would make this the largest single tin mill in the world. Upon completion of the additions, CSN expected tinplate exports to increase to 300,000 tons annually.

Canada

The East Kemptville Tin Corp. Ltd. continued tin mining operations at its open pit at East Kemptville, Nova Scotia. The mine contained 41 million tons of high-grade tin ore and 15 million tons of low-grade tin ore, with an average grade of 0.16% tin. At full capacity, the mill throughput of 9,000 tons daily theoretically projected to yield about 4,800 tons annually of tin-in-concentrate. Plans were approved to construct a flotation circuit, with a 1989 completion date. It was expected the new circuit would improve recovery rates from 65% to 75%. Most of the output of the mine was shipped to the Capper Pass Ltd. tin smelter in North Ferriby, United Kingdom, with some being smelted in Mexico. Rio Algom repurchased this mine in 1988, which it had originally developed and opened in 1985.

The Duck Pond deposit owned by Noranda Minerals Ltd. and B. P. Selco Ltd., at Buchans, Newfoundland, was under active exploration for copper, tin, and zinc.

China

The southern region, especially Guangdong, Guangxi, Hunan, Jiangxi, and Yunnan Provinces, held most of the tin resources. The country's largest tin producer is Yunnan Tin Corp., followed by DaChang Tin Mining Bureau in Guangxi. The combined annual output of these two accounted for about 70% of China's production of tin concentrates. The Gannan tin smelter in south China was closed. The United States was an

TABLE 11

TIN: WORLD ANNUAL MINE AND SMELTER CAPACITY, BY CONTINENT AND COUNTRY DECEMBER 31, 1988

(Metric tons)

Continent and country	Mine capacity	Smelter capacity
North America:		
Canada	5,000	—
Mexico	600	7,000
United States	300	8,000
South America:		
Argentina	1,000	1,000
Bolivia	20,000	16,000
Brazil	50,000	50,000
Peru	6,000	—
Europe:		
Czechoslovakia	1,000	—
German Democratic Republic	2,000	3,000
Portugal	600	1,000
Spain	—	14,000
U.S.S.R.	18,000	20,000
United Kingdom	5,000	12,000
Africa:		
Cameroon	200	—
Namibia	1,500	—
Niger	300	—
Nigeria	2,000	3,000
Rwanda	2,000	2,000
South Africa, Republic of	3,000	3,000
Swaziland	100	—
Tanzania	100	—
Uganda	100	—
Zaire	3,000	1,000
Zambia	100	—
Zimbabwe	2,000	2,000
Asia:		
Burma	2,000	1,000
China	30,000	25,000
Indonesia	35,000	28,000
Japan	—	2,000
Korea, Republic of	100	2,000
Laos	1,000	—
Malaysia	45,000	120,000
Thailand	33,000	44,000
Vietnam	1,000	1,000
Oceania: Australia	10,000	2,000
Total	**281,000**	**368,000**

important export market for tin metal from China.

Kimetal, the Singapore-based tin smelter, planned to build a 200-ton-per-year tin metal capacity smelter in Southwest China, as a joint venture with a Chinese Government agency.

China's tin industry sought to raise tin production by 25% over the next 2 years. China's tin resources are found in both lode and placer deposits. Because it offered easier mining conditions, placer mining had been conducted on a large scale in past decades. As a result, these reserves now face depletion, and the industry is shifting from placer mining to the underground mining of lode deposits.

A Sino-American joint venture, the first of its kind in China's tin industry, was established between the Yunnan Tin Corp. and Alpha Metals (China) Inc. of the U.S. to produce high-quality tin solder in Yunnan. This cooperative project was expected to be operational in 1989 and could produce 2,000 tons of solder yearly. High-quality solder used in China's electronics and aerospace industries is now imported.

France

Pechiney, a major aluminum producer based in France, purchased Triangle Industries Inc., the major can maker in the United States. Triangle owned the American National Can Co., which was a major user of tinplate. The purchase was valued at $1.26 billion.

The leading can-making firm in France, Carnaud S.A., bought the leading can maker in the United Kingdom, Metal Box Group PLC, for $1.3 billion. The goal was to form a major pan-European firm that could compete with American and Japanese can makers. Metal Box had most of its plants in Greece, Italy, Spain, and the United Kingdom. Carnaud was strong in Belgium, France, The Federal Republic of Germany, Italy, and Portugal. The new merged organization was called CMB Packaging S.A. and ranked among the world's top two can makers in size.

India

Sartin Ltd. started construction on its new 300-ton-per-year tin smelter at Chowdwar, near Cuttack, in Orissa State. Sartin was a private company set up by Saru Smelting Ltd. of Delhi to take advantage of State government funding to encourage development by Madhya Pradesh State Mining of local tin deposits in the Bastur-Koraput tin belt. Madhya Pradesh has been producing and stockpiling tin concentrates at a minimal level for the past 5 years, since there was no domestic smelter and because tin concentrates could not be exported since they are considered a strategic material. Base Metal Synergy Associates Ltd. of the United Kingdom provided Sartin with technical assistance in the smelter construction. Orissa Mining Corp. planned to increase tin mine output from Koraput in anticipation of the smelter completion.

Indonesia

Tin mining occurred predominantly at offshore locales, with large-scale dredging the preferred method. The major producer was P.T. Tambang Timah (P.T. Timah), the state-owned mining firm. P.T. Timah ranked as one of the world's largest tin-mining organizations and accounted for about 80% of Indonesia's tin output. P.T. Timah's three primary tin production units were on the islands of Bangka, Belitung, and Singkep. The facility on Bangka accounted for 70% of the firm's tin production.

The Peltim smelter, on Bangka Island, produced tin metal of four types: normal ingot, small ingot, tin anode, and tin shot. This smelter was capable of processing all of Indonesia's tin ore output. Peltim tin was marketed as two different brands: Banka tin (99.92% tin) and Mentok tin (99.85% tin), and both brands were registered on the LME. Domestic consumption of tin was modest at an estimated 1,500 tons annually. Unlike most major world producers, who sell their tin in the United States through independent brokers, Indonesia has for many years sold its tin directly to American users through its own sales agency.

Malaysia

For many decades the world's leading tin producer, Malaysia lost its top ranking in 1988 to Brazil. Malaysia Mining Corp. remained the largest tin-producing organization. The number of workers employed in the country's tin mining sector at the end of the year was 11,445, an increase of about 480 from the end of 1987. Total tin mines were 219 at yearend, compared to about 800 mines in 1980.

Two large tin smelters on the island of Penang, one owned by Datuk Keramat Sdn. Bhd. and the other owned by Malaysia Smelting Corp. Sdn. Bhd., continued operating at fairly high levels. Both depended significantly on toll-smelting of imported tin concentrates, especially from Australia, Bolivia, and China.

Japan was the major buyer of tin metal from Malaysia, followed by the Netherlands, the United States, and the Republic of Korea.

The Government embarked on a $27 million rehabilitation program to reopen and modernize some gravel pump mines, some of which had been closed since 1985. Government officials estimated it could cost about $200,000 to revive a closed gravel pump mine. Gravel pump mines accounted for about 39% of Malaysia's tin output.

Mexico

Tin was mined in the three adjoining States of Durango, Zacatecas, and San Luis Potosí in north-central Mexico. The country's major tin mine, the El Perro Mine was owned by Cía. Minera Pizzuto.

Estāno Electro S.A. de C.V. operated a tin smelter at Tlalnepantla, near Mexico City. Fundidora de Estāno S.A. operated a tin smelter at San Luis Potosí. Metales Potosí S.A. had a smelter in San Luis Potosí as did Minera de Río S.A. All four smelters processed imported tin concentrates primarily.

Namibia

The Uis Mine in the Brandberg area produced most of the country's tin. The Uis Mine was owned by Industrial Minerals Mining Corp. Pty. Ltd., a wholly owned subsidiary of South African Iron and Steel Industrial Corp. Ltd. (Iscor). The Uis tin deposits occurred as low-grade, 0.11% to 0.15%, tin cassiterite mineralization. The tin concentrates were shipped directly to the Vanderbijlpark steelworks in the Republic of South Africa, where they provided a large part of Iscor's tin for use in producing electrolytic tinplate.

Nigeria

The five tin-mining companies were Amalgamated Tin Mines of Nigeria (Holdings) Ltd., Bisichi-Jantar Nigeria Ltd., Kaduna Prospecting Nigeria Ltd., Ex-Lands Nigeria Ltd., and Gold & Base Metal Mines of Nigeria Ltd. All tin concentrates were smelted domestically by Makeri Smelting Co. Ltd. at Jos in Plateau State.

Peru

The sole tin mine was the San Rafael Mine, near Juliaca, owned by Minsur S.A. The mine was within the northern extension of the Bolivian tin belt. Tin grades averaged 1.8%. Peru remained the major supplier of tin concentrate to the United States.

Previously announced plans for Minsur to construct a $10 million tin smelter at Pisco were indefinitely suspended.

Portugal

The new Neves Corvo Mine, which commenced copper production this year, was found to also have rich tin deposits. This mine was developed by Socieded Minera de Neves-Corvo (SOMINCOR), owned 51% by the government-controlled Empresa de Desenvolvimento Mineiro E.P. and 49%

by RTZ Corp. PLC. RTZ announced that the tin reserves at this southern Portugal mine were about 2.8 million tons of tin ore with an average grade of 2.6%. It was expected that since the copper and tin ore bodies were so close, the same underground infrastructure could be used, with both extraction efforts utilizing the cut-and-fill technique. A $60 million tin recovery plant was planned that could process 300,000 tons of tin ore annually and produce 5,000 tons of tin metal annually. Tin production was expected to begin in 1990.

Rwanda

The Government announced plans to resume full-time tin mining but no schedule was set. A new state-controlled organization, Regie d'Exploitation et de Developpement des Mines, was created to manage about 20 mines that were previously owned by Société Minière du Rwanda (SOMIRWA), in which Belgium's Geomines Cie. had a 51% stake. The tin mines operated sporadically since 1985 when SOMIRWA went out of business. The mines suffered from power and water shortages.

South Africa, Republic of

Goldfields of South Africa Ltd. was the parent firm of two moderate-sized tin producers, Rooiberg Tin Ltd. and Union Tin Mines Ltd. Zaaiplaats Tin Mining Co. Ltd. was also a producer.

Thailand

The Vanachai Group announced plans to invest up to $800 million to construct a large-scale steel complex, including a tin mill that would produce 100,000 tons of tinplate annually. But Vanachai requested Government protection from lower priced imports. If this is granted, construction could begin in 1990.

U.S.S.R.

Tin mining was predominantly performed in the far eastern regions of the country. Modernization at the Khingan tin mining complex in Khabarovsk Kray in the Soviet Far East enabled that facility to achieve the highest tin extraction from ore in the Soviet tin industry. Tin used in tinplate production reportedly averaged 10 kilograms per ton of tinplate, which was two to three times the level for industrialized market economy countries. This high Soviet tin usage was attributed to the use of the hot dipping method, which still accounted for 15% of tinplate production. In an effort to conserve tin, which was a net import item for the Soviets, a pilot plant was built based on a new Soviet technology for chromium-plated steel production. This pilot plant was situated at the Lysven'skiy metallurgical plant in the Ukraine, with an expected output of 150,000 tons of chromed steel annually, which could replace tinplate.

United Kingdom

RTZ sold its ownership of Carnon Consolidated Ltd. to Carnon's management and work force. Carnon operated the Wheal Jane and South Crofty Mines in Cornwall.

RTZ, the owner of the Capper Pass tin smelter at Hull, one of the world's largest, reorganized the smelter operation owing to continuing losses. The smelter's capacity, which had been 21,000 tons of tin metal annually, was decreased to 12,000 tons annually. Employment was cut from 800 to 480 people. Most of the feed was expected to come from imported low-grade and complex primary and secondary materials.

Minorco S.A., based in Luxembourg, attempted a $5 billion hostile offer for London-based Consolidated Goldfields PLC. Goldfields sought protection from the takeover through legal and political channels in both the United Kingdom and the United States. Goldfields controlled about 10% of the Western world's tin output. The outcome of the merger attempt was left unsettled at yearend.

Zaire

The major tin producer was Société Minière et Industrielle de Kivu (Sominki) in Kivu. The firm was 28% Government-owned and 72% owned by Empain-Schneider Group of France. Tin concentrates were shipped to Europe for smelting. The second largest producer was Société Zaïretain, with 50% Government ownership and 50% ownership by Geomines.

TECHNOLOGY

The Fourth International Tinplate Conference, sponsored by the International Tin Research Institute, (ITRI) was held in London, United Kingdom, October 10–14, 1988. About 300 people attended from 30 countries. Topics covered included new passivation and brightening techniques, high-current-density electrotinning, methods to resist sulfide staining, improved lacquer-adhesion procedures, the development of high-solids coatings for tinplate food cans, advances in waterborne polymer coatings, and development of organic inhibitors to impede tinplate corrosion. Moderate optimism was expressed that tinplate could continue to regain modest market share worldwide in the beer and beverage can markets against aluminum, as it has done during the past 2 years.[4]

ITRI research found that certain inorganic and mono-organotin salts provided substantial flame-resistance on wool. A series of oxidic tin compounds were found to be effective flame retardants for cotton. The presence of a halogen was generally required for effective treatment.[5]

ITRI discovered that tin oxide either alone or in combination with melaminium beta-octamolybdate, was an effective flame retardant and smoke suppressant for rigid polyvinyl chloride (PVC). Although PVC is intrinsically flame-retardant, it emits large quantities of smoke and toxic gases when it is forced to burn; thus there is considerable interest in developing flame-retardant systems that are also smoke

TABLE 12

TIN: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina	274	451	379	186	150
Australia	7,923	[r]6,363	8,508	7,691	7,247
Bolivia	19,911	16,136	10,479	8,128	[2]10,504
Brazil	19,957	26,514	26,246	27,364	[2]43,700
Burma	2,028	1,751	1,495	939	[2]529
Cameroon	14	9	9	6	6
Canada	217	120	2,485	3,397	3,300
China[e]	15,000	15,000	15,000	[r]20,000	25,000
Czechoslovakia[e]	250	250	[r]200	[r]500	600
German Democratic Republic[e]	[r]2,500	[r]2,800	[r]2,800	[r]3,000	3,000
Indonesia	23,223	21,759	24,910	26,217	[2]30,590
Japan	485	510	500	86	—
Korea, Republic of	19	21	1	3	5
Laos	430	540	[e]550	[e]550	350
Malaysia	41,307	36,884	29,135	30,388	[2]28,866
Mexico	416	380	585	369	312
Namibia	906	984	880	1,097	1,100
Niger	76	134	80	94	100
Nigeria	1,700	[r e]1,500	630	844	[2]432
Peru	3,314	[r]3,807	4,817	5,263	[2]4,378
Portugal	320	263	196	64	60
Rwanda	1,093	813	29	—	—
South Africa, Republic of	2,301	2,153	2,054	1,438	[2]1,362
Spain	438	637	296	71	50
Swaziland	1	—	—	—	—
Tanzania[e]	4	[2]2	2	2	2
Thailand	21,960	16,864	17,066	15,006	[2]14,225
Uganda[e]	18	18	18	10	10
U.S.S.R.[e]	[r]12,000	[r]13,500	[r]14,500	[r]16,000	16,000
United Kingdom	5,216	5,204	4,276	[e]4,000	4,500
United States	W	W	W	W	W
Vietnam[e]	500	600	650	680	700
Zaire[3]	2,708	3,100	2,650	2,378	2,200
Zambia	4	22	3	24	20
Zimbabwe[e]	1,670	1,670	[r]1,470	[r]1,410	1,500
Total	**[r]188,183**	**[r]180,759**	**172,899**	**177,205**	**200,798**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Contained tin basis. Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London. Table includes data available through June 13, 1989.

[2]Reported figure.

[3]Nondupiicated total of content of concentrates plus smelter production.

suppressant.[6]

Research by D. Ozimina and C. Kajdas illustrated that tin chelates, especially when bonded to aliphatic dicarboxylic acid anions, show good potential as additives to lubricants that could offer superior antiwear and antiseizure properties.[7]

Work at ITRI focused on the development of conversion coatings for tinplate drawn and ironed beverage cans. Ironing severely disrupts the tin coating so that some of the steel is exposed. This study found that application of a chemical conversion coating to passivate the steel resulted in considerable reduction in iron porosity. A pilot industrial trial was initiated with several firms.[8]

Investigation at Swansea University, United Kingdom, showed tin oxide as having distinct advantages as a selective gas-sensing material. The need for devices to monitor atmospheres that may contain toxic or potentially inflammable gases has increased dramatically in recent years. This work showed that tin oxide performed well as a gas-sensing material of the semiconductor variety. Tin oxide exhibited such characteristics for these devices as good sensitivity, long-term stability, long lifetime, and low ambient temperature dependence.[9]

The Glacier Metal Co. Ltd., of the United Kingdom, developed several new tin-containing materials that extend the scope of bearing applications. Plain bearings are used to reduce wear, the incidence of seizure, and the risk of fatigue between two surfaces that are in sliding contact. It is the lubricity of tin which leads to its use in the manufacture of these bearings. The ideal condition under which plain bearings should operate is hydrodynamic lubrication, but this is not always possible owing to low oil pressure or fears of contamination. Glacier introduced a dry bearing material made of a porous bronze layer backed by a steel strip, which the firm claims gives superior wear resistance in applications such as automobile suspension systems.[10]

North American Industries Corp. announced development and introduction of a new reverse vending machine that accepts both tinplate and aluminum beer and beverage cans. Funding for development was provided by Crown Cork and Seal Co. and the Pepsi-Cola Bottling Group. Using this machine, the customer presses a start button, deposits the cans, and receives about a half cent per can in payment. The cans are sorted by magnets inside the machine. The machines were introduced at supermarket parking lots. If successful, the machines could encourage used tin can recycling.[11]

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Federal Register. National Defense Stockpile Manager. V. 53, No. 39, Feb. 29, 1988, p. 6114.

[3] Can Manufacturers' Institute. Metal Can Shipments Report 1988. Washington, DC, 1988, p. 4.

[4] Tin and Its Uses. No. 159, 1989, pp. 4-9.

[5] ———No. 155, 1988, p. 2.

[6] Page 3 of work cited in footnote 5.

[7] ———No. 157, 1988, pp. 12-13.

[8] Work cited in footnote 7.

[9] Tin and Its Uses. No. 158, 1988, pp. 8-10.

[10] Pp. 11-13 of work cited in footnote 9.

[11] Tinplate World. No. 3, 1988, p. 3.

TABLE 13

TIN: WORLD SMELTER PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina[2]	292	135	365	[e]350	280
Australia	2,899	2,683	1,399	563	434
Bolivia	15,842	12,859	7,673	2,610	5,300
Brazil	[r]18,877	24,701	24,427	29,365	33,000
Burma[3]	—	388	322	649	500
China[e]	15,000	15,000	15,000	[r]20,000	25,000
Czechoslovakia[2]	425	250	[r e]200	[r e]500	400
German Democratic Republic[e]	[r]3,000	[r]3,300	[r]3,300	[r]3,400	3,400
Germany, Federal Republic of[2]	417	[r e]1,000	346	[r e]250	300
Indonesia	22,467	20,909	22,080	24,200	[4]28,200
Japan	1,354	1,391	1,280	895	[4]846
Malaysia	46,911	45,500	43,788	44,363	[4]49,945
Mexico[5]	1,531	1,492	1,474	1,723	1,700
Netherlands	6,517	6,033	5,104	3,834	[4]3,478
Nigeria	[r]1,334	[r]1,079	91	560	[4]566
Portugal[2]	432	408	199	22	50
Rwanda[e]	1,000	800	—	—	—
Singapore[e]	3,500	4,000	500	1,000	1,000
South Africa, Republic of	1,592	2,069	2,001	1,508	[4]1,399
Spain	[r]2,900	[r]3,300	1,965	1,671	1,800
Thailand	19,729	17,996	19,672	[e]15,300	[4]14,675
U.S.S.R.[e]	[r]14,000	[r]16,000	[r]16,000	[r]17,000	17,000
United Kingdom	7,105	7,548	9,227	[e]12,000	12,000
United States[6]	4,000	[e]3,000	3,213	3,927	[4]1,467
Vietnam[e]	475	570	620	645	600
Zaire	170	85	56	—	—
Zimbabwe	1,210	1,207	1,079	1,038	1,000
Total	**[r]192,979**	**[r]193,703**	**181,381**	**187,373**	**204,340**

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London. Output reported throughout is primary tin only unless otherwise specified. Table includes data available through June 13, 1989.

[2] May include secondary tin.

[3] Data are for fiscal year ending Mar. 31 of that stated.

[4] Reported figure.

[5] Primarily from imported tin concentrate.

[6] Includes tin content of alloys made directly from ores.

TITANIUM

By Langtry E. Lynd[1] and Ruth A. Hough[2]

Production and consumption of titanium dioxide (TiO_2) pigments in 1988 reached new record-high levels for the sixth consecutive year. Consumption of titanium concentrates (ilmenite, slag, rutile, and synthetic rutile) also increased because of the high demand for TiO_2 pigments. As in recent years, the United States relied on imports for about three-quarters of its consumption of TiO_2 in concentrates. U.S. production of titanium sponge metal and demand for titanium mill products also rose as a result of increases in orders for commercial aircraft and equipment for the chemical industry. Imports of sponge metal remained low because of the withdrawal of Japanese producers from the U.S. market. Prices of titanium concentrates, pigments, and metal rose moderately in response to the high demand.

DOMESTIC DATA COVERAGE

Consumption data for titanium raw materials are developed by the Bureau of Mines from a voluntary domestic survey. All of the 31 operations to which a request was sent responded.

LEGISLATION AND GOVERNMENT PROGRAMS

The Government's National Defense Stockpile (NDS) goal for titanium sponge metal remained at 195,000 short tons. The Government stockpile inventory in December contained 25,965 tons of specification metal and 10,866 tons of nonspecification material. The Government stockpile goal for rutile was unchanged at 106,000 tons. The total rutile stockpile inventory at yearend was 39,186 tons, including 56 tons of nonspecification material.

The Fiscal Year 1989 Defense Appropriations Bill, House bill 4781-13, appropriated $6 million for the Title III Program of the Defense Production Act to "develop a reliable supply of titanium ore from ilmenite." A major objective of this appropriation is to help reduce U.S. import reliance for titanium concentrates, which was about 80% of consumption in 1988.

To assist the President and the Congress in determining the national implications of a prohibition of strategic and critical materials imports from the Republic of South Africa, the direct costs to this nation, which would result from a U.S. embargo on South African strategic and critical materials, including rutile and rutile substitutes, were assessed by the Bureau of Mines.[3]

TABLE 1

SALIENT TITANIUM STATISTICS

(Short tons unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Ilmenite concentrate:					
Mine shipments	W	W	W	W	W
Value thousands	W	W	W	W	W
Imports for consumption	409,605	506,804	465,617	338,977	434,498
Consumption	783,391	756,071	806,270	r820,413	748,478
Titanium slag:					
Imports for consumption	209,839	291,828	361,872	450,608	479,110
Consumption	200,858	252,027	276,324	r277,146	330,708
Rutile concentrate, natural and synthetic:					
Imports for consumption	180,508	179,663	174,820	218,188	254,770
Consumption	317,902	305,278	329,151	353,296	388,406
Sponge metal:					
Production	24,326	23,257	17,402	19,675	24,549
Imports for consumption	[1]2,667	[1]1,717	1,626	1,018	1,504
Consumption[e]	24,713	21,606	19,489	19,812	23,152
Price, Dec. 31, per pound	$5.55	$3.50-4.00	$3.90-4.30	$4.00-4.20	$4.25-4.75
Titanium dioxide pigment:					
Production	834,889	863,543	930,653	r968,444	1,021,562
Imports for consumption	193,501	196,213	202,674	192,043	204,443
Consumption, apparent[2]	916,198	984,579	1,000,960	r1,065,018	1,092,981
Price, Dec. 31, cents per pound:					
Anatase	69.0	72.0	77.0	77.0	95.0
Rutile	75.0	78.0	82.0	82.0	97.0
World: Production:					
Ilmenite concentrate[3]	r3,831,203	r3,809,555	3,768,664	p4,273,517	e4,237,146
Rutile concentrate, natural[3]	375,684	r411,960	434,790	p484,951	e505,820
Titaniferous slag	1,260,000	1,410,000	1,417,000	p1,737,000	e1,902,000

e Estimated. p Preliminary. r Revised. W Withheld to avoid disclosing company proprietary data.
1 Excludes sponge imported for the national stockpile.
2 Production plus imports minus exports plus stock decrease or minus stock increase.
3 Excludes U.S. production data to avoid disclosing company proprietary data.

DOMESTIC PRODUCTION

Concentrates

U.S. producers of ilmenite were Associated Minerals (USA) Ltd. Inc. (AMU) at Green Cove Springs, FL, and E. I. du Pont de Nemours & Co. Inc. at Starke and Highland, FL. AMU is a subsidiary of Renison Goldfields Consolidated Ltd. of Australia.

As in 1987, AMU was the only domestic producer of natural rutile concentrate. Kerr-McGee Chemical Corp. was the sole U.S. producer of synthetic rutile, at Mobile, AL.

P. W. Gillibrand Co. continued to separate and stockpile heavy minerals containing ilmenite at its rock, sand, and gravel operation in the Soledad Canyon area, Los Angeles County, CA.

Ferrotitanium

Ferrotitanium was produced by Ashland Chemical Co., Columbus, OH; HTP Co., Sharon, PA; Reactive Metals and Alloys Corp., West Pittsburg, PA; and Shieldalloy-GFE Corp., Newfield, NJ. Most of the production consisted of the 70% titanium grades.

Metal

RMI Co. installed a pilot plant to produce titanium by an electrolytic process developed by Elettrochimica Marco Ginatta S.A., Turin, Italy. The pilot plant was built next to RMI's titanium sponge plant in Ashtabula, OH, and was expected to start operating in early 1989 and to have annual production capacity of 300,000 to 500,000 pounds of electrolytic titanium. Potential cost savings of the electrolytic process compared with existing commercial sponge production processes were estimated at about 30%, attributed to reduced energy use. Testing of the pilot plant was expected to continue through the third quarter of 1989 before a decision would be made on whether to scale up production. In late 1988, RMI was expanding production of its existing sodium-reduction-process sponge plant by 1.5 million pounds per year to about 21 million pounds per year.

Also near yearend, Oregon Metallurgical Corp. (Oremet) completed repair of its 4,500-ton sponge-compaction press, which had been out of service for a few months, and added a seventh sponge reactor, bringing its annual capacity to 10.5 million pounds. Installation of an eighth reaction furnace was planned for July 1989 startup to raise Oremet's sponge capacity to 12 million pounds per year.

Teledyne Allvac, Monroe, NC, announced plans to install a new plasma-arc cold-hearth melting system that will increase its titanium melting capacity by 60%. The melting system was being manufactured for Teledyne by Retech Inc, Ukiah, CA, and will be the first of its type dedicated to titanium ingot production, Teledyne said. The system is designed to produce high-quality alloys free of high- and low-density inclusions and to process a wider variety of scrap than other systems.

TABLE 2

U.S. TITANIUM METAL PRODUCTION CAPACITY IN 1988

Company	Ownership	Plant location	Yearend capacity (short tons)	
			Sponge	Ingot[1]
Howmet Corp., Titanium Ingot Div.	Pechiney, France	Whitehall, MI	—	7,000
International Light Metals Corp.	Martin Marietta Corp., 60%; Nippon Kokan K.K., 40%	Torrance, CA	—	5,500
A. Johnson Metals Corp.	Axel Johnson Group, Stockholm, Sweden	Lionville, PA	—	[2]2,000
Lawrence Aviation Industries Inc.	Self	Port Jefferson, NY	—	1,500
Oregon Metallurgical Corp (Oremet)	Oremet employees, 67%; public, 33%	Albany, OR	5,250	11,000
RMI Co.	USX Corp., 50%; Quantum Chemical Co., 50%	Ashtabula, OH	10,500	—
		Niles, OH	—	18,000
Teledyne Allvac	Teledyne Inc.	Monroe, NC	—	4,000
Teledyne Wah Chang Albany	do.	Albany, OR	—	1,000
Titanium Metals Corp. of America	NL Industries Inc., 50%; Allegheny International Inc., 50%	Henderson, NV	14,000	17,500
Viking Metallurgical Corp.	Quanex Corp.	Verdi, NV	—	[2]3,500
Wyman-Gordon Co.	Self	Worcester, MA	—	2,500
Total			**29,750**	**73,500**

[1] Based on 7 days per week full production. Includes 68,000 tons vacuum arc double/triple melt, of which triple melt generally ranged from 10% to 30%. The remaining 5,500 tons was single-melt electron-beam capacity for remelt electrodes and commercially pure ingot and slab.
[2] Single melt only.

Pigment

Titanium dioxide pigment supply and demand continued to be in very close balance in 1988, and producers were operating their plants very close to full capacity. In response to the persistently growing demand, producers were taking steps to increase production capacity both in the United States and abroad.

SCM Chemicals Inc., Baltimore, MD, added 55,000 tons to annual world TiO_2 capacity by completing an 18,000-ton-per-year expansion at one of its two plants in Ashtabula, OH, and adding 37,000 tons per year capacity in the course of converting its plant in Bunbury, Western Australia, from the sulfate to the chloride process.

Kemira Inc., Savannah, GA, began expansion of its TiO_2 capacity by about 50% to 160,000 tons per year, to be completed by 1990. Kerr-McGee was expanding its Hamilton, MS, TiO_2 plant from 85,000 tons per year to 106,000 tons per year with completion scheduled for early 1989. Du Pont announced plans to build a new 100,000-ton-per-year TiO_2 pigment plant at De Lisle, MS, and to expand its existing 150,000-ton-per-year plant at De Lisle to 170,000 tons per year, which would bring Du Pont's total U.S. TiO_2 capacity to about 715,000 tons per year by 1990. The cost of Du Pont's expansions was expected to be about $100 million.

NL Chemicals Inc. announced plans to build a 90,000-ton-per-year chloride-process TiO_2 pigment plant at Lake Charles, LA, at an estimated cost of $200 million. This will be the first TiO_2 pigment plant to be built in the United States on a new site since 1978. Plant construction was to start in 1989, with initial plant operation scheduled for 1991. Completion of this project will mark the return of NL to the ranks of U.S. TiO_2 pigment producers after an absence of several years following closure of its Sayreville, NJ, plant in 1982. NL is currently the world's fourth-largest TiO_2 producer, with pigment plants in Belgium, Canada, the Federal Republic of Germany, and Norway.

TABLE 3

COMPONENTS OF U.S. TITANIUM METAL SUPPLY AND DEMAND

(Short tons)

Component	1984	1985	1986	1987	1988
Production:					
Sponge	24,326	23,257	17,402	19,675	24,549
Ingot	39,964	35,387	35,093	37,216	42,831
Exports:					
Sponge	171	51	69	94	88
Other unwrought	204	181	207	225	232
Scrap	4,109	6,760	6,403	5,603	6,602
Ingot, slab, sheet bar, etc.	2,071	2,248	2,119	2,719	2,296
Other wrought	778	1,147	1,132	1,985	2,953
Total	**7,333**	**10,387**	**9,930**	**10,626**	**12,171**
Imports:					
Sponge	[1]2,667	[1]1,717	1,626	1,018	1,504
Scrap	1,850	2,134	2,375	2,445	4,668
Ingot and billet	176	179	106	75	261
Mill products	840	1,449	[r]1,087	983	906
Total[2]	**5,533**	**5,478**	**[r]5,194**	**4,521**	**7,339**
Stocks, yearend:					
Government:					
Sponge (total inventory)	32,470	36,831	36,831	36,831	36,831
Industry:					
Sponge	3,147	4,755	3,180	2,504	2,689
Scrap	12,489	11,686	11,558	10,155	9,476
Ingot	4,526	4,000	4,100	4,458	4,335
Other	18	34	33	15	9
Total industry	**20,180**	**20,475**	**18,871**	**17,132**	**16,509**
Reported consumption:					
Sponge	24,713	21,606	19,489	19,812	23,152
Scrap	15,549	14,720	16,487	18,037	19,906
Ingot	39,062	35,020	33,801	35,561	39,194
Mill products (net shipments)[3]	[r]22,715	22,760	20,842	22,286	24,866
Castings (shipments)[3]	[r]266	[r]384	[r]424	475	605

[r] Revised.
[1] Excludes sponge imported for the national stockpile.
[2] Data may not add to totals shown because of independent rounding.
[3] Bureau of the Census, Current Industrial Reports, Ser. ITA-991.

TABLE 4

CAPACITIES OF U.S. TITANIUM DIOXIDE PIGMENT PLANTS ON DECEMBER 31, 1988[1]

Company and plant location	Pigment capacity (short tons per year)	
	Sulfate process	Chloride process
E.I. du Pont de Nemours & Co. Inc.:		
Antioch, CA	—	40,000
De Lisle, MS	—	150,000
Edge Moor, DE	—	130,000
New Johnsonville, TN	—	275,000
Kemira Inc., Savannah, GA	60,000	45,000
Kerr-McGee Chemical Corp., Hamilton, MS	—	85,000
SCM Chemicals Inc., Hanson Industries U.S.A.:		
Ashtabula, OH	—	118,000
Baltimore, MD	66,000	50,000
Total	**126,000**	**893,000**

[1] The table does not include Hitox Corp.'s Corpus Christi, TX, production capacity of about 20,000 tons per year of buff TiO_2, which is made by refining and fine-grinding synthetic rutile.

CONSUMPTION AND USES

Concentrates

Total consumption of TiO_2 in concentrates increased about 4%, mainly because of the increased production of titanium pigment. A 7% decrease in ilmenite consumption was more than offset by increases in the consumption of rutile and slag.

Ferrotitanium

Consumption of titanium in the form of ferrotitanium and scrap in steel increased by one-fifth, in line with the increased production of steel. Consumption of these forms of titanium in alloys other than steel, cast irons, and superalloys rose nearly fivefold, mainly because of large increases in the reported use for welding materials and aluminum alloys.

Metal

Consumption of sponge increased 17% while that of ingot rose 10%, and net shipments of mill products were up 12%. Consumption of scrap increased 10%, and the proportion of scrap in ingot feedstock dropped slightly to 46.2%. Castings shipments increased 27%. Mill product shipments were 47% in the form of billet; 37% sheet, strip, plate, tubing, pipe, extrusions and other; and 16% rod and bar. Estimated mill product usage by application was as follows: aerospace, 80%; chemical industry, including pulp and paper, 10%; powerplant condensers, 5%; naval and other marine uses, 2%; medical implants, 1%; and other uses, mainly oil drilling, flue-gas desulfurization, and automotive, 2%.

Current use of titanium in large com-

TABLE 5

COMPONENTS OF U.S. TITANIUM DIOXIDE PIGMENT SUPPLY AND DEMAND

(Short tons unless otherwise specified)

Component	1985		1986[1]		1987[1]		1988[1]	
	Gross weight	TiO content	Gross weight	TiO content	Gross weight	TiO content	Gross weight	TiO content
Production	863,543	802,827	930,653	865,182	[r]968,444	[r]904,788	1,021,562	945,966
Shipments:[2]								
Quantity	950,637	884,758	1,085,084	1,013,079	1,149,853	1,077,425	1,209,765	1,124,927
Value thousands	$1,275,131	$1,275,131	$1,530,225	$1,530,225	$1,700,644	$1,700,644	$1,954,656	$1,954,656
Exports	101,954	[e]92,434	112,227	[e]102,506	120,029	[e]109,953	130,538	[e]118,398
Imports for consumption	196,213	[e]179,912	202,674	[e]188,416	192,043	[e]179,420	204,443	[e]189,314
Stocks, yearend	56,756	[e]52,041	76,896	[e]71,486	52,336	[e]48,896	54,822	[e]50,765
Consumption, apparent[3]	984,579	[e]916,008	1,000,960	[e]931,647	[r]1,065,018	[r]996,845	1,092,981	[e]1,015,013

[e] Estimated. [r] Revised.

[1] Data coverage beginning in 1986 was extended to include additional major importers.

[2] Includes interplant transfers.

[3] Production plus imports minus exports plus stock decrease or minus stock increase.

Sources: Bureau of the Census and Bureau of Mines.

mercial aircraft represents about 6% of aircraft empty weight. Titanium is utilized where high-strength toughness, heat resistance, and high structural efficiency are required. Typical military aircraft uses are for structural forgings and wing skins for F-14 and F-15 aircraft; rotor parts for helicopter blade systems; B-1B fracture-critical forgings and wing support sections; and rotor discs, blades, and compressor blades on various engines. Major nonaerospace industrial uses are those requiring superior resistance to corrosion.

Pigment

Apparent domestic consumption of TiO_2 pigments was about 1.1 million tons, 4% higher than in 1987. Pigment supply continued to be very tight, with no indication of any easing of demand.

STOCKS

The 18% decrease in the TiO_2 content of ilmenite stocks was offset by increases in stocks of rutile and titanium slag. Stocks of TiO_2 pigment rose 2%, but were still at a relatively low level. A 7% increase in stocks of sponge metal was accompanied by a 7% drop in stocks of scrap.

FOREIGN TRADE

Exports of TiO_2 continued to increase in 1988 as they have each year since 1985, and imports of TiO_2 for 1988 increased after a 1-year drop. Both exports and imports of these pigments reached new record-high levels in 1988.

Increases of imports of all classes of titanium concentrates occurred during the year with imports of ilmenite and synthetic rutile increasing 28% and 47%, respectively.

An 8% decrease in wrought titanium imports was more than offset by substantial increases in imports of sponge, waste and scrap, and ingot and billet.

PRODUCTION CAPACITY

The data in table 15 are rated capacity for mines and refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of

TABLE 6

U.S. CONSUMPTION OF TITANIUM CONCENTRATES

(Short tons)

Year	Ilmenite[1]		Titanium slag		Rutile (natural and synthetic)[2]	
	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]
1984	783,391	498,977	200,858	152,534	317,902	298,639
1985	756,071	481,011	252,027	199,610	305,278	286,488
1986	806,270	512,725	276,324	221,959	329,151	309,384
1987:						
Alloys and carbide	(3)	(3)	(4)	(4)	—	—
Pigments	r818,224	r508,632	r277,146	r223,425	288,761	271,658
Welding-rod coatings and fluxes	(3)	(3)	—	—	4,388	4,168
Miscellaneous[5]	2,189	r1,817	—	—	60,147	56,558
Total	**r820,413**	**r510,449**	**r277,146**	**r223,425**	**353,296**	**332,384**
1988:						
Alloys and carbide	(3)	(3)	(4)	(4)	—	—
Pigments	747,553	473,053	330,708	267,414	308,196	289,906
Welding-rod coatings and fluxes	(3)	(3)	—	—	4,350	4,119
Miscellaneous[5]	925	650	(4)	(4)	75,860	71,255
Total	**748,478**	**473,703**	**330,708**	**267,414**	**388,406**	**365,280**

[e] Estimated. [r] Revised.
[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.
[2] Includes synthetic rutile made in the United States.
[3] Included with "Miscellaneous" to avoid disclosing company proprietary data.
[4] Included with "Pigments" to avoid disclosing company proprietary data.
[5] Includes ceramics, chemicals, glass fibers, and titanium metal.

TABLE 7

U.S. DISTRIBUTION OF DOMESTIC TITANIUM PIGMENT SHIPMENTS, TITANIUM DIOXIDE CONTENT, BY INDUSTRY[1]

(Percent)

Industry	1984	1985	1986	1987	1988
Paint, varnish, lacquer	54.8	54.3	52.6	49.5	48.1
Paper	19.9	20.5	20.7	24.3	24.2
Plastics (except floor covering and vinyl-coated fabrics and textiles)	15.4	16.2	15.8	17.0	17.0
Rubber	2.0	1.7	2.0	1.8	1.7
Printing ink	1.2	1.0	1.4	1.2	1.7
Ceramics	1.0	.7	2.2	.6	.4
Other	5.7	5.6	5.3	5.6	6.9
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

[1] Data coverage beginning in 1986 was extended to include additional major importers.

TABLE 8

U.S. CONSUMPTION OF TITANIUM PRODUCTS[1] IN STEEL AND OTHER ALLOYS

(Short tons)

	1984	1985	1986	1987	1988
Carbon steel	659	483	732	784	967
Stainless and heat-resisting steel	1,851	2,104	2,185	2,457	3,023
Other alloy steel (includes HSLA)	677	491	297	358	274
Tool steel	W	W	W	W	W
Total steel	**3,187**	**3,078**	**3,214**	**3,599**	**4,264**
Cast irons	62	23	65	W	W
Superalloys	622	657	630	689	708
Alloys, other than above	473	357	322	320	1,711
Miscellaneous and unspecified	18	18	35	45	60
Total consumption	**4,362**	**4,133**	**4,266**	**4,653**	**6,743**

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] Includes ferrotitanium containing 20% to 70% titanium and titanium metal scrap.

TABLE 9

U.S. STOCKS OF TITANIUM CONCENTRATES AND PIGMENT, DECEMBER 31

(Short tons)

	Gross weight	TiO content
Ilmenite:[1]		
1986	279,106	169,723
1987	[r]218,361	[r]132,295
1988	191,110	108,878
Titanium slag:[1]		
1986	80,885	65,213
1987	[r]131,786	[r]106,918
1988	142,790	116,216
Rutile:[1]		
1986	113,988	107,491
1987	118,655	110,217
1988	129,798	119,424
Titanium pigment:[2]		
1986	76,896	[e]71,486
1987	52,336	[e]48,896
1988	54,822	[e]50,765

[e] Estimated. [r] Revised.
[1] Producer, consumer, and dealer stocks.
[2] Bureau of the Census. Producer stocks only.

product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Mine and mill capacity for production of titanium concentrates, metal reduction plant capacity, and TiO_2 pigment plant capacity are generally based on close to 365 days per year operation, 3 shifts per day. Capacity figures are based on information obtained from the producing companies, from news items, or from Bureau of Mines estimates.

WORLD REVIEW

World production of TiO_2 in concentrates increased about 4% in 1988. World production and demand for TiO_2 were again at new record levels, with demand estimated at about 2.9 million tons. Producers were proceeding with new as well as previously announced plans for adding production capacity.

Titanium sponge metal production in the market economy countries increased 37% to about 44,000 tons, reflecting general recovery of demand in the United States, Western Europe, and Japan.

TABLE 10

PUBLISHED PRICES OF TITANIUM CONCENTRATES AND PRODUCTS

		1987[1]	1988[1]
Concentrates:			
Ilmenite, f.o.b. eastern U.S. ports	per metric ton	([2])	([2])
Ilmenite, f.o.b. Australian ports	do.	\$46.00–\$52.00	\$64.00–\$77.00
Ilmenite, large lots, bulk, f.o.b. U.S. east coast	do.	50.00– 56.00	NA
Rutile, bagged, f.o.b. Australian ports	per short ton	398.00–418.00	496.00–519.00
Rutile, bulk, f.o.b. Australian ports	do.	372.00–392.00	453.00–492.00
Rutile, large lots, bulk, f.o.b. U.S. east coast	do.	355.00–375.00	NA
Synthetic rutile, f.o.b. Mobile, AL	do.	350.00	NA
Titanium slag, 80% TiO_2, f.o.b. Sorel, Quebec[e]	per metric ton	215.00–225.00	235.00–255.00
Titanium slag, 85% TiO_2, f.o.b. Richards Bay, Republic of South Africa[e]	do.	235.00–245.00	250.00–275.00
Metal:			
Sponge, reported sales	per pound	4.00– 4.20	4.25– 4.75
Sponge, Japanese, under contract, c.i.f. U.S. ports, including import duty	do.	No quotation	No quotation
Mill products:			
Bar	do.	8.50– 9.61	10.50– 11.50
Billet	do.	6.45– 6.52	7.75
Plate	do.	10.33– 10.74	10.70– 12.50
Sheet	do.	8.50– 9.50	8.75– 9.25
Strip	do.	10.10– 10.60	10.25– 10.60
Pigment:			
Titanium dioxide pigment, f.o.b. U.S. plants, anatase	do.	.75– .77	.92– .95
Titanium dioxide pigment, f.o.b. U.S. plants, rutile	do.	.80– .82	.95– .97

[e]Estimated. NA Not available.
[1]Yearend.
[2]List price suspended effective Jan. 1, 1985.

Sources: American Metal Market, Industrial Minerals (London), Metals Week, and industry contacts.

Australia

Australia was again the largest producer of titanium minerals, with exports of ilmenite, in order of decreasing volume, mainly to the United States, the United Kingdom, Japan, and Spain; and exports of rutile, in order of decreasing quantity, mainly to the United States, the United Kingdom, the Netherlands, and Japan.

CRA Ltd., Melbourne, released details of significant heavy mineral reserves in a deposit in the Horsham region of Victoria. The part of the deposit that had been proved in detail was described as one of the world's largest deposits of heavy minerals. Reserves of contained heavy minerals in the primary exploration area include about 3.4 million tons of rutile and anatase, 4.6 million tons of leucoxene, 12.5 million tons of ilmenite, 5.1 million tons of zircon, 580,000 tons of monazite, and 170,000 tons of xenotime. It was stated that the deposit appears amenable to standard dredging techniques, but the minerals are fine grained and the company was investigat-

TABLE 11

U.S. EXPORTS OF TITANIUM PRODUCTS, BY CLASS

Class	1986		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Concentrates	5,314	\$1,414	4,435	\$1,395	10,326	\$3,729
Metal:						
Sponge	69	461	94	746	88	574
Other unwrought	207	1,757	225	2,254	232	1,480
Scrap	6,403	10,652	5,603	9,721	6,602	23,374
Ingots, billets, slabs, etc.	2,119	38,754	2,719	44,203	2,296	33,312
Other wrought	1,132	31,413	1,985	40,534	2,953	71,958
Total	**9,930**	**83,037**	**10,626**	**97,458**	**12,171**	**130,698**
Pigment and oxides:						
Titanium dioxide pigments	112,227	145,920	120,029	181,707	130,538	219,237
Titanium compounds, except pigment-grade	3,220	10,415	13,028	28,478	4,936	14,885
Total	**115,447**	**156,335**	**133,057**	**210,185**	**135,474**	**234,122**

Source: Bureau of the Census.

ling various methods of concentration.

Kerr-McGee Corp. and TiO_2 Corp., owned by Minproc Holdings Ltd., were planning to develop the world's first fully integrated heavy mineral mining, concentrating, and refining operation at Cooljarloo, Western Australia. The $240 million development will involve mining the deposit, upgrading ilmenite concentrate to synthetic rutile, and manufacturing TiO_2 pigment. Mining was to start in 1989.

Hansen Industries U.S.A. announced that its new chloride-process TiO_2 pigment plant near Bunbury, Western Australia, with production capacity of 77,000 tons per year, began operating in December 1988. The new plant is operated by SCM. SCM will continue to operate an existing sulfate-process TiO_2 plant at Bunbury until late 1990 when it will be phased out in favor of the new plant.

Germany, Federal Republic of

Early in 1988, a decision was made to merge the titanium operations of Krupp Stahl AG and Thyssen Stahl AG. A new company, Deutscher Titan, was formed that was to include Thyssen's

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM CONCENTRATES, BY COUNTRY

Concentrate and country	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Ilmenite:						
Australia	427,453	$13,846	333,523	$10,640	384,005	$16,657
Ghana[1]	—	—	—	—	3,628	178
India	18,783	1,831	5,454	1,341	—	—
Sierra Leone	—	—	—	—	23,717	1,625
Sri Lanka	19,381	1,160	—	—	23,148	1,029
Total	**465,617**	**16,837**	**338,977**	**11,981**	**434,498**	**19,489**
Titanium slag:						
Canada	194,058	35,696	219,364	41,625	245,403	48,597
South Africa, Republic of	167,814	29,030	231,244	41,381	233,707	44,292
Total	**361,872**	**64,726**	**450,608**	**83,006**	**479,110**	**92,889**
Rutile, natural:						
Australia	73,844	25,222	112,749	41,199	110,158	44,546
Brazil	1,126	214	—	—	—	—
Namibia	11,052	3,852	—	—	—	—
Sierra Leone	19,439	7,039	19,090	6,668	39,865	16,163
South Africa, Republic of	37,124	9,521	28,885	9,542	19,898	6,167
Other	90	16	6	3	218	23
Total	**142,675**	**[2]45,865**	**160,730**	**57,412**	**170,139**	**66,899**
Rutile, synthetic:						
Australia	32,035	6,315	50,722	12,021	68,653	20,462
China	110	34	101	34	35	13
India	—	—	3,227	1,127	8,826	3,203
Japan	—	—	3,401	1,497	7,117	3,372
Netherlands	—	—	7	22	—	—
Total	**32,145**	**6,349**	**57,458**	**14,701**	**84,631**	**27,050**
Titaniferous iron ore:[3]						
Canada	710	23	13,148	757	27,339	1,534

[1] Country of transshipment rather than country of origin.
[2] Data do not add to total shown because of independent rounding.
[3] Includes materials consumed for purposes other than production of titanium commodities, aggregate, and steel furnace flux.

Source: Bureau of the Census. Data adjusted by the Bureau of Mines.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM DIOXIDE PIGMENTS, BY COUNTRY

Country	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)	1988 Quantity (short tons)	1988 Value (thousands)
Australia	5,271	$6,604	3,923	$5,398	3,146	$4,392
Belgium-Luxembourg [1]	18,009	20,649	16,941	19,451	17,563	23,886
Brazil	19	21	46	53	1,396	3,649
Canada	24,509	28,476	17,533	21,352	34,386	41,533
China	773	709	1,223	1,258	5,212	6,195
Finland	5,930	6,995	4,293	5,501	5,428	8,426
France	36,818	44,719	26,921	32,325	23,161	36,431
Germany, Federal Republic of	48,867	57,902	47,707	60,630	35,372	54,277
Italy	3,239	4,338	3,167	4,423	10,676	14,592
Japan	5,083	5,586	5,000	6,693	5,664	8,644
Mexico	1,424	1,595	74	206	876	1,989
Netherlands	2,760	3,307	623	690	2,037	4,270
Norway	7,495	8,282	9,218	10,519	6,349	7,547
Poland	—	—	—	—	1,110	2,714
South Africa, Republic of	1,708	2,160	2,046	2,571	1,461	1,847
Spain	17,292	20,965	22,616	27,620	16,276	21,091
United Kingdom	21,876	25,885	29,538	36,640	32,168	45,929
Yugoslavia	412	631	332	652	974	2,064
Other [2]	r1,189	r1,234	r842	r963	1,188	2,356
Total	**202,674**	**240,058**	**192,043**	**236,945**	**204,443**	**291,832**

r Revised.

[1] For 1986 and 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

[2] Includes Algeria, Austria, Camaroon, Dominica, Greece, Hong Kong, Jordan, the Republic of Korea, Macao, Malaysia, Mali, New Zealand, Panama, Peru, Portugal, Singapore, Sweden, Switzerland, and Taiwan, in one or more of these years.

Source: Bureau of the Census.

2,400-ton-per-year melting facilities in Krefeld and Krupp's 2,750-ton-per-year operations at Essen. Deutscher Titan, to be based in Essen, was to be a fully owned subsidiary of Vereinigte Schmeideverke, which was organized in mid-February. Krupp, Thyssen, and Klockner Stahl AG each own one-third of Vereinigte Schmeideverke. Both the Essen and Krefeld plants had reportedly been operating at about 50% of capacity.

Japan

Production of titanium sponge in Japan increased about 64% to 18,200 tons, reflecting higher demand in Japan and Europe. Exports to the United States remained low because of the high value of the Japanese yen relative to the dollar. Titanium sponge production capacities by company were estimated to be the same as in 1987: Osaka Titanium Co. Ltd., 13,200 tons; Toho Titanium Co. Ltd., 10,600 tons; and Showa Titanium Co. Ltd., 2,200 tons.

Madagascar

Qit-Fer et Titane, Montreal, Canada, in partnership with the Government of Madagascar, continued exploration work on a mineral sands deposit near Fort Dauphin and planned to produce 660,000 tons per year of 60% TiO_2 ilmenite beginning in 1992.

Malaysia

Tioxide Group PLC, London, England, was planning to build a $189 million TiO_2 pigment plant in Malaysia. Industry sources said the plant has been approved by the Malaysian Industrial Development Authority and that details concerning capacity and site location were being worked out. A Tioxide Australia Ltd. executive indicated that Malaysia was chosen for the project because of its raw materials, energy resources, and political stability.

Mozambique

Kenmare Resources PLC, Dublin, Ireland, was developing a mineral sands deposit in the Congolone area, near

TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY

Class and country	1986		1987		1988	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Unwrought: Sponge:						
China	20	$77	18	$54	430	$2,656
Germany, Federal Republic of[1]	—	—	([2])	15	—	—
Hong Kong	—	—	—	—	3	27
Japan	1,606	9,504	1,000	6,252	1,046	7,668
United Kingdom	—	—	—	—	25	172
Total[3]	**1,626**	**9,583**	**1,018**	**6,321**	**1,504**	**10,523**
Ingot and billet:						
Canada	8	83	2	5	7	35
Germany, Federal Republic of	47	778	14	245	19	629
Israel	8	232	12	338	12	342
Japan	40	590	46	436	67	740
United Kingdom	3	56	1	29	151	1,300
Other	([2])	8	([2])	58	5	117
Total[3]	**106**	**1,747**	**75**	**1,112**	**261**	**3,163**
Waste and scrap:						
Austria	236	512	310	673	477	1,597
Belgium-Luxembourg[4]	52	50	149	206	69	175
Canada	260	461	156	280	380	1,539
China	54	90	71	112	160	981
France	205	630	234	631	198	1,157
Germany, Federal Republic of	110	327	213	694	447	2,609
Japan	338	1,112	603	1,893	2,098	10,181
Sweden	51	149	20	47	69	430
Switzerland	238	470	99	286	39	179
U.S.S.R.	149	311	—	—	—	—
United Kingdom	584	1,567	515	1,641	614	3,619
Other	96	246	75	116	117	396
Total[3]	**2,375**	**5,927**	**2,445**	**6,579**	**4,668**	**22,863**
Wrought titanium:						
Canada	376	5,874	387	7,112	328	5,548
Germany, Federal Republic of	25	454	46	463	86	1,012
Japan	633	9,083	480	6,683	391	6,117
United Kingdom	43	1,269	43	790	72	1,884
Other	10	266	27	698	29	1,178
Total[3]	**1,087**	**16,946**	**983**	**15,747**	**906**	**15,739**

[1] Country of transshipment rather than country of production.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
[4] For 1986 and 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

TABLE 15

WORLD TITANIUM ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988

Thousand short tons of: TiO_2 content of concentrates, gross weight of sponge (over 99% Ti), and gross weight of pigment (average about 95% TiO_2)

	Ilmenite	Rutile	Rutile, synthetic	Sponge metal	TiO_2 pigment		
					Sulfate[1]	Chloride[2]	Total
North America:							
Canada	[3]904	—	—	—	82	42	124
Mexico	—	—	—	—	—	66	66
United States	195	28	102	30	126	893	1,019
Total	**1,099**	**28**	**102**	**30**	**208**	**1,001**	**1,209**
South America: Brazil	30	[4]13	—	—	60	—	60
Europe:							
Belgium	—	—	—	—	77	—	77
Czechoslovakia	—	—	—	—	24	—	24
Finland	—	—	—	—	88	—	88
France	—	—	—	—	248	—	248
Germany, Federal Republic of	—	—	—	—	267	88	355
Italy	—	—	—	—	83	—	83
Netherlands	—	—	—	—	42	—	42
Norway	495	—	—	—	30	—	30
Poland	—	—	—	—	40	—	40
Spain	—	—	—	—	72	—	72
U.S.S.R.	270	11	—	55	110	—	110
United Kingdom	—	—	—	5	150	141	291
Yugoslavia	—	—	—	—	31	—	31
Total	**765**	**11**	**—**	**60**	**1,262**	**229**	**1,491**
Africa:							
Sierra Leone	25	134	—	—	—	—	—
South Africa, Republic of	[5]656	57	—	—	39	—	39
Total	**681**	**191**	**—**	**—**	**39**	**—**	**39**
Asia:							
China	100	—	—	3	28	—	28
India	215	20	150	—	14	24	38
Japan	—	—	50	26	281	48	329
Korea, Republic of	—	—	—	—	20	—	20
Taiwan	—	—	—	—	11	—	11
Malaysia	275	—	50	—	—	—	—
Sri Lanka	87	14	—	—	—	—	—
Total	**677**	**34**	**250**	**29**	**354**	**72**	**426**
Oceania: Australia	984	265	279	—	79	77	156
Grand total	**4,236**	**542**	**631**	**119**	**2,002**	**1,379**	**3,381**

[1] Sulfate process.
[2] Chloride process.
[3] Contained in 80% TiO_2 slag made from ilmenite.
[4] Anatase.
[5] Contained in 85% TiO_2 slag made from ilmenite.

Source: Technical publications, especially Industrial Minerals; industry contacts; and Bureau of Mines estimates.

TABLE 16

TITANIUM: WORLD PRODUCTION OF CONCENTRATES (ILMENITE, LEUCOXENE, RUTILE, AND TITANIFEROUS SLAG), BY COUNTRY[1]

(Short tons)

Concentrate type and country	1984	1985	1986	1987[p]	1988[e]
Ilmenite and leucoxene:[2]					
Australia:					
Ilmenite	1,645,937	1,564,031	1,364,322	1,651,356	[3]1,774,912
Leucoxene	35,395	15,222	15,590	12,445	[3]12,943
Brazil	45,134	84,166	63,194	123,072	110,000
China[e]	154,000	154,000	154,000	154,000	165,000
Finland	184,100	[r]58,400	—	—	—
India[4]	154,323	157,630	[e]154,000	[e]154,000	154,000
Malaysia	295,959	346,937	457,394	561,298	507,000
Norway	718,522	811,126	885,841	939,523	965,000
Portugal	181	[r]250	256	155	190
Sierra Leone	—	—	—	6,173	[3]46,427
Sri Lanka	112,489	126,605	143,198	141,647	[3]81,907
Thailand	163	1,188	14,869	29,848	[3]20,122
U.S.S.R.[e]	485,000	490,000	496,000	500,000	507,000
United States	W	W	W	W	W
Total	**[r]3,831,203**	**[r]3,809,555**	**3,768,664**	**4,273,517**	**4,344,501**
Rutile:					
Australia	187,860	233,265	237,850	271,458	[3]254,233
Brazil	454	786	546	563	600
India[e 4]	6,600	[3]7,496	8,000	8,000	8,000
Sierra Leone	100,641	88,858	107,034	124,892	[3]139,286
South Africa, Republic of[e]	62,000	61,000	61,000	61,000	61,000
Sri Lanka	7,129	9,434	9,307	7,937	[3]5,793
Thailand	—	121	53	101	[3]141
U.S.S.R.[e]	11,000	11,000	11,000	11,000	11,000
United States	W	W	W	W	W
Total	**375,684**	**[r]411,960**	**434,790**	**484,951**	**480,053**
Titaniferous slag:					
Canada[e 5]	800,000	930,000	937,000	[r]1,020,000	1,130,000
South Africa, Republic of[e 6]	460,000	480,000	480,000	[r]717,000	772,000
Total	**1,260,000**	**1,410,000**	**1,417,000**	**1,737,000**	**1,902,000**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table exludes production of unbeneficiated anatase ore in Brazil, in short tons, as follows: 1984—2,943,538; 1985—2,861,731; 1986—3,055,694; 1987—3,100,000 (revised, estimated); and 1988—3,100,000 (estimated). This material reportedly contains 20% TiO_2. Table excludes data available through June 19, 1989.

[2]Ilmenite is also produced in Canada and in the Republic of South Africa, but this output is not included here because an estimated 90% of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally as steel furnace flux and heavy aggregate.

[3]Reported figure.

[4]Data are for fiscal year beginning Apr. 1 of year stated.

[5]Contains 80% TiO_2.

[6]Contains 85% TiO_2.

Angoche, and planned to produce 385,000 tons per year of ilmenite, starting in early 1991.

Senegal

Du Pont signed an agreement with the Government of Senegal to explore for titanium minerals in the coastal area of that country. The agreement provides for 4 years of exploration with options for two renewals. Du Pont obtained mining rights for 25 years, with an automatic right of renewal for an additional 25 years. The projected startup date and initial production capacity of the project will depend on the results of exploration. Preliminary exploration shows the size of the deposits and grade of the ore to be competitive with Du Pont's other sources of titanium minerals.

South Africa, Republic of

Two heavy mineral sands deposits were being considered for development. Rhombus Mining, an independent South African Mining group, called for tenders to construct major items of a plant that would produce 330,000 tons per year of ilmenite, 28,000 tons per year of rutile, and 30,000 tons per year of zircon from a heavy mineral sands deposit in the Transkei, about 50 miles north of East London. The deposit was estimated to contain 275 million tons of sand grading 5% ilmenite, 0.4% rutile, and 0.6% zircon. Another project was being considered by Sevcor, another small South African mining group, to exploit a 28-million-ton heavy mineral sands deposit just south of Richards Bay on the Natal coast.

U.S.S.R.

Production of titanium sponge was estimated to be 50,000 tons. Sponge production capacity was estimated to be about 55,000 tons per year.

TECHNOLOGY

As part of a cooperative program with the General Electric Co., the Bureau of Mines has undertaken research that evaluates the Bureau's induction slag melting (ISM) process as a method of causing dissolution of hard alpha defects compared with commercial consumable electrode vacuum arc melting; determines the detectability, by ultrasonic inspection, of hard alpha defects; and characterizes the defects found using metallographic techniques.[4] The Bureau also carried out research to determine the effect of removing the nonconducting molten calcium fluoride (CaF_2) slag used in induction slag melting as an insulator between the titanium and the segmented copper crucible. The mechanical properties of single-induction-melted ingots prepared with or without the CaF_2 insulating slag exceeded the minimum properties specified for aerospace materials. Although the removal of the insulating slag is a desirable change, the data from the specimens with the previously standard 4% slag addition showed no detrimental effect from the slag inclusions.[5]

Bureau of Mines research on a single-melt system to purify pressed-alloy-sponge electrodes and produce titanium alloy streams was described. Melting was done in a vacuum arc furnace under an inert atmosphere using a single, funnel-shaped, water-cooled copper anode. Melt parameters were varied to increase the superheat and produce a stream of molten titanium that could ultimately be fed to rotary atomizing equipment.[6]

Several aircraft engine manufacturers were planning to use components made of silicon-carbide-reinforced titanium in four demonstration engines to be built over the next 3 years. The material is also to be used by National Aerospace Plane prime contractors in test structures. The reinforced titanium for these test components was to be supplied by Textron Specialty Metals, Lowell, MA, a Division of Textron Inc. Reinforced titanium and titanium aluminides have greatly improved stiffness and retain their strength at much higher temperatures than does unreinforced titanium.[7]

The advantages of using titanium rather than other materials in seawater service were described. Titanium is virtually immune to general corrosion in seawater, whether aerated, polluted, sulfide-containing, or chlorinated, and the metal is available in a family of alloys with properties suitable for a wide variety of applications, such as heat exchangers, high-pressure tubing and vessels, water boxes, pumps, valves, and fasteners.[8]

Fundamental data were acquired for a process that combines the chlorination treatment of rutile or ilmenite and subsequent electrowinning of titanium metal in a single melt. The results of electrochemical experiments were used to predict operating conditions for the proposed process, which would employ a molten lithium chloride-potassium chloride eutectic at 470° C.[9]

Acid recovery technology for treating wastes from TiO_2 pigment plants was reviewed. Increased concern in recent years regarding the environmental effects of disposing of acidic wastes in waterways has given new impetus to developing practical methods for recovering acid and sulfate values from sulfate-process pigment plant effluents. Discussion of sulfuric acid reconcentration focused mainly on processes developed by Bayer AG of the Federal Republic of Germany, Chemetics International Co. of Canada, and Sulzer-Escher Wyss AG of Switzerland.[10]

The continued high demand and tight supply of TiO_2 pigments led to renewed consideration of ways to extend the use of TiO_2 or replace it with other materials. In a theme issue on "Efficient Use of Titanium Dioxide," American Paint and Coatings Journal published several papers that discussed a variety of ways to better utilize the available supply of TiO_2.[11] Topics included use of the proper TiO_2 grade and concentration, the benefits of using buff TiO_2, the use of zinc sulfide and fine extenders, extending TiO_2 with calcium silicate, the use of opaque polymers in latex paints, and the role of calcium carbonate in reducing TiO_2 requirements.

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Supervisory mineral data assistant, Branch of Nonferrous Metals.

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TUNGSTEN

By Gerald R. Smith[1]

Only one U.S. tungsten mine was open during 1988 while prices for concentrates rose only modestly from the previous year. Consequently, the United States continued to be highly import-dependent for tungsten concentrate and intermediate materials. A significant portion of these materials came from China. Domestic production of ammonium paratungstate (APT) increased by nearly 57%. This was due not only to increases in demand for tungsten products but also to the positive effects of the quota restrictions on imports of APT from China since the signing of the Orderly Marketing Agreement (OMA) in September 1987.

DOMESTIC DATA COVERAGE

Domestic production data for tungsten are developed by the Bureau of Mines by means of three separate, voluntary surveys. These surveys are "Tungsten Ore and Concentrate," "Tungsten Concentrate and Tungsten Products," and "Tungsten Concentrate." Of the 47 operations to which survey requests were sent, all responded, representing 100% of the total production shown in table 1.

LEGISLATION AND GOVERNMENT PROGRAMS

In February 1988, an Executive order designated the Secretary of Defense as the manager of the National Defense Stockpile. Subsequently, the duties of administering stockpile activities were transferred from the General Services Administration to the Defense Logistics Agency (DLA). Physical disposals of tungsten from the National Defense Stockpile totaled 524,000 kilograms during the year. The tungsten, contained in nonstockpile-grade ores and concentrates, was released as payment material in support of DLA's ferroalloy upgrading program, under the National Defense Authorization Act. DLA was authorized to release 459,000 kilograms of tungsten in the fiscal year beginning October 1, 1988. Of that quantity, 268,000 kilograms remained for disposal at calendar yearend.

The Environmental Protection Agency (EPA) added tungsten carbide powder to the list of substances to be tracked under the Preliminary Assessment Information Rule. This rule permitted EPA to accumulate data on potential risks associated with specific substances. Effective May 16, 1988, manufacturers and importers of tungsten carbide were required to submit to EPA data on production volume, end use, and exposure.

EPA's proposed list of processing wastes to be exempted from the strict guidelines of the Resource Conservation and Recovery Act included sludges produced from tungsten ore leaching and tungsten waste treatment.

Effective October 1, 1988, the $0.17 per pound tariff on imports of tungsten ores and concentrates was waived through December 31, 1990. The tariff suspension stemmed from a provision in the Omnibus Trade and Competitiveness Act signed into law on August 23,

TABLE 1

SALIENT TUNGSTEN STATISTICS

(Metric tons of tungsten content unless otherwise specified)

		1984	1985	1986	1987	1988
United States:						
Concentrate:						
Mine production		1,203	996	780	34	W
Mine shipments		1,173	983	817	34	W
Value	thousands	$13,409	$9,143	$5,774	$216	W
Consumption		8,577	6,838	4,804	5,506	7,832
Shipments from Government stocks		1,368	902	301	708	524
Exports		129	124	34	2	153
Imports for consumption		5,807	4,746	2,522	r4,414	8,045
Stocks, Dec. 31:						
Producer		46	60	21	21	21
Consumer		959	1,077	502	329	499
Ammonium paratungstate:						
Production		7,339	6,527	5,604	5,336	8,357
Consumption		8,808	7,941	6,475	6,363	8,014
Stocks, Dec. 31: Producer and consumer		1,191	1,056	468	292	911
Primary products:						
Production		9,799	8,219	6,408	r7,424	8,068
Consumption		10,216	8,096	7,214	7,228	8,298
Stocks, Dec. 31:						
Producer		1,850	1,968	1,484	1,646	1,890
Consumer		1,585	1,206	860	787	930
World: Concentrate:						
Production		r46,162	r46,583	42,799	p42,174	e43,236
Consumption		r49,799	r47,774	44,596	p41,133	e45,610

e Estimated. p Preliminary. r Revised. W Withheld to avoid disclosing company proprietary data.

1988. Tungsten producer nations affected by this action included Australia, Canada, China, France, Portugal, and Spain.

DOMESTIC PRODUCTION

Dispositions of tungsten concentrate from the National Defense Stockpile provided about 6% of the supply for domestic processing.

U.S. Tungsten Corp. resumed mining and milling operations at its Pine Creek facilities near Bishop, CA. Production of tungsten concentrate at the mill, closed since May 1986, was begun on a limited scale. The concentrate supplemented imported feedstock for the company's production of APT.

Curtis Tungsten Inc. was registered by the Securities and Exchange Commission on December 28, 1988, to sell shares of its common stock. This action enabled the company to begin production of scheelite concentrate at its Andrew Mine near Los Angeles, CA. The mine and mill were last operated in 1985.

GTE Products Corp. increased APT production capacity by 20% at its Towanda, PA, facility. The company's plans were to double its production of finely divided tungsten carbide powders.

Canada Tungsten Mining Corp. Ltd. reopened its Fort Madison, IA, APT plant in August 1988. The plant, formerly operated by AMAX Inc., was closed during the first quarter of 1987 because of a depressed tungsten market and excess inventories.

CONSUMPTION AND USES

Domestic consumption of tungsten in primary products increased by about 15% in 1988. In particular, demand for cemented tungsten carbide cutting and wear-resistant components increased as the traditional metal-working and

TABLE 2

U.S. GOVERNMENT TUNGSTEN STOCKPILE MATERIAL INVENTORIES AND GOALS

(Metric tons of tungsten content)

Material	Goals	Inventory by program, Dec. 31, 1988		
		National stockpile	DPA[1] inventory	Total
Tungsten concentrate:				
Stockpile grade	25,152	24,694	72	24,766
Nonstockpile grade	—	10,330	5	10,335
Total	**25,152**	**35,024**	**77**	**35,101**
Ferrotungsten:				
Stockpile grade	—	385	—	385
Nonstockpile grade	—	533	—	533
Total[2]	**—**	**919**	**—**	**919**
Tungsten metal powder:				
Stockpile grade	726	711	—	711
Nonstockpile grade	—	150	—	150
Total	**726**	**861**	**—**	**861**
Tungsten carbide powder:				
Stockpile grade	907	871	—	871
Nonstockpile grade	—	51	—	51
Total	**907**	**922**	**—**	**922**

[1] Defense Production Act (DPA) of 1950.

[2] Data may not add to totals shown because of independent rounding.

TABLE 3

TUNGSTEN CONCENTRATE SHIPPED FROM MINES IN THE UNITED STATES

Year	Quantity		Reported value, f.o.b. mine[1]		
	Metric ton units[2] of WO_3	Tungsten content (metric tons)	Total (thousands)	Average per unit of WO_3	Average per kilogram of tungsten
1984	147,958	1,173	$13,409	$90.63	$11.43
1985	123,944	983	9,143	73.77	9.30
1986	103,053	817	5,774	56.04	7.07
1987	4,288	34	216	[3]50.34	6.35
1988	W	W	W	—	—

W Withheld to avoid disclosing company proprietary data.

[1] Values apply to finished concentrate and are in some instances f.o.b. custom mill.

[2] A metric ton unit equals 10 kilograms of tungsten trioxide (WO_3) and contains 7.93 kilograms of tungsten.

[3] Metals Week, U.S. spot quotations-annual average.

TABLE 4

MAJOR PRODUCERS OF TUNGSTEN CONCENTRATE AND PRINCIPAL TUNGSTEN PROCESSORS IN THE UNITED STATES IN 1988

Company	Location of mine, mill, or processing plant
Producers of tungsten concentrate:	
U.S. Tungsten Corp., a division of Strategic Minerals Corp.	Bishop, CA.
Processors of tungsten:	
Buffalo Tungsten Inc.	Depew, NY.
Canada Tungsten Mining Corp. Ltd.	Fort Madison, IA.
General Electric Co.	Euclid, OH.
GTE Products Corp.	Towanda, PA.
Kennametal Inc.	Latrobe, PA, and Fallon, NV.
Teledyne Firth Sterling	La Vergne, TN.
Teledyne Wah Chang Huntsville	Huntsville, AL.
U.S. Tungsten Corp., a division of Strategic Minerals Corp.	Bishop, CA.

TABLE 5

PRODUCTION, DISPOSITION, AND STOCKS OF TUNGSTEN PRODUCTS IN THE UNITED STATES IN 1988

(Metric tons of tungsten content)

	Hydrogen-reduced metal powder	Tungsten carbide powder: Made from metal powder	Tungsten carbide powder: Crushed and crystal-line	Chemicals	Other	Total
Gross production during year	7,324	4,602	W	W	3,692	15,618
Used to make other products listed here	4,736	—	W	W	2,814	7,550
Net production	2,588	4,602	W	W	878	8,068
Stocks, Dec. 31: Producer	1,049	503	W	76	262	1,890

W Withheld to avoid disclosing company proprietary data; included with "Other."

metal-forming sectors, including aerospace, defense, and automotive, strengthened from the previous year. The combined consumption of tungsten in mill products, specialty steels, superalloys, welding and hard-facing rods, chemicals, and ceramics increased modestly over 1987 levels. Demand for tungsten in the oil and gas drilling industry remained weak owing to continued low oil prices. During 1988, the average number of oil drilling rigs operating in the United States declined slightly to 937, compared with 945 in 1987.

PRICES

According to Metal Bulletin (London) quotations, average wolframite and scheelite concentrate prices rose by about 14% and 6%, respectively, in 1988.

China was the major supplier of primary and intermediate tungsten materials in the world market. The country's marketing practices were influential in shaping the tungsten price structure. In September 1988, China proposed target prices for wolframite and scheelite concentrate of $69.00 to $72.00 and $76.00 to $79.00 per metric ton unit (7.93 kilograms of tungsten), respectively. The proposed APT price would be fixed at about 36% above the wolframite price. Target prices for concentrate were an average of 28% above the September 1988 levels and were last reached in world market quotations during the first quarter of 1985. At yearend, the average concentrate prices had risen about 6% above the September 1988 levels.

Domestic APT prices rose by about 7% during the year from a range of $82.12 to $87.63 per metric ton unit in January 1988 to $87.63 to $89.29 per metric ton unit in December 1988. A high of $90.39 to $92.04 per metric ton unit was reached in May. Average prices for metal powder and tungsten carbide powder increased by about 7% since October 1987, reaching $22.00 and $21.60 per kilogram, respectively, in December 1988.

FOREIGN TRADE

Total U.S. imports of tungsten materials increased by nearly 60% in 1988. Most of this increase occurred in imports from China. Although the OMA, signed in September 1987, restricted the APT and tungstic acid (TA) that China could export to the United States, this was offset by large increases in exports to the United States of concentrates, oxides, and sodium tungstate. The total share of tungsten imports arriving from China reached 53% in 1988, compared with 41% in 1987 and only 15% in 1980.

In January 1988, the U.S. Trade Representative adjusted the OMA quotas for APT and TA imported from China. The original OMA provided for such adjustments should the specified limits be exceeded in any period throughout the duration of the agreement. China's imports in 1987 exceeded the limits agreed upon by 862 metric tons of

TABLE 6

CONSUMPTION AND STOCKS OF TUNGSTEN PRODUCTS IN THE UNITED STATES IN 1988, BY END USE

(Metric tons of tungsten content)

End use	Ferro-tungsten	Tung-sten metal powder	Tung-sten carbide powder	Scheelite (natural-synthetic)	Tung-sten scrap [1]	Other tungsten materials [2]	Total [3]
Steel:							
Stainless and heat-resisting	73	—	—	W	W	W	73
Alloy	77	W	—	W	—	W	77
Tool	317	—	—	W	W	—	317
Superalloys	W	W	43	W	236	W	279
Alloys (excludes steels and superalloys):							
Cutting and wear-resistant materials	—	75	4,573	—	W	W	4,651
Other alloys [4]	W	6	W	—	W	—	6
Mill products made from metal powder	—	2,066	W	—	—	W	2,066
Chemical and ceramic uses	—	W	W	—	—	84	84
Miscellaneous and unspecified	10	20	129	184	199	205	748
Total [3]	**478**	**2,168**	**4,745**	**184**	**434**	**290**	**8,298**
Stocks, Dec. 31: Consumer	56	20	724	24	76	30	930

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] Excludes that used in making primary tungsten products.
[2] Includes tungsten chemicals and others.
[3] Data may not add to totals shown because of independent rounding.
[4] Includes welding and hard-facing rods and materials and nonferrous alloys.

TABLE 7

MONTHLY PRICE QUOTATIONS OF TUNGSTEN CONCENTRATE IN 1988

Month	Metal Bulletin (London), scheelite, European market, 70% WO_3 basis [1]				Metal Bulletin (London), wolframite, European market, 65% WO_3 basis [2]				Metals Week, U.S. spot quotations, 65% WO_3 basis, c.i.f. U.S. ports [3]				International Tungsten Indicator, weighted average price,[4] 60% to 79% WO_3	
	Dollars per metric ton unit			Dollars per short ton unit	Dollars per metric ton unit			Dollars per short ton unit	Dollars per short ton unit			Dollars per metric ton unit		
	Low	High	Average	Average	Low	High	Average	Average	Low	High	Average	Average	Dollars per metric ton unit	Dollars per short ton unit
January	57.00	65.00	61.00	55.34	49.00	58.00	53.50	48.53	48.00	56.00	52.00	57.32	56.44	51.20
February	57.00	65.00	61.00	55.34	49.11	58.00	53.56	48.59	48.00	56.00	52.00	57.32	56.63	51.37
March	57.67	66.33	62.00	56.25	51.89	58.67	55.28	50.15	51.80	59.80	55.80	61.51	57.07	51.77
April	58.00	67.00	62.50	56.70	55.00	60.00	57.50	52.16	55.00	64.00	59.50	65.59	55.99	50.79
May	58.00	67.00	62.50	56.70	55.63	60.75	58.19	52.79	58.00	64.00	61.00	67.24	61.64	55.92
June	57.11	67.00	62.06	56.30	50.89	60.67	55.78	50.60	47.40	54.60	51.00	56.22	62.46	56.66
July	54.25	64.38	59.32	53.81	45.13	56.63	50.88	46.16	41.50	49.00	45.25	49.88	58.38	52.96
August	53.00	64.00	58.50	53.07	50.00	57.75	53.88	48.88	49.00	56.50	52.75	58.15	57.72	52.36
September	53.00	64.00	58.50	53.07	51.75	61.25	56.50	51.26	54.80	62.40	58.60	64.60	59.54	54.01
October	53.00	64.00	58.50	53.07	54.21	62.00	58.11	52.72	51.00	57.00	54.00	59.52	57.93	52.55
November	54.38	66.00	60.19	54.60	55.00	62.75	58.88	53.42	50.00	55.00	52.50	57.87	61.27	55.58
December	56.00	67.38	61.69	55.96	55.38	63.13	59.26	53.76	50.80	55.00	52.90	58.31	60.37	54.77

[1] Low and high prices are reported semiweekly. Monthly averages are arithmetic averages of semiweekly low and high prices. The average price per metric ton unit of WO_3, which is an average of all semiweekly low and high prices, was $60.65 for 1988. The average equivalent price per short ton unit of WO_3 was $55.02 for 1988.
[2] Low and high prices are reported semiweekly. Monthly averages are arithmetic averages for semiweekly low and high prices. The average price per metric ton unit of WO_3, which is an average of all semiweekly low and high prices, was $55.94 for 1988. The average equivalent price per short ton unit of WO_3 was $50.75 for 1988.
[3] Low and high prices are reported weekly. Monthly averages are arithmetic averages of weekly low and high prices. The average price per short ton unit of WO_3, which is an average of all weekly low and high prices, excluding duty, was $53.94 for 1988. The average equivalent price per metric ton unit of WO_3 was $59.46 for 1988.
[4] Weighted average price per metric ton unit of WO_3 was $58.78 for 1988. The equivalent weighted average price per short ton unit of WO_3 was $53.33 for 1988.

contained tungsten. Accordingly, the 1988, 1989, and 1990 limits were reduced by 431,259, and 172 metric tons, respectively.

WORLD CAPACITY

The data in table 18 are rated capacity for mines and mills as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for tungsten is based on published reports, maximum production statistics, and estimates. The latter is utilized particularly for the centrally planned economy countries where capacity information is either incomplete or unavailable.

WORLD REVIEW

The Committee on Tungsten of the United Nations Conference on Trade and Development (UNCTAD) convened its 20th session in Geneva, Switzerland, in November 1988. The Sessional Working Group, focusing on recent developments and the short-term outlook for the tungsten market, reported that a reasonably stable tungsten market appears to be emerging. Stabilizing factors such as rising demand for cemented carbide cutting-tool inserts, decreasing production of concentrates, and improving pricing policies by China were cited. An UNCTAD Secretariat paper also ob-

TABLE 8

U.S. EXPORTS OF TUNGSTEN ORE AND CONCENTRATE, BY COUNTRY

Country	1987		1988	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Colombia	(1)	$9	—	—
Finland	1	20	—	—
Germany, Federal Republic of	—	—	140	$1,604
India	(1)	2	—	—
Mexico	—	—	(1)	8
Pakistan	—	—	7	104
Singapore	—	—	6	100
Total [2]	**2**	**31**	**153**	**1,815**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 9

U.S. EXPORTS OF AMMONIUM PARATUNGSTATE, BY COUNTRY

Country	1987			1988		
	Gross weight (metric tons)	Tungsten content [1] (metric tons)	Value (thousands)	Gross weight (metric tons)	Tungsten content [1] (metric tons)	Value (thousands)
Belgium-Luxembourg	237	168	$1,384	110	78	$599
Canada	69	49	568	—	—	—
France	1	1	11	1	(2)	5
Germany, Federal Republic of	2	1	28	58	41	365
Hungary	—	—	—	10	7	73
Japan	2	1	23	8	6	93
Mexico	2	1	15	(2)	(2)	2
Portugal	10	7	61	—	—	—
South Africa, Republic of	—	—	—	2	1	31
United Kingdom	80	57	615	48	34	398
Venezuela	—	—	—	10	7	37
Total [3]	**403**	**285**	**2,705**	**246**	**174**	**1,601**

[1] Tungsten content estimated by multiplying gross weight by 0.7066.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

served that the OMA signed between the United States and China in September 1987 was a stabilizing influence. In particular, the OMA was said to help arrest the shift toward imports of underpriced intermediate products and away from ores and concentrates.

Demand for tungsten materials in the short term was expected to be favorable, assuming the continuation of the recent economic growth in key consuming countries. Tungsten was expected to retain its market share in most traditional end-use sectors. However, in the two key consuming sectors of mining and oil drilling, prospects for any substantial increase in demand were considered remote. Although there was consensus that the supply-demand balance was improving, delegates for the producer countries of Australia, Bolivia, Canada, France, Peru, Portugal, and Spain continued to express concern regarding their inability to justify reopening closed mines. Specifically, they stated that the tungsten market had grown much more slowly compared with recent overall industrial growth. Furthermore, tungsten prices had not risen in proportion to those of other metals.

Explanations for tungsten's slower growth rate were highlighted in a paper presented by the Secretariat entitled "Major Aspects of Structural Change in Consumption." Essentially, the report concluded that certain structural and technological changes within the tungsten industry had contributed significantly to the recent market characteristics. These changes included the application of coatings on cutting-tool inserts to extend tool life, the use of substitutes for traditional cemented tungsten carbides in cutting and wear-resistance applications, and the development of near-net shaping techniques and downsizing methods that effectively reduce tool consumption. A Secretariat model of the market suggested that 10% to 15% of potential demand had been lost to ceramics, cermets, and other new materials and application processes.

TABLE 10

U.S. EXPORTS OF TUNGSTEN CARBIDE POWDER, BY COUNTRY

Country	1987		1988	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Argentina	([1])	$14	1	$25
Australia	4	160	41	944
Austria	11	263	4	113
Belgium-Luxembourg	—	—	6	250
Brazil	7	272	2	79
Canada	69	1,744	150	4,366
Chile	—	—	1	24
Denmark	1	27	1	31
Finland	6	93	([1])	13
France	—	—	1	43
Germany, Federal Republic of	97	2,183	149	3,445
Hong Kong	—	—	1	22
India	4	82	1	24
Ireland	([1])	30	([1])	7
Israel	([1])	3	3	63
Italy	33	1,050	50	2,052
Japan	24	704	64	1,372
Korea, Republic of	—	—	1	72
Malaysia	—	—	1	20
Mexico	6	126	23	450
Netherlands	10	594	9	460
Peru	2	30	—	—
Singapore	([1])	2	1	17
South Africa, Republic of	—	—	3	82
Spain	—	—	6	146
Sweden	12	87	([1])	10
Switzerland	3	106	5	101
Taiwan	—	—	10	265
United Kingdom	62	487	85	802
Venezuela	6	216	—	—
Other	26	790	1	40
Total[2]	**383**	**9,063**	**618**	**15,340**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 11

U.S. EXPORTS OF TUNGSTEN AND TUNGSTEN ALLOY POWDER, BY COUNTRY

Country	1987			1988		
	Gross weight (metric tons)	Tungsten content[1] (metric tons)	Value (thousands)	Gross weight (metric tons)	Tungsten content[1] (metric tons)	Value (thousands)
Australia	20	16	$479	26	20	$647
Austria	1	1	17	29	23	630
Belgium-Luxembourg	5	4	100	12	9	248
Brazil	6	5	167	8	7	220
Canada	42	34	1,197	70	56	1,630
Denmark	—	—	—	23	19	478
Finland	12	10	179	28	22	443
France	—	—	—	57	46	1,051
Germany, Federal Republic of	84	67	2,147	138	110	3,841
India	—	—	—	1	(2)	23
Ireland	1	(2)	13	—	—	—
Israel	36	29	572	101	81	1,249
Italy	37	28	660	55	44	1,149
Japan	7	5	178	10	8	200
Korea, Republic of	—	—	—	1	1	18
Mexico	7	6	157	5	4	181
Netherlands	360	288	3,682	227	182	2,620
Pakistan	—	—	—	2	1	41
Singapore	(2)	(2)	8	22	18	360
South Africa, Republic of	—	—	—	13	10	206
Sweden	—	—	—	68	54	1,206
Switzerland	101	81	1,577	31	25	544
Taiwan	—	—	—	7	6	162
Turkey	—	—	—	3	2	96
United Kingdom	8	7	198	14	11	367
Other	110	88	1,988	(2)	(2)	5
Total[3]	**837**	**669**	**13,319**	**948**	**759**	**17,616**

[1] Tungsten content estimated by multiplying gross weight by 0.80.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

As a result of the Secretariat's paper and comments from country delegates, the Secretariat was directed to prepare two papers for the committee's next meeting: (1) An in-depth analysis of substitution prospects with an emphasis on ceramics and cermets and (2) A review of existing research and development programs to promote new applications for tungsten and a survey of industry and Government views on the need for additional programs. In addition, it was agreed that the Secretariat will undertake longer term research on a number of topics, including trade in intermediate products, price elasticities of demand, and a survey of all mining and processing facilities worldwide.

The newly created International Tungsten Industry Association (ITIA) was officially formed in February 1988 at a meeting of its founding members in Brussels, Belgium. Among founding members, representing 19 countries, were 27 processors and consumers, 16 trading companies, 12 mining companies, and 2 assayers. The ITIA held its first annual general meeting in Washington, DC, in September 1988. Consistent with one of its objectives to monitor potential environmental and health problems within the industry, speakers from the medical and legal communities presented information on the incidence of respiratory disease in the manufacture of hard metals. Government and industry representatives as well as the ITIA Secretariat addressed the market situation, including supply-demand balance, prices, and international trade, with specific emphasis on the status of the OMA between the United States and China 1 year after being signed.

In response to a complaint by European producers of upgraded tungsten products, the European Commission initiated an antidumping investigation into imports of several tungsten products from China and from the Republic of Korea. Notice of the probe was given in December 1988. Imported materials included in the investigation were APT, tungsten metal powder, tungsten carbide and fused tungsten carbide from both China and the Republic of Korea, and tungsten oxide and TA from China. The Commission continued to consider taking action on a similar complaint filed in April 1988 involving imports of tungsten ores and concentrates from China.

Australia

Concentrate production at Peko-Wallsend Ltd.'s King Island scheelite mine increased about 11% in 1988 compared with that of 1987. Peko-Wallsend reportedly lost to less expensive ferrotungsten some of the market share for scheelite concentrate consumed in the specialty steel industries in the Federal Republic of Germany and Italy. However, this was more than offset by new sales to the German Democratic Republic for use in APT production and by increased sales to Japanese specialty steel producers who had been buying scheelite from the Republic of Korea.

Austria

Metallgesellshaft AG acquired state-owned Voest-Alpine AG's 47.5% interest in the tungsten mine and mill near Mittersill and its refinery at Bergla. This acquisition doubled its percentage of ownership in the operations. Teledyne Inc. retained ownership of the remaining 5%.

India

The Uttar Pradesh Mineral Development Corp. was reported to have discovered one of India's largest reserves of tungsten ore in the Almora District. Reserves were provisionally estimated at 10 million metric tons of ore containing an average of 0.4% tungsten. A pilot plant was set up by the corporation.

Korea, Republic of

Production of concentrate at Korea Tungsten Mining Co. Ltd.'s Sang Dong Mine was about 15% below the 1987 level of 2,375 metric tons of contained tungsten, owing to poor market conditions. As a result, sales of concentrates into the open market were halted. Concentrates produced during the year were processed into downstream products for both internal consumption and sale to foreign consumers.

Mongolia

According to published reports, trial operations were begun at the Tsagaan Davaa Mine on September 10, 1988. The operation was built by several

TABLE 12

U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1987		1988	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Tungsten and tungsten alloy wire:				
Argentina	2	$512	5	$491
Belgium-Luxembourg	—	—	1	149
Brazil	9	936	9	635
Bulgaria	—	—	2	257
Canada	26	3,226	28	3,125
Colombia	—	—	2	310
Costa Rica	—	—	1	244
France	2	206	2	248
Germany, Federal Republic of	9	2,042	22	2,250
Hong Kong	2	169	1	114
India	6	530	15	943
Israel	—	—	1	119
Italy	5	604	7	662
Japan	3	783	19	1,933
Korea, Republic of	5	962	5	653
Mexico	6	562	8	725
Netherlands	—	—	1	146
Poland	([1])	18	2	102
Switzerland	—	—	1	125
Taiwan	8	716	8	567
United Kingdom	6	868	9	1,132
Venezuela	—	—	7	1,388
Other	12	2,608	1	158
Total [2]	**101**	**14,742**	**153**	**16,475**
Unwrought tungsten and alloy in crude form, waste, and scrap:				
Australia	1	24	—	—
Austria	31	332	12	266
Belgium-Luxembourg	—	—	4	136
Canada	4	49	53	506
Chile	—	—	1	23
France	—	—	1	33
Germany, Federal Republic of	457	1,504	214	2,362
Israel	([1])	2	27	257
Japan	([1])	5	4	102
Korea, Republic of	—	—	3	17
Sweden	1	6	25	307
Taiwan	—	—	1	37
United Kingdom	73	523	1	42
Other	6	70	([1])	8
Total [2]	**573**	**2,515**	**346**	**4,098**
Other tungsten metal:				
Australia	3	184	1	215
Austria	1	31	2	85
Belgium-Luxembourg	—	—	2	210
Brazil	—	—	([1])	87
Canada	19	2,975	23	3,101
Colombia	—	—	1	151

See footnotes at end of table.

TABLE 12—Continued

U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1987 Tungsten content (metric tons)	1987 Value (thousands)	1988 Tungsten content (metric tons)	1988 Value (thousands)
France	6	$495	3	$564
Germany, Federal Republic of	14	679	6	856
Hong Kong	—	—	(1)	59
India	—	—	1	116
Ireland	—	—	1	138
Italy	(1)	37	1	95
Japan	23	2,751	14	3,523
Korea, Republic of	—	—	2	457
Mexico	5	335	1	252
Netherlands	2	542	1	378
Singapore	(1)	8	1	92
South Africa, Republic of	1	62	1	107
Spain	—	—	1	65
Sweden	(1)	13	(1)	24
Switzerland	4	285	3	329
Taiwan	7	399	2	376
Thailand	—	—	1	52
United Kingdom	11	1,053	7	817
Venezuela	(1)	11	(1)	50
Other	12	769	1	108
Total	**108**	**10,629**	**76**	**12,307**
Other tungsten compounds:				
Australia	—	—	1	21
Austria	(1)	13	2	40
Belgium-Luxembourg	(1)	3	(1)	10
Brazil	(1)	25	1	111
Canada	1	37	1	40
Chile	—	—	1	25
China	(1)	2	34	130
Finland	—	—	(1)	33
France	13	199	5	297
Germany, Federal Republic of	34	334	2	121
Hong Kong	1	23	1	61
Ireland	(1)	10	(1)	53
Israel	(1)	12	(1)	11
Italy	1	51	1	89
Japan	5	102	1	67
Korea, Republic of	3	119	2	233
Mexico	2	63	3	112
Netherlands	(1)	28	1	128
Singapore	(1)	6	(1)	16
Spain	—	—	2	75
Sweden	(1)	6	(1)	23
Taiwan	—	—	1	27
United Kingdom	10	387	34	547
Venezuela	(1)	12	(1)	2
Other	50	180	1	27
Total	**120**	**1,612**	**94**	**2,299**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

Hungarian interests at a cost of $5.4 million under an agreement signed with Mongolia in 1984. At full capacity, the operation is expected to treat 36,000 metric tons of ore annually.

Rwanda

A new Government-controlled company, Regi d'Exploitation et de Developpement des Mines, was created to take over tungsten and other mines previously owned and operated by Société Minierè du Rwanda (SOMIRWA). Before the financial collapse of SOMIRWA in 1985, Rwanda produced about 260 metric tons of contained tungsten in concentrate per year.

Spain

The Spanish General Workers Union (UGT) initiated discussions with the autonomous government of Estremadura regarding the future of the La Parilla mining operation, closed since April 1987. In its belief that La Parilla can be operated competitively, UGT offered several suggestions for reviving the mine. These included the drafting of a technical and economic viability plan, the creation of a new organization that would absorb the four distinct parts of the present La Parilla ownership, the participation of the Society for Industrial Development of Estremadura, and the intervention of the European Community in formulating a reference price.

TECHNOLOGY

Research and development during the year produced some potential new applications for tungsten-bearing materials as well as opportunities to improve their current uses. By replacing a portion of the molybdenum in molybdenum disilicide with tungsten, a Swedish company, Kanthal AB, raised the peak operating temperature of a furnace heating element by 100° C in oxidizing environments. The heating element also was stronger.[2] Field trials lasting 1 year confirmed the superior performance of the element compared with conventional molybdenum disilicide and lanthanum chromite heating elements.

Bioengineering scientists have utilized tungsten in a rather unique manner in the development of methods to improve the yield of farm crops.[3] Massive doses of animal or bacterial genes are introduced into the plants to effect changes in the plant's cell structure using an apparatus that functions similarly to a genetic shotgun. Millions of microscopic, heavy tungsten spheres laden with genes are propelled through the cell walls of the plant, where alteration of the cells then begins.

Scientists at the Naval Research Laboratory in Washington, DC, produced polycrystalline diamonds, approximately 0.5 millimeter in diameter, when methane gas obtained from a sewage treatment plant was passed over a hot tungsten filament (2,200° C).[4] Although this process represents a potential new use for tungsten filaments, the diamonds could reduce tungsten consumption if they can be substituted for cemented tungsten carbides in wear-resistant components.

Powder injection molding (PIM) techniques were successfully employed in the production of dense, heavy alloy (93% W) components.[5] Components of greater complexity can be fabricated by this process than by traditional die compaction methods, thus offering the potential for expanded application of such alloys. Studies to determine the feasibility of using the PIM techniques to produce tungsten carbide-based hard metals were also reported.[6] In another development in fabrication technology, tungsten-carbide-coated roller-cone oil drilling bits were prepared by a proprietary densification method that reduced labor requirements and material losses by 70% and 60%, respectively.[7] This Ceracon process involves the predensified formation of the uncoated part in a cold

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF TUNGSTEN ORE AND CONCENTRATE, BY COUNTRY

Country	1987		1988	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Australia	65	$343	235	$1,683
Belgium	—	—	35	90
Bolivia	750	3,476	978	5,685
Burma	96	478	43	214
Canada	312	4,283	134	1,381
Chile	86	268	10	102
China	1,139	5,799	4,082	24,097
France	—	—	24	128
Germany, Federal Republic of	69	450	29	164
Hong Kong	46	249	416	2,328
Japan	—	—	57	376
Mexico	227	853	167	945
Netherlands	11	63	129	877
Peru	362	1,790	370	2,185
Portugal	422	2,632	466	3,423
Rwanda	101	386	—	—
Singapore	—	—	13	74
Spain	16	55	4	38
Sweden	—	—	4	19
Switzerland	10	36	105	732
Taiwan	—	—	21	136
Thailand	418	2,013	378	2,043
Turkey	284	790	244	920
United Kingdom	—	—	101	625
Total	**4,414**	**23,964**	**8,045**	**48,265**

Source: Bureau of the Census.

TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM TUNGSTATE, BY COUNTRY

Country	1987		1988	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
China	1,239	$9,768	267	$2,615
Germany, Federal Republic of	65	664	308	3,029
Korea, Republic of	61	491	60	553
Taiwan	1	6	—	—
United Kingdom	36	193	—	—
Total	**1,402**	**11,122**	**635**	**6,197**

Source: Bureau of the Census.

TABLE 15

U.S. IMPORTS FOR CONSUMPTION OF FERROTUNGSTEN, BY COUNTRY

Country	1987 Tungsten content (metric tons)	1987 Value (thousands)	1988 Tungsten content (metric tons)	1988 Value (thousands)
Austria	40	$316	—	—
Canada	17	68	2	$10
China	220	1,284	468	2,537
Germany, Federal Republic of	—	—	13	83
Netherlands	—	—	13	69
Peru	15	36	—	—
Switzerland	8	72	43	—
United Kingdom	—	—	60	317
Total	**300**	**1,776**	**599**	**3,261**

Source: Bureau of the Census.

isostatic press followed by coating in a slurry of tungsten carbide and finally bonding the coating via the densification step. A principal advantage of the new method over existing methods is said to be the reduced cycle time at the elevated temperatures required for densification. The potential for detrimental changes in the microstructure of the substrate is thereby avoided.

Recent advances in plasma arc spraying technology have produced new ways to apply coatings of tungsten carbide. The coatings have been used with increasing effectiveness in several industries, including paper, steel, textile, chemical, and oil and gas.[8] For example, in the paper industry, tungsten carbide coatings on winder drums provide a surface that will not damage the finish on the wound paper products. In sheet metal production, tungsten carbide-cobalt coatings have provided the required gripping action to tightly wrap the sheet into coils. The latter coatings have been demonstrated to outlast chrome-plated, hardened steel rolls by 40 times.

Interest in the development and marketing of ceramic cutting-tool inserts as substitutes for the traditional cemented tungsten carbide inserts continued during the year. Greenleaf Corp. began marketing its WG-300 silicon carbide whisker-reinforced ceramic inserts as well as its WG-70 aluminum oxide composite material, which contains toughening agents rather than whisker reinforcements.[9] The WG-300 is designed primarily for the machining of nickel-base alloys used in the aerospace industry, whereas the WG-70 has been engineered specifically for machining iron-base alloys. Using a process called rheocasting, developed at the Massachusetts Institute of Technology, researchers there have produced a metal-matrix composite observed to exhibit superior wear resistance.[10] A 40% fraction of titanium carbide whiskers, distributed in a steel matrix by the rheocasting method, resulted in a composite with wear-resistant properties exceeding those of cemented tungsten carbide. Silicon nitride powders designed, in part, to be used as cutting-tool insert materials were introduced by Ferro Corp.[11] The powders can be formed into usable shapes by a variety of methods including pressing, casting, extrusion, and injection molding.

Research by the Bureau of Mines demonstrated that a tungstate-bearing sodium chloride phase recovered by a molten-salt extraction method can be a suitable feed material for preparing APT.[12] A combined crossflow-countercurrent flow solvent extraction process effectively produced a high-purity APT.

Using a hydrometallurgical process, Bureau of Mines researchers demonstrated the recovery of 90% of the tungsten in hardface alloy grinding waste.[13] The process involved deoiling the grinding waste, followed by a chloride-based dissolution step. Subsequent caustic leaching and precipitation steps conducted on the residue yielded a high-grade calcium tungstate.

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[1] Physical scientist, Branch of Ferrous Metals.

[2] Advanced Materials and Processes Incorporating Metal Prog. Heating Element Operates at 1,900° C in Air. V. 134, No. 1, 1988, p. 21.

[3] Discover, The World of Science. High Tech Hits the Dirt. V. 9, No. 11, 1988, pp. 58-59.

[4] Time. Say It With Sewage Gas. V. 132, No. 18, 1988, p. 74.

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[8] Advanced Materials and Processes Incorporating Metal Prog. Reliable Coatings Via Plasma Arc Spraying. V. 134, No. 6, 1988, pp. 41-44.

[9] Metalworking News. Greenleaf Makes Ceramic Cutting Inserts. V. 15, No. 703, p. 32.

[10] Irving, R. R. Metal Matrix Composites Can Claim Advantages Over Monolithic Metals in Terms of Desirable Properties. Metalworking News. V. 15, No. 671, pp. 17-18.

[11] American Metal Market. New Silicon-Nitride Powders Make Debut at Ferro Corp. V. 96, No. 72, 1988, p. 4.

[12] Raddatz, A. E., J. M. Gomes, and T. G. Carnahan. Preparation of Ammonium Paratungstate From a Sodium Tungstate-Sodium Chloride Phase. BuMines RI 9165, 1988, 10 pp.

[13] Redden, L. D., R. D. Groves, and D. C. Seidel. Hydrometallurgical Recovery of Critical Metals From Hardface Alloy Grinding Waste: A Laboratory Study. BuMines RI 9210, 1988, 31 pp.

TABLE 16

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1987		1988	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Other metal-bearing materials in chief value of tungsten:				
United Kingdom	1	$5	—	—
Total	**1**	**5**	**—**	**—**
Waste and scrap containing not over 50% tungsten:				
Belgium-Luxembourg	—	—	2	$8
Canada	1	6	6	93
China	—	—	7	92
France	8	64	—	—
Hong Kong	—	—	1	27
Japan	—	—	6	31
Sweden	—	—	7	37
Other	2	11	1	4
Total	**11**	**81**	**30**	**292**
Waste and scrap containing over 50% tungsten:				
Australia	—	—	8	94
Austria	9	88	3	25
Canada	21	287	15	99
China	148	955	555	3,634
France	16	82	([1])	1
Germany, Federal Republic of	34	205	92	675
Hong Kong	3	25	3	27
Hungary	—	—	5	37
Israel	195	1,133	1	94
Italy	11	25	17	107
Japan	11	112	23	243
Mexico	10	86	2	23
Netherlands	270	1,429	261	1,435
Portugal	—	—	3	15
Singapore	16	256	42	643
South Africa, Republic of	15	155	44	351
Sweden	72	327	215	973
Switzerland	8	52	3	10
Taiwan	—	—	5	24
United Kingdom	121	568	121	656
Total	**960**	**5,785**	**1,418**	**9,166**
Unwrought tungsten, except alloys, in lump, grains, and powders:				
Belgium-Luxembourg	([1])	21	3	106
Canada	—	—	1	40
Germany, Federal Republic of	21	536	20	581

See footnote at end of table.

TABLE 16—Continued

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1987		1988	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Japan	3	$150	2	$82
Korea, Republic of	1	25	2	22
Mexico	—	—	1	14
United Kingdom	—	—	13	190
Other	1	40	([1])	5
Total	**26**	**772**	**42**	**1,040**
Unrought tungsten, ingots, and shot	2	70	2	69
Unrought tungsten, other	5	236	2	141
Unwrought tungsten, alloys:				
Austria	1	57	([1])	45
Belgium-Luxembourg	—	—	1	33
Canada	([1])	13	1	61
China	—	—	([1])	7
Germany, Federal Republic of	3	72	1	14
Other	3	94	([1])	3
Total	**7**	**236**	**3**	**163**
Wrought tungsten:[2]				
Austria	([1])	29	8	769
Belgium-Luxembourg	5	458	6	647
China	—	—	1	60
France	—	—	([1])	5
Japan	35	2,662	17	3,016
Korea, Republic of	—	—	4	72
Netherlands	—	—	1	136
United Kingdom	1	27	([1])	19
Other	1	165	1	147
Total	**42**	**3,341**	**38**	**4,871**
Tungstic Acid:				
China	276	1,560	90	718
Japan	—	—	3	10
Total[3]	**276**	**1,560**	**92**	**729**
Calcium tungstate:				
Germany, Federal Republic of	7	204	6	260
Japan	1	52	1	70
Other	([1])	8	—	—
Total[3]	**8**	**264**	**7**	**329**
Potassium tungstate	([1])	20	4	221
Sodium tungstate:				
China	—	—	207	1,896
Germany, Federal Republic of	([1])	5	—	—
Total	**([1])**	**5**	**207**	**1,896**

See footnotes at end of table.

TABLE 16—Continued

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1987 Tungsten content (metric tons)	1987 Value (thousands)	1988 Tungsten content (metric tons)	1988 Value (thousands)
Tungsten carbide:				
Austria	([1])	$3	([1])	$4
Belgium-Luxembourg	21	626	27	957
Canada	4	111	6	193
China	3	105	28	467
Germany, Federal Republic of	422	7,059	459	8,515
Japan	1	52	1	69
Korea, Republic of	12	212	36	652
United Kingdom	5	49	12	263
Other	26	519	8	194
Total	**494**	**8,736**	**578**	**11,315**
Other tungsten compounds:				
Austria	—	—	84	794
Canada	([1])	4	7	188
China	15	68	738	6,977
Germany, Federal Republic of	—	—	1	37
Japan	—	—	9	261
United Kingdom	—	—	5	67
Other	10	196	—	—
Total	**25**	**268**	**844**	**8,324**
Mixtures, inorganic compounds, chief value in tungsten: Other	8	208	—	—

[1] Less than 1/2 unit.
[2] Estimated from reported gross weight.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 17

U.S. IMPORT DUTIES ON TUNGSTEN

TSUS No.	Item	Rate of duty effective Jan. 1, 1987	
		Most favored nation (MFN)	Non-MFN
601.54	Tungsten ore	17 cents per pound on tungsten content.	50 cents per pound on tungsten content.
603.45	Other metal-bearing materials in chief value of tungsten.	10 cents per pound on tungsten content and 4.8% ad valorem.	60 cents per pound on tungsten content and 40% ad valorem.
606.48	Ferrotungsten and ferrosilicon tungsten	5.6% ad valorem	35% ad valorem.
629.25	Waste and scrap containing by weight not over 50% tungsten.	4.9% ad valorem	50% ad valorem.
629.26	Waste and scrap containing by weight over 50% tungsten.	4.2% ad valorem	Do.
629.28	Unwrought tungsten, except alloys, in lumps, grains, and powders.	10.5% ad valorem	58% ad valorem.
629.29	Unwrought tungsten, ingots, and shot	6.0% ad valorem	50% ad valorem.
629.30	Unwrought tungsten, other	6.6% ad valorem	60% ad valorem.
629.32	Unwrought tungsten, alloys, containing by weight not over 50% tungsten.	4.7% ad valorem	35.5% ad valorem.
629.33	Unwrought tungsten, alloys, containing by weight over 50% tungsten.	6.6% ad valorem	60% ad valorem.
629.35	Wrought tungsten	6.5% ad valorem	Do.
416.40	Tungstic acid	10.5% ad valorem	55% ad valorem.
417.40	Ammonium tungstate	10.0% ad valorem	49.5% ad valorem.
418.30	Calcium tungstate	do.	43.5% ad valorem.
420.32	Potasssium tungstate	do.	50.5% ad valorem.
421.56	Sodium tungstate	do.	46.5% ad valorem.
422.40	Tungsten carbide	10.5% ad valorem	55.5% ad valorem.
422.42	Other tungsten compounds	10.0% ad valorem	45.5% ad valorem.
423.92	Mixtures of two or more inorganic compounds in chief value of tungsten.	do.	Do.

TABLE 18

WORLD TUNGSTEN ANNUAL MINE PRODUCTION CAPACITY, DECEMBER 31, 1988

(Metric tons tungsten content)

	Rated capacity[1]
North America:	
Canada	3,000
Mexico	300
United States	3,700
Total	**7,000**
South America:	
Argentina	40
Bolivia	1,300
Brazil	1,100
Peru	700
Total	**3,140**
Europe:	
Austria	1,600
Czechoslovakia	50
Mongolia	2,000
Portugal	1,400
Spain	400
Sweden	350
U.S.S.R.	9,200
Total	**15,000**
Africa:	
Rwanda	330
Uganda	10
Zaire	30
Zimbabwe	30
Total	**400**
Asia:	
Burma	500
China	21,000
India	30
Japan	600
Korea, North	500
Korea, Republic of	2,700
Malaysia	10
Thailand	750
Turkey	200
Total	**26,290**
Oceania:	
Australia	3,300
New Zealand	10
Total	**3,310**
World total	**55,140**

[1] Includes capacity at operating mines as well as mines on standby basis.

TABLE 19

TUNGSTEN: WORLD CONCENTRATE PRODUCTION, BY COUNTRY[1]

(Metric tons of tungsten content)

Country	1984	1985	1986	1987[p]	1988[e]
Argentina	37	17	20	15	20
Australia	1,709	1,971	1,600	1,150	[2]1,261
Austria	1,632	1,481	1,387	1,250	[2]1,507
Bolivia	1,893	1,643	1,095	638	950
Brazil	1,037	1,090	875	672	700
Burma	1,096	945	715	493	400
Canada	3,715	3,174	1,416	—	—
China[e]	13,500	15,000	15,000	[r]21,000	21,000
Czechoslovakia[e]	50	50	50	45	50
France	796	735	982	—	—
Guatemala	[r]14	[r]17	([3])	([3])	—
India	21	28	23	26	25
Japan	477	568	579	259	270
Korea, North[e]	1,000	1,000	1,000	[r]500	500
Korea, Republic of	2,702	2,579	2,455	2,375	[2]2,029
Malaysia	25	[e]20	2	([3])	—
Mexico	274	282	294	213	216
Mongolia[e]	1,500	1,500	1,500	1,500	2,000
New Zealand	6	5	[e]5	[e]5	5
Peru	699	[r]771	742	259	[2]545
Portugal	1,509	[r]1,766	1,657	1,207	1,400
Rwanda	260	167	13	—	—
Spain	565	458	495	81	20
Sweden	385	402	357	334	320
Thailand	741	586	475	705	[2]651
Turkey[e]	153	100	50	[2]187	[2]142
Uganda[e]	4	4	4	4	4
U.S.S.R.[e]	9,100	9,200	9,200	9,200	9,200
United States	1,203	996	780	34	W
Zaire	30	18	27	21	20
Zimbabwe	29	10	[r]1	[r]1	1
Total	**[r]46,162**	**[r]46,583**	**42,799**	**42,174**	**43,236**

[e] Estimated. [p] Preliminary. [r] Revised.
W Withheld to avoid disclosing company proprietary data; not included in "Total".
[1] Table includes data available through May 17, 1989.
[2] Reported figure.
[3] Revised to zero.

TABLE 20

TUNGSTEN: WORLD CONCENTRATE CONSUMPTION, BY COUNTRY[1]

(Metric tons of tungsten content)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Consumption, reported:					
Argentina	[3]37	[r]28	25	65	[3]60
Australia	[r]136	[r]111	94	95	120
Austria	2,096	[e]2,000	[e]2,000	[e]1,800	[3]1,800
Belgium-Luxembourg	142	341	30	[e]50	[3]50
Canada[3]	12	12	12	10	10
France	815	808	667	269	34
Italy	78	92	80	86	[3]80
Japan	2,302	2,616	2,145	2,116	2,170
Korea, Republic of	2,070	2,048	1,987	1,700	[3]1,750
Mexico	77	79	42	64	9
Portugal	159	[r]158	40	20	20
Sweden	765	820	855	567	570
United Kingdom	610	600	580	550	575
United States	8,577	6,838	4,804	5,506	[4]7,832
Consumption, apparent:[5]					
Brazil	538	1,048	672	678	800
Bulgaria[3]	100	100	100	100	100
China[3]	7,000	7,500	7,500	5,000	5,000
Czechoslovakia[3]	1,300	1,300	1,300	1,300	1,300
German Democratic Republic[3]	270	270	270	250	250
Germany, Federal Republic of	3,934	2,073	1,720	1,863	4,400
Hungary[e]	400	400	400	400	400
India	157	250	[e]250	[e]250	[3]250
Korea, North[3]	1,000	1,000	1,000	1,000	1,000
Netherlands[e]	300	400	350	300	[3]300
Poland	594	603	1,264	744	380
South Africa, Republic of[e]	250	250	250	250	[3]250
Spain	80	29	159	[e]100	100
U.S.S.R.[3]	16,000	16,000	16,000	16,000	16,000
Total	**[r]49,799**	**[r]47,774**	**44,596**	**41,133**	**45,610**

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Source, unless otherwise specified is a preprint from the UNCTAD Committee on Tungsten Published in part in Tungsten Statistics, Apr. 1989.

[2]In addition to the countries listed, Denmark, Finland, Israel, Norway, Romania, Switzerland, and Yugoslavia may consume tungsten concentrate, but consumption levels are not reported, and available general information is inadequate to develop reliable estimates of consumption levels.

[3]Estimated by the Bureau of Mines.

[4]Reported figure.

[5]Production plus imports minus exports. For a few countries where data were available, variations in stocks were used in determining consumption.

VANADIUM

By Henry E. Hilliard[1]

As 1988 began, it was apparent to many in the vanadium industry that the year would be much different from previous years of slumping demand and low prices. By yearend, some plants were running close to capacity. Plans were made to expand processing capacity. Demand was strong, both in domestic and foreign markets. Prices were rising and profits surged. Altogether, 1988 was a much better year than 1987.

However, there also had been some clouds on the horizon. If they lacked captive sources, producers of the intermediate compound vanadium pentoxide (V_2O_5) were faced with severe shortages of raw materials and fast-rising raw materials costs. Prices were increased to compensate, but doing so was not always easy, and, as a result, most producers were faced with a cost-price squeeze. Even so, sales were strong and profits improved throughout the year.

Riding on a weaker U.S. dollar and strong international demand, vanadium exports increased to more than $19 million, a level heretofore unattained by the industry.

Meanwhile, vanadium imports weighed in at about $15 million, only about $45,000 higher than in 1987. With this surprisingly small increase, the U.S. vanadium industry ended the year with a trade surplus of about $5 million. All in all, then, the vanadium industry ended 1988 riding on strong momentum.

DOMESTIC DATA COVERAGE

Domestic production data for vanadium are developed by the Bureau of Mines from four voluntary surveys of U.S. mills and processing facilities. Of the 10 plants and mills surveyed 9 responded with complete data representing more than 90% of U.S. production. Production for the lone nonrespondent was estimated using reported prior-year production levels adjusted by trends in employment and other guidelines. Data on uranium-vanadium mining operations were obtained from an independent survey conducted by the U.S. Department of Energy.

LEGISLATION AND GOVERNMENT PROGRAMS

The National Defense Stockpile (NDS) had a 1988 goal of 7,700 short tons of vanadium (V) contained in V_2O_5 and 1,000 tons in ferrovanadium (FeV). Actual yearend stockpile inventories were only 721 tons of vanadium contained in V_2O_5. On July 3, 1988, responsibility for the NDS was transferred from the General Services Administration to the U.S. Department of Defense, in accordance with Executive Order 12626. The fiscal year 1989 Defense Authorization Act required Defense to outline plans for at least $20 million worth of upgrading projects. In November, Defense promptly submitted to Congress an ambitious $30 million plan to upgrade the columbium, ferrochrome, tantalum, titanium, and vanadium stored in the NDS. The plan was in addition to separately mandated cobalt and ferroalloy upgrading projects. If the program is approved by Congress, producers would upgrade the

TABLE 1

SALIENT VANADIUM STATISTICS

(Short tons of contained vanadium unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Production:					
Ore and concentrate:					
Recoverable vanadium[1]	1,617	W	W	W	W
Value thousands	$24,551	W	W	W	W
Vanadium oxide recovered from ore[2]	2,620	W	W	W	W
Vanadium recovered from petroleum residue[3]	1,701	2,695	2,330	2,508	3,252
Consumption	4,761	4,883	4,308	4,653	5,329
Exports:					
Ferrovanadium (gross weight)	469	453	513	436	629
Ore and concentrate	12	3	86	—	—
Vanadium pentoxide anhydride (gross weight)	3,712	1,527	1,544	1,461	1,220
Other compounds (gross weight)	305	322	343	479	978
Imports (general)					
Ferrovanadium (gross weight)	1,461	977	747	422	148
Ore, slag, residue	633	303	2,013	2,264	3,986
Vanadium pentoxide, anhydride	149	63	443	357	421
World: Production from ore, concentrate, slag	34,291	[4]33,299	[4]32,530	[p, 4]34,300	[e 4]33,658

[e] Estimated. [p] Preliminary. W Withheld to avoid disclosing company proprietary data.
[1] Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mills, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.
[2] Produced directly from all domestic ores and ferrophosphorus; includes metavanadates.
[3] Includes vanadium recovered from ash, and spent catalysts.
[4] Excludes U.S. production.

stockpiled materials to higher purity.

There was more bad news for the uranium-vanadium mining and milling industry in June when the U.S. Supreme Court ruled that the Government was not required to restrict foreign uranium imports to help maintain a viable domestic uranium industry. The Court's ruling reversed one made in 1987 by the 10th U.S. Circuit Court of Appeals in Denver, CO. The lawsuit had been initiated by a group of uranium producers with support from State governments in Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. All contended that their State economies were hurt by the collapse of the uranium industry.

In July, the House Interior Subcommittee began deliberations on Senate bill (S.) 1100, introduced by a New Mexico Senator, to revitalize the industry. Major provisions of S.-1100 included a $1 billion mill tailings cleanup program to be financed by utility companies, the uranium industry, and the Federal Government; establishment of a new corporation to run the uranium enrichment program; and an agreement to drop all plans for import restrictions in exchange for the purchase of $750 million of domestic uranium over the next 5 years. According to supporters of the legislation, the $750 million purchase would revitalize the industry and result in the reopening of uranium mines nationwide. Although the bill passed the House in August, it died in a joint House-Senate conference committee.

In September, the General Accounting Office (GAO) issued a report that caused some concern to importers of South African minerals and ferroalloys. The report said that chrome (including ferrochrome), manganese (including ferromanganese), and vanadium (including ferrovanadium), should not be considered strategic and should be removed from the President's list of strategic and critical materials that were excluded from sanctions against the Republic of South Africa. The GAO report, released as the Senate Foreign Relations Committee began considering tougher sanctions against the Republic of South Africa, agreed with an earlier Bureau of Mines report.[2] The Bureau report estimated the 5-year economic cost of a U.S. embargo on 6 of the 10 materials now certified by the President to be strategic and critical to the defense and economic health of the nation. The estimate was $9.25 billion, or $1.85 billion per year. The 5-year cumulative embargo cost for vanadium was estimated to be $35 million. The Bureau report also concluded that in the event of a total embargo, there would be sufficient alternative sources for manganese, chromium, palladium, titanium, and vanadium. Producer reaction to the report was that the cost of an embargo was understated and was overly optimistic about the ability of other mineral-producing nations to replace South African imports by the United States.

DOMESTIC PRODUCTION

V_2O_5 is the principal starting material for the production of most vanadium compounds. U.S. production of V_2O_5 and shipments of finished products continued the increase that began in the fourth quarter of 1987. Pentoxide production from all sources increased about 6% to more than 7,000 tons. Recoverable production, which represents receipts of domestic ore and ferrophosphorus slag, declined in 1988 as it had each year since 1983; actual production was withheld to avoid disclosing company proprietary data. Idaho was the leading producing State, followed by Utah and Colorado. Increased recovery of vanadium from low-cost petroleum residues, spent catalyst, utility ash, and furnace bottoms partially compensated for the low level of domestic mine production.

Strategic Minerals Corp. (Stratcor), based in Danbury, CT, announced in January that it would resume operating the roaster at its vanadium mill in Hot Springs, AR. To meet the projected March startup, Stratcor called back 60 employees immediately and hired an additional 30 in February. Feed for the roaster was ore previously mined and stockpiled at the Hot Springs mill. Production from the older roaster was in addition to production from the more versatile leach-leach process installed by Stratcor after it purchased the mill from Union Carbide Corp. In May, Stratcor signed an agreement with a Venezuelan company, Processadora Paraguana CA (Propaca), to buy vanadium feedstocks. Propaca, formed in 1986, began construction of a plant in Punto Fijo in the Venezuelan State of Falcón. The plant will concentrate low-grade vanadium-bearing petroleum coke to a higher grade material suitable for export to Stratcor's Hot Springs plant for processing. The agreement should insulate Stratcor from the decline in availability of vanadium-bearing oil residues as oil-burning utilities switch to low sulfur oils with lower vanadium content. The plant was scheduled for completion in early 1989.

In another move to ensure an adequate supply of vanadium feedstocks, Stratcor announced in December that it would reopen its vanadium mine at Hot Springs in early 1989. The mine was closed in 1985 because of market conditions. However, with the reduced availability of vanadium raw materials, the price of vanadium products increased substantially, making it economical to operate the mine. The mine was the only primary vanadium operation in the United States.

In January, Metallurg Inc. and Shieldalloy Corp. merged under the name Shieldalloy Metallurgical Corp., with corporate headquarters in New York, NY. The new company continued with previous production and distribution activities, which included sales of products from Metallurg's overseas units and distribution of other materials purchased abroad. Ferrovanadium production was transferred out of Shieldalloy's plant in Newfield, NJ, and consolidated at the Cambridge, OH, plant where Shieldalloy also makes vanadium chemicals. Ferrocolumbium, ferroalloy powders, carbides, and glass-polishing powders continued to be made at Newfield. At about the same time as the merger with Metallurg, Shieldalloy entered into a joint venture with Affiliated Metals and Minerals Inc. The venture involved construction of new facilities at Affiliated to recover V_2O_5 from low-grade, vanadium-bearing fly ash that was not currently being used. Production from this plant was to be used internally by Shieldalloy. Affiliated is a privately owned company that produces ferrovanadium and ferromolybdenum, much of it by tolling arrangements, and it initially developed the vanadium recovery process on its own. In November, Affiliated filed for chapter 11 protection in Pittsburgh, PA; the joint venture with Shieldalloy was unaffected by the filing.

In August, Atlas Minerals, a division of Atlas Corp., began implementation of an earlier decision to decommission and reclaim its uranium-vanadium milling operations near Moab, UT. The mill had been on standby since March 1984 due to depressed economic conditions in the domestic uranium industry. Atlas had maintained the mill on standby at a cost of about $2 million per year in the hope that pending court decisions and legislation would make the industry more viable. During this time, the company shifted its primary emphasis to gold exploration and production. Reclamation of the Moab mill would involve reshaping and covering a 130-acre impoundment of uranium tailings with soil and rock and planting self-sustaining vegetation. Reclamation was designed to control radon gas emanations and protect against erosion for at least 1,000 years. In November, Atlas completed the sale of all of its Colorado and Utah vanadium and uranium properties, including equipment and supplies. At yearend, Atlas was reviewing an engineering study with the Nuclear Regulatory Commission, that would allow it to finalize the decommissioning and reclamation plan.

Umetco Minerals Corp., Danbury, CT, resumed operations at its White Mesa uranium-vanadium mill in July with about 115 employees back on the job. An additional 10 to 15 employees were recalled when vanadium processing circuit was resumed in November. The mill, near Blanding, UT, was closed in December 1987 because of low supplies of ore for processing. During the shutdown, about 45 employees remained to perform major maintenance. Ore stockpiles were built up, and revisions were made to the vanadium recovery circuit. The White Mesa mill, with the capacity to produce about 15 million pounds of V_2O_5 per year, initially came on-line in 1982 but then was idle for more than a year. Milling resumed in the fall of 1985 and continued until being closed in December 1987.

In September, Kerr-McGee Chemical Corp., Oklahoma City, OK, began a construction project that would expand the capacity of its Soda Springs, ID, vanadium operations by 30%. The expansion was prompted by increasingly tight supplies of vanadium raw materials and rising prices for V_2O_5 and products containing vanadium. The expansion, which was to take about a year to complete, would increase Kerr-McGee's pentoxide capacity by 1 million pounds to 4.3 million pounds per year. Kerr-McGee's vanadium plant had operated across the street from Monsanto's much larger elemental phosphorus complex since 1963, recovering vanadium byproducts from waste slag generated by Monsanto's three large electric furnaces. The company employed 52 company and contractor personnel. About 10 more workers will be hired when the expansion is completed.

CONSUMPTION, USES, AND STOCKS

Reported domestic consumption of vanadium in 1988 was 5,329 tons of contained V, a 15% increase over 1987 consumption. This relatively large increase could be directly attributed to increased production of steel, which accounted for about 85% of 1988 U.S. consumption of vanadium. U.S. production of 100 million tons of raw steel in 1988 represented a 12% increase over the 1987 output of 89.2 million tons.[3] Worldwide raw steel production hit an all-time high of 860 million tons, a 6% increase over 1987 production. Consequently, vanadium consumption increased globally, placing severe strains on producer and consumer stocks and supplies of vanadium raw materials.

There are a number of well-established uses of vanadium as an alloying element in steels and irons, uses that have persisted over the years and represent a stable demand that will rise or fall with the demand for these steels and irons. The use of vanadium in aerospace titanium alloys was also a stable pattern. There was a wide variety of applications for vanadium oxides in the chemical and polymer industries, which represented about 5% of total U.S. consumption of vanadium in 1988. With the possible exception of titanium alloys, there were few applications of vanadium in metals for which other alloying elements could not be substituted. Such substitutions were more likely as vanadium prices increased. However, the usages of vanadium are based on sound technical preferences as competitive pricing making substitution of other alloying agents less likely as vanadium prices increased. As the price of vanadium continues to rise, consumers may begin to substitute columbium and manganese for vanadium in steel sections smaller than 1 inch. Vanadium would still be required for sections larger than 1 inch. In most chemical industry uses, there were no acceptable alternatives to vanadium oxides and chemicals.

Vanadium has been studied in connection with the absorption of ultraviolet radiation in glass. Most metals impart faint, often objectional, colors to glass. Although vanadium-bearing glass is practically colorless, it blocks out virtually all radiation below 3,580 angstroms. At one time vanadium was used in shatterproof glass to prevent deterioration of the embedded layer of celluloid, particularly in the strong ultraviolet radiation of the tropics. Such glasses appear to offer the possibility of protecting pictures, fabrics, and other perishable art objects from deterioration by sunlight. Similar applications have gained acceptance in the U.S. food and beverage industry. By incorporating vanadium in the glass container, it was possible to prevent loss of the vitamin content in fruits, fruit drinks, etc., that were sensitive to ultraviolet and actinic rays.

Reported consumers' and producers' stocks of vanadium oxides, metal, alloys, and chemicals totaled 1,396 tons of contained vanadium at yearend 1988, compared with 2,057 tons at yearend 1987.

TABLE 2

PRODUCERS OF VANADIUM ALLOYS OR METAL IN THE UNITED STATES IN 1988

Producer	Plant location	Products[1]
Affiliated Metals and Minerals Inc.	Newcastle, PA	FeV.
KB Alloys Inc.	Henderson, KY	VAl, ZrVAl.
Do.	Wanatchee, WA	VAl, ZrVAl.
Reading Alloys Inc.	Robesonia, PA	FeV, VAl, V.
Shieldalloy Metallurgical Corp.	Cambridge, OH	FeV, Ferovan.[2]
Strategic Minerals Corp.	Niagara Falls, NY	FeV, VAl, Nitrovan.[2]
Teledyne Wah Chang Albany	Albany, OR	V, VAl.

[1] FeV, ferrovanadium; V, vanadium metal: VAl, vanadium-aluminum alloy; ZrVAl, zirconium-vanadium-aluminum alloy.
[2] Registered trademarks for proprietary products.

PRICES

Demand for FeV, and indeed all vanadium compounds, was significantly higher in 1988 than in 1987. The U.S. V_2O_5 industry increased its output by more than 6%. With demand pressing tightly against plant capacity and customers clamoring for more products, vanadium companies found themselves with the unusual ability to raise selling prices as well as output. Evidence of this was indicated by the price increases instituted by two of the largest U.S. FeV producers. At the end of 1987, Stratcor and Shieldalloy sold FeV for about $6.75 per pound of V content. By third-quarter 1988, the price had increased to about $8.82 per pound. In an effort to dampen runaway prices, Stratcor promised to hold firm at that price through the remainder of the year. Shieldalloy increased its price in September to $10.80 per pound and again in December to $11.90. Although Stratcor maintained its $8.90 per pound price through the remainder of the year, it announced in mid-December that prices would be increased to $12.50 per pound, effective with January 2, 1989 shipments. Producers fourth-quarter prices per pound for other selected vanadium compounds were as follows:

Compound	Price per pound
65% vanadium-aluminum (Stratcor)	$14.25
Nitrovan[1] (Stratcor)	13.00
Ferovan[1] (Shieldalloy)	11.60
Vanox[1] (Stratcor)	11.00
V_2O_5, high purity (Stratcor)	8.40
Ammonium metavanadate (Stratcor)	6.95
V_2O_5, technical flake and granular (Stratcor)	6.30
Sodium ammonium vanadate (Shieldalloy)	5.95

[1] Registered trademarks for proprietary compounds.

FOREIGN TRADE

Exports of vanadium products were 21% higher than in 1987. Most, if not all, of the increase could be attributed to the weakened U.S. dollar and higher producer prices in Europe. Canada, Brazil, the Republic of Korea, and Mexico were the leading importers. Other major importers were Belgium and Japan. Most countries imported almost exclusively V_2O_5. Austria, Canada, and the Republic of Korea also imported substantial quantities of FeV. Exports of V_2O_5 and catalyst containing V_2O_5 totaled 1,220 tons, slightly less than the 1,461 tons exported in 1987. The average declared value of the V_2O_5 was about $3.53 per pound. Exports of FeV totaled 909 tons gross weight compared with 622 tons in 1987. The average declared value of FeV exports was $5.36 per pound.

Imports for consumption of major vanadium compounds continued the decline that began in 1987. Imports of vanadium raw materials increased significantly over 1987 imports. Imports for consumption of FeV totaled 147 tons gross weight, down from 422 tons in 1987. The imported FeV averaged about 81% V with a mean customs value of $9.53 per pound of contained V. Austria was the largest exporter to the United States followed by Canada, Belgium, and the Federal Republic of Germany. V_2O_5 imports totaled 437 tons gross weight with a mean custom value of $3.37 per pound. Imports of vanadium contained in ores, slag, and petroleum residues totaled 2,232 tons of contained V. About 43% of these imports was in the form of vanadiferous iron slags from Highveld Steel and

TABLE 3

U.S. CONSUMPTION AND CONSUMER STOCKS OF VANADIUM MATERIALS, BY FORM

(Short tons of contained vanadium)

Type	1987 Consumption	1987 Ending stocks	1988 Consumption	1988 Ending stocks
Ferrovanadium[1]	3,925	322	4,498	631
Oxide	17	10	18	17
Ammonium metavanadate	W	W	W	W
Other[2]	711	40	812	56
Total[3]	**4,653**	**372**	**5,329**	**704**

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Includes other vanadium iron-carbon alloys as well as vanadium oxides added directly to steel.
[2] Consists principally of vanadium-aluminum alloy, plus relatively small quantities of other vanadium alloys and vanadium metal.
[3] Data may not add to totals shown because of independent rounding.

TABLE 4

U.S. CONSUMPTION OF VANADIUM IN 1988, BY END USE

(Short tons of contained vanadium)

End use	Quantity
Steel:	
Carbon	1,388
Stainless and heat-resisting	45
Full alloy	978
High-strength, low-alloy	1,476
Tool	530
Unspecified	W
Total	**[1]4,418**
Cast irons	22
Superalloys	10
Alloys (excluding steel and superalloys):	
Cutting and wear-resistant materials	W
Welding and alloy hard-facing rods and materials	6
Nonferrous alloys	W
Other alloys[2]	648
Chemicals and ceramics:	
Catalysts	12
Other[3]	W
Miscellaneous and unspecified	213
Grand total	**[1]5,329**

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] Data do not add to total shown because independent rounding.
[2] Includes magnetic alloys.
[3] Includes pigments.

Vanadium Corp. Ltd., Republic of South Africa. The remaining 57% consisted of an assortment of petroleum residues, spent catalyst, and utility ash from, in order of decreasing tonnages, Mexico, Italy, Canada, Venezuela, and 24 other countries.

WORLD CAPACITY

The data in table 10 are rated capacity for mills producing vanadium oxides as of December 31, 1988. Included in this data is the capacity to produce vanadium-bearing iron slag and petroleum coke. Rated capacity is defined as the maximum quantity of product that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that can be brought back into production within a short period with minimum capital expenditure.

Vanadium oxide mill capacity, rather than mine capacity, was chosen because vanadium oxide is the starting material for all commercial vanadium products. Also, a significant amount of vanadium is recovered from sources other than ore. Mill capacity is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines. This capacity is based on 360 working days per year, three shifts per day.

WORLD REVIEW

Australia

In March, Agnew Clough announced that it was considering a proposal to recommission and expand its V_2O_5 plant at Wundowie, Western Australia, at a cost of about $29 million. The expansion would include adding an ferrovanadium plant and doubling the capacity to about 3,200 tons per year. The recommissioned plant would use ore from the nearby Coats deposit, which had 30 years of proven reserves. Target date for renewed operation was mid-1989.

Brazil

The announcement by the Brazilian company, Vanadium de Maracas, of plans to begin production of V_2O_5 in early 1990 appeared to have been premature. The company was founded in 1987 with plant and process technology purchased from Finland's Rautaruukki Oy. The plant would use ore from magnetite deposits in Maraca and Campo Alegre de Lordes. All of the chemistry and engineering work had been completed. However, the company had yet to obtain permission from the State government of Bahia to mine the ore or erect a plant to process the ore.

Canada

After many years of research and false starts, a process for producing byproduct V_2O_5 from Alberta tar sands may finally be put to use in Canada. Using fly ash from a refinery that extracts oil from tar sands, Carbovan

TABLE 5

U.S. EXPORTS OF VANADIUM IN 1988, BY COUNTRY

(Thousand pounds and thousand dollars)

Country	Ferrovanadium (gross weight)		Vanadium ore and concentrate (vanadium content)		Vanadium compounds (gross weight)			
					Pentoxide (anhydride)[1]		Other[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	—	—	—	—	76	248	—	—
Australia	80	452	—	—	11	20	143	185
Austria	101	833	—	—	40	216	40	164
Belgium-Luxembourg	16	87	—	—	198	1,005	227	253
Brazil	—	—	—	—	432	1,623	326	608
Canada	625	3,005	—	—	294	720	208	472
Chile	1	5	—	—	4	5	5	6
Colombia	5	29	—	—	—	—	([3])	15
Denmark	—	—	—	—	—	—	21	24
Finland	—	—	—	—	2	16	—	—
France	—	—	—	—	—	—	9	48
Germany, Federal Republic of	50	224	—	—	231	1,280	3	30
Indonesia	—	—	—	—	8	24	3	4
Israel	—	—	—	—	15	20	—	—
Italy	—	—	—	—	2	15	—	—
Jamaica	—	—	—	—	10	16	—	—
Japan	69	468	—	—	80	433	208	458
Korea, Republic of	95	512	—	—	386	551	31	169
Malaysia	2	9	—	—	1	3	([3])	11
Mexico	80	390	—	—	344	731	181	224
Netherlands	47	258	—	—	270	1,582	—	—
Pakistan	—	—	—	—	6	31	11	14
Peru	—	—	—	—	—	—	7	10
Philippines	—	—	—	—	14	19	71	76
Singapore	—	—	—	—	—	—	76	99
South Africa, Republic of	—	—	—	—	—	—	103	126
Sweden	—	—	—	—	—	—	121	677
Taiwan	—	—	—	—	5	10	53	91
Thailand	—	—	—	—	—	—	19	76
Trinidad	13	51	—	—	6	28	—	—
United Kingdom	—	—	—	—	([3])	2	—	—
Venezuela	74	409	—	—	2	7	89	592
Total[4]	**1,258**	**6,732**	**—**	**—**	**2,440**	**8,604**	**1,956**	**4,429**

[1] May include catalyst-containing vanadium pentoxide.
[2] Excludes vanadates.
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 6

U.S. IMPORTS OF FERROVANADIUM, BY COUNTRY

(Thousand pounds and thousand dollars)

Country	1987 Gross weight	1987 Vanadium content	1987 Value	1988 Gross weight	1988 Vanadium content	1988 Value
General imports:						
Austria	449	367	2,045	112	92	631
Belgium-Luxembourg	—	—	—	86	69	839
Canada	275	228	1,202	88	71	730
Germany, Federal Republic of	86	62	392	10	6	70
South Africa, Republic of	34	28	138	—	—	—
Total [1]	**843**	**685**	**3,777**	**296**	**238**	**2,271**
Imports for consumption:						
Austria	449	367	2,045	112	92	631
Belgium-Luxembourg	—	—	—	86	69	839
Canada	275	228	1,202	88	71	730
Germany, Federal Republic of	86	62	392	10	6	70
South Africa, Republic of	34	28	138	—	—	—
Total [1]	**843**	**685**	**3,777**	**296**	**238**	**2,271**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 7

U.S. IMPORTS OF VANADIUM PENTOXIDE (ANHYDRIDE), BY COUNTRY

Country	1987 Gross weight (pounds)	1987 Vanadium content (pounds)	1987 Value	1988 Gross weight (pounds)	1988 Vanadium content (pounds)	1988 Value
General imports:						
China	534,379	299,359	$1,349,202	703,936	394,321	$2,230,293
France	—	—	—	700	392	24,265
Germany, Federal Republic of	1,055	591	6,258	550	308	2,084
Japan	18	10	1,201	—	—	—
South Africa, Republic of	740,254	414,690	2,012,907	799,506	447,856	2,724,431
Total [1]	**1,275,706**	**714,651**	**3,369,568**	**1,504,692**	**842,887**	**4,981,073**
Imports for consumption:						
China	74,957	41,991	189,787	169,836	95,136	502,923
France	—	—	—	700	392	24,265
Germany, Federal Republic of	1,055	591	6,258	550	308	2,084
Japan	18	10	1,201	—	—	—
South Africa, Republic of	740,254	414,690	2,012,907	689,981	386,504	2,419,680
Total [1]	**816,284**	**457,282**	**2,210,153**	**861,067**	**482,340**	**2,948,952**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Inc., Edmonton, Alberta, planned to produce 2.5 million pounds of V_2O_5 annually, beginning in October 1989. Carbovan was an $8.3 million joint venture owned by Agra Industries Ltd., Toronto, Ontario, and Renzy Mines Ltd., North York, Ontario. Potential customers for Carbovan's material included Masterloy Products Ltd., of Canada and U.S. chemical companies.

China

China's production of V_2O_5 from domestic vanadium-bearing slag was estimated at 7,700 tons in 1988, only 61% of total capacity. About 5,500 tons was consumed internally with 2,200 tons going for export. Approximately 4,400 tons was tolled for the Soviet Union bringing total production to more than 12,000 tons. The Chinese planned to increase capacity to 16,500 tons by 1990. They also planned to expand crude steel production to 66 million tons in 1989, which would also increase domestic demand for vanadium. Increased demand for vanadium would leave a limited amount of material for export.

Whether or not steel capacity can be expanded will depend on China's ability to attract foreign investments. The Beijing-based Metallurgical Ministry had negotiated with bankers, steel producers, and machinery manufacturers from Austria, Belgium, France, the Federal Republic of Germany, Japan, the United Kingdom, and the United States. Five steel plant projects had been planned at a cost of several billion dollars, one-half of which was to be raised abroad through Government loans and export credits. The money would be used to buy advanced steelmaking technology from abroad and building materials from domestic producers. The five plants were expected to be operational by early 1991 adding an annual steel production capacity of more than 6.6 million tons.

In 1987 China produced about 62 million metric tons of steel and imported more than 10 million tons.

TABLE 8

WORLD VANADIUM PENTOXIDE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1988[1]

(Short tons of vanadium content)

Country	Rated capacity[2]
Australia	1,600
Canada	850
Chile	2,500
China	9,000
South Africa, Republic of	23,500
U.S.S.R.	10,500
United States	12,100
Venezuela	2,700
Other market economy countries	600
Total	**63,350**

[1] Includes V_2O_5 in vanadiferous iron slags and petroleum refinery residues.

[2] Includes capacity of operating plants as well as plants on standby basis.

Republic of South Africa

Vansa Vanadium S.A. Ltd., South Africa's fourth and newest vanadium producer, went on-line in 1988 and began building toward a planned output of 3,000 tons of V_2O_5 per year. The mine, in the Steelpoort area of northeastern Transvaal, was previously operated by Highveld from 1960 to 1972. The Vansa Mine was managed by African Explorations and effectively controlled by Rand Mines, which held 42% of the equity. Rand Mines held the marketing contract for Vansa's production and eventually took over the management contract as well.

The ore body at the Vansa Mine sits on the crest of a low hill, which rises from an elevation of 818 to 950 meters. Initial mining operations involved cutting open benches to take the top off the hill. Once the top was removed, mining continued as in conventional open pit operations. The life of the mine was estimated at about 17 years. All of Vansa's production from the mine was to be exported, but company officials refused to disclose details of sales contracts or the destination of shipments. Many South African metal producers decided against revealing commercial information because of the growing pressure for sanctions against the country.

Highveld, South Africa's largest vanadium producer, announced a plan to expand capacity for the first time since the early 1980's.[4] The company planned to spend about $63 million on four projects that would increase vanadium, silicomanganese, and ferrosilicon production. One of these projects involved the construction of a rotary kiln at the company's Vantra Div. Vanadium pentoxide capacity at Vantra would be increased from the current 13 million pounds annually to about 17 million pounds. The expansion was expected to be completed by the end of 1989. The planned expansion at Vantra was in addition to the vanadium-bearing slag produced by Highveld as a byproduct of pig iron production. Vanadium-bearing slag and V_2O_5 were produced at two plants located near Witbank. Despite being cut off from its major steel markets in the European Community, Japan, and the United States by sanctions against its iron and steel products, the company reported that the plants operated at maximum capacity throughout 1988.

TECHNOLOGY

Researchers at the University of Texas at Austin, and the California Institute of Technology, Pasadena, CA, have characterized an unusual vanadium- and chromium-bearing andalusite (Al_2SiO_5).[5] The andalusite occurred abundantly as porphyroblasts in a very fine-grained graphite-rich quartz-muscovite schist west of Sandy Mountain in the Llano uplift of Central Texas. Electron micrograph analysis revealed highly unusual concentrations

TABLE 9

VANADIUM: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons of contained vanadium)

Country	1984	1985	1986	1987[p]	1988[e]
Production from ores, concentrates, slag:[2]					
China (in vanadiferous slag product)[e]	5,000	5,000	5,000	5,000	5,000
Finland (in vanadium pentoxide product)	3,376	2,350	—	—	—
South Africa, Republic of:[3]					
Content of pentoxide and vanadate products[e]	6,633	6,537	6,350	[r]4,580	5,600
Content of vanadiferous slag product[e 4]	7,165	8,912	10,580	[r]11,135	12,460
Total	**13,798**	**15,449**	**16,930**	**15,715**	**18,060**
U.S.S.R.[e]	10,500	10,500	10,600	10,600	10,600
United States (recoverable vanadium)	1,617	W	W	W	W
Total	**34,291**	**[5]33,299**	**[5]32,530**	**[5]31,315**	**[5]33,660**
Production from petroleum residues, ash, spent catalysts:[6]					
Japan (in vanadium pentoxide product)[e]	770	840	[7]929	925	925
United States (in vanadium pentoxide and ferrovanadium products)	1,701	2,695	2,330	2,508	[7]3,252
Total	**2,471**	**3,535**	**3,259**	**3,433**	**4,177**
Grand total	**36,762**	**36,834**	**35,789**	**34,748**	**37,837**

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]In addition to countries listed, vanadium is also recovered from petroleum residues in the Federal Republic of Germany, the U.S.S.R., and several other European countries, but available information is insufficient to make reliable estimates. Table includes data available through July 12, 1989.
[2]Production in this section is credited to the country that was the origin of the vanadiferous raw material.
[3]Includes production for Bophuthatswana.
[4]Data on vanadium content of vanadium slag are estimated on the basis of a reported tonnage of vanadium-bearing slag (gross weight) multiplied by an assumed grade of 14.1% vanadium.
[5]Excludes U.S. production.
[6]Production in this section credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.
[7]Reported figure.

of vanadium and chromium while manganese, iron, and magnesium were present at lower levels than were typical of pleochroic andalusites. The material contained, by weight, up to 0.81% V_2O_5 and 0.12% chromic oxide, but less than 0.07% ferric oxide, 0.22% titanium dioxide, and 0.004% manganese dioxide.

The Stretford process was developed to remove hydrogen sulfide from gas streams. The process, originally developed in the United Kingdom, was a cyclic process that produced elemental sulfur and a solution containing sodium thiosulfate and anthraquinone disulfonate. An improvement in the process involved the addition of a sodium metavanadate catalyst. The Stretford solution has a limited lifetime because of the buildup of byproduct sodium thiosulfate. The solution also averages 3.2 grams per liter of vanadium. This buildup results in the disposal of all or part of the solution. AMAX Metals Recovery Inc., Braithwaite, LA, developed a process that recovers the vanadium, oxidizes the anthraquinone disulfonate, and converts the thiosulfate to sodium sulfate.[6] The vanadium was sold as the oxide and the sodium sulfate could be safely discharged into industrial sewers.

[1]Physical scientist, Branch of Ferrous Metals.

[2]Bureau of Mines, U.S. Department of the Interior. Estimated Direct Economic Impact of a U.S. Import Embargo on Strategic and Critical Minerals Produced in South Africa. OFR 19-88, 54 pp.

[3]American Metal Market. IISI Figures Indicate Raw Steel Production Hit All-Time High in '88. V. 97, No. 18, Jan. 26, 1989, p. 3.

[4]Financial Mail. Highveld Steel: Expanding Again. Feb. 17, 1989, p. 105.

[5]Carlson, W. D., and G. Rossman. Vanadium and Chromium Bearing Andalusite: Occurrence and Optical-Absorbance Spectroscopy. Am. Mineral., v. 73, Nos. 11 and 12, Nov.-Dec. 1988, pp. 1366–1369.

[6]Delaney, D. D., J. W. Koepke, E. Wiewiorowski, R. Tinnin, and G. Garretson. Recovery of Vanadium From Spent Stretford Solution. Presented to the AIChE 1988 Annual Meeting, Washington, DC, Nov. 27-Dec. 2, 1988.

VERMICULITE

By Arthur C. Meisinger[1]

U.S. output of vermiculite concentrate increased slightly, but sales of exfoliated vermiculite were slightly lower than that of 1987. Average values of vermiculite concentrate and exfoliated vermiculite increased $3 and $4 per ton, respectively. South Carolina was again the leading State in vermiculite concentrate production followed by Montana and Virginia. World production of vermiculite was estimated to be 596,000 short tons, a slight decline from that in 1987.

DOMESTIC DATA COVERAGE

Domestic production data for vermiculite are developed by the Bureau of Mines from two separate voluntary surveys, one for domestic mine operations and the other for exfoliation plant operations. Of the six mining operations to which a survey request was sent, five responded. The one nonrespondent's data were estimated using previous years' production levels adjusted by trends in employment and other guidelines. Of the 45 exfoliating plants to which a survey request was sent, 41 responded. The 40 active respondents accounted for 82% of the total exfoliated vermiculite sold and used shown in table 1. The four nonrespondent's data were estimated using previous years' production levels adjusted by trends in employment and other guidelines.

DOMESTIC PRODUCTION

Production of vermiculite concentrate was 304,000 tons valued at $33.9 million, only slightly higher than that of 1987.

The leading domestic producer continued to be W. R. Grace & Co. with operations near Libby, MT, and Enoree, SC. Other producers during the year were Virginia Vermiculite Ltd., Louisa County, VA; Strong-Lite Products Corp.'s Carolina Vermiculite mine near Woodruff, SC; Patterson Vermiculite Co., Enoree, SC; and Enoree Minerals Corp., with initial output from the company's mine in Spartanburg County, SC. South Carolina, with four producers, was the leading producing State for the second consecutive year.

Domestic sales of exfoliated vermiculite by 15 producers declined slightly in quantity and increased slightly in value. Output came from 44 plants in 29 States, of which 29 plants in 24 States were operated by W. R. Grace.

In descending order of output sold and used, the principal exfoliated vermiculite-producing States were Ohio, California, South Carolina, Florida, New Jersey, Illinois, Texas, and Arkansas.

CONSUMPTION AND USES

Apparent domestic consumption of vermiculite concentrate increased slightly from 315,000 tons (revised) to 319,000 tons.

The quantities of exfoliated vermiculite sold and used in the agricultural and insulation markets increased 16% and 9%, respectively, compared with 1987 quantities. The quantity sold and used as aggregates for construction, however, continued to decline to 14%

TABLE 1

SALIENT VERMICULITE STATISTICS

(Thousand short tons and thousand dollars unless otherwise specified)

		1984	1985	1986	1987	1988
United States:						
Sold and used by producers:						
Concentrate		315	314	317	303	304
Value		$31,500	$32,400	$34,400	r$33,100	$33,900
Average value[1]	dollars per ton	$100.00	$103.18	$108.52	$109.24	$111.51
Exfoliated		264	258	253	252	249
Value		$56,500	$47,900	$53,200	$54,600	$55,100
Average value[1]	dollars per ton	$214.02	$185.66	$210.28	$216.67	$221.29
Exports to Canada		22	e23	e25	e20	e20
Imports for consumption		32	e38	e35	r32	e35
World: Production[2]		545	556	580	p598	e596

e Estimated. p Preliminary. r Revised.
[1] Based on rounded data.
[2] Excludes production by centrally planned economy countries.

TABLE 2

EXFOLIATED VERMICULITE SOLD AND USED IN THE UNITED STATES, BY END USE

(Short tons)

End use	1987	1988
Aggregates:		
Concrete	49,200	40,100
Plaster	700	1,400
Premixes[1]	81,300	71,600
Total	**131,200**	**113,100**
Insulation:		
Loose-fill	19,600	22,000
Block	35,700	31,700
Other[2]	1,700	8,200
Total	**57,000**	**61,900**
Agricultural:		
Horticultural	23,100	16,700
Soil conditioning	8,100	16,800
Fertilizer carrier	30,600	37,900
Total	**61,800**	**71,400**
Other[3]	2,200	2,600
Grand total	**[4]252,000**	**249,000**

[1] Includes acoustic, fireproofing, and texturizing uses.
[2] Includes high-temperature and packing insulation and sealants.
[3] Includes various industrial uses not specified.
[4] Data do not add to total shown because of independent rounding.

below the 1987 sales total of 131,200 tons. Other uses of exfoliated vermiculite increased 18% to 2,600 tons.

PRICES

The average value of vermiculite concentrate sold and used by U.S. producers was about $112 per ton, f.o.b. plant, a slight increase over that of 1987. The average value of exfoliated vermiculite, f.o.b. plant, increased slightly from $217 per ton to $221 per ton.

TABLE 3

ACTIVE VERMICULITE EXFOLIATING PLANTS IN THE UNITED STATES IN 1988

Company	County	State
A-Tops Corp.	Beaver	Pennsylvania.
Anitox Corp.	Gwinnett	Georgia.
Brouk Co.	St. Louis	Missouri.
Enoree Minerals Corp.	Spartanburg	South Carolina.
W. R. Grace & Co., Construction Products Div.	Maricopa	Arizona.
	Pulaski	Arkansas.
	Alameda	California.
	Orange	Do.
	Denver	Colorado.
	Broward	Florida.
	Duval	Do.
	Hillsborough	Do.
	Du Page	Illinois.
	Campbell	Kentucky.
	Orleans	Louisiana.
	Prince Georges	Maryland.
	Hampshire	Massachusetts.
	Wayne	Michigan.
	Hennepin	Minnesota.
	St. Louis	Missouri.
	Douglas	Nebraska.
	Mercer	New Jersey.
	Cayuga	New York.
	Guilford	North Carolina.
	Oklahoma	Oklahoma.
	Multnomah	Oregon.
	Lawrence	Pennsylvania.
	Greenville[1]	South Carolina.
	Davidson	Tennessee.
	Bexar	Texas.
	Dallas	Do.
Intermountain Products Inc.	Salt Lake	Utah.
Koos Inc.	Kenosha	Wisconsin.
O. M. Scott & Sons	Union	Ohio.
Patterson Vermiculite Co.	Laurens	South Carolina.
Robinson Insulation Co.	Cascade	Montana.
The Schundler Co.	Middlesex	New Jersey.
Strong-Lite Products Corp.	Jefferson	Arkansas.
Do.	De Kalb	Illinois.
Verlite Co.	Hillsborough	Florida.
Vermiculite Industrial Corp.	Allegheny	Pennsylvania.
Vermiculite Products Inc.	Harris	Texas.

[1] Two plants in county.

FOREIGN TRADE

Imports of vermiculite concentrate from the Republic of South Africa were estimated to be 35,000 tons, compared with 32,000 tons (revised) in 1987. Exports to Canada were estimated to be 20,000 tons, about 7% of total U.S. sales of vermiculite concentrate.

WORLD CAPACITY

The data in table 4 are rated annual capacity for vermiculite plants as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Plant capacity for vermiculite is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines.

[1] Industry economist, Branch of Industrial Minerals.

TABLE 4

WORLD VERMICULITE ANNUAL PRODUCTION CAPACITY DECEMBER 31, 1988

(Thousand short tons)

Country	Rated capacity[1]
North America:	
Mexico	1
United States	355
Total	**356**
South America:	
Argentina	25
Brazil	20
Total	**45**
Africa:	
Egypt	1
Kenya	5
South Africa, Republic of	260
Total	**266**
Asia:	
India	8
Japan	20
Total	**28**
World total	**695**

[1] Includes capacity at operating plants as well as at plants on standby basis.

TABLE 5

VERMICULITE: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Argentina	4,906	5,387	5,740	1,049	[3]22,267
Brazil	10,094	10,242	15,598	[r] [e]17,000	17,000
Egypt	[e]360	538	546	[e]550	550
India	2,153	1,990	7,365	2,689	2,800
Japan[e]	19,000	19,000	17,000	17,000	17,000
Kenya	961	1,670	2,804	4,285	[3]4,086
Mexico	557	[r]386	243	177	[3]211
South Africa, Republic of	191,536	202,902	213,470	252,278	[3]227,791
United States (sold and used by producers)	315,000	314,000	317,000	303,000	[3]304,000
Total	**544,567**	**[r]556,115**	**579,766**	**598,028**	**595,705**

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Excludes production by centrally planned economy countries. Table includes data available through July 12, 1989.

[2] In addition to the countries listed, Tanzania may produce vermiculite, but available information is inadequate to make reliable estimates of output levels, if any.

[3] Reported figure.

ZINC

By James H. Jolly[1] [2]

Domestic mine output of zinc increased for the second straight year, partly because of the reopening of a zinc-lead mine in Idaho that had closed in 1981. Production of refined zinc metal declined despite near-capacity output at U.S. primary smelters. Secondary metal production continued to increase owing largely to increased zinc recovery from steelmaking dusts. In 1988, U.S. mines produced 3.8% of world zinc mine production, and U.S. smelters produced 4.6% of world refined zinc metal output.

Domestic zinc metal consumption increased for the fourth straight year and was at its highest level since 1974. However, zinc oxide production declined, and consumption also fell although imports were at a record high.

World mine production fell substantially from 1987's record output but world smelter production attained record-high levels. World mine and smelter capacity utilization rates were high throughout the year, however, little new capacity was added to either category in 1988. A smelter in Texas, which was placed on standby status in 1985, was closed permanently resulting in a 25% reduction in potential U.S. zinc smelting capacity.

World zinc consumption attained record-high levels in 1988, exceeding 7 million tons for the second straight year. High consumption caused world metal stock levels to fall and led to steadily rising zinc prices as the year progressed. The world zinc pricing structure underwent substantial change in 1988. The London Metal Exchange (LME) was reestablished as the principal basis for world zinc pricing. The European Producer Price (EPP), the price basis of most world zinc sales from 1964 to 1988, was abandoned.

DOMESTIC DATA COVERAGE

Domestic data for zinc are developed by the Bureau of Mines from five separate, voluntary surveys of U.S. operations. Typical of these is the "Slab Zinc" consumption survey. Of the 309 operations to which the survey request was sent, 291 responded, representing an estimated 94% of the total reported slab zinc consumption shown for 1988 in tables 1, 15, 16, and 17. Consumption for the nonrespondents was estimated using prior year consumption levels.

TABLE 1

SALIENT ZINC STATISTICS

(Metric tons unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Production:					
Domestic ores, recoverable content	252,768	226,545	202,983	r216,327	244,314
Value thousands	$270,833	$201,607	$170,050	r$199,924	$324,249
Slab zinc:					
From domestic ores	197,912	r198,005	191,079	r205,275	196,476
From foreign ores	55,220	63,204	r62,290	r56,070	44,818
From scrap	78,113	r72,563	r62,912	r82,589	88,492
Total	**331,245**	**r333,772**	**316,281**	**r343,934**	**329,786**
Secondary zinc[1]	318,018	r256,455	r255,752	r269,319	253,858
Exports:					
Ores and concentrates (zinc content)	30,579	23,264	3,269	16,921	33,590
Slab zinc	760	1,011	1,938	1,082	482
Imports for consumption:					
Ores and concentrates (zinc content)	86,172	90,186	75,786	46,464	62,966
Slab zinc	639,228	610,900	665,126	705,985	749,133
Stocks of slab zinc, Dec. 31:					
Industry	r137,895	119,892	r100,563	r96,372	85,531
Government stockpile	340,577	340,577	340,577	340,577	340,577
Consumption:					
Slab zinc:					
Reported	848,903	770,671	705,963	r798,148	832,425
Apparent (rounded)[2]	980,000	961,000	999,000	1,052,000	1,089,000
All classes (rounded)[3]	r1,344,000	r1,257,000	r1,274,000	r1,324,000	1,345,000
Price: High Grade, cents per pound (delivered)	48.60	40.37	38.00	41.92	60.20
World:					
Production:					
Mine thousand metric tons	6,524	r6,799	6,936	p7,242	e6,977
Smelter do	6,527	r6,798	6,699	p7,014	e7,109
Price: London, cents per pound	40.46	36.23	34.19	36.20	53.37

e Estimated. p Preliminary. r Revised.

[1] Excludes secondary slab and remelt zinc.

[2] Domestic production plus net imports plus or minus stock changes.

[3] Based on apparent consumption of slab zinc plus zinc content of ores and concentrates and secondary materials.

LEGISLATION AND GOVERNMENT PROGRAMS

In August, the U.S. Circuit Court upheld a 1986 decision by the Environmental Protection Agency (EPA) that high-volume mine waste generated in the mining and milling of nonfuel minerals did not necessarily constitute hazardous waste under the terms of subtitle C of the Resource Conservation and Recovery Act (RCRA). Nevertheless, further characterization of ore extraction and benefication waste would be required before any of these wastes could be permanently excluded from subtitle C regulation. In a related ruling, the same court ordered EPA to amend its regulations under RCRA by relisting as hazardous six wastes generated from metal smelting operations.[3] The six wastes, which included sludges from treatment of process wastewater and/or acid plant blowdown from primary zinc production, were previously listed as hazardous; however, the listings were suspended by EPA in response to enactment of the Bevill Amendment (exclusion) in 1980. As a result of the relisting, these wastes also fell under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or more commonly, Superfund) regulations that designates them as hazardous substances and establishes the reportable quantities applicable to each waste.

In October, EPA proposed rulemaking that would eliminate all but 15 special wastes from the processing of ores and minerals from the Bevill Amendment.[4] Blowdown from acid plants and process wastewater from primary zinc smelting were kept in the exclusion and would be further studied and subject to a subsequent regulatory determination. In December, additional wastes, including goethite and zinc-lean slag from primary zinc smelting, were added to the Bevill exclusion list for consideration. A final rule on these wastes was expected in 1989.

DOMESTIC PRODUCTION

Mine Production

U.S. zinc mine output increased for the second straight year owing to the reopening of the Bunker Hill Mine in Idaho and to a full year's production at the new Montana Tunnels Mine in Montana. The continuing strong market outlook for zinc also resulted in renewed interest in opening a number of closed domestic zinc mining properties. The 20 leading U.S. zinc-producing mines accounted for more than 98% of production, with the 5 leading mines accounting for 52%. Tennessee was the principal zinc-producing State, followed by New York, Missouri, Montana, and Colorado. Zinc production in the Western States, although less than one-fifth of the national total, was the highest since 1981. The leading domestic zinc mine producers were ASARCO Incorporated, Jersey Minière Zinc Co. (JMZ), and Zinc Corporation of America (ZCA).

In Tennessee, zinc was produced from zinc ore at six underground mines. JMZ, operator of the Elmwood-Gordonsville Mine in central Tennessee; Asarco, operator of four eastern Tennessee mines; and USX Corp., operator of one mine, also in eastern Tennessee, accounted for all the State's output.

In March, Asarco purchased two closed eastern Tennessee mines, Beaver Creek and Jefferson City, from Inspiration Resources Corp. Asarco restarted operations at the Beaver Creek Mine in May and integrated its production into that of the adjacent Young Mine and mill. Asarco's mines operated at full capacity and achieved record output. According to the company's annual report, Asarco milled 2.7 million tons of ore producing 67,850 tons of zinc in concentrates in 1988, compared with 2.7 million tons of ore milled yielding 65,050 tons of zinc in 1987. At yearend, ore reserves at the four mines, including Beaver Creek, were 5.8 million tons averaging about 3.25% zinc, about the same tonnage and zinc grade as reported at the end of 1987.

Zinc was produced as a coproduct of lead at eight underground lead mines along the Viburnum Trend in southeastern Missouri. The State's output was up substantially from that of 1987 mainly because of higher production at Asarco's West Fork Mine, which reached full capacity in August following completion of a ventilation shaft. According to Asarco's annual report, the company milled 726,000 tons of ore yielding 45,000 tons of lead, 269,000 ounces of silver, and 10,800 tons of zinc in concentrates in 1988. Zinc production was double that produced in 1987.

The Sweetwater Mine, acquired by Asarco in late 1986 and started up in December 1987, operated at about 40% capacity during the year. Zinc production in concentrate amounted to 1,450 tons. At yearend, ore reserves at the Sweetwater Mine were 22.6 million tons averaging 4.84% lead and 0.59% zinc and at the West Fork Mine were 9.3 million tons averaging 5.93% lead and 1.47% zinc with some silver and copper.

The Doe Run Co. produced about 24,000 tons of zinc in concentrate at two mills that processed about 4 million tons of ore from five of six company mines in Missouri in 1988. Ore reserves at Doe Run's Missouri mines were virtually unchanged from the previous year and totaled about 67 million tons averaging 5.1% lead, 0.9% zinc, and 0.3% copper at yearend. In December, Doe Run won a court case that gave it the right to explore but not mine ore bodies in the environmentally sensitive Mark Twain National Forest, south of Winona, MO. The preference right leases, totaling 3,740 acres, contained a "no guaranteed development" stipulation that would deny any mine development activities pending further review by the U.S. Forest Service.

Zinc production at the Magmont

Mine, a joint venture of Cominco American Incorporated (a subsidiary of Cominco Ltd.) and Dresser Industries Inc., fell substantially from 1987 owing to a one-third decrease in the zinc content of ore milled. According to Cominco's annual report, the Magmont mill processed 1 million tons of lead ore grading 1% zinc yielding about 8,000 tons of zinc in 13,600 tons of zinc concentrate in 1988, compared with a production of 12,950 tons of zinc in 21,800 tons of zinc concentrate in 1987. Ore reserves continued to decline and were expected to be exhausted in about 4 years. At yearend, ore reserves totaled 3.9 million tons averaging 6.8% lead, 1.1% zinc, and 0.3% copper.

In Colorado, zinc production was a coproduct of gold-silver operations at the Leadville Unit (managed by Asarco but jointly owned with the Resurrection Mining Co.) and at the Sunnyside Mine (a joint venture between Alta Gold Co., 40%; Washington Mining Co., 33%; and Echo Bay Mines Ltd., 27%). The ownership and operating company of the Sunnyside Mine changed twice in 1988. In June, Alta Gold and Echo Bay agreed to joint ownership of certain mine properties, including Sunnyside, with Alta Gold becoming the operator. In November, a further change occurred in which Washington Mining will become the operating company as of January 1, 1989. Asarco produced 13,500 tons of zinc in concentrates at its Leadville Unit, up about 500 tons from 1987. The tonnage mined and milled (about 197,000 tons) was the same for both years but the average zinc grade was higher in 1988. At yearend, ore reserves were up about 50,000 tons from 1987 and totaled 763,000 tons averaging 8.41% zinc, 3.37% lead, 0.19% copper, 1.7 ounces of silver per ton, and 0.05 ounce of gold per ton.

In Idaho, the Bunker Hill Mine, which operated for almost 100 years until it closed at the end of 1981, was reopened by the Bunker Hill Mining Co. Inc. in September. The company was mining a 9-million-ton zinc-rich ore body discovered just a few years prior to the mine's closure in 1981. The ore body was estimated to average about 10% zinc, 3% lead, and 2 ounces of silver per ton. Bunker Hill reportedly had raised its milling rate to about 700 tons of ore per day by yearend and planned to double that rate by mid-1989. The zinc concentrate was exported, and the lead concentrate was shipped to Montana for smelting. Hecla Mining Co. continued the phased-in startup of its "underhand longwall mining method" at the Lucky Friday Mine near Mullan. Five of six planned stopes were in production in 1988, with the sixth scheduled to come on-line in late 1989. The new mining system was introduced to reduce rockburst problems in the deep workings of the mine. In 1988, zinc production totaled about 2,100 tons in concentrates, more than double that of 1987 when the mine was closed for nearly half the year. Ore reserves declined about 37,000 tons in 1988 and at yearend totaled 542,000 tons grading 13% lead, 2.3% zinc, and 14 ounces of silver per ton.

In Alaska, the Greens Creek Mining Co., the operating company and a wholly owned subsidiary of BP Minerals America Inc., and minority partners, Hecla, Exalas Resources Corp., and CSX Oil and Gas Corp. planned to have the Greens Creek silver-gold-zinc-lead mine on Admiralty Island on-stream in February 1989. Zinc output in concentrates was expected to be about 30,000 tons annually at the planned ore production rate of 900 tons per day. About 210 workers were expected to be employed. Ore reserves were 3.2 million tons averaging 9.7% zinc, 3.9% lead, 22 ounces of silver per ton, and 0.16 ounce of gold per ton. An additional 2 million tons of slightly higher grade possible ore had been discovered by exploration drilling and could extend the life of the mine beyond the anticipated 10 years.

Development of the Red Dog zinc-lead-silver deposit in northwest Alaska continued satisfactorily. Cominco Alaska Inc., a subsidiary of Cominco Ltd., rescheduled the startup date to October 1989. However, shipments of concentrates from the company's port facility on the Chukchi Sea were not expected until the sea ice broke up in the summer of 1990. At capacity by 1991, Cominco Alaska planned to produce annually 325,000 tons of zinc and 70,000 tons of lead in concentrates. Ore reserves, totaling 77 million tons and averaging 17.1% zinc, 5% lead, and 2.6 ounces of silver per ton, was expected to be sufficient for a 50-year operation. Most of the zinc concentrate produced was to be processed at Cominco Ltd.'s zinc refinery at Trail, British Columbia.

New Butte Mining Co. applied for permits to reopen a number of closed underground mines in the Butte District in Montana. Beginning in mid-1989, the company planned to mine about 900 tons per day of zinc-lead-silver-gold ore from two previously untouched ore deposits on Butte Hill. About 0.5 million tons of ore averaging about 7% zinc, 2% lead, 14 ounces of silver per ton, and 0.1 ounce of gold per ton had been blocked out. Zinc production at Butte Hill made Montana the leading zinc-producing State in the early 1950's; however, by 1967 production fell to a few thousand tons annually and virtually ceased by the early 1970's.

Smelter and Refinery Production

Refined metal production declined slightly from that of 1987 despite near capacity operations at the four domestic primary smelters. Three companies, ZCA, JMZ, and Big River Zinc Co., operated four zinc refineries in 1987. Secondary zinc metal was produced at eight secondary plants from scrap materials; however, the largest producer of secondary zinc metal was ZCA at its primary electrothermic smelter at Monaca, PA. A substantial part of the plant's feed was secondary material, principally a crude zinc calcine recovered from steelmaking electric arc furnace (EAF) dusts by a sister company, Horsehead Resource Development Co. (HRD), at Palmerton, PA. The largest producers of metal at secondary plants were Huron Valley Steel Corp., Interamerican Zinc Co., and Gulf Metals Corp.

Big River, a privately held company, became the owner and operator of AMAX Inc.'s 76,000-ton-per-year electrolytic custom zinc refinery in Sauget, IL, in September; this essentially ended Amax's involvement in the domestic zinc industry. Asarco's electrolytic smelter in Corpus Christi, TX, which had been closed since April 1985, was permanently shut down by the company and converted into a waste treatment facility late in the year, thereby reducing potential U.S. primary zinc smelter capacity by about one-fourth.

HRD, a subsidiary of Horsehead Industries Inc., continued to increase zinc recovery from EAF dust recycle by bringing a new Waelz-kiln facility in Chicago, IL, on-stream in 1988. The annual EAF dust processing capacity of the new plant and the company's Palmerton, PA, Waelz-kiln operations totaled about 320,000 tons with a potential to recover 50,000 tons of zinc units in the form of zinc calcine. In December, HRD purchased a rotary-kiln facility in Rockwood, TN, and in 1989 it planned to convert this facility into a 55,000-ton-per-year EAF dust-processing plant for zinc recovery.

Other types of EAF dust-processing units were also scheduled for operation to meet EPA deadlines and requirements. HRD was considering the commercialization of its 18,000-ton-per-year demonstration flame-reactor unit at Monaca, PA, to process EAF dust. Florida Steel Corp. and Nucor-Yamato Steel Co. were constructing plasma furnaces based on technology developed by Tetronics Research and Development Co. for on-line EAF processing at their respective plants at Jackson, TN, and Blytheville, AR. Florida Steel was scheduled to have a 7,200-ton-per-year EAF dust-processing plant on-stream in January 1989, and Nucor-Yamato Steel planned to complete its 11,000-ton-per-year plant in May 1989. Because the plasma furnaces would be outfitted with zinc splash condensers, the plants were expected to produce commercial-grade zinc metal at annual rates of about 1,400 and 1,800 tons, respectively.

In December, ZCA permanently closed its zinc dust plant at Depue, IL, citing overcapacity and the need to rationalize company operations resulting from the merger that formed the company in 1987. Dust production was to be concentrated at the company's Monaca, PA, facility.

Zinc Oxide.—Domestic American- and French-process zinc oxide was produced entirely from zinc metal and scrap by eight companies in 1988. All but one company, Eagle Zinc Co. of Hillsboro, IL, produced French-process zinc oxide. Several plants produced impure grades, most of which were derived from the processing of EAF dust. Most of these impure materials were processed to zinc metal at the smelter in Monaca, PA, owned by ZCA. The remainder was sold for use as agricultural nutrients, trace elements for animal feeds, and conversion into various zinc chemicals or put into landfills.

Asarco and Eagle Zinc planned to expand their Hillsboro, IL, zinc oxide plants in 1989 to meet anticipated future zinc oxide market demand. Asarco was adding a new furnace and Eagle Zinc planned a 50% capacity increase, raising plant capacity to about 11,000 tons annually. In 1988, zinc oxide production at Asarco's 20,000-ton-per-year plant was 11,070 tons, up from 10,400 tons in 1987.

Pasco Zinc Corp., a subsidiary of CRA Ltd., sold its 18,000-ton-per-year zinc oxide facility in Memphis, TN, to Pigment & Chemical Inc., a Canadian company. The Memphis plant, built in 1981, was initially designed to process zinc scrap materials but in the last few years slab zinc had been almost exclusively used to produce oxide.

Zinc Salts.—Zinc sulfate was produced by nine companies from secondary zinc materials and waste streams from electrolytic zinc plants. Zinc sulfate, produced in both solid and liquid form, was used mainly for agricultural purposes. Zinc-chloride-type chemicals were produced at four plants from secondary zinc materials and chemical waste streams. Output of zinc sulfate increased, whereas zinc chloride output declined in 1988.

Byproduct Sulfur.—Production of sulfur in byproduct sulfuric acid at four primary zinc plants using sphalerite concentrate as feed material was 136,000 tons, up marginally from the 134,000 tons produced in 1987.

CONSUMPTION AND USES

Domestic zinc consumption for most end-use categories increased in 1988, continuing the uptrend in consumption that started in 1986. Galvanizing and electrogalvanizing, mainly for sheet and strip, continued to be the principal use of slab zinc, consuming an estimated 51%, followed by zinc-base die-cast alloys, 23%; brass alloys, 13%; and other uses, 13%. Special High Grade (SHG) accounted for about 50% of the reported slab zinc consumed, followed by Prime Western, 27%; High Grade (HG), 12%; and other grades, 11%.

Overall, the construction sector of the economy was the largest consumer of zinc, accounting for an estimated 45%, followed by transportation, 23%; machinery, 12%; electrical, 10%; and chemical and other industries, 10%. About 27,600 tons of SHG was used by the U.S. Mint to produce 11.35 billion pennies in 1988.

According to the American Iron and Steel Institute, shipments of galvanized sheet and strip totaled 10.25 million tons, up from 8.25 million tons in 1987 and 7.06 million tons in 1986. Of the total shipments, electrogalvanized sheet accounted for 21% compared with only 16% in 1987 and 7% in 1986. The substantial increase in electrogalvanized sheet shipments was due not only to continued strong demand by the automobile industry but also to increasingly greater demand by appliance, office furniture, and steel door manufacturers. Electrogalvanized steel continued to replace zinc-rich primer and Zincrometal (a patented zinc-rich coil coating material for corrosion protection) usage in the transportation industry. The use of Zincrometal-coated steel fell from about 1.3 million tons in 1984 to 430,000 tons in 1988.

According to the Bureau of the Census, zinc-base alloy die and foundry casting shipments totaled about 223,000 tons, down from 228,000 tons reported in 1987. The zinc consumption by weight was estimated to be equally distributed between automotive, hardware, and other uses.

Zinc consumption in the production of copper-base alloys by brass mills, ingot makers, and foundries increased 5% over that of 1987 and was at the highest consumption level since 1984, according to the Copper Development Association Inc. (CDA). The brass and bronze industries consumed about 308,000 tons of zinc, the source of which was about equally divided between refined zinc metal and brass and bronze scrap metal. According to CDA data, brass mills accounted for 85% of the total zinc consumed as metal and scrap.

The zinc content in typical U.S.-manufactured automobiles was estimated to average about 40 pounds in 1988, about the same as in 1987. Diecastings accounted for about 20 pounds; corrosion protection via galvanizing and coatings, 15 pounds; and other, including rubber, brass, and zinc solder, 5 pounds.

The apparent domestic consumption of zinc oxide was about 190,000 tons, down from 198,000 tons in 1987. Domestic production fell marginally from the previous year owing in part to increased market penetration from imports. Imported zinc oxide reached record-high levels in 1988 and accounted for about 38% of domestic consumption, up from 29% in 1987 and 27% in 1986. Because the Bureau of Mines information on zinc oxide consumption by industry sector reflects only shipments as reported by the domestic producers, the consumption data listed in table 20 only accounts for about two-thirds of the apparent market. Of the reported amounts, the rubber industry continued to be the principal consumer followed by chemicals and paint.

STOCKS

Metal stocks held at yearend by domestic producers, consumers, and merchants fell again in 1988. The decline was the seventh straight yearly decrease and in 1988 reflected strong world demand for zinc during the year relative to available supply. Prior years generally reflected trends by holders of zinc stocks to minimize inventories and reduce investment in stocks. The 1988 ending domestic stock levels were only 42% of those held at the end of 1981. Domestic stock levels fell in the early months, but tended to rise and stabilize from midyear with rising prices despite marginal improvement in supply. Metal stock levels in the market economy countries, according to the International Lead and Zinc Study Group (ILZSG), fell from 568,000 tons at the end of 1987 to 528,000 tons at the end of 1988.[5] Monthly stocks, as reported by ILZSG, followed U.S. trends gradually declining in the first half of the year to a low of 471,000 tons in June but slowly rising in the second half.

The LME zinc metal stocks of HG declined from about 45,000 tons in January to 33,000 tons in August, and declined further to about 27,000 tons in September following the introduction of the new SHG contract on September 1. Because of tightness in the SHG physical market, the buildup of SHG stocks on the LME was slow, reaching only 3,025 tons by the end of October. Concern for liquidity of the new contract led European producers to build up SHG stocks in the last 2 months. Yearend zinc stocks at the LME totaled 14,400 tons of HG and 26,050 tons of SHG.

Inventories of zinc in concentrates at domestic primary smelters totaled 49,400 tons at yearend compared with 38,450 tons at the end of 1987, according to the American Bureau of Metal Statistics Inc. Domestic stocks were lowest in March and highest at yearend.

PRICES

Zinc prices trended upward every month except August and reached all-time highs in December. The main impetus for the zinc increases was tightness of supply brought about by strong world demand. However, strikes, most notable in Peru, reactions to prices on the LME, bid prices for zinc at U.S. Mint tenders, technical problems at some smelters, and hurricane-related zinc-shipment delays in Mexico in October, were also contributing factors. The high zinc prices also led to numerous increases in zinc- and copper-base alloy prices and to premiums on the price of products such as galvanized steel. In some cases, zinc-metal-consuming companies, in part concerned with possible substitution, did not pass the full zinc price increases on to their customers.

The introduction of the new SHG contract on the LME in September substantially changed the world zinc-pricing structure. It led to the demise of the EPP system on which most of the world's zinc concentrate and metal sales and trades were based since 1964, and to the resurrection of the LME as the principal world price basis for zinc. In addition, zinc transactions on the LME were switched to a U.S. dollar basis from British pounds. Also European custom smelters dropped the Good Ordinary Brand zinc producer price at yearend.

The pricing changes in 1988 also affected the way zinc mine producers and custom smelting companies determine concentrate treatment charges. At yearend, most of those involved with 1989 concentrate transactions were unsure of the final forms these contracts would take, although most were expected to involve a spread of SHG price quotations at the LME.

Zinc oxide prices, as quoted in American Metal Market, rose as the price of zinc metal increased during the year. The price ranged from a low of 52 to 77 cents per pound and averaged about 66.5 cents. In 1987, zinc oxide averaged about 53.5 cents per pound. Imported zinc oxide averaged 49.4 cents per pound compared with 36.9 cents in 1987.

The price quoted in Chemical Marketing Reporter (CMR) for zinc sulfate, monohydrate industrial grade, 36% zinc in bags in carload lots, ranged from $30 to $32 per 100 pounds. Agricultural zinc sulfate in bulk was quoted by CMR at $26.50 per 100 pounds. CMR's quotes for standard pigment-grade zinc dust, types 1 and 2 in drums, ranged from 59 to 67 cents per pound. Technical-grade zinc chloride, 50% solution in tanks, was quoted as $20.20 per 100 pounds in January but rose to $22 by December.

FOREIGN TRADE

Exports of waste and scrap reached record-high levels. Exports of zinc in concentrates doubled and were largely exported to Canada by western U.S. zinc producers. U.S. imports of slab zinc were the highest ever and accounted for almost 70% of domestic metal consumption.

General imports of zinc concentrate continued at high levels compared with the quantities of zinc concentrate imported for domestic consumption. The disparity was due to shipments of concentrate through Skagway, AK, to world markets from Canada's Faro zinc-lead mine in the Yukon Territory. Concentrate exports have increased over the last 2 years; however, the net imports of concentrate for each of these years has remained at about the 30,000-ton level.

WORLD CAPACITY

Both world mine and smelter capacity recorded small gains in 1988. Mine capacity was about 7.7 million tons at yearend, up about 0.1 million tons from 1 year earlier. Eleven zinc producing mines closed in 1988 reducing world mine capacity by 150,000 tons. However, more than balancing the closures were 14 mines that opened or expanded, adding 280,000 tons to zinc mine capacity. Canada and Sweden, where four and three mines, respectively, closed, accounted for most of the loss in capacity. In the Federal Republic of Germany, the famous Rammelsberg-zinc-lead-silver mine was permanently closed after almost 1,000 years of operation. Four mines that accounted for about two-thirds of the new added mine capacity in 1988 were Caribou, Zenmac, and Isle Dieu in Canada and Cadjebut in Australia. The United States accounted for 25,000 tons of new capacity owing largely to the reopening of the Bunker Hill Mine. In the 1989–1991 period, new mines and expansions were expected to add up to 1 million tons of capacity. The United States and Australia were expected to account for about two-thirds of the new capacity. The largest single increase, 325,000 tons, was expected in late 1989 when the Red Dog Mine was to come on-stream. More than 300,000 tons of additional capacity was expected in Australia, where five significant zinc mining properties, Hellyer, Golden Grove, Hilton, Thalanga, and Lady Loretta, were being developed or expanded.

Annual world primary smelter capacity, about 7.9 million tons, had a net gain of about 45,000 tons in 1988 owing to upgrades and modifications at 10 smelters. The 70,000-ton-per-year vertical retort zinc refinery at Harlingerode, in the Federal Republic of Germany, was the only zinc plant that closed in 1988. A number of minor capacity additions were underway in a number of countries, and "greenfield" smelters were under construction in India and Iran. In Australia, Canada, the Republic of Korea, and Spain, major zinc plant expansions were proposed; however, despite the favorable market outlook for zinc in 1989, few of these expansion programs were given final approval in 1988.

The data in table 33 are rated annual production capacity for zinc mines and primary zinc refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable, long-term operating rate, based on the physical equipment of the mine or plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Refinery capacity is based on engineering capacity provided by the companies or as estimated by the Bureau of Mines. Capacity includes both operating plants and plants temporarily closed that in the judgment of the author can be brought into production within a short period of time with minimum capital expenditure.

WORLD REVIEW

World zinc consumption continued its record-setting pace, exceeding 7 million tons for the second straignt year.

World mine production declined from the record high of 1987, whereas metal production rose to record-high levels.

World zinc metal consumption increased for the sixth straight year and totaled about 7.2 million tons in 1988. The market economy countries, according to ILZSG, consumed 5.24 million tons or 73% of the world total in 1988, an increase of about 0.2 million tons from that of 1987. The centrally planned economies consumed about 2 million tons, about 27% of the total. The world's leading consuming nations, in order of estimated consumption, were the United States, the U.S.S.R., Japan, the Federal Republic of Germany, China, and France. The United States, Japan, and Western Europe accounted for slightly more than 50% of world consumption and about 70% of the market economy countries' consumption. According to the ILZSG the principal uses of zinc metal in 1987 in the major market economy countries, including the United States, were galvanizing, 44.8%; brass and bronze, 20.7%; zinc-base alloys, 15.1%; chemicals, 8.2%; zinc semimanufactures, 6.9%; zinc dust and powder, 1.4%; and miscellaneous, 2.9%. In 1988, galvanizing was estimated to have increased its proportion of zinc metal use to about 46%; other major consuming sectors, brass, zinc-base alloys, and zinc semimanufacturers, accounted for about 21%, 15%, and 7%, respectively.

World zinc mine output declined about 0.26 million tons from the record-high 7.24 million tons produced in 1987. The decrease was largely the result of the permanent closure of the Pine Point Mine in Canada, and production problems in Peru owing to industrial disputes and terrorist activity. Of the 52 countries mining zinc in 1988, Bolivia, China, and the United States were the only countries recording significant increases in production. Most countries produced at their 1987 level or slightly below that level. On a geographical basis, North and South America accounted for about 39% of world mine production in 1988, Europe, including the U.S.S.R., 32%; and Australia, 11%. Canada continued to be the leading world zinc mine producer despite the sharp decrease in output, and together with Australia, Peru, and the U.S.S.R. accounted for about one-half of world output.

World exports of zinc in concentrates totaled about 2.3 million tons, of which about 90% were from the market economy countries. Australia, Canada, and Peru accounted for about 70% of the total concentrate shipments. Japan was by far the leading importer of zinc concentrate, followed by the Federal Republic of Germany, France, Belgium, and the Netherlands. The above countries accounted for about 70% of world zinc concentrate imports in 1988. The U.S.S.R., officially reporting trade data to ILZSG for the first time since the mid-1970's, imported 38,000 tons of zinc in concentrates in 1988 from all sources. According to ILZSG, the market economy countries exported 103,000 tons of zinc in concentrate to the centrally planned economy nations in 1988, resulting in net exports of 76,000 tons.

World refined metal production was up about 0.2 million tons to 7.1 million tons in 1988. According to ILZSG, the market economy countries increased metal output to 5.24 million tons from 5.05 million tons in 1987. The higher output was mainly attributable to increased production in Canada, France, the Republic of Korea, and Spain. Canada, Japan, and the U.S.S.R., the three largest world producers, accounted for about one-third of world refined zinc metal production.

Further corporate concentration of the world zinc industry took place in 1988. Two of Europe's largest zinc producers, Preussag Metall AG and Société Miniére et Métallurgique de Peñarroya, merged their zinc, lead, and high purity metal operations, forming a new company called Metaleurop S.A. In Spain, the merger of the country's two largest banks resulted in the new bank having control of all Spanish refined zinc production. In Australia, CRA Ltd. and North Broken Hill Holdings Ltd. merged their lead and zinc mining and smelting production facilities, forming Pasminco Ltd., one of the largest vertically integrated zinc-lead mining and smelting companies in the world. Annual zinc mine production of Pasminco was expected to total about 380,000 tons, whereas refined zinc metal production would total about 530,000 tons.

The world zinc supply-demand position shifted further to the demand side in 1988 as reflected by increasing world zinc prices and reductions in zinc stocks as the year progressed. Metal stocks in the market economy countries fell for the third straight year and were 40,000 tons less than 1 year earlier. Net exports of metal from the market economy countries to the centrally planned economy countries totaled 48,000 tons in 1988 and essentially accounted for the drop in stock levels. In 1987, the reverse situation occurred when the market economy countries had net imports of 13,000 tons. ILZSG, at its annual meeting in October, forecast a continuing tight supply-demand situation for zinc in 1989. Zinc mine and smelter production and zinc consumption in the market economy countries in 1989 were expected to increase over those of 1988.

TECHNOLOGY

A plasma furnace demonstration project for on-site treatment of steelmaking EAF dust for zinc recovery was completed.[6] The project, financed by 22 companies and the Electric Power Institute, demonstrated the capability of the plasma furnace for recovering zinc as metal and for producing a nonhazardous slag suitable for construction uses or on-site disposal in accordance with EPA regulations. Economic analysis indicated that the on-site process was sensitive to electricity and labor rates and the zinc content in EAF dusts. The analysis also indicated that the process was probably not economical for EAF producers generating less than 1,400 tons of dust per year.

The feasibility of smelting bulk concentrates of intimately associated base metal sulfides was investigated using a slag fuming process.[7] The study indicated that high recoveries of zinc, copper, and lead might be obtained using 1 ton of coal per ton of zinc recovered. Fine grained, mixed ores that cannot be separated by flotation or by other means, such as those deposited in the Red Sea or at the McArthur River deposit in Australia, were considered likely candidates for the process.

A comprehensive coverage of zinc-related investigations and an extensive review of current world literature on zinc extraction, alloys, uses, products, and research was available in quarterly issues of Zincscan, published by the Zinc Development Association, London, United Kingdom.

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] The author would like to acknowledge the invaluable assistance of the following coworkers: Lura M. Nightlinger and Tony E. Morris for table structure and preparation, and Colleen Wilson for preparing the paper in the new format.

[3] Federal Register. Hazardous Waste Management System: Identification and Listing of Hazardous Waste; and Designation, Reportable Quantities, and Notification. V. 53, No. 177, Sept. 3, 1988, pp. 35412-35421.

[4] ———. Mining Waste Exclusion. V. 53, No. 203, Oct. 20, 1988, pp. 41288-41300.

[5] International Lead and Zinc Study Group. Lead and Zinc Statistics. V. 29, No. 5, May 1989, p. 46.

[6] MacRae, D. R., and P. M. Cowx. Plasma Furnace Treatment of Electric Arc Furnace Dust as Demonstrated by Bethlehem-Tetronics. Center for Metal Production. CMP Rept. No. 88-2, Nov. 1988, 139 pp.

[7] Quarm, T. A. A. A Submerged Smelting Process for Complex Zinc Concentrates. Min. Mag. (London), v. 158, No. 2, Feb. 1988, pp. 120-122.

TABLE 2

MINE PRODUCTION OF RECOVERABLE ZINC IN THE UNITED STATES, BY MONTH

(Metric tons)

Month	1987[r]	1988
January	17,807	16,837
February	17,782	18,327
March	19,018	22,462
April	18,021	21,531
May	17,837	22,187
June	18,098	22,563
July	17,813	19,006
August	19,091	21,710
September	18,292	20,095
October	18,311	20,107
November	15,904	20,058
December	18,353	19,431
Total	**216,327**	**244,314**

[r] Revised.

TABLE 3

MINE PRODUCTION OF RECOVERABLE ZINC IN THE UNITED STATES, BY STATE

(Metric tons)

State	1984	1985	1986	1987	1988
Colorado	W	W	W	W	W
Idaho	W	W	351	W	W
Illinois	W	W	W	W	W
Kentucky	W	W	—	10	W
Missouri	45,458	49,340	37,919	34,956	41,322
Montana	—	—	—	W	18,935
New Jersey	W	W	W	—	—
New York	W	W	W	W	W
Pennsylvania	—	—	—	—	—
Tennessee	116,526	104,471	102,118	115,699	119,954
Utah	W	—	—	—	—
Total	**252,768**	**226,545**	**202,983**	**[r]216,327**	**244,314**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

TABLE 4

LEADING ZINC-PRODUCING MINES IN THE UNITED STATES IN 1988, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of zinc
1	Elmwood-Gordonsville	Smith, TN	Jersey Minière Zinc Co.	Zinc ore.
2	Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Do.
3	Young[1]	Jefferson, TN	ASARCO Incorporated	Do.
4	Immel	Knox, TN	do.	Do.
5	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Gold ore.
6	Balmat	St. Lawrence, NY	Zinc Corporation of America	Zinc ore.
7	New Market	Jefferson, TN	ASARCO Incorporated	Do.
8	Buick	Iron, MO	The Doe Run Co.	Lead ore.
9	Zinc Mine Works	Jefferson, TN	USX Corp.	Zinc ore.
10	Leadville Unit	Lake, CO	ASARCO Incorporated	Lead-zinc ore.
11	West Fork	Reynolds, MO	do.	Lead ore.
12	Coy	Jefferson, TN	do.	Zinc ore.
13	Magmont	Iron, MO	Cominco American Incorporated	Lead-zinc ore.
14	Sunnyside	San Juan, CO	Alta Gold Co.	Gold ore.
15	Fletcher	Reynolds, MO	The Doe Run Co.	Lead-zinc ore.
16	Viburnum No. 29	Washington, MO	do.	Lead ore.
17	Rosiclare	Hardin and Pope, IL	Ozark-Mahoning Co.	Fluorspar.
18	Bunker Hill	Shoshone, ID	Bunker Hill Mining Co. (U.S.) Inc.	Lead-zinc ore.
19	Sweetwater	Reynolds, MO	ASARCO Incorporated	Lead ore.
20	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Silver ore.
21	Casteel	Iron, MO	The Doe Run Co.	Copper-lead ore.
22	Viburnum No. 28	do	do.	Lead ore.
23	Camp Bird	Ouray, CO	Western Mining Corp.	Gold ore.
24	Salem	Livingston, KY	Kentucky-Illinois Fluorspar Inc.	Fluorspar.

[1] Includes Beaver Creek Mine.

TABLE 5

PRIMARY AND SECONDARY SLAB ZINC PRODUCED IN THE UNITED STATES

(Metric tons)

	1984	1985[r]	1986[r]	1987[r]	1988
Primary:					
From domestic ores	197,912	198,005	191,079	205,275	196,476
From foreign ores	55,220	63,204	62,290	56,070	44,818
Total	**253,132**	**261,209**	**253,369**	**261,345**	**241,294**
Secondary:					
At primary smelters	44,930	39,720	49,852	W	W
At secondary smelters	33,183	32,843	13,060	W	W
Total	**78,113**	**72,563**	**62,912**	**82,589**	**88,492**
Grand total (excludes zinc recovered by remelting)	**331,245**	**333,772**	**316,281**	**343,934**	**329,786**

[r] Revised. W Withheld to avoid disclosing company proprietary data.

TABLE 6

DISTILLED AND ELECTROLYTIC ZINC, PRIMARY AND SECONDARY, PRODUCED IN THE UNITED STATES, BY GRADE

(Metric tons)

Grade	1984	1985	1986	1987	1988
Special High	123,325	98,282	r78,979	85,010	90,034
High	71,892	98,979	r84,737	88,952	74,870
Continuous Galvanizing	48,200	26,139	20,589	38,751	44,890
Controlled Lead	9,384	20,952	18,883	W	W
Prime Western	78,444	r89,420	113,093	131,221	119,992
Total	**331,245**	**r333,772**	**316,281**	**343,934**	**329,786**

r Revised. W Withheld to avoid disclosing company proprietary data, included in "Prime Western."

TABLE 7

ANNUAL SLAB ZINC CAPACITY OF PRIMARY ZINC PLANTS IN THE UNITED STATES, BY TYPE OF PLANT AND COMPANY

Type of plant and company	Slab zinc capacity (metric tons)	
	1987	1988
Electrolytic:		
Big River Zinc Corp., Sauget, IL[1]	76,000	76,000
ASARCO Incorporated, Corpus Christi, TX[2]	104,000	—
Jersey Miniere Zinc Co., Clarksville, TN	82,000	95,000
Zinc Corp. of America, Bartlesville, OK	51,000	51,000
Electrothermic:		
Zinc Corp. of America, Monaca, PA[3]	101,000	101,000
Total available capacity	**414,000**	**323,000**
Total operating capacity	**310,000**	**323,000**

[1] Sold by AMAX Inc. in Aug. 1988.
[2] Zinc plant closed indefinitely in Apr. 1985 and permanently closed in 1988.
[3] Includes secondary capacity.

TABLE 8

SECONDARY ZINC PLANT CAPACITY IN THE UNITED STATES, BY COMPANY

Company	Plant location	Capacity (metric tons)	
		1987	1988
Arco Alloys Corp.	Detroit, MI		
W. J. Bullock Inc.	Fairfield, AL		
T. L. Diamond & Co. Inc.	Spelter, WV		
Gulf Reduction Corp.	Houston, TX		
Hugo Neu-Proler Co.	Terminal Island, CA		
Huron Valley Steel Corp.	Belleville, MI	r55,000	55,000
Interamerican Zinc Co.	Adrian, MI		
New England Smelting Works Inc.	West Springfield, MA		
Pasco Zinc Corp.	Memphis, TN		
Zinc Corp. of America	Palmerton, PA		

r Revised.

TABLE 9

STOCKS AND CONSUMPTION OF NEW AND OLD ZINC SCRAP IN THE UNITED STATES IN 1988, BY TYPE OF SCRAP

(Metric tons, zinc content)

Type of scrap	Stocks, Jan. 1[r]	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
Diecastings	950	4,535	—	5,122	5,122	363
Flue dust	4,848	W	3,744	3,739	7,483	W
Fragmentized diecastings	105	W	—	13,640	13,640	W
Galvanizer's dross	7,036	61,039	63,212	—	63,212	4,863
Old zinc[1]	132	3,331	—	3,313	3,313	150
Remelt die-cast slab	562	14,575	—	14,574	14,574	563
Remelt zinc[2]	68	379	425	—	425	22
Skimmings and ashes[3]	20,526	29,029	45,267	—	45,267	4,288
Steelmaking dust	2,905	35,928	—	36,111	36,111	2,722
Other[4]	330	25,031	3,695	—	3,695	5,496
Total	**37,462**	**173,847**	**116,343**	**76,499**	**192,842**	**18,467**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Other."
[1] Includes engraver's plates and rod and die scrap.
[2] Includes new clippings.
[3] Includes sal skimmings and die-cast skimmings.
[4] Includes chemical residues.

TABLE 10

PRODUCTION OF ZINC PRODUCTS FROM ZINC-BASE SCRAP IN THE UNITED STATES

(Metric tons)

Product	1984[r]	1985[r]	1986[r]	1987[r]	1988
Redistilled slab zinc	78,113	72,563	62,912	82,589	88,492
Zinc dust	35,254	30,754	26,682	28,620	24,206
Other metal alloys	253	982	99	163	317
Remelt die-cast slab	3,380	3,651	2,564	825	907
Other zinc metal products	8,549	6,695	7,098	6,741	8,016
Secondary zinc in chemical products	50,851	44,598	44,891	79,361	61,413

[r] Revised.

TABLE 11

ZINC RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Metric tons)

	1987[r]	1988
KIND OF SCRAP		
New scrap:		
Zinc-base	146,394	111,133
Copper-base	123,969	133,881
Magnesium-base	35	122
Total	**270,398**	**245,136**
Old scrap:		
Zinc-base	59,964	74,632
Copper-base	21,125	22,053
Aluminum-base	262	349
Magnesium-base	159	180
Total	**81,510**	**97,214**
Grand total	**351,908**	**342,350**
FORM OF RECOVERY		
Metal:		
Slab zinc	82,589	88,492
Zinc dust	28,620	24,206
Other[1]	6,741	8,016
Total	**117,950**	**120,714**
In zinc-base alloys	988	907
In brass and bronze	153,141	158,999
In other metal alloys	468	317
In chemical products:		
Zinc oxide (lead free)	49,901	34,527
Zinc sulfate	17,302	18,404
Zinc chloride	12,158	8,482
Miscellaneous	—	—
Total	**233,958**	**221,636**
Grand total	**351,908**	**342,350**

[r] Revised.
[1] Includes electrogalvanizing anodes and zinc content of slab made from remelt die-cast slab.

TABLE 12

U.S. CONSUMPTION OF ZINC

(Metric tons)

	1984	1985[r]	1986[r]	1987[r]	1988
Slab zinc, apparent (rounded)	980,000	961,000	999,000	1,052,000	1,089,000
Ores and concentrates (zinc content)[1]	45,487	39,886	19,236	2,536	2,412
Secondary (zinc content)[2]	318,018	256,455	255,752	269,319	253,858
Total (rounded)[3]	**1,344,000**	**1,257,000**	**1,274,000**	**1,324,000**	**1,345,000**

[r] Revised.
[1] Includes ore used directly in galvanizing.
[2] Excludes secondary slab and remelt zinc.
[3] Data have been revised based on apparent consumption; previously based on reported consumption.

TABLE 13

ESTIMATED[1] APPARENT CONSUMPTION OF SLAB ZINC, ACCORDING TO INDUSTRY USE AND PRODUCT

(Metric tons)

Industry and product	1987	1988
Galvanizing:		
Sheet and strip	382,000	403,000
Other	168,000	156,000
Total	**550,000**	**559,000**
Brass and bronze	140,000	146,000
Zinc-base alloys	229,000	254,000
Rolled zinc	36,000	W
Zinc oxide	64,000	65,900
Other uses[2]	33,000	64,100
Estimated apparent consumption	1,052,000	1,089,000

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1] Based on reported slab zinc consumption.
[2] Includes zinc used in making zinc dust, wet batteries, desilverizing lead, powder, alloys, anodes, chemicals, castings, light metal alloys, and miscellaneous uses not elsewhere specified.

TABLE 14

U.S. REPORTED CONSUMPTION OF SLAB ZINC, BY INDUSTRY AND PRODUCT

(Metric tons)

Industry and product	1987[r]	1988
Galvanizing:		
Sheet and strip	276,386	303,050
Other	128,316	103,491
Total	**404,702**	**406,541**
Brass and Bronzê	84,361	89,995
Zinc-base alloy	178,683	205,566
Rolled zinc[1]	35,426	W
Zinc oxide	64,400	61,367
Other uses[2]	30,576	68,956
Grand total	**798,148**	**832,425**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1] Includes zinc used in penny production.
[2] Includes zinc used in making zinc dust, wet batteries, desilverizing lead, powder, alloys, anodes, chemicals, castings, light metal alloys, and miscellaneous uses not elsewhere specified.

TABLE 15

U.S. REPORTED CONSUMPTION OF SLAB ZINC IN 1988, BY INDUSTRY AND GRADE

(Metric tons)

Industry	Special High Grade	High Grade	Prime Western	Remelt and other grades	Total[1]
Galvanizing	93,804	67,385	167,834	77,519	406,541
Zinc-base alloys	203,570	W	—	W	205,566
Brass and bronze	43,328	32,941	W	W	89,995
Rolled zinc[2]	W	—	—	W	W
Zinc oxide	23,540	W	W	—	61,367
Other	W	W	W	W	68,956
Total[1]	**412,417**	**104,235**	**221,921**	**93,852**	**832,425**

W Withheld to avoid disclosing company proprietary data, included in "Total."
[1] Data may not add to totals shown because of withheld figures.
[2] Included with "Other."

TABLE 16

U.S. REPORTED CONSUMPTION OF SLAB ZINC IN 1988, BY STATE

(Metric tons)

State	Galvanizers	Brass mills[1]	Diecasters[2]	Other[3]	Total
Alabama	8,155	W	—	—	W
Arkansas	W	—	—	—	W
California	24,870	W	—	W	26,587
Colorado	W	—	W	W	W
Connecticut	1,754	2,286	W	W	8,981
Delaware	W	—	—	—	W
Florida	5,247	—	—	—	5,247
Georgia	W	—	W	—	1,738
Hawaii	W	—	—	—	W
Illinois	67,104	W	32,287	W	139,764
Indiana	W	W	W	W	48,105
Iowa	W	—	W	W	W
Kentucky	W	—	—	—	W
Louisiana	1,892	—	W	—	W
Maryland	W	—	W	—	W
Massachusetts	1,965	W	—	W	3,083
Michigan	W	W	43,925	W	78,638
Minnesota	W	—	—	—	W
Mississippi	W	—	—	—	W
Missouri	3,433	—	—	W	W
Nebraska	7,994	—	—	W	W
New Jersey	1,180	W	—	W	1,797
New York	3,777	W	74,216	W	100,487
North Carolina	W	—	W	W	2,788
Ohio	48,673	7,741	W	W	90,174
Oklahoma	2,843	—	—	W	W
Oregon	W	W	—	—	W
Pennsylvania	W	W	W	W	151,579
South Carolina	W	—	—	—	W
Tennessee	2,955	—	—	W	W
Texas	11,184	—	—	W	W
Utah	W	W	—	—	W
Virginia	W	W	—	W	W
Washington	W	—	—	1,164	W
West Virginia	W	—	—	W	W
Wisconsin	W	W	W	W	W
Undistributed	213,282	79,770	55,042	126,437	170,208
Total[4]	**406,308**	**89,797**	**205,470**	**127,601**	**829,176**

W Withheld to avoid disclosing company proprietary data; included in "Total" and "Undistributed."

[1] Includes brass mills, brass ingot makers, and brass foundries.

[2] Includes producers of zinc-base alloys for diecastings, stamping dies, and rods.

[3] Includes slab zinc used in rolled zinc products and in zinc oxide.

[4] Excludes remelt zinc.

TABLE 17

ROLLED ZINC PRODUCED AND QUANTITY AVAILABLE FOR CONSUMPTION IN THE UNITED STATES

(Metric tons)

	1987	1988
Production[1]	42,771	49,771
Exports	1,732	3,814
Imports for consumption	960	4,100
Available for consumption	40,342	50,436

[1] Includes other plate over 0.375 inch thick and rod and wire.

TABLE 18

ZINC CONTENT OF PRODUCTION AND SHIPMENTS OF ZINC PIGMENTS AND COMPOUNDS[1] IN THE UNITED STATES

(Metric tons)

	1987[r]		1988	
	Production	Shipments	Production	Shipments
Zinc oxide	112,420	110,577	93,527	98,031
Zinc sulfate	19,752	18,030	20,816	21,644
Zinc chloride[2]	12,035	10,446	8,482	8,552

[r] Revised.
[1] Excludes leaded zinc oxide and lithopone.
[2] Includes zinc content of zinc ammonium chloride.

TABLE 19

ZINC CONTENT OF ZINC PIGMENTS[1] AND COMPOUNDS PRODUCED BY DOMESTIC MANUFACTURERS, BY SOURCE

(Metric tons)

	1987				1988			
	Zinc in pigments and compounds produced from			Total	Zinc in pigments and compounds produced from			Total
	Ore	Slab zinc	Secondary material		Ore	Slab zinc	Secondary material	
Zinc oxide	—	[r]60,826	[r]51,594	[r]112,420	—	59,000	34,527	93,527
Zinc sulfate	W	—	19,752	19,752	W	—	20,816	20,816
Zinc chloride[2]	—	—	[r]12,035	[r]12,035	—	—	8,482	8,482

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Secondary material."
[1] Excludes leaded zinc oxide, zinc sulfate, and lithopone.
[2] Includes zinc content of zinc ammonium chloride.

TABLE 20

REPORTED DISTRIBUTION OF ZINC CONTAINED IN ZINC OXIDE SHIPMENTS, BY INDUSTRY[1]

(Metric tons)

Industry	1984[r]	1985[r]	1986[r]	1987[r]	1988
Agriculture	1,904	2,060	3,128	3,477	1,988
Ceramics	5,978	5,829	4,010	4,901	3,302
Chemicals	18,889	17,982	18,163	22,789	21,898
Paint	6,494	6,572	8,638	8,007	3,441
Photocopying	7,397	6,659	W	W	W
Rubber	63,512	57,259	56,246	63,589	55,213
Other	13,360	12,572	6,999	7,814	12,189
Total	**117,534**	**108,933**	**97,184**	**110,577**	**98,031**

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] In addition, zinc oxide was imported as follows: 1984—35,741; 1985—39,375; 1986—43,924; 1987—57,276; and 1988—73,042; distribution cannot be distinguished by industry.

TABLE 21

DISTRIBUTION OF ZINC CONTAINED IN SULFATE SHIPMENTS

(metric tons)

Industry	1984[r]	1985[r]	1986[r]	1987[r]	1988
Agriculture	11,406	13,683	18,616	14,934	18,609
Other	3,624	3,532	3,171	3,096	3,035
Total	**15,030**	**17,215**	**21,787**	**18,030**	**21,644**

[r] Revised.

TABLE 22

UNITED STATES PRODUCERS OF ZINC OXIDE AND CAPACITY, BY COMPANY

Company	Plant location	Capacity (metric tons) 1987[1]	Capacity (metric tons) 1988
ASARCO Incorporated	Hillsboro, IL	210,000	156,000
Big River Zinc Corp.[2]	Sauget, IL		
Eagle Zinc Co.	Hillsboro, IL		
Interamerican Zinc Corp.	Adrian, MI		
Midwest Zinc Corp.	Chicago, IL		
Pasco Zinc Corp.	Memphis, TN		
Zinc Corp. of America	Monaca, PA		
do.	Palmerton, PA		

[1] Includes Pasco Zinc Corp. Torrance, CA. plant.
[2] Big River Zinc Corp. aquired plant from AMAX in Sept. 1988.

TABLE 23

UNITED STATES PRODUCERS OF ZINC SULFATE AND CHLORIDE PRODUCTS IN 1988

Company	Plant location	Sulfate production	Chloride production
B & W Micronutrients	Bartlesville, OK	X	
Bay Zinc Co.	Moxee City, WA	X	
Big River Zinc Corp.	Sauget, IL	X	
The Chemical & Pigment Co.	Pittsburg, CA	X	X
Cozinco Inc.	Denver, CO	X	
Eagle-Picher Industries Inc.	Joplin, MO	X	
Frit Industries Inc.	Ozark, AL	X	
Liquid Chemical Corp.	Hanford, CA	X	
Madison Industries Inc.	Old Bridge, NJ	X	X
Mineral Research & Development Corp.	Harrisburg, NC		X
Zaclon Inc.	Cleveland, OH		X

TABLE 24

STOCKS OF SLAB ZINC IN THE UNITED STATES, DECEMBER 31

(Metric tons)

	1984	1985	1986	1987[r]	1988
Primary producers	42,025	29,030	16,722	13,448	5,700
Secondary producers	4,303	3,389	3,203	3,162	695
Consumers	[r]72,775	60,310	[r]54,079	57,410	64,846
Merchants	18,792	27,163	26,559	22,352	14,290
Total	**[r]137,895**	**119,892**	**[r]100,563**	**96,372**	**85,531**

[r] Revised.

TABLE 25

AVERAGE MONTHLY U.S., LME,[1] AND EUROPEAN PRODUCER PRICES FOR EQUIVALENT ZINC

(Metallic zinc, cents per pound)

Month	1987 United States[2]	1987 LME cash	1987 European producer	1988 United States[2]	1988 LME cash	1988 European producer
January	41.40	34.43	37.87	44.44	39.65	39.81
February	38.38	33.56	34.92	45.44	40.37	39.72
March	37.70	33.16	34.92	47.90	42.38	44.50
April	38.19	34.53	34.92	51.50	45.29	48.46
May	42.23	38.01	37.06	56.04	49.03	53.33
June	45.05	39.80	37.65	62.55	55.05	61.87
July	45.67	37.59	39.01	65.64	56.13	56.08
August	44.43	36.44	39.01	66.46	54.43	59.35
September	42.59	34.28	37.19	68.26	60.91	60.30
October	41.75	34.89	37.19	69.75	63.11	68.85
November	42.38	38.42	37.67	71.25	65.83	70.63
December	43.31	39.25	39.01	73.44	68.04	72.24
Average	41.92	36.20	37.20	60.20	53.37	51.11

[1] London Metal Exchange.
[2] Based on High Grade zinc delivered.

Source: Metals Week.

TABLE 26

U.S. EXPORTS OF ZINC AND ZINC ALLOYS, BY COUNTRY

Country	1986		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Unwrought zinc and zinc alloys:						
Belgium-Luxembourg [1]	5	$18	6	$21	23	$81
Canada	1,081	2,550	1,059	2,608	1,574	4,175
Chile	(2)	3	—	—	5	8
Finland	33	31	—	—	—	—
Germany, Federal Republic of	9	33	120	34	60	48
Hong Kong	11	55	1	5	67	99
India	34	32	—	—	100	84
Israel	—	—	—	—	18	57
Jamaica	59	50	77	99	62	68
Japan	27	72	27	77	10	28
Korea, Republic of	431	774	4,257	8,603	2,281	3,364
Malaysia	11	8	—	—	—	—
Mexico	93	133	44	134	45	115
Netherlands	11	19	2	5	15	54
Panama	32	52	42	54	4	5
Salvador	21	22	1	2	1	2
Singapore	—	—	14	21	63	107
Spain	6	14	—	—	1	10
Switzerland	21	63	3	7	—	—
Taiwan	1,610	1,074	1,113	775	1,186	875
Trinidad	17	19	—	—	—	—
United Kingdom	1	11	7	16	602	1,194
Venezuela	—	—	50	305	1	5
Other [3]	r35	r150	r84	r171	112	275
Total	**3,548**	**5,183**	**6,907**	**12,937**	**6,230**	**10,654**
Wrought zinc and zinc alloys:						
Argentina	8	21	1	2	—	—
Australia	10	16	—	—	2	16
Bahamas	10	21	39	33	67	151
Brazil	1	5	—	—	—	—
Canada	1,300	1,599	1,087	1,744	1,076	2,130
Chile	3	7	53	94	6	28
Colombia	10	26	7	25	14	47
Costa Rica	200	90	1	2	4	14
Dominican Republic	1	10	23	50	9	21
Ecuador	13	23	2	7	14	34
El Salvador	10	41	23	36	—	—
France	—	—	—	—	307	101
Germany, Federal Republic of	49	84	863	542	2,091	1,121
Guyana	1	2	6	11	6	10

See footnotes at end of table.

TABLE 26—Continued

U.S. EXPORTS OF ZINC AND ZINC ALLOYS, BY COUNTRY

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Hong Kong	—	—	7	12	181	239
India	18	11	2	7	77	53
Jamaica	1	2	—	—	124	186
Japan	47	108	59	126	83	225
Korea, Republic of	2	3	4	7	108	77
Leeward and Windward Islands	34	48	18	19	—	—
Mexico	288	613	521	775	712	1,170
Netherlands Antilles	6	12	46	55	41	39
Pakistan	6	11	—	—	(2)	3
Panama	2	12	22	44	12	23
Philippines	24	54	42	116	26	74
Saudi Arabia	—	—	1	5	380	370
Singapore	—	—	—	—	101	591
South Africa, Republic of	8	24	3	5	4	18
Spain	20	11	1	3	3	11
Sudan	—	—	—	—	153	231
Taiwan	20	42	2	3	72	77
Trinidad and Tobago	1	5	10	10	—	—
United Kingdom	75	158	11	46	6	35
Venezuela	40	56	29	45	39	114
Other[4]	r44	r104	r120	r224	112	278
Total	**2,252**	**3,219**	**3,003**	**4,048**	**5,830**	**7,487**

r Revised.

1 For 1986 and 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

2 Less than 1/2 unit.

3 Includes Angola, Argentina, Australia, Barbados, Brazil, China, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, France, Guatemala, Guyana, Honduras, Indonesia, Italy, Jordan, Kenya, Kuwait, Leeward & Windward Islands, Libya, Netherland Antilles, New Guinea, New Zealand, Norway, Peru, Philippines, Republic of South Africa, Saudi Arabia, Sweden, Thailand, the United Arab Emirates, and Yugoslavia.

4 Includes Angola, Austria, Belgium, Belgium-Luxembourg, Belize, Bermuda, British Virgin Islands, Cayman Islands, China, Cyprus, Denmark, El Salvador, Finland, French Guiana, Ghana, Guatemala, Iran, Ireland, Israel, Italy, Jordan, Kuwait, Libya, Morocco, Mozambique, the Netherlands, New Zealand, Nicaragua, Norway, Paraguay, Peru, Portugal, Qatar, Somalia, Sri Lanka, Suriname, Sweden, Turkey, the United Arab Emirates, and Uruguay.

Source: Bureau of the Census.

TABLE 27

U.S. EXPORTS OF ZINC

Year	Zinc oxide		Ores and concentrates		Blocks, pigs, anodes, etc.			
					Unwrought		Unwrought alloys	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	791	$1,124	3,269	$1,590	1,938	$3,533	1,610	$1,650
1987	265	531	16,921	8,304	1,082	2,114	5,825	10,823
1988	530	822	33,590	19,699	482	933	5,748	9,721

Year	Wrought zinc and zinc alloys				Waste and scrap (zinc content)		Dust and flakes	
	Sheets, plates, strips		Angles, bars, pipes, rods, etc.					
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	721	$1,513	1,531	$1,706	68,660	$32,803	1,551	$2,104
1987	1,732	2,337	1,271	1,711	88,277	46,182	1,927	3,300
1988	3,814	4,416	2,016	3,071	103,732	66,052	2,221	3,929

Source: Bureau of the Census.

TABLE 28

U.S. EXPORTS OF ZINC ORES AND CONCENTRATES, BY COUNTRY

(Zinc content)

	1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	12,972	$7,359	33,260	$19,510
Germany, Federal Republic of	3,857	881	—	—
India	—	—	42	24
Japan	—	—	249	143
Mexico	8	4	—	—
Philippines	—	—	1	3
Sweden	—	—	29	16
Taiwan	83	59	9	3
Total [1]	**16,921**	**8,304**	**33,590**	**19,699**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 29

U.S. GENERAL IMPORTS OF ZINC, BY COUNTRY

Country	1986		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	1,981	$262	476	$63	458	$61
Bolivia	—	—	—	—	50	6
Canada	150,100	23,512	399,755	61,634	365,175	73,816
Chile	68	57	12	2	—	—
China	—	—	223	30	—	—
Germany, Federal Republic of	—	—	5,103	3,044	—	—
Honduras	14,218	1,756	6,469	869	1,172	614
Mexico	6,251	1,693	5,494	1,648	7,218	3,164
Peru	25,118	5,057	7,978	3,001	31,633	11,748
Total	**197,736**	**32,337**	**425,510**	**70,291**	**405,706**	**89,409**
BLOCKS, PIGS, OR SLABS[1]						
Algeria	—	—	505	389	2,300	2,152
Australia	40,686	28,421	51,435	42,451	25,000	26,701
Austria	—	—	—	—	300	243
Belgium-Luxembourg[2]	—	—	9,769	8,371	11,635	13,993
Brazil	—	—	—	—	3,997	5,318
Canada	349,335	253,110	360,729	301,773	424,390	474,621
China	1,342	1,185	4,199	3,474	93	105
Colombia	200	162	—	—	—	—
Costa Rica	147	92	—	—	—	—
Finland	23,134	18,896	18,336	15,702	14,779	17,591
France	5,756	4,933	10,539	8,575	9,308	9,818
French Polynesia	2,938	1,962	—	—	—	—
Germany, Federal Republic of	9,712	7,236	15,272	13,065	7,321	7,806
Greece	1,011	884	—	—	—	—
Hong Kong	40	48	1,289	1,020	—	—
Italy	12,743	9,668	16,388	12,752	7,981	8,155
Japan	1,951	1,283	11,943	9,892	1,492	1,298
Korea, Republic of	—	—	3,868	4,184	18,122	20,702
Mauritius	430	292	—	—	—	—
Mexico	49,619	36,372	53,344	42,368	60,947	70,494
Netherlands	20,767	15,538	28,281	23,451	11,097	12,332
New Zealand	300	257	500	423	—	—
Norway	12,809	10,133	17,507	15,440	31,695	30,150
Panama	—	—	—	—	—	—
Peru	43,590	30,720	22,383	17,235	11,943	12,213
Poland	1,183	973	250	232	4,177	4,909
South Africa, Republic of	11,730	7,106	—	—	—	—
Spain	48,948	40,515	55,427	42,256	65,231	76,679
Taiwan	22	27	—	—	200	202

See footnotes at end of table.

TABLE 29—Continued

U.S. GENERAL IMPORTS OF ZINC, BY COUNTRY

Country	1986		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
U.S.S.R.	812	544	—	—	—	—
United Kingdom	5,968	3,929	3,570	2,875	4,311	5,206
Yugoslavia	3,979	3,398	2,035	1,550	792	1,010
Zaire	15,974	9,346	17,338	12,870	21,086	22,830
Zambia	—	—	1,078	873	1,000	1,304
Zimbabwe	—	—	—	—	1,663	1,421
Total	**665,126**	**487,030**	**705,985**	**581,221**	**740,860**	**827,253**

[1] In addition, in 1988, 4,371 tons of zinc anodes were imported from Canada, China, Denmark, the Federal Republic of Germany, Hong Kong, Italy, Japan, Mexico, the Netherlands, Norway, the Republic of Korea, Sweden, Switzerland, Taiwan, and the United Kingdom.

[2] For 1986 and 1987 Belgium-Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

TABLE 30

U.S. IMPORTS FOR CONSUMPTION OF ZINC, BY COUNTRY

Country	1986		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	1,226	$477	—	—	—	—
Canada	28,645	10,069	28,960	$7,130	25,463	$10,934
Honduras	14,218	1,756	6,469	869	1,172	614
Mexico	6,251	1,693	5,422	1,639	5,967	2,618
Peru	25,446	5,101	5,613	2,684	30,364	11,580
Total	**75,786**	**19,096**	**46,464**	**12,322**	**62,966**	**25,746**
BLOCKS, PIGS, OR SLABS[1]						
Algeria	—	—	505	389	2,300	2,152
Australia	40,686	28,421	51,435	42,451	25,000	26,701
Austria	—	—	—	—	300	243
Belgium-Luxembourg[2]	—	—	9,769	8,371	16,739	17,037
Brazil	—	—	—	—	3,997	5,318
Canada	349,335	253,110	360,729	301,773	427,558	477,855
China	1,342	1,185	4,199	3,474	93	105
Colombia	200	162	—	—	—	—
Costa Rica	147	92	—	—	—	—
Finland	23,134	18,896	18,336	15,702	14,780	17,591
France	5,756	4,935	10,539	8,575	9,308	9,818
French Polynesia	2,938	1,962	—	—	—	—
Germany, Federal Republic of	9,712	7,236	15,272	13,065	7,321	7,806
Greece	1,011	884	—	—	—	—
Hong Kong	40	48	1,289	1,020	—	—
Italy	12,743	9,668	16,388	12,752	7,982	8,155
Japan	1,951	1,283	11,943	9,892	1,492	1,298
Korea, Republic of	—	—	3,868	4,184	18,122	20,702
Mauritius	430	292	—	—	—	—
Mexico	49,619	36,372	53,344	42,368	60,947	70,494
Netherlands	20,767	15,537	28,281	23,451	11,097	12,332
New Zealand	300	257	500	423	—	—
Norway	12,809	10,133	17,507	15,440	31,695	30,150
Peru	43,590	30,720	22,383	17,235	11,943	12,213
Poland	1,183	973	250	232	4,176	4,909
South Africa, Republic of	11,730	7,106	—	—	—	—
Spain	48,948	40,515	55,427	42,256	65,231	76,679
Taiwan	22	27	—	—	200	202
U.S.S.R.	812	544	—	—	—	—
United Kingdom	5,968	3,928	3,570	2,875	4,311	5,206
Yugoslavia	3,979	3,398	2,035	1,550	792	1,010
Zaire	15,974	9,346	17,338	12,870	21,086	22,830
Zambia	—	—	1,078	873	1,000	1,304
Zimbabwe	—	—	—	—	1,663	1,421
Total	**665,126**	**487,030**	**705,985**	**581,221**	**749,133**	**833,531**

[1] In addition, in 1988, 4,371 tons of zinc anodes were imported from Canada, China, Denmark, the Federal Republic of Germany, Hong Kong, Italy, Japan, Mexico, the Netherlands, Norway, the Republic of Korea, Sweden, Switzerland, Taiwan, and the United Kingdom.
[2] For 1986 and 1987 Belgium-Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

TABLE 31

U.S. IMPORTS FOR CONSUMPTION OF ZINC

Year	Ores and concentrates (zinc content)		Blocks, pigs, slabs[1]		Sheets, plates, strips, other forms	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	75,786	$19,096	665,126	$487,030	3,811	$3,048
1987	46,464	12,322	705,985	581,221	960	1,384
1988	62,966	25,746	749,130	833,531	4,100	5,395

Year	Waste and scrap		Dross, ashes, and fume (zinc content)		Dust, powder, flakes		Total value[2] (thousands)
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	
1986	4,521	$1,937	6,098	$3,100	7,446	$8,260	$522,473
1987	4,025	1,928	6,727	3,461	7,001	7,940	608,256
1988	5,727	3,615	6,346	4,279	7,652	11,958	884,524

[1] Unwrought alloys of zinc were imported as follows, in metric tons: 1986—113 ($107,389); 1987—60 ($53,687); and 1988—50 ($76,864).
[2] In addition, the value of manufactures of zinc imported was as follows: 1986—$1,206,175; 1987—$1,569,545; and 1988—$1,415,747.

Source: Bureau of the Census.

TABLE 32

U.S. IMPORTS FOR CONSUMPTION OF ZINC PIGMENTS AND COMPOUNDS

	1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Zinc oxide	57,276	$46,572	73,042	$79,465
Zinc sulfide	997	1,693	2,487	3,622
Lithopone	1,282	810	2,386	1,628
Zinc chloride	1,254	1,096	1,306	1,181
Zinc sulfate	3,339	1,964	3,445	1,784
Zinc cyanide	229	425	160	307
Zinc hydrosulfite	231	427	213	391
Zinc compounds, n.s.p.f.	4,064	7,091	5,188	9,076

Source: Bureau of the Census.

TABLE 33

ZINC: WORLD MINE AND PRIMARY SMELTER CAPACITY, BY COUNTRY

(Thousand metric tons)

Country	Mine	Smelter
Algeria	15	40
Argentina	35	33
Australia	775	339
Austria	20	25
Belgium	—	325
Bolivia	50	—
Brazil	130	161
Bulgaria[e]	70	90
Burma	5	—
Canada	1,360	717
Chile	35	—
China[e]	380	350
Colombia	5	—
Congo	3	—
Czechoslovakia	8	—
Ecuador	1	—
Finland	65	170
France	40	315
German Democratic Republic	—	18
Germany, Federal Republic of	80	350
Greece	30	—
Greenland	75	—
Honduras	50	—
Hungary	1	—
India	66	99
Indonesia	1	—
Iran	100	—
Ireland	200	—
Italy	85	253
Japan	170	893
Korea, North	230	260
Korea, Republic of	25	205
Mexico	340	217
Morocco[e]	25	—
Namibia	40	—
Netherlands	—	200
Norway	25	140
Peru	620	171
Philippines	2	—
Poland	205	175
Portugal	—	11
Romania	45	60
Saudi Arabia	3	—
South Africa, Republic of	115	105
Spain	300	298
Sweden	200	—
Thailand	85	70
Tunisia	10	—
Turkey	50	30
U.S.S.R.[e]	870	1,050
United Kingdom	7	100
United States	350	323
Vietnam	10	10
Yugoslavia	100	170
Zaire	80	72
Zambia	40	55
Total	**7,632**	**7,900**

[e] Estimated.

Source: U.S. Bureau of Mines and International Lead and Zinc Study Group.

TABLE 34

ZINC: WORLD MINE PRODUCTION (CONTENT OF CONCENTRATE AND DIRECT SHIPPING ORE UNLESS NOTED), BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Algeria	14.6	13.5	14.0	[r e]13.0	12.0
Argentina	34.9	35.7	39.5	35.6	[2]36.3
Australia	676.5	759.1	712.0	778.4	765.7
Austria	20.9	21.7	16.3	15.7	17.0
Bolivia	37.8	37.1	33.5	39.3	[2]57.0
Brazil	113.7	123.8	123.9	133.4	[2]134.9
Bulgaria[e]	68.0	68.0	70.0	70.0	70.0
Burma	5.3	4.4	4.6	2.6	[2]2.7
Canada	1,207.1	1,172.2	1,290.8	1,504.4	[2]1,351.7
Chile	19.2	22.3	10.5	19.6	[2]19.2
China[e]	160.0	300.0	[2]396.0	[2]458.0	[2]527.0
Colombia	—	2.0	[e]6.0	[e]—	—
Congo (Brazzaville)	2.8	2.3	[e]2.3	[e]2.3	2.3
Czechoslovakia	7.2	7.2	6.7	7.0	7.0
Ecuador[e]	([3])	([3])	([3])	([3])	([3])
Finland[e]	[2]60.2	61.0	60.0	55.1	63.9
France	36.2	40.6	39.5	31.3	31.1
Germany, Federal Republic of	113.1	117.6	103.7	98.9	75.4
Greece	22.5	21.5	22.5	21.0	[2]22.6
Greenland	71.3	70.3	62.1	69.2	77.5
Honduras	41.5	44.0	25.4	15.4	[2]23.5
Hungary[e]	2.3	2.2	[2]—	—	—
India	44.3	45.3	49.2	53.4	57.9
Indonesia	0.8	0.5	0.5	—	—
Iran	47.1	50.0	36.0	40.0	42.0
Ireland	206.1	191.6	181.7	177.0	[2]176.5
Italy	42.3	45.4	26.3	33.2	[2]39.2
Japan	252.7	253.0	222.1	165.7	[2]147.2
Korea, North[e]	140.0	180.0	[r]225.0	[r]220.0	225.0
Korea, Republic of	49.2	45.7	37.3	23.5	[2]21.8
Mexico	303.6	291.9	278.1	271.5	[2]262.2
Morocco[e]	10.7	14.7	13.1	[2]10.3	[2]10.9
Namibia	32.2	30.3	35.4	39.7	36.0
Nigeria[e]	([3])	([3])	—	—	—
Norway	28.5	27.8	27.5	22.2	17.8
Peru	465.9	523.4	597.6	612.5	[2]488.8
Philippines	2.2	1.9	1.6	1.1	[2]1.4
Poland	190.7	[r]188.0	185.0	184.0	184.0
Romania[e]	44.0	43.0	43.0	[r]41.0	41.0
South Africa, Republic of	106.1	96.9	101.9	112.7	89.1
Spain	230.4	234.7	223.1	266.0	[2]255.5

See footnotes at end of table.

TABLE 34—Continued

ZINC: WORLD MINE PRODUCTION (CONTENT OF CONCENTRATE AND DIRECT SHIPPING ORE UNLESS NOTED), BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Sweden	210.0	216.4	219.6	218.6	[2]186.9
Thailand	41.4	77.5	97.2	88.7	[2]78.0
Tunisia	6.7	5.6	4.5	5.9	[2]9.4
Turkey	50.4	37.4	41.1	39.2	43.0
U.S.S.R.[e]	810.0	810.0	810.0	810.0	810.0
United Kingdom	7.5	5.3	5.6	6.5	5.4
United States	277.5	251.9	220.8	232.9	[2]256.4
Vietnam[e]	7.0	5.0	5.0	5.0	5.4
Yugoslavia[4]	85.8	89.3	94.6	80.5	80.0
Zaire	74.8	77.5	81.3	74.7	74.0
Zambia[4]	41.1	32.0	33.0	35.4	35.0
Total[5]	**[r]6,524.3**	**[r]6,798.9**	**6,936.2**	**7,241.5**	**6,976.7**

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through July 10, 1989.
[2] Reported figure.
[3] Less than 1/2 unit.
[4] Content in ore hoisted.
[5] Data may not add to totals shown because of independent rounding.

TABLE 35

ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Algeria, primary	35.0	35.7	29.0	19.0	18.0
Argentina:					
Primary	27.7	30.4	29.1	31.9	29.0
Secondary	2.2	2.5	3.0	2.6	2.4
Total	**29.9**	**32.9**	**32.1**	**34.5**	**31.4**
Australia:					
Primary[2]	301.9	288.7	303.1	307.6	[3]302.5
Secondary[e]	4.5	4.5	4.5	4.5	4.5
Total	**306.4**	**293.2**	**307.6**	**312.1**	**307.0**
Austria, primary and secondary	24.0	25.0	24.0	24.3	24.0
Belgium, primary and secondary	285.3	[r]290.5	288.8	308.6	325.2
Brazil:					
Primary	106.9	116.1	130.6	138.7	[3]140.2
Secondary	7.5	4.6	5.9	9.4	9.5
Total	**114.4**	**120.7**	**136.5**	**148.1**	**149.7**
Bulgaria, primary and secondary[e]	90.0	90.0	90.0	[3]92.0	90.0
Canada, primary	683.2	692.4	571.0	609.9	[3]703.2
China, primary and secondary[e]	185.0	275.0	[3]336.0	[r]383.0	340.0
Czechoslovakia, secondary[e]	9.1	9.2	9.0	9.0	9.0
Finland, primary	158.8	160.4	155.4	152.0	156.0
France, primary and secondary	[r]258.8	[r]247.2	257.4	249.3	274.0
German Democratic Republic, primary and secondary[e]	17.0	17.0	17.0	[r]18.0	18.0
Germany, Federal Republic of:					
Primary	325.6	339.9	344.3	348.2	309.6
Secondary	30.8	27.9	26.6	29.3	[3]42.4
Total	**356.4**	**367.8**	**370.9**	**377.5**	**352.0**
Hungary, secondary[e]	.6	.6	.6	.6	.6
India:					
Primary	55.8	70.9	72.0	68.9	[3]68.9
Secondary[e]	.2	.2	.2	.2	.2
Total[e]	**56.0**	**71.1**	**72.2**	**[r]69.1**	**69.1**
Italy, primary and secondary	169.7	215.6	229.4	242.4	[3]242.1
Japan:					
Primary	644.4	629.5	626.5	591.5	[3]601.1
Secondary	110.1	110.1	81.5	74.1	[3]77.1
Total	**754.5**	**739.6**	**708.0**	**665.6**	**[3]678.2**
Korea, North, primary[e]	120.0	180.0	180.0	210.0	210.0
Korea, Republic of, primary	108.5	111.7	127.4	186.1	[3]223.0
Mexico, primary	167.0	175.4	173.7	184.8	[3]192.5
Netherlands, primary and secondary	209.7	201.7	196.2	207.1	[3]211.0
Norway, primary	94.2	92.7	90.4	116.5	120.0
Peru, primary	148.4	[r]162.7	155.8	144.6	[3]123.1

See footnotes at end of table.

TABLE 35—Continued

ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Poland, primary and secondary	176.0	180.0	179.0	177.0	180.0
Portugal, primary	6.4	5.9	5.7	5.8	6.0
Romania, primary and secondary[e]	41.0	40.0	39.0	39.0	42.0
South Africa, Republic of, primary	88.4	93.7	81.0	96.1	85.0
Spain, primary	207.4	213.3	202.0	224.0	256.0
Thailand, primary	—	62.1	58.9	66.9	[3]68.6
Turkey, primary	19.9	22.2	15.4	18.0	21.0
U.S.S.R.:[e]					
Primary	900.0	[r]890.0	[r]880.0	[r]890.0	848.0
Secondary	95.0	100.0	105.0	110.0	115.0
Total	**995.0**	**[r]990.0**	**[r]985.0**	**[r]1,000.0**	**963.0**
United Kingdom, primary and secondary	85.6	74.3	85.9	81.4	77.0
United States:					
Primary	253.1	261.2	253.4	261.3	[3]241.3
Secondary	78.1	72.6	62.9	82.6	[3]88.5
Total	**331.2**	**333.8**	**316.3**	**343.9**	**[3]329.8**
Vietnam, primary[e]	6.0	4.2	4.2	4.2	4.2
Yugoslavia, primary and secondary	[r]92.7	83.4	82.0	118.1	127.5
Zaire, primary	66.1	64.0	63.9	54.9	60.0
Zambia, primary	29.2	22.8	22.5	21.0	22.0
Grand total[4]	**[r]6,526.8**	**[r]6,797.8**	**6,699.2**	**7,014.4**	**7,109.2**
Of which:					
Primary	[r]4,553.9	[r]4,725.9	4,575.3	4,751.9	4,809.2
Secondary	[r]338.1	[r]332.2	299.2	322.3	349.2
Undifferentiated	[r]1,634.8	[r]1,739.7	1,824.7	1,940.2	1,950.8

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Wherever possible, detailed information on raw material source of output (primary—directly from ores, and secondary—from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undifferentiated (primary and secondary). To the extent possible, this table reflects metal production at the first measurable stage of metal output. Table includes data available through July 10, 1989.
[2] Excludes zinc dust.
[3] Reported figure.
[4] Detail may not add to totals shown because of independent rounding.

ZIRCONIUM AND HAFNIUM

By James B. Hedrick[1]

Domestic mine production of zircon, the principal ore mineral of zirconium and hafnium, increased in 1988. Zircon was mined by two companies in Florida as a coproduct of the titanium minerals ilmenite and rutile and by one company in New Jersey from tailings previously accumulated as a byproduct of processing ilmenite. The world supply of zircon was essentially unchanged from the 1987 level and was slightly below the level of demand, resulting in limited availability and increased prices.

Major nonenergy uses for zirconium were in foundry sands, refractories, ceramics, abrasives, chemical manufacture, and metallurgical applications. Hafnium was used in metallurgical applications, refractory alloys, and ceramic cutting tools.

Advanced technology applications of zirconium included stabilized and partially stabilized zirconia used in extrusion dies, industrial cutting blades, ceramic engine parts, liners for engine exhaust chambers, thermal barrier coatings for jet engine compressor blades, and in rocket nozzles. Zirconium fluoride and hafnium fluoride glasses were used in fiber optics.

DOMESTIC DATA COVERAGE

Domestic mine production data for zircon are developed by the Bureau of Mines from a voluntary survey of U.S. operations, entitled "Production of Zircon". Of the three mining companies to which the form was sent, all responded, representing 100% of mine production.

DOMESTIC PRODUCTION

Domestic production of zircon concentrates was 114,651 metric tons, placing the United States as the third largest producer of zircon in the world.

Zircon was mined, along with titanium minerals, by E. I. du Pont de Nemours & Co. Inc. at Starke and Trail Ridge, FL, and by Associated Minerals (USA) Inc. at Green Cove Springs, FL.

Heritage Minerals Inc. recovered zircon from tailings at a closed ilmenite mine at Lakehurst, NJ. The company expected the tailings to be depleted by about yearend 1990. Heritage planned, if strong demand for zircon continues, to install dredging equipment to recover zircon and other heavy minerals from remaining reserves at the site. The additional mining would extend the operation an estimated 6 years.

Nord Ilmenite Corp., a wholly owned subsidiary of Nord Resources Corp., was formed in 1988 to recover zircon and other heavy minerals from tailings near Lakewood, NJ.[2] The minesite reportedly contains 280,000 tons of tailings containing zircon, ilmenite, and rutile. Production was expected to commence in the second half of 1989. The minelife was expected to be at least 19 months at a zircon production rate of 1,300 tons per month.

Five processors produced 64,393 tons of milled (ground) zircon from domestic and imported zircon. Zirconium oxide (zirconia) production was 4,438 tons from five companies, excluding zirconia produced as an intermediate product in making zirconium metal. Two companies in the Western United States produced zirconium sponge, ingot, and alloys, along with hafnium sponge and crystal bar. Cubic zirconia, used as simulated diamond and other gem stones, was produced by three companies.

CONSUMPTION AND USES

Zirconium was consumed primarily as the silicate mineral, zircon, and the oxide, zirconia, while lesser quantities were consumed as the pure metal, in various alloys, and in inorganic and organic chemicals.

Zircon was used in sand molds and cores, mold washes, and mold facings.

TABLE 1

SALIENT U.S. ZIRCONIUM STATISTICS

(Metric tons)

	1984	1985	1986	1987	1988
Zircon:					
Production	W	W	W	W	$117,606
Exports	8,644	15,291	15,852	20,054	21,775
Imports for consumption	60,270	39,723	68,764	67,917	76,331
Consumption, apparent[1]	117,934	117,934	143,335	132,800	171,502
Stocks, Dec. 31: Dealers and consumers[2]	29,811	26,570	28,074	39,218	38,197
Zirconium oxide:					
Production[e 3]	6,689	8,322	7,148	5,226	4,438
Exports	383	951	1,648	1,206	1,809
Imports for consumption	719	1,332	464	1,274	1,089
Consumption, apparent	5,262	6,804	6,078	3,800	6,328
Stocks, Dec. 31: Producers[e 3]	1,073	1,383	2,002	1,213	1,079

[e] Estimated. W Withheld to avoid disclosing company proprietary data.
[1] Includes insignificant amounts of baddeleyite.
[2] Excludes foundries.
[3] Excludes oxide produced by zirconium metal producers.

TABLE 2

PRODUCERS OF ZIRCONIUM AND HAFNIUM MATERIALS IN 1988

Company	Location	Materials
ZIRCONIUM MATERIALS		
AluChem	Reading, OH	Milled zircon.
American Minerals Inc.	Camden, NJ	Do.
Associated Minerals (USA) Ltd. Inc.	Green Cove Springs, FL	Zircon.
Ceres Corp.	North Billerica, MA	Cubic zirconia.
Ciba-Geigy Corp., Drakenfeld Colors	Washington, PA	Ceramic colors and milled.
Continental Mineral Processing Corp.	Sharonville, OH	Milled zircon.
Corhart Refractories Corp.	Buckhannon, WV	Refractories.
Do.	Corning, NY	Do.
Do.	Louisville, KY	Do.
Didier-Taylor Refractories Corp.	Cincinnati, OH	Do.
Do.	South Shore, KY	Do.
E. I. du Pont de Nemours & Co. Inc.	Starke, FL, and Trail Ridge, FL	Zircon and foundry mixes.
Elkem Metals Co.	Alloy, WV	Alloys.
Harshaw Chemical Co.	Elyria, OH	Oxide and other compounds.
Heritage Minerals Inc.	Lakehurst, NJ	Zircon.
I.C.T. Inc.	Shelby, MI	Cubic zirconia.
Leco Corp., Ceramics Div.	St. Joseph, MI	Refractories and milled zircon.
Lincoln Electric Co. Inc.	Cleveland, OH	Welding rods.
M & T Chemicals Inc.	Andrews, SC	Ultrox and milled zircon.
Magnesium Elektron Inc.	Flemington, NJ	Compounds.
Muscle Shoals Minerals	Barton, AL	Oxide.
Norton Co.	Huntsville, AL	Do.
Shieldalloy Corp.	Newfield, NJ	Welding rods and alloys.
Singh Industries[1]	Cedar Knolls, NJ	Cubic zirconia.
Do.	Cambridge, OH	Alloys.
Sola Basic Industries, Engineered Ceramics Div.	Gilberts, IL	Ceramics.
Standard Oil Engineered Materials Co.	Falconer, NY	Refractories.
TAM Ceramics	Niagara Falls, NY	Milled zircon, oxide, compounds.
Teledyne Wah Chang Albany	Albany, OR	Oxide, sponge, ingot, mill products.
Thiokol Corp., Ventron Chemicals Div.	Beverly, MA	Oxide.
Transelco, a division of Ferro Corp.	Penn Yan, NY	Do.
Western Zirconium Inc.	Ogden, UT	Oxide, sponge, ingot, mill products.
Z-Tech Corp.	Bow, NH	Oxide.
Zedmark Inc.	Dover, OH	Refractories.
Zicar Products Inc.	Florida, NY	Fibrous ceramics.
ZIRCOA Products, Ceramic Products	Solon, OH	Oxide and ceramics.
HAFNIUM MATERIALS		
Teledyne Wah Chang Albany	Albany, OR	Oxide, sponge, ingot, crystal bar.
Western Zirconium Inc.	Ogden, UT	Do.

[1] Formerly Foote Mineral Co.

Stabilized zirconia molds and washes were used in casting reactive and refractory metals.

Zircon and zirconia were also used in refractory applications, principally for brick for lining steel ladles and for other applications as fused, cast, and bonded bricks and shapes. Other refractory applications were as synthetic alumina-zirconia (AZ) abrasives, zirconia kiln furniture, zirconia crucibles, alumina-zirconia-silica (AZS) glass, and bubble insulation. Zircon was used in refractories for glass and aluminum melting; furnaces; flow-control devices and high-wear parts; in castable mixes, ramming mixes, heat transfer pebbles, and refractory paint; and in fiber, felt, cloth, and paper insulation. Zirconia also was used in high-temperature thermal insulators in high frequency induction furnaces and in titania-zirconia glass polish.

Glass and ceramic applications for zirconia and zircon were as crucibles, substrates for electronic equipment, and opacifiers for sanitary ware including sinks, tubs, basins, toilets, and floor and wall tiles. Zirconia was used as a component of glazes, stains, and porcelain enamels, and in electronic and piezoelectronic equipment, it was used in glass to decrease thermal expansion, increase infrared and ultraviolet adsorption, and increase chemical resistance. Zircon was used in ceramics as a base coat opacifier in porcelain enamels.

Transformation-toughened and partially stabilized zirconia was used in many advanced ceramic applications including automotive engine parts, nonferrous extrusion dies, wear-resistant coatings, erosion and corrosion resistant check valves and valve seats, structural and thermal-barrier coatings on jet engines, and in industrial cutting blades. Yttria-stabilized zirconia ceramics were also used in oxygen sensors in automobile exhaust systems to supply microprocessor data for automatically adjusting the air-fuel ratio to improve fuel efficiency and reduce pollution emissions.

Zirconium and hafnium glasses used in fiber-optic systems provided high-rate data transmission.

Zirconium and hafnium metals and alloys were used in nuclear reactor fuel cladding (zirconium), nuclear reactor structural components, and in control rods (hafnium). Zirconium metal was used in reactors as fuel cladding and structural components owing to its low-thermal-neutron cross section and excellent corrosion resistance.

Zirconium's corrosion resistance is attributed to its ability to form a very thin, dense oxide layer that is impervious to the diffusion of ions.[3] In nonnuclear applications, nuclear-grade zirconium was alloyed with tin, iron, chromium, and nickel to further improve its corrosion resistance at high temperatures and high pressures. Zirconium was used by the chemical and textile industries in corrosive environments for piping, heat exchangers, tank coils, thermosiphon evaporators, and bayonet heaters.[4] The electronic industry also used small amounts of zirconium, including lead-lanthanum-zirconium titanates (PLZT) for optical arrays and electro-optic devices. A columbium-hafnium alloy was used in F-15 and F-16 fighter jet aircraft engines.

Other uses of zirconium were in rectifier tubes, surgical implants, metal powder booster for explosive armaments, low-temperature superconducting magnets, and in armor piercing shells.

Zirconium additions to ferroalloys (ferrozirconium) increases the cold strength of steel, deoxidizes molten steel, scavenges nonmetallic inclusions (getter), inhibits grain growth in ferrous and nonferrous alloys, and is a hardening agent in heat treating.

Zirconium compounds were used in

TABLE 3

ESTIMATED CONSUMPTION[1] OF ZIRCON[2] IN THE UNITED STATES, BY END USE

(Metric tons)

End use	1987	1988
Zircon refractories[3]	20,000	25,000
AZS refractories[4]	11,800	12,000
Zirconia[5] and AZ abrasives[6]	W	W
Alloys[7]	5,000	5,300
Foundry applications	47,000	46,600
Other[8]	W	W
Total	**132,800**	**133,000**

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Based on total apparent consumption.
[2] Includes insignificant amounts of baddeleyite.
[3] Dense and pressed zircon brick and shapes.
[4] Fused cast and bonded alumina-zirconia-silica-based refractories.
[5] Excludes oxide produced by zirconium metal producers.
[6] Alumina-zirconia-based abrasives.
[7] Excludes alloys above 90% zirconium.
[8] Includes chemicals, metallurgical-grade zirconium tetrachloride, sandblasting, welding rods, and miscellaneous uses.

TABLE 4

ESTIMATED CONSUMPTION[1] OF ZIRCONIUM OXIDE[2] IN THE UNITED STATES, BY END USE

(Metric tons)

End use	1987	1988
AZ abrasives	W	W
AZS refractories[3]	600	700
Other refractories	1,300	1,500
Chemicals	1,200	1,300
Glazes, opacifiers, colors	700	900
Total	**3,800**	**4,400**

W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1] Based on total apparent consumption.
[2] Excludes oxide produced by zirconium metal producers. Includes baddeleyite.
[3] Fused cast and bonded.

TABLE 5

YEAREND STOCKS OF ZIRCONIUM AND HAFNIUM MATERIALS IN THE UNITED STATES

(Metric tons)

Item	1987	1988
Zircon concentrate held by dealers and consumers excluding foundries	36,251	35,983
Milled zircon held by dealers and consumers excluding foundries	2,967	2,214
Zirconium:[1]		
Oxide[e]	1,213	1,079
Sponge, ingot, scrap, alloys	489	434
Refractories	4,380	5,469
Hafnium: Sponge and crystal bar[e]	27	27

[e] Estimated.
[1] Excludes material held by zirconium sponge metal producers.

TABLE 6

PUBLISHED PRICES OF AUSTRALIAN ZIRCON

(U.S. dollars per metric ton)

Date of publication	Standard grade	Intermediate grade	Premium grade
December 1987	152–166	173–195	202–224
December 1988	265–316	299–342	367–641

Source: Industrial Minerals (London). No. 243, Dec. 1987, p. 103; and No. 225, Dec. 1988, p. 83.

antiperspirants, poison ivy ointments, toothpaste fluoriding agents, leather tanning; waterproofing and dirt-resisting treatments for textiles, dryers in paint, lacquers, and inks; stainless steel protective coatings; stomach ulcer medicine; and in ion exchangers for kidney dialysis.

Zirconium oxide was used as a phosphor activator, fluorescent light cathode, incandescent light-bulb-filament additive, and in the gem stone simulant, cubic zirconia.

Baddeleyite was used primarily in the manufacture of alumina-zirconia abrasives. Other uses were in ceramic coloring, refractories, and miscellaneous applications.

WORLD CAPACITY

The data in table 13 were rated production capacity for mines as of December 31, 1988. Rated capacity was defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

WORLD REVIEW

Zircon, the principal zirconium ore mineral, was produced as a coproduct or byproduct of mining the titanium minerals ilmenite, rutile, and leucoxene, or as a byproduct of mining for the tin minerals cassiterite and stannite. Other zirconium ore minerals produced were baddeleyite and caldasite. Principal world zirconium mineral producers are shown in figure 1.

TABLE 7

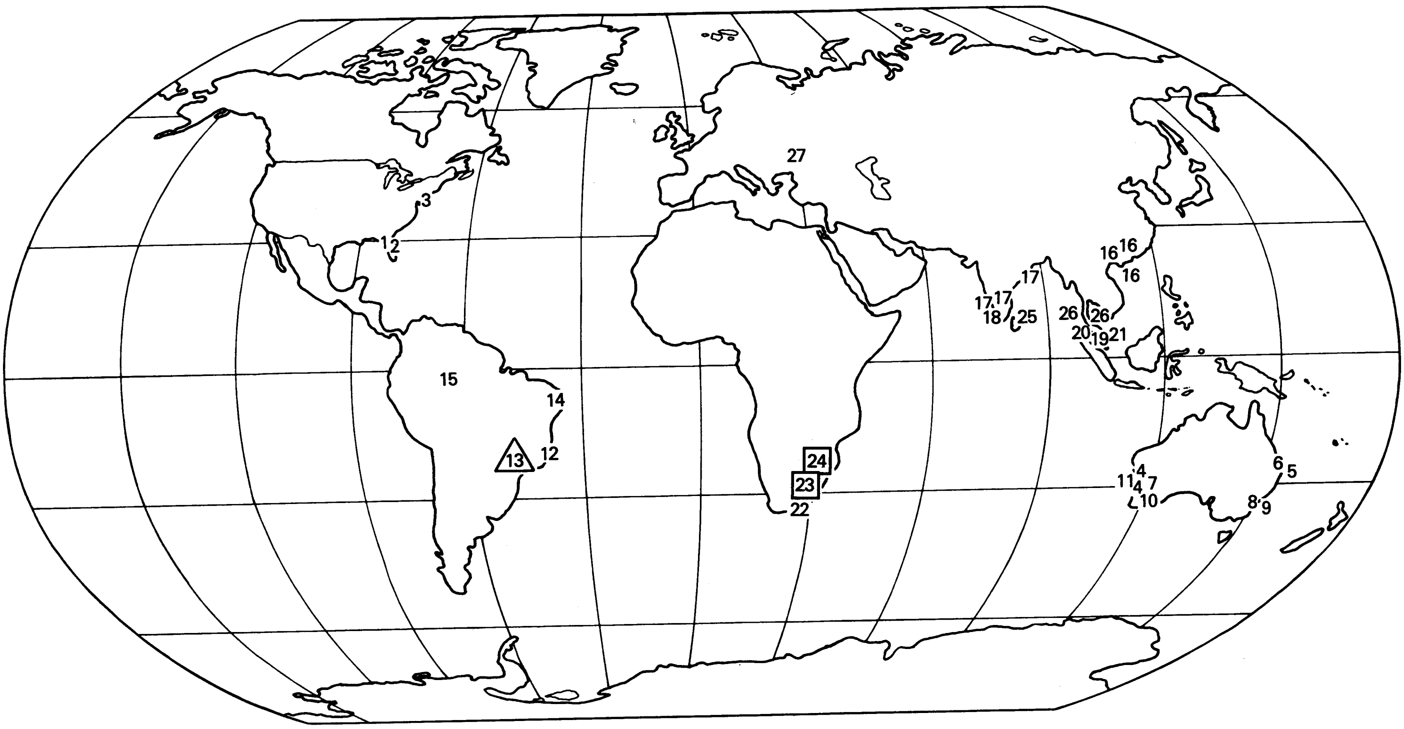
PUBLISHED YEAREND PRICES OF ZIRCONIUM AND HAFNIUM MATERIALS

Specification of material	1987	1988
Zircon:		
Domestic, standard-grade, f.o.b. Starke, FL, bulk, per short ton[1]	$202.00	$242.00
Domestic, 75% minimum quantity zircon and aluminum silicates, Starke, FL, bulk, per short ton[1]	121.00	161.00
Imported sand, containing 65% ZrO_2, f.o.b., bulk, per metric ton[2]	[r]198.00– 209.00	237.00– 259.00
Domestic, granular, bags, bulk rail, from works , per short ton[3]	165.00– 177.00	300.00– 350.00
Domestic, milled, 200- and 325-mesh, rail, from works, bags per short ton[3]	225.00	350.00– 450.00
Baddeleyite, imported concentrate:[4]		
96% to 98% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	.50	.51
99%+ ZrO_2, minus 325-mesh, c.i.f. Atlantic ports, per pound	1.02	.91
Zirconium oxide:[3]		
Powder, commercial grade, drums, 2,000-pound minimum, per pound	4.25	5.80– 5.85
Electronic, same basis, per pound	7.25	8.50
Insulating, stabilized, 325° F, same basis, per pound	3.31– 3.82	4.50
Insulating, unstabilized, 325° F, same basis per pound	3.55– 3.75	5.00
Dense, stabilized 30° F, same basis, per pound	2.82	3.00
Zirconium oxychloride: Crystal, cartons, 5-ton lots, from works per pound[3]	.91– 1.04	.91– 1.04
Zirconium acetate solution:[3]		
25% ZrO_2, drums, carlots, 15-ton minimum, from works, per pound	.97	.97
22% ZrO_2, same basis, per pound	.78	.78
Zirconium hydride: Electronic-grade, powder, drums, 100-pound lots, from works, per pound[3]	.31– .75	.31– .75
Zirconium:[5]		
Powder, per pound	60.00– 150.00	70.00– 150.00
Sponge, per pound	12.00– 17.00	12.00– 18.00
Sheets, strip, bars, per pound	16.00– 45.00	16.00– 45.00
Hafnium: Sponge, per pound[5]	75.00– 135.00	75.00– 135.00

[r] Revised.
[1] E. I. du Pont de Nemours & Co. Inc. price lists. Dec. 1987 (effective Jan. 1, 1988); and Dec. 1988 (effective Jan 1, 1989).
[2] Industrial Minerals (London). No. 243, Dec. 1987, p. 103; and No. 255, Dec. 1988, p. 83.
[3] Chemical Marketing Reporter. V. 231, No. 25, Dec. 21, 1987, p. 49; and v. 234, No. 26, Dec. 26, 1988.
[4] The Applegate Group Inc., Newark, NJ, Jan.1, 1987, and American Vermiculite Corp., Atlanta, GA. Baddeleyite price lists.
[5] American Metal Market. V. 95, No. 245, Dec. 18, 1987, p. 6; and v. 96, No. 253, Dec. 30, 1988, p. 6.

FIGURE 1

PRINCIPAL WORLD ZIRCONIUM MINERALS PRODUCERS



LEGEND

Zirconium Minerals

Zircon 1-12, 14-22, 25-27

Baddeleyite 23, 24

Caldasite 13

COMPANY	LOCATION
UNITED STATES	
1 E.I. du Pont de Nemours & Co. Inc.	Starke and Lawtey, Florida
2 Associated Minerals (USA) Inc.	Green Cove Springs, Florida
3 Heritage Minerals Inc.	Lakehurst, New Jersey
AUSTRALIA	
4 Associated Minerals Consolidated Ltd.	Capel and Eneabba, Western Australia
5 Consolidated Rutile Ltd.	Amity, Bayside, Gordon, Dunwich, and Pinkenba, Queensland
6 Currumbin Minerals Pty. Ltd.	Kirra, Kingscliff, Gympie, Gold Coast, Rainbow Beach, Cudgen, and Currumbin, Queensland
7 Cable Sands (WA) Pty. Ltd.	North Capel, Waroona, and Bunbury, Western Australia
8 Mineral Deposits Ltd.	Stockton, Durness and Hawks. Nest, New South Wales
9 RZ Mines (Newcastle) Pty. Ltd.	Tomago and Nabiac, New South Wales
10 Westralian Sands Ltd.	North Capel, Yoganup, Yoganup North, and North Capel, Western Australia
11 TiO_2 Corp. (Kerr-McGee Corp. and Minproc Holdings)	Cooljarloo, Western Australia (planned 1990)
BRAZIL	
12 Nuclebras de Monazita e Associados Ltda. (NUCLEMON)	Aracruz/Guarapari, Espirito Santo; Sao Joao da Barra, Rio de Janeiro; Usina de Santo Amaro, Sao Paulo
13 MINEGRAL	Aguas da Prata, Sao Paulo; Caldas and Pocos de Caldas, Minas Gerais

COMPANY	LOCATION
14 Rutilo e Ilmenita do Brasil Ltda.	Mataraca, Paraiba
15 Grupo Paranapanema	Presidente Figueiredo, Amazonas
CHINA	
16 State-owned	Hainan Island, Guangdong Province, and Guangxi Province
INDIA	
17 Indian Rare Earths Ltd.	Chavara and Alwaye, Kerala; Manavalakuruchi, Tamil Nadu; Chatrapur, Orissa
18 Kerala Minerals & Metals Ltd.	Chavara, Kerala
MALAYSIA	
19 Malaysian Mining Corp. Berhad	Various locations in Perak and Selangor States
20 Beh Minerals Sendirian Berhad	Lahat, Perak
21 Others	Various locations
SOUTH AFRICA	
22 Richards Bay Minerals	Richards Bay, Natal
23 Palabora Mining Co.	Palabora, Transvaal
24 Phosphate Development Corp. (Foskor)	Palabora, Transvaal
SRI LANKA	
25 Ceylon Mineral Sands Corp.	Pulmoddai
THAILAND	
26 Various companies	Prachuap Khiri Khan, Chumphon, Phuket, and Takua Pa
U.S.S.R.	
27 State-owned	Verkhnedneprovskiy complex, Dnepropetrovsk Oblast

TABLE 8

U.S. EXPORTS OF ZIRCONIUM ORE AND CONCENTRATE, BY COUNTRY

Country	1987		1988	
	Metric tons	Value	Metric tons	Value
Argentina	242	$125,540	840	$450,722
Australia	—	—	171	154,937
Belgium	340	206,128	468	450,356
Canada	848	339,726	386	157,189
Colombia	1,552	728,565	1,244	851,578
Ecuador	461	212,720	276	269,028
France	91	44,080	505	231,905
Germany, Federal Republic of	4,868	1,542,716	8,938	5,741,389
Guatemala	—	—	58	37,305
Guinea	—	—	88	29,183
India	19	7,810	5	4,750
Ireland	18	3,600	18	2,996
Italy	3,303	809,333	14	5,697
Japan	18	11,437	776	140,558
Korea, Republic of	148	75,287	302	228,102
Mexico	6,048	1,798,707	6,346	2,661,654
Netherlands	—	—	109	103,194
Thailand	—	—	88	64,548
United Kingdom	732	219,315	125	32,746
Venezuela	1,042	520,051	875	583,751
Other	324	157,276	162	137,397
Total	**20,054**	**6,802,291**	**21,794**	**12,338,985**

Source: Bureau of the Census.

Australia

Wimmera Industrial Minerals, a subsidiary of CRA Ltd., announced the commissioning of a 120-ton-per-day pilot plant at its mineral sands deposit near Horsham, Victoria. The deposit, designated WIM 150, contains reserves of 1 billion tons of sand grading in excess of 3% heavy minerals, including 5.1 million tons of zircon.[5]

Mineral Deposits Ltd. (MDL) announced plans to expand its mineral sands production to Queensland, primarily to meet strong demand for zircon and rutile. In addition to operations in New South Wales, MDL plans to double its capacity to produce zircon and rutile by opening a new mine in the second half of 1990 at Rocky Point, Queensland. The new mine reportedly will produce 25,000 tons of zircon per year at full capacity. MDL also announced plans to increase zircon production at its Hawks Nest dry mill in New South Wales from 25,000 tons to 27,000 tons.[6]

Brazil

Production of zircon concentrates in 1986 was 15,116 tons, 4,378 tons from the State of Amazonas, 278 tons from the State of Espírito Santo, 459 tons from the State of Minas Gerais, and 10,001 tons from the State of Rio de Janeiro.

Measured reserves of zirconium minerals were 60.4 million tons with a zirconium oxide content of 1.1 million tons. Zirconium mineral reserves were located in the States of Amazonas, Bahia, Espírito Santo, Paraíba, Paraná, Rio de Janeiro, and São Paulo.[7]

Madagascar

QIT-Fer et Titane Inc. (QIT) of Canada and the Government of Madagascar announced a joint venture to produce mineral sands, including zircon, in Madagascar. QIT was expected to commence mineral sands production in Madagascar in 1993.

Mozambique

Kenmare Resources PLC of Ireland and the Geological Survey of Yugoslavia, were 50-50 partners in a joint venture to recover mineral sands including zircon at the Congolone deposit, northwest of Angoche. Measured and indicated reserves at Congolone were 123 million tons of ore grading 4% heavy minerals. Analysis of the heavy minerals indicated a zircon content of 4.4%.[8]

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[1] Physical scientist, Branch of Nonferrous Metals.

[2] Nord Resources Corp. 1988 Annual Report. Nord Ilmenite Corp. pp. 22-23.

[3] Kane, R., and W. Boyd. Use of Titanium and Zirconium in Chemical Environments. ch. in Industrial Applications of Titanium and Zirconium, ASTM STP 728, E. Kleefisch, Ed., American Society for Testing and Materials, 1981, pp. 3-8.

[4] Bowen, L. Use of Titanium and Zirconium in Chemical Environments. Industrial Applications of Titanium and Zirconium, ASTM STP 728, E. Kleefisch, Ed., American Society for Testing and Materials, 1981, pp. 119-125.

[5] CRA Ltd. Press Release. Wimmera Industrial Minerals Granted Development Lease. Dec. 8, 1988, 1 p.

[6] Industrial Minerals. Mineral Deposits to Increase Minsands Production. No. 252, Sept. 1988, pp. 16-17.

[7] Anuário Mineral Brasileiro 1987. Zirconio (translated from Portuguese). Pp. 339-341.

[8] Kenmare Resources PLC Annual Report 1988. Pp. 14-15.

TABLE 9

U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY

Class and country	1987		1988	
	Metric tons	Value	Metric tons	Value
Zirconium and zirconium alloys, wrought:				
Belgium	5	$355,807	3	$149,231
Canada	207	10,896,627	168	7,659,888
Finland	9	384,285	3	128,133
France	70	2,562,785	58	2,233,020
Germany, Federal Republic of	87	6,657,124	188	12,488,473
Greece	—	—	140	3,526,325
Italy	([1])	2,332	([1])	15,120
Japan	361	25,074,231	311	20,405,228
Korea, Republic of	8	404,706	12	1,797,720
Spain	10	2,011,195	6	1,257,300
Sweden	80	2,681,434	107	4,582,500
Switzerland	—	—	16	1,408,592
Taiwan	16	959,682	5	166,711
United Kingdom	104	3,897,200	64	2,480,389
Other	26	701,785	11	635,420
Total	**983**	**56,589,193**	**1,092**	**58,934,050**
Zirconium and zirconium alloys, unwrought and waste and scrap:				
Belgium	—	—	36	321,498
Canada	5	76,441	9	88,986
France	35	365,969	7	64,152
Germany, Federal Republic of	6	226,604	3	50,418
Japan	71	3,569,960	61	2,703,837
Netherlands	20	62,445	14	47,703
Peru	32	670,250	—	—
Sweden	38	935,252	11	250,260
Switzerland	—	—	2	13,824
United Kingdom	30	324,967	20	100,490
Other	5	71,140	2	71,264
Total	**242**	**6,303,028**	**165**	**3,712,432**

[1] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 10

U.S. EXPORTS OF ZIRCONIUM OXIDE, BY COUNTRY

Country	1987 Metric tons	1987 Value	1988 Metric tons	1988 Value
Argentina	15	$79,635	5	$28,500
Australia	47	49,519	56	115,600
Belgium	([1])	3,465	51	80,655
Brazil	8	63,867	4	38,345
Canada	226	649,447	135	383,127
Ecuador	([1])	2,521	—	—
France	4	18,205	13	75,789
Germany, Federal Republic of	30	229,152	14	119,231
Hong Kong	1	7,035	1	5,365
Italy	21	81,001	3	75,575
Japan	55	265,764	60	204,856
Korea, Republic of	([1])	10,899	2	29,895
Mexico	105	175,508	332	822,010
Netherlands	5	33,494	23	104,583
Singapore	5	15,208	—	—
Sweden	1	24,779	([1])	48,556
Taiwan	14	85,757	70	302,945
United Kingdom	646	2,073,739	955	2,892,207
Venezuela	—	—	70	62,963
Other	19	79,360	15	74,209
Total[2]	**1,206**	**3,948,355**	**1,809**	**5,464,411**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
Source: Bureau of the Census.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM ORES, BY COUNTRY

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)	1988 Quantity (metric tons)	1988 Value (thousands)
Argentina	8,104	$847	—	—	—	—
Australia	37,255	4,233	50,641	$6,917	52,929	$13,739
Canada[1]	669	81	207	20	86	29
Italy	120	46	20	13	—	—
Netherlands	28	4	—	—	—	—
South Africa, Republic of[2]	22,588	2,625	16,964	3,266	23,280	6,212
Other	—	—	85	27	36	24
Total	**68,764**	**7,836**	**67,917**	**10,243**	**76,331**	**20,004**

[1] Believed to be country of shipment rather than country of origin.
[2] In addition, very small quantities of baddeleyite were imported.
Source: Bureau of the Census.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM IN 1988, BY CLASS AND COUNTRY

Class and country	Metric tons	Value (thousands)
Zirconium, wrought:		
Canada	11	$1,376
France	212	10,840
Germany, Federal Republic of	([1])	71
Other	1	54
Total[2]	**224**	**12,342**
Zirconium, unwrought and waste and scrap:		
Canada	12	13
France	27	110
Germany, Federal Republic of	24	274
United Kingdom	20	218
Other	2	11
Total[2]	**85**	**624**
Zirconium alloys, unwrought:		
Canada	([1])	4
Germany, Federal Republic of	([1])	26
United Kingdom	5	50
Total	**5**	**80**
Zirconium oxide:		
Belgium	21	88
Canada	38	62
France	89	320
Japan	97	1,349
Netherlands	37	34
South Africa, Republic of	119	141
United Kingdom	680	3,958
Other	8	119
Total	**1,089**	**6,071**
Zirconium compounds:		
France	209	668
Germany, Federal Republic of	4	253
Japan	6	113
South Africa, Republic of	2,042	1,956
United Kingdom	539	1,147
Other	5	32
Total[2]	**2,804**	**4,169**
Hafnium, unwrought and waste and scrap:		
France	4	720
Switzerland	([1])	39
Taiwan	([1])	5
Total	**4**	**764**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 13

WORLD ANNUAL ZIRCONIUM MINERAL PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand metric tons)

Country	Rated capacity[1]
Australia	494
Brazil[2]	22
China[e]	35
India	16
Malaysia	12
South Africa, Republic of[3]	190
Sri Lanka	6
Thailand	2
United States	130
U.S.S.R.[e]	30
Total	**937**

[e] Estimated.
[1] Capacity for the zirconium minerals, zircon baddeleyite, and caldasite.
[2] Includes 500 tons of capacity for caldasite.
[3] Includes 20,000 tons of capacity for baddeleyite.

TABLE 14

ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country	1984	1985	1986	1987[p]	1988[e]
Australia	457,599	501,440	451,824	456,590	490,000
Brazil[2]	6,375	21,039	15,116	18,131	20,000
China[e]	15,000	15,000	15,000	15,000	15,000
India[e 3]	12,000	[4]14,800	16,000	16,000	17,000
Malaysia	7,993	11,652	12,633	17,828	19,100
South Africa, Republic of[5]	153,123	160,533	[r e]140,000	[r e]140,000	150,000
Sri Lanka	3,708	4,061	[e]4,000	[r e]4,000	4,000
Thailand	290	1,292	1,705	1,532	[4]5,098
U.S.S.R.[e]	80,000	85,000	85,000	85,000	85,000
United States	W	W	W	W	[4]117,606
Total	**736,088**	**814,817**	**741,278**	**754,081**	**922,804**

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total."
[1] Includes data available through May 16, 1989.
[2] Includes production of zircon and caldasite.
[3] Data are for fiscal year beginning Apr. 1 of that stated.
[4] Reported figure.
[5] Includes production of zircon and baddeleyite.

MINOR METALS

By Staff, Branches of Nonferrous and Ferrous Metals

ARSENIC[1]

Small amounts of arsenic trioxide were shipped in 1988 from remaining stocks at ASARCO Incorporated's closed plant at Tacoma, WA. Imports of arsenic trioxide were at about the same level in 1988 as in the previous year.

Legislation and Government Programs

The Occupational Safety and Health Administration (OSHA) levied a $1.6 million fine against Asarco for exposing its workers at its East Helena lead smelter in Helena, MT, to unacceptably high levels of lead and arsenic. The bulk of the fine was for violations of a respiratory protection program. The same smelter and its environs has been listed as a Superfund toxic-waste site by the Environmental Protection Agency (EPA). Tests had shown high levels of lead, cadmium, and arsenic in the soil near the smelter. EPA planned to extend the cleanup to areas within the town of East Helena because high levels of arsenic had been found in shallow test wells outside the smelter site. Federal and State health officials have warned residents living in the vicinity of East Helena to avoid eating certain home-grown vegetables because of high concentrations of heavy metals.[2]

Officials of the Montana Water Quality Bureau were concerned about excessive levels of arsenic in water in Three Forks, MT. Reportedly, there is an increased risk of developing skin cancer when drinking water with arsenic levels higher than the current Federal standard of 50 micrograms per liter. The arsenic was believed to have come from natural sources in Yellowstone National Park and carried to Three Forks by the Madison River. The water, which is diverted for irrigation purposes, eventually finds its way into drinking water supplies.[3]

Local officials in Montana complained that EPA was not taking action on rising water in underground mines at Butte. Mine water containing arsenic and other heavy metals reportedly was threatening to flood and pollute nearby creeks and water supplies.[4]

The last residents of Mill Creek, MT, sold their homes to Anaconda Minerals Co. EPA began relocating residents in April 1986 after the discovery of high levels of arsenic in the town. Anaconda Minerals planned to demolish all of the homes and clean the area up in accordance with EPA guidelines.[5]

Artech Recovery Systems Inc., Redmond, WA, negotiated with ARCO Coal Co. on joint efforts to use the Cashman process to treat arsenical flue dusts at Anaconda's former smelter site at Anaconda, MT. Artech hopes to be able to profitably extract copper from the dusts while at the same time fixing the arsenic in an insoluble residue that meets EPA's standards for safe disposal. Artech constructed a pilot plant to test the process.

Domestic Production

Koppers Co. Inc., Conley, GA, a major producer of arsenical wood preservatives, produced arsenic trioxide, which it converted to arsenic acid. The acid was marketed or consumed internally in the production of chromated copper arsenate (CCA) wood preservatives. The Applied Research Group, Charlotte, NC, and Hickory Grove Industries, Hickory Grove, SC, both owned by Hickson International PLC, United Kingdom, produced arsenic acid for use in the wood industry. In addition, Mineral Research Development Corp., Harrisburg, NC, and Chemical Specialties Inc., Valdosta, GA, both owned by LaPorte PLC, Luton, United Kingdom, also produced arsenic acid for use in the wood industry. W. R. Metals Inc., Wheat Ridge, CO, produced arsenic acid in Wyoming from arsenic-bearing lead-smelter flue dusts containing about 50% arsenic.

Consumption and Uses

Arsenic compounds, principally arsenic trioxide, accounted for 98% of the arsenic consumed in 1988. Demand for arsenic was at about the same level in 1988 as it was in the previous year. The wood industry continued to be the dominant industry using trioxide. The estimated end-use distribution of elemental arsenic was 69% in wood preservatives, 23% in agricultural products (principally herbicides and desiccants), 4% in glass, 2% in metallic form in nonferrous alloys and electronics, and 2% in other uses (animal feed additives, pharmaceuticals, etc.).

A zinc producer in Illinois used arsenic trioxide as a collector to separate zinc from copper, cobalt, and nickel. The arsenic and other elements were collected in a residue called copper cake and shipped to a copper producer for processing.

Phoenix Research Corp., La Mesa, CA, a producer of phosphine and arsine, moved its plant to Kingman, AZ. Phosphine (hydrogen phosphide) and

TABLE 1

ARSENIC PRICE QUOTATIONS

(Cents per pound, yearend)

	1986	1987	1988
Trioxide, domestic, 95% As_2O_3, f.o.b. Tacoma, WA	33	(1)	(1)
Trioxide, Mexican, 99.13% As_2O_3, f.o.b. Laredo, TX	44	44	(1)
Metal, 99% As[2]	185	249	271

[1] Price suspended.

[2] 1986—price of domestic metal quoted from Metals Week; price suspended after 1986. 1987 & 1988—prices quoted from Metal Bulletin and converted based on an exchange rate of $1.6389 per British pound in 1987 and $1.7814 per British pound in 1988.

arsine (hydrogen arsenide) are poisonous gases used in manufacturing semiconductor chips.

The bulk of metallic arsenic was used in lead- and copper-based alloys as a minor additive (about 0.01% to 0.5%) to increase strength in the posts and grids of lead-acid storage batteries and to improve corrosion resistance and tensile strength in copper alloys.

A relatively small amount, on the order of 15 metric tons, of high-purity arsenic metal was used in the electronics industry. Gallium arsenide and its alloys have been used in such products as light-emitting diodes and displays, room-temperature lasers, microwave devices, solar cells, and photoemissive surfaces. Compared with silicon circuits, gallium arsenide integrated circuits, currently undergoing commercial development, have higher operating frequencies, lower power consumption, lower noise, and superior resistance to radiation damage. Because of these superior properties, they are expected to have extensive military and commercial applications.

Prices

Arsenic trioxide produced in Mexico had a published price in the United States of $0.44 per pound until February 3, after which Minera Mexico Industrial SA dropped its list price.[6] For the rest of the year, prices were negotiated directly between buyer and seller. According to one company, prices for trioxide were probably less than $0.40 per pound in 1988. One producer said that arsenic trioxide prices were low because copper production was high in 1988. Largely because of environmental concerns, arsenic, being a byproduct of copper, was produced regardless of whether there was a demand for arsenic.

World Capacity

The data in table 3 represent rated capacity for primary refineries on December 31, 1988. Rated capacity is defined as the maximum quantity of arsenic trioxide that can be produced at

TABLE 2

U.S. IMPORTS FOR CONSUMPTION OF ARSENICALS, BY CLASS AND COUNTRY

Class and country	1986		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:						
Belgium-Luxembourg	1,255	$967	1,643	$1,325	1,563	$1,241
Bolivia	—	—	16	10	—	—
Canada	1,924	310	2,012	703	2,068	1,589
Chile	1,659	727	4,800	1,935	6,709	2,648
China	39	25	233	136	18	8
France	6,274	4,072	5,341	3,180	6,909	3,664
Germany, Federal Republic of	200	169	—	—	16	13
Hong Kong	—	—	36	18	54	42
Iran	—	—	241	87	—	—
Japan	141	74	48	33	1	3
Korea, Republic of	—	—	102	70	—	—
Mexico	4,408	3,471	4,457	3,550	4,187	3,064
Namibia	354	224	93	60	—	—
Philippines	936	335	1,280	436	1,850	792
Portugal	36	24	—	—	—	—
Saudi Arabia	96	53	—	—	—	—
South Africa, Republic of	1,210	475	1,380	848	1,017	559
Sweden	7,069	5,341	4,824	4,140	3,664	2,836
Switzerland	—	—	307	248	—	—
United Kingdom	128	80	30	22	(1)	2
Total[2]	**25,728**	**16,347**	**26,843**	**16,800**	**28,056**	**16,461**
Arsenic acid:						
Australia	—	—	16	28	—	—
British Virgin Islands	—	—	—	—	7	9
Germany, Federal Republic of	(1)	1	—	—	—	—
Netherlands	—	—	—	—	(1)	1
United Kingdom	1,381	999	1,038	824	181	161
Total	**1,381**	**1,000**	**1,054**	**852**	**188**	**171**
Arsenic sulfide:						
Canada	—	—	—	—	12	2
Germany, Federal Republic of	—	—	15	10	15	29
Sweden	16	2	—	—	—	—
United Kingdom	(1)	12	—	—	—	—
Total	**16**	**14**	**15**	**10**	**27**	**31**

See footnotes at end of table.

TABLE 2—Continued

U.S. IMPORTS FOR CONSUMPTION OF ARSENICALS, BY CLASS AND COUNTRY

Class and country	1986		1987		1988	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic metal:						
Belgium-Luxembourg	—	—	2	$18	—	—
Canada	8	$731	16	1,054	19	$899
China	295	951	463	972	421	675
Dominica	—	—	(1)	1	—	—
Germany, Federal Republic of	7	272	2	174	1	162
Hong Kong	34	115	139	291	75	139
Japan	2	382	9	951	5	613
Mexico	—	—	—	—	78	137
Netherlands	(1)	4	—	—	—	—
Sweden	34	124	(1)	1	—	—
Switzerland	10	53	—	—	—	—
United Kingdom	5	17	(1)	8	(1)	17
Total [2]	**395**	**2,649**	**631**	**3,471**	**600**	**2,642**
Lead arsenate:						
Germany, Federal Republic of	6	56	—	—	—	—
United Kingdom	60	114	50	95	—	—
Total	**66**	**170**	**50**	**95**	**—**	**—**
Sodium arsenate:						
Germany, Federal Republic of	—	—	—	—	(1)	6
Israel	—	—	421	72	700	283
Italy	—	—	—	—	137	24
Total	**—**	**—**	**421**	**72**	**837**	**313**
Arsenic compounds, n.s.p.f.:						
Brazil	9	482	—	—	—	—
Canada	(1)	1	—	—	—	—
United Kingdom	(1)	175	(1)	41	(1)	89
Other	(1)	13	(1)	42	(1)	32
Total [2]	**10**	**671**	**(1)**	**83**	**(1)**	**121**

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Arsenic is principally a byproduct of copper, lead, and gold production. When production of these metals increases, production of arsenic increases. Arsenic capacity figures are based on historical production rates and published capacity data. Arsenic capacity is related to the arsenic content of ores being mined and the roaster capacity at smelters recovering arsenic.

TABLE 3

WORLD ANNUAL ARSENIC TRIOXIDE REFINERY PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand metric tons)

	Capacity
North America:	
Canada	4
Mexico	8
Total	**12**
South America:	
Chile	8
Peru	2
Total	**10**
Europe:	
Belgium	5
France	10
Sweden	11
U.S.S.R.	10
Total	**36**
Africa:	
Namibia	3
Asia:	
Philippines	8
World total (rounded)	**70**

World Review

Arsenic is recovered as arsenic trioxide in about 20 countries from the smelting or roasting of nonferrous metal ores or concentrates. Arsenic metal, which accounts for only 3% of world demand for arsenic, is produced by the reduction of arsenic trioxide. Commercial-grade arsenic metal, 99% pure, is produced in only a few countries, and this grade accounts for the majority of arsenic metal production. High-purity arsenic, 99.99% pure or greater, for use in the semiconductor industry is produced by about 10 companies. Furukawa Electric Co. Ltd. in Japan and Preussag AG in the Federal Republic of Germany are believed to be the world's largest producers, with reported capacities of 30 and 15

TABLE 4

ARSENIC TRIOXIDE:[1] WORLD PRODUCTION, BY COUNTRY[2]

(Metric tons)

Country[3]	1984	1985	1986	1987[p]	1988[e]
Belgium[e]	3,000	3,000	3,000	3,500	3,500
Bolivia	144	361	241	132	[4]191
Canada[e]	3,000	3,000	3,000	[r]2,000	2,000
Chile[e]	3,500	4,000	[r]4,000	[4]5,029	7,000
France[e]	[4]3,828	8,000	10,000	[r]10,000	10,000
Germany, Federal Republic of[e]	360	360	360	360	360
Japan[e]	500	500	500	500	500
Korea, Republic of	NA	NA	NA	([5])	—
Mexico	[r]4,164	[r]4,782	5,315	5,304	[4]4,992
Namibia[6]	2,504	2,471	2,208	1,864	1,800
Peru[7]	1,090	1,257	1,273	1,757	1,500
Philippines[e 8]	—	5,000	5,000	5,000	5,000
Portugal[e]	180	170	150	150	160
Sweden[e 9]	10,000	10,000	10,000	10,000	10,000
U.S.S.R.[e]	8,000	8,100	8,100	8,100	8,100
United States	6,800	2,200	—	—	—
Total	**[r]47,070**	**[r]53,201**	**53,147**	**53,696**	**55,103**

[e]Estimated [p]Preliminary. [r]Revised. NA Not available.
[1] Including calculated arsenic trioxide equivalent of output of elemental arsenic and arsenic compounds other than arsenic trioxide where inclusion of such materials would not duplicate reported arsenic trioxide production.
[2] Table includes data available through June 7, 1989.
[3] Austria, China, Czechoslovakia, the German Democratic Republic, Hungary, Spain, the United Kingdom, and Yugoslavia have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to make reliable estimates of output levels, if any.
[4] Reported figure.
[5] Revised to zero.
[6] Output of Tsumeb Corp. Ltd. only.
[7] Output of Empresa Minera del Centro del Peru (Centromin Peru) as reported by the Ministerio de Energia y Mines.
[8] The Philippines may have had some arsenic output in 1984 from the Philippine Smelting and Refining Corp. (PASAR) copper smelter, but available information is inadequate to make reliable estimates of output levels, if any.
[9] Based on arsenic trioxide exported plus the arsenic trioxide equivalent of the output of metallic arsenic exported.

metric tons per year, respectively. Other high-purity arsenic producers include: Johnson Matthey Electronics, in Canada; Mitsubishi Metal Corp. and Rasa Industries Ltd., in Japan; and Johnson Matthey Ltd. and MCP Electronic Materials Ltd., in the United Kingdom. Johnson Matthey Electronics, formerly a division of Cominco Ltd., produced high-purity arsenic at Trail, British Columbia, and fabricated electronic products such as gallium arsenide wafers in Spokane, WA.

The Con Mine, Yellowknife, Northwest Territories, Canada, produced 99.5% arsenic trioxide as a byproduct from gold tailings and residues. Nerco Minerals Co., Vancouver, WA, purchased the Con Mine in 1986 from Cominco.

Technology

Researchers at Nippon Telephone and Telegraph's (NTT) Electrical Communications Laboratories in Tokai, Japan, fabricated aluminum-gallium-arsenide/gallium-arsenide tandem solar cells with an efficiency of 20%. In prior experiments by NTT with the same kind of cell, an efficiency of only 16% was achieved.[7]

Scientists at AT&T Bell Laboratories created a new infrared detector using gallium arsenide. Mercury-cadmium-telluride detectors have been used for some time in aerospace and defense applications, but the material is less stable, more expensive and harder to grow and to work with than gallium arsenide.[8]

CESIUM AND RUBIDIUM[9]

Cesium and rubidium metals and compounds were produced from pollucite and lepidolite ores imported from Canada. Cabot Corp., Revere, PA, produced cesium and rubidium metals and compounds. Carus Chemical Co., LaSalle, IL, produced cesium compounds. Domestic production capacities for the metals and their compounds, in terms of cesium and rubidium contents, are estimated at 7 to 10 metric tons for cesium, and about 3 metric tons for rubidium.

Cabot's prices for cesium and rubidium materials in quantities under 50 pounds remained unchanged from its 1987 prices for most materials. Per pound quotes to the nearest dollar for technical grades (and high-purity grades) were as follows: cesium metal $275 ($325); rubidium metal $300 ($375); and common cesium compounds $36 to $44 ($73 to $79). Prices for common rubidium compounds increased in 1988 and ranged from $108 to $121 ($162 to $183).

GERMANIUM[10]

The estimated domestic refinery production of germanium decreased while consumption remained at the same level as that of 1987. Infrared systems and fiber optics continued to be the major end uses. The domestic fiber-optic market decreased for the third successive year, and germanium consumption for this application decreased about 20% compared to that of 1987. In 1988, the only operation in the world where germanium and gallium were recovered as principal products filed for chapter 11 bankruptcy protection, having ceased production in 1987.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF CESIUM COMPOUNDS, BY CLASS AND COUNTRY

Class and country	1986 Quantity (pounds)	1986 Value	1987 Quantity (pounds)	1987 Value	1988 Quantity (pounds)	1988 Value
Cesium chloride:						
Germany, Federal Republic of	27,924	$952,998	29,098	$1,078,217	34,064	$1,150,221
Netherlands	44	2,639	—	—	—	—
Norway	210	12,187	345	14,986	—	—
Sweden	124	9,096	8	1,110	231	7,596
United Kingdom	—	—	352	12,557	176	4,960
Total	**28,302**	**976,920**	**[r]29,803**	**[r]1,106,870**	**34,471**	**1,162,777**
Cesium compounds, n.s.p.f.:						
Germany, Federal Republic of	7,140	165,717	12,500	241,659	12,183	406,905
Italy	—	—	82	4,783	3,204	11,132
Japan	1,984	5,821	—	—	—	—
Netherlands	58	11,390	62	12,214	—	—
United Kingdom	3	1,076	—	—	9	2,093
Total	**9,185**	**184,004**	**12,644**	**258,656**	**15,396**	**420,130**

[r] Revised.

Source: Bureau of the Census.

Domestic Data Coverage

Domestic refinery production and consumption data for germanium are estimated by the Bureau of Mines based on discussions with domestic producers.

Legislation and Government Programs

On February 25, 1988, the President signed Executive Order 12626, designating the Secretary of Defense to be the manager of the National Defense Stockpile (NDS).[11] The Secretary delegated operational management functions of the NDS to the Defense Logistics Agency (DLA). Previously, the NDS responsibilities were distributed among the Department of Defense, the Federal Emergency Management Agency, and the General Services Administration.

In September, the DLA contracted to purchase 15,000 kilograms of germanium metal for the NDS. The agency's solicitation for germanium was divided into three separate portions of 5,000 kilograms each, and, in an effort not to disrupt the market, delivery times were stretched out from January 1990 to September 1990. The contract to supply all three portions was awarded to a single company, Minemet Inc., Paris, France, at respective prices of $710, $705, and $699 per kilogram.

The NDS goal for germanium metal remained at 146,000 kilograms. Part of the metal inventory acquisitions made in 1987 were delivered in 1988, and as of December 31, 1988, the stockpile inventory was 11,729 kilograms of germanium metal.

Domestic Production

Domestic refinery production from both primary and secondary materials was estimated to be 21,000 kilograms, a decrease of 16% compared with that of 1987. Refined germanium products were produced by Eagle-Picher Industries Inc., Quapaw, OK; KBI Div. of Cabot, Revere, PA; and Atomergic Chemetals Corp., Plainview, NY.

The Jersey Minière Zinc Co. in

Clarksville, TN, continued to produce germanium-rich residues as a byproduct of processing zinc ores from its Gordonsville and Elmwood Mines. These residues were shipped to Métallurgie Hoboken-Overpelt S.A. (MHO) in Belgium for germanium recovery and refining.

St. George Mining Corp. of St. George, UT, a subsidiary of the Canadian company Musto Explorations Ltd. and the only firm in the world to recover germanium and gallium as principal products, filed for chapter 11 bankruptcy protection. The mine and refinery had been closed since September 1987 owing to technical problems in the germanium solvent-extraction process and weak gallium prices. Hecla Mining Co., Wallace, ID, a leading silver- and gold-producing company, entered into an option agreement to acquire the assets of the insolvent company. The agreement was subject to the approval of the U.S. Bankruptcy Court in Utah.[12]

Consumption and Uses

The consumption of germanium was estimated at 40,000 kilograms, the same level as that of 1987. The estimated consumption pattern by end use of germanium in 1988 was as follows: infrared systems, 67%; fiber optics, 8%; gamma-ray, X-ray, and infrared detectors, 7%; semiconductors, 6%; and other, 12%.

The largest end use for germanium continued to be in infrared optics, mainly for military use in guidance and weapon-sighting systems. Germanium-containing lenses and windows transmit thermal radiation in the same way that optical glass transmits visible light. Germanium glass also was used for nonmilitary surveillance and monitoring systems in fields such as satellite systems and fire alarms.

The U.S. fiber-optic market continued the downtrend that began 2 years ago, and consumption of germanium in this application decreased about 20% compared with that of 1987.

Prices

Domestic producer prices for germanium metal and dioxide, published by Metals Week, remained at the levels established in late 1981 ($1,060 and $660 per kilogram, respectively), throughout 1988.

The Belgian producer prices, published by Metal Bulletin (London), for germanium metal and germanium dioxide remained throughout the year at $809 and $463 per kilogram, respectively.[13]

Foreign Trade

A comparison of the value per kilogram of imported germanium material with the published foreign producer price for germanium metal, less estimated processing charges, was used to estimate the germanium content of imported scrap. In 1988, the germanium content of total imports was calculated to be approximately 14,000 kilograms.

World Capacity

The data in table 7 represent rated annual production capacity for refineries on December 31, 1988. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

The rated capacity of germanium refineries was estimated based on discussions with some officials from private industry, past and present production rate, the author's knowledge of the type of facility, and published capacity data.

World Review

World refinery production was estimated at 84,000 kilograms. Germanium was produced by MHO, Belgium; Cominco Ltd., Canada; Société Minière et Métallurgique de Peñarroya S.A.(Peñarroya), France; Preussag and Otavi Minon AG, Federal Republic of Germany; Societá Mineraria e Metallurgica di Pertusola Sud S.A., Italy; Dowa Mining Co., Nippon Denshi Kinzoku, Rasa Industries, Sumitomo Metal Mining, and Tokyo Denshi Yakin, Japan. Germanium also was recovered at refineries in China and the U.S.S.R.

TABLE 6

WORLD ANNUAL GERMANIUM REFINERY PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand kilograms)

	Capacity
North America:	
Canada	5
United States	40
Total	**45**
Europe:	
Belgium	50
France and Italy	35
Germany, Federal Republic of	35
Centrally planned economy countries	40
Total	**160**
Asia:	
China	10
Japan	35
Total	**45**
World total	**250**

Canada.—During the last quarter of 1988, Cominco completed construction of its germanium refinery plant at Trail, British Columbia. Initial germanium capacity was 5,000 kilograms per year, with a capacity expansion provision depending on market conditions.

Cominco sold its electronic materials plants at Spokane, WA, and Trail to Johnson Matthey PLC, United Kingdom, parent company of Johnson Matthey Ltd. of Canada. Cominco's Crystar Research Inc. at Victoria, British

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM, BY CLASS AND COUNTRY

Class and country	1987 Gross weight (kilograms)	1987 Value	1988 Gross weight (kilograms)	1988 Value
Unwrought and waste and scrap:				
Australia	—	—	100	$33,960
Belgium-Luxembourg[1]	1,401	$1,455,925	6,419	4,105,962
Canada	35	22,903	88	54,337
China	5,168	2,402,457	1,986	1,184,120
France	5,448	2,737,307	3,949	2,154,821
Germany, Federal Republic of	1,121	755,366	244	162,147
Hong Kong	549	240,630	—	—
Israel	195	5,985	—	—
Japan	15	23,415	—	—
Netherlands	—	—	140	78,501
Switzerland	391	46,588	—	—
United Kingdom	686	296,238	2,765	1,597,641
Total	**15,009**	**7,986,814**	**15,691**	**9,371,489**
Wrought:				
Belgium-Luxembourg[1]	1,340	1,348,383	2,646	3,211,285
France	—	—	259	191,942
Germany, Federal Republic of	584	652,902	254	330,467
Israel	549	499,518	78	36,233
Netherlands	16	3,496	54	49,821
United Kingdom	—	—	309	347,583
Total	**2,489**	**2,504,299**	**3,600**	**4,167,331**

[1] For 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.

Source: Bureau of the Census.

Columbia, was also included in the sale. Johnson Matthey expected to continue operating both plants using feedstock from Cominco. The company, Johnson Matthey Electronics, will have its headquarters at Spokane.

Japan.—Germanium metal production was 4,160 kilograms, a decrease of about 10% compared with 1987 metal production levels. However, dioxide production increased from 13,358 kilograms in 1987 to 13,883 kilograms in 1988.[14]

Korea, Republic of.—A submarine fiber-optic-cable construction-and-maintenance agreement was signed in Cheju Island, Korea, by over 20 telecommunications companies. The proposed system, known as the H-J-K cable systems, will link Hong Kong, Japan, and Korea, using about 4,600 kilometers of fiber-optic cable.

Technology

Flight tests of a ground-fired missile, under development by Aerospatiale of France and Messerschmitt-Boelkow-Blohm of the Federal Republic of Germany, were conducted to define the effectiveness of this antitank and antihelicopter missile weapon. The demonstrator missile was equipped with an optical-fiber cable on a spool and a small television camera. During the flight, the cable enabled the gunner at the launch site to see the battlefield and choose a target. The final version of this missile was expected to have a range of 10 kilometers.[15]

A spark plug fitted with fiber-optic cables was devised to study rough automobile engine idling, a problem the auto industry would like to eliminate. Eight 1-millimeter holes were drilled through the spark plug, perpendicular to the threads. Each hole was flush fitted with a fiber-optic cable individually attached to a light detector. This arrangement enabled the researchers to observe the shape of the flame caused by the gasoline-air mixture explosion after ignition. Researchers at Sandia National Laboratories' Combustion Research Facility in Livermore, CA, believed that this fiber-optic plug had great potential as a research tool for engine design and for diagnosis of engine combustion problems.[16]

INDIUM[17]

Arconium Corp., Providence, RI, and Indium Corp. of America, Utica, NY, were the domestic producers of indium. Data on domestic primary production in 1988 was not available, but output apparently increased slightly over 1987. Several specialty metal firms recovered small quantities of secondary indium. Indium Corp. announced a joint venture, with Falconbridge Ltd. of Canada, to recover indium at its Kidd Creek facility in Timmons, Ontario. Production was expected to begin in late 1989 and could eventually increase Indium Corp.'s annual output by 1 million troy ounces.

Legislation and Government Programs

The Department of Defense added indium to the NDS, with a proposed goal of 1,350,000 ounces. Annual purchases of 80,000 ounces were recommended for fiscal years 1990 and 1991.

Consumption and Uses

Domestic consumption increased to an estimated 900,000 ounces in 1988. Applications such as indium-tin oxide coatings for aircraft and automobile windshields and windows continued to expand. Estimated usage patterns were as follows: solders, alloys, and coatings, 50%; electrical and electronic components, 35%; and research and other, 15%.

World Capacity

The data in table 8 are rated primary production capacity for refineries as of December 31, 1988. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimal capital expenditure.

Refinery capacities for indium are based on a combination of engineering capacities provided by some companies and estimates by the Bureau of Mines.

Prices

The producer price of indium, as published in Metals Week, decreased for the first time since 1985. The price was at $9.95 per ounce from January 1 until April 1988, when it rose briefly to $10.50 per ounce. It then gradually decreased to a low of $9.35 per ounce in October and finished the year at $9.49 per ounce. The slight decline in price was attributed to an increase in the world supply of indium.

World Review

World production of indium was estimated to be between 2.5 to 3 million ounces. Cominco announced plans to construct a new indium recovery facility at its Trail, British Columbia, oper-

TABLE 8

WORLD ANNUAL INDIUM PRODUCTION CAPACITY, DECEMBER 31, 1988

(Thousand troy ounces)

Country	Refinery
Belgium	800
Canada	300
China	400
France	500
German Democratic Republic	100
Germany, Federal Republic of	500
Italy	400
Japan	1,500
Netherlands	100
Peru	200
U.S.S.R.	500
United Kingdom	200
United States	1,000
Total	**6,500**

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF INDIUM, BY CLASS AND COUNTRY

(Thousand troy ounces and thousand dollars)

Class and country	1986		1987		1988	
	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought and waste and scrap:						
Belgium-Luxembourg[1]	313	$751	335	$1,994	288	$2,855
Bulgaria	—	—	—	—	1	76
Canada	41	107	43	286	54	619
China	218	520	148	933	109	542
France	113	411	341	1,614	152	1,576
Germany, Federal Republic of	2	50	9	102	14	111
Hong Kong	26	72	15	144	—	—
Italy	331	759	185	1,121	241	2,553
Japan	6	104	29	478	11	416
Netherlands	23	50	46	219	57	182
Peru	60	139	102	643	55	487
Switzerland	8	17	—	—	—	—
United Kingdom	221	1,159	262	1,887	208	3,452
Total[2]	**1,362**	**4,138**	**1,515**	**9,421**	**1,189**	**12,870**
Wrought:						
China	9	21	([3])	17	([3])	11
France	—	—	—	—	([3])	1
Germany, Federal Republic of	1	9	—	—	([3])	5
Japan	1	17	1	61	3	34
United Kingdom	6	440	5	297	5	401
Other	([3])	7	—	—	26	63
Total[2]	**18**	**495**	**7**	**375**	**35**	**516**

[1] For 1986 and 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

ations. The plant was scheduled to begin operation in mid-1989 and would increase production capacity to 1 million ounces.

Production in Japan increased 77% from that of 1987, to 1.5 million ounces. However, production at this level was not expected to continue due to a shortage of feedstock for the refineries and a decline in zinc production, of which indium is a byproduct. Demand in Japan continued to grow, as consumption was estimated at 1.9 million ounces.

Peñarroya, the largest producer of indium in Europe, which operated refineries in France and Italy, and Preussag, which produced high-purity indium in the Federal Republic of Germany, merged to create Metaleurop SA. The new company was expected to continue production of indium at all existing plants. Other world refiners included: MHO in Belgium; Dowa Mining Co. Ltd., Mitsui Mining & Smelting Co. Ltd., and Nippon Mining Co. in Japan; Empresa Minera del Centro del Perú, S.A. (Centromin-Peru) in Peru; Mining and Chemical Products Ltd. in the United Kingdom; and government metallurgical complexes in China and the U.S.S.R.

Technology

Indium phosphide solar cells were expected to be used on Japan's lunar satellite, which was scheduled to be launched in February 1990. Despite the higher cost, indium phosphide was chosen because it has a higher energy-conversion efficiency than silicon-based cells, 18% compared to 14%, and greater resistance to cosmic radiation than gallium arsenide cells.[18]

RHENIUM[19]

Cyprus Minerals Co., Englewood, CO, was the only domestic producer to recover rhenium in 1988. Rhenium contained in molybdenite was mined as a byproduct of porphyry copper ore from seven mines in the Southwestern United States. Consumption of rhenium increased about 10% in 1988. Imports for consumption decreased about 8%. The major use continued to be bimetallic platinum-rhenium catalysts to produce unleaded gasoline. The price of rhenium metal increased from $500 in 1987 to $700 per pound, and the price of ammonium perrhenate increased from $200 to $500 per pound.

Domestic Data Coverage

Domestic mine production data for rhenium are developed by the Bureau of Mines from the reported molybdenum production at the seven operating porphyry-copper-molybdenum-rhenium mines in the United States.

Foreign Trade

Imports for consumption decreased. Most of the ammonium perrhenate came from Chile, the Federal Republic of Germany, the Netherlands, and Sweden, whereas Chile and the Federal Republic of Germany supplied the rhenium metal.

World production of rhenium was estimated to be 45,000 pounds, exclusive of U.S. production. Rhenium was recovered from byproduct molybdenite concentrates from porphyry copper deposits in Canada, Chile, China, Iran, Peru, the U.S.S.R., and the United States. In addition, the U.S.S.R. also recovered rhenium as a byproduct from the Dzhezkazgan sedimentary copper deposit in Kazakhstan. Rhenium metal and compounds were recovered from molybdenum concentrates in Chile, France, the Federal Republic of Germany, Sweden, the U.S.S.R., the United Kingdom, and the United States. Chile's recovery of

TABLE 10

SALIENT U.S. RHENIUM STATISTICS

(Pounds of contained rhenium)

	1984	1985	1986	1987	1988
Mine production[1]	17,200	21,100	21,700	21,800	26,300
Recovered[2]	W	W	W	W	W
Consumption[e]	10,200	13,000	13,000	15,500	17,000
Imports (metal)	1,962	4,943	5,495	7,436	6,821
Imports for consumption of ammonium perrhenate	4,754	3,325	12,189	7,225	5,979
Stocks, Dec. 31	W	W	W	W	W

[e] Estimated. W Withheld to avoid disclosing company proprietary data.
[1] Calculated rhenium contained in molybdenite concentrates.
[2] In prior years, this was shown as mine production.

TABLE 11

U.S. IMPORT DUTIES FOR RHENIUM MATERIALS

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1988	Non-MFN Jan. 1, 1988
Unwrought metal	628.9000	3.7% ad valorem	25% ad valorem
Wrought metal	628.9500	5.5% ad valorem	45% ad valorem
Ammonium perrhenate	417.4520	3.1% ad valorem	25% ad valorem
Perrhenic acid	416.4540	4.2% ad valorem	25% ad valorem

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY

(Rhenium content)

Country	1986		1987		1988	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg	76	$22	—	—	—	—
Brazil	1,022	175	70	$27	—	—
Chile	8,360	1,502	4,906	1,426	3,449	$1,892
China	—	—	4	2	—	—
Ecuador	—	—	154	61	—	—
Germany, Federal Republic of	1,938	352	547	176	427	278
Japan	158	28	209	89	192	125
Netherlands	635	120	—	—	761	390
Sweden	—	—	1,040	272	1,150	729
United Kingdom	—	—	295	69	—	—
Total	**12,189**	**2,199**	**7,225**	**2,122**	**5,979**	**3,414**

Source: Bureau of the Census.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF RHENIUM METAL, BY COUNTRY

Country	1986		1987		1988	
	Gross weight (pounds)	Value	Gross weight (pounds)	Value	Gross weight (pounds)	Value
Chile	3,150	$2,014,000	5,463	$1,445,049	5,359	$2,144,211
Germany, Federal Republic of	1,904	432,000	1,867	593,093	1,442	1,003,724
United Kingdom	441	171,000	—	—	—	—
Other[1]	—	—	106	34,342	20	13,100
Total	**5,495**	**2,617,000**	**7,436**	**2,072,484**	**6,821**	**3,161,035**

[1] Includes France, Sweden, Switzerland, and Uruguay.

Source: Bureau of the Census.

rhenium was the largest amount produced by a market economy country.

SCANDIUM[20]

Scandium was produced, as a byproduct concentrate, at one location in the United States, a copper mine in Utah. Demand for scandium decreased substantially as a result of decreased demand for scandium-containing laser crystals. Prices for scandium compounds showed a corresponding sharp decline. As advanced materials, scandium-containing synthetic garnet crystals were components in high-energy lasers, and scandium-aluminum alloys were used in aerospace applications.

Domestic Data Coverage

Domestic production data for scandium are developed by the Bureau of Mines from the voluntary survey "Rare Earths, Thorium and Scandium." The one mine and four processors to which the survey was sent responded, representing 100% of total production of concentrate and refined scandium products. Data are withheld to avoid disclosing proprietary data.

Domestic Production

The open pit Bingham Canyon copper mine in Utah, owned by BP Minerals America, was the only domestic producer of ore containing byproduct scandium. Scandium was also contained in tailings previously produced from fluorite mining at Crystal Mountain, MT, and in tungsten concentrates previously derived as a byproduct of processing molybdenum at AMAX Inc.'s Climax Mine, Climax, CO.

Energy Fuels Nuclear Inc. produced scandium concentrate from leachate at the byproduct uranium recovery plant it operated at the Bingham Canyon Mine. The company announced that it would close the plant in the first half of 1989 unless uranium prices increased.

Refined scandium products, principally scandium oxide, were produced domestically by four organizations. Sausville Chemical Co. and Boulder Scientific produced refined scandium products primarily from the Bingham Canyon concentrates. Research Chemicals Division of Rhône-Poulenc Inc., Phoenix, AZ, and Materials Preparation Center, Ames, IA, upgraded domestic and imported scandium materials.

Consumption and Uses

Domestic consumption of scandium decreased substantially in 1988. Demand decreased primarily as a result of cutbacks in government spending for gadolinium-scandium-gallium garnet (GSGG) synthetic crystals used in research on high energy lasers. The principal uses of scandium in 1988 were in aluminum alloys, laser crystals, lighting, and electronic applications.

GSGG crystals are more than twice as energy efficient as yttrium-aluminum garnets (YAG) crystals as a lasing medium. Laser applications for GSGG were in communications, high-average-energy applications such as fusion research and antimissile defense systems, and lower energy laser systems used in medical, electronic, and industrial applications.

Scandium is used in high-intensity mercury vapor lights to produce a highly efficient illumination that simulates natural daylight for color television broadcasting. Approximately 3 to 5 milligrams of scandium are added per bulb.

The use of scandium as an alloying agent became quantitatively important in 1988. Additions of scandium to aluminum reduces grain size and brittleness, imparting improved plasticity and increased strength. Scandium-aluminum alloys were used in aerospace and other metallurgical applications requiring lightweight, high-strength alloys.

The radioactive isotope scandium-46 was used as a tracing agent in petroleum refineries and in exploratory oil wells.

Scandium metal, backed by molybdenum, was used in dual-anode tubes in X-ray spectrometers. Excitation efficiency of the dual-anode system is reportedly excellent for detection of light elements.

Small amounts of scandium metal reportedly were used in semiconductors, petroleum catalysts, and collimators in neutron lenses.

Additions of scandium to titanium carbide reportedly create a binary carbide with a hardness close to that of diamond.

Prices

As the scandium market softened in 1988, prices for scandium metal and compounds decreased significantly. Yearend nominal prices for scandium oxide per kilogram, quoted by Sausville Chemical, were as follows: 99% purity, $5,200; 99.9% purity, $7,750; 99.99% purity, $9,500; 99.995% purity, $10,700; 99.999% purity, $13,000. Scandium metal prices varied considerably, depending on the quantity of material being purchased and its purity. Scandium metal prices quoted by the Aesar Group of Johnson Matthey Inc. were as follows: powder 99.9% purity, $444.00 per 2 grams; vacuum remelted ingot 99.9% purity, $322.00 per 2 grams; sublimed dendritic lump 99.99% purity, $248.20 per gram.

Foreign Trade

No trade data were available for scandium as an individual item. However, analysis of small shipments of high value from probable scandium import sources suggested that 3 kilograms of scandium oxide were imported from Norway.

Based on data compiled by the Bureau of Mines, the United States was not dependent on foreign sources for its current demands.

World Capacity

The data in table 14 were estimated rated production capacity for refined scandium as of December 31, 1988. Rated capacity was defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance.

TABLE 14

WORLD ANNUAL SCANDIUM OXIDE REFINERY PRODUCTION CAPACITY, DECEMBER 31, 1988

(Kilograms)

Country	Capacity
China	NA
France	100
Japan	NA
Norway	120
U.S.S.R.	NA
United States	500

NA Not available.

World Review

Countries that mined scandium-bearing ore in 1988 included Australia, China, Norway, the U.S.S.R., and the United States. Refined scandium was processed in France, Japan, Norway, the United Kingdom, and the United States.

Australia.—SX Holdings Ltd. announced plans to study the feasibility of recovering scandium from tailings at the Radium Hill deposit in South Australia. Scandium at Radium Hill occurs in davidite, a mineral containing iron, rare earths, uranium, titanium, vanadium, and chromium. SX planned to investigate in situ recovery methods for beneficiating scandium and other metals.[21]

Technology

Researchers at Iowa State University's Ames Laboratory developed an improved process to produce ultrahigh-purity scandium by displacement ion-exchange chromatography. Improved extraction was obtained by optimizing temperature and pH and by reducing iron impurities. The process was reported to be suitable for raising kilogram quantities of 98% pure scandium to 99.995% purity.[22]

SELENIUM[23]

Domestic Data Coverage

Domestic data for selenium are developed by the Bureau of Mines from a voluntary survey of the three U.S. producers. All three producers responded to the survey, supplying all of the stocks, production, and shipments data shown in table 15.

Domestic Production

Primary selenium was recovered as a byproduct of the electrolytic refining of copper by three domestic copper refiners: Asarco at Amarillo, TX; Phelps Dodge Refining Corp. at El Paso, TX; and BP Minerals America at Magna, UT. Selenium and precious metals accumulated in anode slimes generated in the electrolytic cells. Only a small part of the selenium initially present in the copper ores was ultimately recovered. Selenium present in copper ores processed by leaching was not recovered. Selenium-bearing anode slimes from other domestic primary copper refineries were exported for processing.

Production of refined selenium increased significantly owing to increased copper production from high-selenium copper mines. The Magna refinery, which closed in 1985 following closure of the Bingham Canyon Mine, reopened during the third quarter of 1987. It accounted for most of the production increase for 1988.

Most domestic selenium production was as commercial-grade material, averaging a minimum of 99.5% selenium, and available in various forms including shot, powder and lumps, or as pigment-grade powder having a minimum 99.8% selenium content. There was no domestic production of high-purity selenium suitable for electronics applications.

About 150 tons of selenium contained in scrap derived from the manufacture of photoconductor drums and from used photoconductor drums was exported for processing. There was no domestic production of secondary selenium.

TABLE 15

SALIENT SELENIUM STATISTICS

(Kilograms of contained selenium unless otherwise specified)

	1984	1985	1986	1987	1988
United States:					
Production, primary refined	253,598	W	W	W	285,633
Shipments to consumers	224,401	W	W	W	260,838
Exports, metal, waste and scrap	122,929	154,122	161,007	162,217	243,096
Imports for consumption	376,946	400,658	462,646	495,862	474,234
Apparent consumption[1]	[r]550,000	W	W	W	650,000
Stocks, yearend, producer[2]	139,159	W	W	W	W
Dealers' price, average per pound, commercial grade[3]	$9.02	$7.44	$5.70	$6.51	$9.84
World: Refinery production	1,493,851	1,324,756	1,224,500	[p]1,228,632	[e]1,502,671

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1] Apparent consumption was calculated using reported shipments and estimated selenium content of imported selenium compounds and estimated exports of selenium metal, excluding scrap.
[2] Granular selenium, a semirefined form of selenium, is included in stocks.
[3] Source: Metals Week. 1985-88 calculated from published price ranges.

Consumption and Uses

Selenium end uses can be divided broadly into four categories: electronics (including photoconductor); glass and ceramics; pigments and chemicals; and other uses including metallurgical and agricultural. In electronics, the largest end-use market, high-purity selenium was used principally as a photoconductor on the drums of plain-paper copiers. Other electronics uses include rectifier and photoelectric applications. In glass manufacturing, selenium was used principally as a decolorant to compensate for the yellow-green tint imparted by ferrous ions. Selenium was also used to reduce solar heat transmission in architectural plate glass. Cadmium sulfoselenide red pigments have good heat stability and were used in ceramics and plastics. Chemical uses of selenium included rubber compounding chemicals, gun bluing, catalysts, antidandruff shampoos, and vitamin supplements. In metallurgical applications, selenium was added to steel, copper, and lead alloys to improve machinability and casting and forming properties. In agriculture, sodium selenate and selenite were added to animal feed to compensate for lack of selenium in feed grown in selenium-deficient soils.

Domestic demand for selenium in 1988 remained at about the same high level as in 1987 as a result of continued strength in the photocopier and agricultural markets. Demand for selenium by end use was estimated as follows: electronics, 42%; pigments and chemicals, 23%; glass manufacturing, 17%; and other, including agriculture and metallurgy, 18%. Domestic demand for high-purity selenium for use in photoreceptors grew an estimated 20% over the 2-year period 1987-88. The growth was encouraged by lower U.S. dollar exchange rates and the resulting shift of production facilities to the United States by several Japanese photoreceptor producers. However, demand for selenium in photoreceptors was expected to stabilize or even decline owing to increased use of organic photoreceptors and lengthening of the life of selenium-based photoreceptors. The United States continued to be the world's largest consumer of selenium, accounting for 35% to 40% of total world demand.

Prices

In response to strong demand and declining world stocks, the merchant price of commercial-grade selenium, quoted by Metals Week on a weekly basis, rose during the first quarter of the year to about $11 per pound, continuing the upward trend begun in 1987. Prices were stable during the second quarter, then declined during the second half of the year, to an average of $9.30 per pound at yearend. Significant premiums were charged for higher purity grades of selenium.

Foreign Trade

Total imports of selenium, as measured in terms of contained selenium, declined slightly, owing to increased shipments by domestic producers. Canada continued to be the major source of imports, accounting for about one-third of total imports, followed by the United Kingdom, Belgium, and Japan. Combined, these four countries accounted for 88% of total selenium imports. Total exports of selenium metal, waste, and scrap, increased by about 50% to 243 tons. It was estimated that about 150 tons of this material was selenium scrap.

TABLE 16

U.S. EXPORTS OF SELENIUM METAL, WASTE AND SCRAP, BY COUNTRY

Country	1986		1987		1988	
	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value
Argentina	2,907	$44,163	998	$10,704	—	—
Belgium	—	—	17,941	140,504	48,299	$365,430
Brazil	319	5,099	59	3,250	—	—
Canada	324	5,171	2,772	44,307	2,110	54,872
China	—	—	1,955	28,290	—	—
Colombia	7,387	144,870	—	—	5,987	129,809
France	1,011	16,150	1,159	18,526	6,966	111,358
Germany, Federal Republic of	—	—	—	—	23,788	468,050
India	—	—	—	—	200	6,600
Italy	1,883	21,835	299	4,290	299	4,290
Japan	42,875	245,381	34,611	270,252	27,746	347,881
Korea, Republic of	10,165	52,265	1,031	21,662	4,049	64,717
Malaysia	4,802	76,752	—	—	2,654	42,426
Mexico	15,231	237,033	30,385	462,450	10,113	161,641
Netherlands	19,421	180,238	7,484	83,160	26,090	452,636
Philippines	17,178	43,486	9,072	6,000	—	—
Portugal	272	3,350	—	—	—	—
Spain	—	—	1,014	12,258	427	5,158
Switzerland	2,984	32,763	—	—	—	—
United Kingdom	34,200	342,461	51,246	546,020	79,879	926,756
Venezuela	48	1,446	1,814	28,987	412	6,593
Other	—	—	377	5,520	4,077	49,107
Total [1]	**161,007**	**1,452,463**	**162,217**	**1,686,180**	**243,096**	**3,197,324**

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

World Capacity

Annual capacity to produce primary selenium in market economy countries has increased by about 200 tons over the past 5 years. Additional capacity came on-stream in Belgium (1988), the Philippines (1984), and the United States (1984). Table 18 provides a listing of major primary producers and estimates of their capacities. Company-reported capacity data for selenium refineries is not generally available. In addition to producing primary selenium, several refineries recover refined selenium from scrap, principally xerographic materials. Capacity is here defined as the maximum quantity of selenium that can be produced in a year at a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. The production rate for selenium, a byproduct of other nonferrous metals, is determined more by the production rate of the principal metal, than by the production capacity, or the demand for selenium.

World Review

Market economy country (MEC) demand for selenium was estimated to be about 1,900 tons in 1988, up slightly from that of the previous year, and up by about 16% compared with demand in 1986. Growing exports to China and growing U.S. demand accounted for most of the increase. Exports of selenium from MEC's to China grew from 25 tons in 1984 to more than 200 tons in

TABLE 17

U.S. IMPORTS FOR CONSUMPTION OF SELENIUM, BY CLASS AND COUNTRY

Class and country	1986		1987		1988	
	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value
Unwrought and waste and scrap:						
Belgium	86,143	$2,736,960	94,477	$2,649,893	66,197	$2,087,313
Canada	130,038	2,386,721	136,621	2,784,833	163,066	4,226,140
Chile	3,000	42,118	—	—	—	—
China	—	—	4,475	47,503	—	—
Costa Rica	362	11,940	—	—	—	—
Finland	—	—	1,000	13,302	2,296	45,958
Germany, Federal Republic of	205	9,496	1,940	25,767	2,000	38,327
Japan	87,858	1,958,821	85,657	1,759,989	57,358	1,456,867
Korea, Republic of	2,000	19,852	1,500	13,524	1,000	14,881
Netherlands	3,680	61,216	—	—	2,296	49,386
Peru	—	—	—	—	475	9,270
Philippines	10,000	86,200	12,000	111,667	18,275	291,962
Sweden	—	—	—	—	50	1,709
United Kingdom	97,408	1,501,694	76,379	1,245,330	100,854	1,640,007
Yugoslavia	5,000	43,572	20,000	153,657	—	—
Total	**425,694**	**8,858,590**	**434,049**	**8,805,465**	**413,867**	**9,861,820**
Selenium dioxide:						
Belgium	8	1,011	—	—	—	—
Canada	—	—	—	—	8	1,491
Germany, Federal Republic of	5,405	113,472	3,594	70,990	9,791	271,507
Japan	—	—	6,227	138,782	—	—
United Kingdom	142	3,114	1,314	29,724	1,527	54,250
Total[1]	**5,555**	**117,597**	**11,135**	**239,496**	**11,325**	**327,248**
Selenium salts:						
France	—	—	46	1,233	—	—
Korea, Republic of	1,626	2,662	—	—	—	—
United Kingdom	650	7,798	300	7,677	125	5,325
Total	**2,276**	**10,460**	**346**	**8,910**	**125**	**5,325**
Sodium selenite:						
Belgium	—	—	230	5,550	2,300	58,825
Canada	4	1,648	345	8,454	4,600	144,119
Germany, Federal Republic of	14,987	125,108	19,734	259,174	19,819	61,619
Japan	230	15,917	414	35,260	184	19,798
United Kingdom	10,931	258,425	26,640	597,024	13,708	402,691
Total[1]	**26,152**	**401,098**	**47,363**	**905,462**	**40,610**	**687,052**
Other selenium compounds:						
Belgium	—	—	464	35,478	324	24,444
Canada	—	—	48	2,400	—	—
Germany, Federal Republic of	338	10,351	250	5,324	22	2,225
Italy	—	—	—	—	12	1,238
Japan	—	—	—	—	3	4,027
Sweden	—	—	264	6,296	—	—
United Kingdom	2,631	152,070	1,943	99,668	7,946	226,418
Total	**2,969**	**162,421**	**2,969**	**149,166**	**8,307**	**258,352**
Grand total	**462,646**	**9,550,166**	**495,862**	**10,108,499**	**474,234**	**11,139,797**

[1] Data may not add to totals shown due to independent rounding.

Source: Bureau of the Census, figures adjusted by U.S. Bureau of Mines.

TABLE 18

PRINCIPAL MARKET ECONOMY COUNTRY PRODUCERS OF SELENIUM AND ANNUAL CAPACITY, DECEMBER 31, 1988

(Metric tons)

Continent and country	Company	Primary capacity
North America:		
Canada	Noranda Mines Ltd.	[1] 400
	INCO Ltd.	50
Mexico	Cobre de Mexico S.A.	45
United States	ASARCO Incorporated	W
	BP Minerals America	W
	Phelps Dodge Corp.	W
Total		**400**
South America:		
Brazil	Caráiba Metais S.A. Indústria e Comercio	20
Chile	Empresa Nacional de Minéria	40
Peru	Empresa Minera del Centro del Péru	20
Europe:		
Belgium	Metallurgie Hoboken-Overpelt S.A.	[1] 360
Finland	Outokumpu Oy	90
Sweden	Boliden Metall AB.	70
Yugoslavia	Rudarsko Topionicarski Bazen Bor	50
Africa: Zambia	Zambia Consolidated Copper Mines Ltd.	25
Asia:		
Japan	Mitsubishi Metal Corp.	250
	Mitsui Mining and Smelting Co. Ltd.	100
	Nippon Mining Co. Ltd.	120
	Sumitomo Metal Mining Co. Ltd.	70
Philippines	Philippine Associated Smelting and Refining Corp.	70
Grand total (rounded)		**2,200**

W Withheld to avoid disclosing company proprietary data.
[1] Includes secondary capacity.

1988. It was believed that the growing demand for clear container glass and the development of its manganese industry have accounted for most of China's apparent increase in demand.

Production of refined selenium in the MEC's in 1988 was insufficient to meet demand, with the result that world stocks of refined selenium continued the downward trend begun in 1981. According to the American Bureau of Metal Statistics, which compiled data from companies that account for an estimated 60% to 70% of MEC selenium production, stocks of refined selenium declined 120 tons during 1988 and over 600 tons, about 40%, since their 1981 peak. However, at the prevailing rate of consumption, yearend reported stocks still constituted about a 5-month supply.

Belgium.—MHO completed expansion of the selenium refinery at its Hoboken operations from 260 to 360 tons of selenium per year. Selenium was recovered from copper anode slimes generated at its Olin refinery, from zinc slimes from its Overpelt refinery, and from significant quantities of imported scrap.

Canada.—Noranda Inc. commissioned a new slimes treatment plant at its Canadian Copper Refiners Division at Montreal East. In addition to processing slimes from its own copper refinery, Noranda processed the high-selenium anode slimes generated at Kidd Creek Mines Ltd.'s refinery.

Philippines.—International Recoveries Inc., of Manila, began processing scrap photoconductor materials during 1987 for the recovery of secondary selenium. The scrap was processed on a toll arrangement from Nippon Mining Co. Ltd. of Japan.

TABLE 19

SELENIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Kilograms, contained selenium)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Belgium[e]	180,000	230,000	250,000	230,000	250,000
Canada[3]	[e]354,000	361,000	345,000	300,000	300,000
Chile	25,450	50,037	47,000	45,909	[4]44,051
Finland	16,975	14,038	5,693	[e]10,000	10,000
India	4,191	4,850	[e]4,800	4,026	4,000
Japan	464,524	496,835	426,567	481,109	[4]471,020
Mexico	44,000	42,000	23,000	29,000	13,000
Peru	20,758	14,506	12,035	11,438	11,000
Sweden	68,000	46,000	[e]50,000	[e]50,000	50,000
United States	253,598	W	W	W	[4]285,600
Yugoslavia[e]	45,000	46,000	45,000	45,000	44,000
Zambia[5]	17,355	19,490	15,405	22,150	20,000
Total	**1,493,851**	**1,324,756**	**1,224,500**	**1,228,632**	**1,502,671**

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1] Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but did not recover refined selenium from these materials indigenously, were excluded to avoid double counting. Table includes data available through June 7, 1989.

[2] In addition to the countries listed, Australia, the Federal Republic of Germany, and the U.S.S.R. produced refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilities for processing imported anode slimes for the recovery of selenium and precious metals, the United Kingdom has facilities for processing selenium scrap.

[3] The 1984-85 refinery output is from all sources including imported materials and secondary sources; 1986-88 excludes secondary production.

[4] Reported figure.

[5] Data for fiscal year ending Mar. 31 of year stated. In addition to refined selenium produced domestically as shown, Zambia exported anode slimes from electrolytic copper production that, since 1984, have been estimated to contain at least 30,000 kilograms per year of recoverable selenium.

TELLURIUM[24]

Commercial-grade tellurium metal (minimum 99% tellurium) and tellurium dioxide were produced by Asarco as byproducts of copper refining at its electrolytic copper refinery at Amarillo, TX. Asarco provided tellurium production data to the Bureau of Mines; however, the data are withheld to avoid disclosing company proprietary data.

Domestic production and shipments of refined tellurium were about the same as in the previous year. Tellurium producer stocks, crude plus refined, continued to decline owing to a production deficit caused by the lower tellurium content of anode slimes being processed in recent years. The closure of Asarco's Tacoma, WA, smelter in 1985, which had processed high-tellurium Philippine concentrates, significantly reduced the tellurium content of the company's anode slimes, and hence tellurium recovery.

Apparent domestic demand for tellurium and its compounds, as calculated from production, trade, and stock data, increased significantly. The increase in apparent demand resulted largely from the increase in tellurium imports; imports of tellurium metal increasing nearly fivefold. Consumer and merchant inventory buildup was believed to account for at least some of the increase in calculated demand.

The principal use of tellurium was as an alloying metal in the production of free-machining low-carbon steels, where addition of up to 0.1% tellurium, usually in conjunction with lead, greatly improves machinability. Similarly, the addition of tellurium to copper and other nonferrous alloys improves their machinability, strength, and corrosion resistance. Tellurium chemicals were used as catalysts, principally in the oxidation of organic compounds, and as curing and accelerating agents in rubber compounding. Electronic applications for high-purity tellurium included its use as an alloying element in selenium-based photoreceptors for plain-paper copiers, and as an infrared sensing material in mercury-cadmium-telluride thermal imaging devices such as those used in military night-vision systems. Estimated consumption of tellurium by end-use category was iron and steel, 55%; nonferrous metals, 20%; chemicals and rubber manufacturing, 17%; and other uses, including xerographic and electronic applications, 8%.

In response to a continued production deficit, world stocks, according to data compiled by the World Bureau of Metal Statistics, fell to less than 30 metric tons by yearend, or, at the prevailing rate of consumption, less than a 2-month supply. The upward trend in price that began in 1987 continued, and by yearend 1988, the price of tellurium metal was about $35 per pound, more than triple the 1986 price.

Capacity to produce refined tellurium in the MEC's is estimated to be about 400 tons per year, with Belgium, Japan, and the United States the largest producers. In the Philippines, International Recoveries added new capacity to produce up to 40 tons of tellurium metal per year from accumulated stocks and imported tellurium residues. International Recoveries previously produced only tellurium dioxide.

TABLE 20

U.S. IMPORTS FOR CONSUMPTION OF TELLURIUM, BY CLASS AND COUNTRY

Class and country	1986 Gross weight (kilograms)	1986 Value	1987 Gross weight (kilograms)	1987 Value	1988 Gross weight (kilograms)	1988 Value
Unwrought and waste and scrap:						
Belgium	47	$1,021	1,041	$32,401	1,246	$73,622
Canada	7,159	504,983	4,525	463,462	5,966	543,787
Germany, Federal Republic of	—	—	5	1,441	6	3,080
Hong Kong	—	—	—	—	321	13,760
Japan	754	43,891	347	38,149	15,044	705,514
Mexico	—	—	—	—	1,500	78,540
Netherlands	—	—	—	—	1,000	42,108
Peru	4,863	70,244	—	—	—	—
Philippines	—	—	—	—	13,700	302,033
United Kingdom	9,000	175,543	2,962	72,904	13,419	626,424
Total	**21,823**	**795,682**	**8,880**	**608,357**	**52,202**	**2,388,868**
Compounds:						
Belgium	10	1,277	—	—	—	—
Canada	—	—	(1)	1,879	1,416	71,688
Germany, Federal Republic of	—	—	133	6,463	10,706	107,605
Japan	63	7,161	188	9,743	200	10,821
Netherlands	—	—	—	—	1,901	22,661
Switzerland	—	—	7	1,633	42	7,577
United Kingdom	359	76,545	932	114,192	645	37,564
Total	**432**	**84,983**	**1,260**	**133,910**	**14,910**	**257,916**
Salts:						
Germany, Federal Republic of	8,466	30,397	16,550	64,238	9,778	41,732
United Kingdom	—	—	10	1,355	—	—
Total	**8,466**	**30,397**	**16,560**	**65,593**	**9,778**	**41,732**
Grand total	**30,721**	**911,062**	**26,700**	**807,860**	**76,890**	**2,688,516**

[1] Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 21

TELLURIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Kilograms, contained tellurium)

Country[2]	1984	1985	1986	1987[p]	1988[e]
Canada[3]	[e]21,000	19,000	[e]20,000	13,000	10,000
Japan	64,500	65,600	55,600	53,305	[4]55,181
Peru	14,066	15,007	9,836	7,457	7,500
United States	W	W	W	W	W

[e] Estimated. [p] Preliminary. W Withheld to avoid disclosing company proprietary data.

[1] Insofar as possible, data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but did not recover refined tellurium, are excluded to avoid double counting. Table is not totaled because of the exclusion of data from major world producers, notably the U.S.S.R. and the United States. Table includes data available through June 7, 1989.

[2] In addition to the countries listed, Australia, Belgium, the Federal Republic of Germany, and the U.S.S.R. are known to produce refined tellurium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Moreover, the other major copper-refining nations such as Chile and Zambia may produce refined tellurium, but output in these nations is conjectural.

[3] Refinery output from all sources, including imports and secondary sources.

[4] Reported figure.

THALLIUM[25]

In 1988, thallium metal was not recovered from ores mined in the United States, and domestic demand was met from imports and withdrawals from stocks. Imported materials were marketed as thallium compounds or as metal in the form of sticks, ingots, or wire. The toxicity of thallium is the factor that will continue to influence domestic dependence on foreign sources for its supply.

Consumption and Uses

Based on import data and discussions with metal traders, the domestic consumption of thallium was estimated to be 2,000 pounds in 1988, 33% less than in 1987. Thallium was used in superconductivity research and gamma radiation-detection equipment. It was also used in additives for changing the refractive index and density of glass, low-temperature mercury-thallium alloy switches, high-density liquids, alloys, photosensitive devices, and radioactive isotopes for cardiovascular diagnostic procedures.

Prices

Thallium metal was sold at various prices during the year according to its purity. Metal traders reported that the average price of thallium metal in 200-pound lots ranged from $80 per pound for 99.9%-pure thallium metal to about $125 per pound for 99.999%-pure metal, compared with $60 and $100 per pound, respectively, in 1987. Based on the average value per pound of metal imported into the United States, the price of thallium metal in 1988 was estimated to be about $55 per pound.

World Capacity

The thallium contained in zinc ores that were mined in 1988 was about 36,000 pounds. However, only about 25% of the thallium contained in zinc ores was recovered. In 1988, the principal producers of refined thallium were Belgium and Japan. The annual world rated capacity of refined thallium is not known, but it is believed to be between 20,000 and 30,000 pounds.

Technology

In February, researchers at the University of Arkansas in Fayetteville synthesized a bulk ceramic material that started to lose its resistance to electrical current at about 120 K (−153° C) and at about 106 K (−167° C) became a true superconductor. Superconductors are materials that offer no resistance to electric currents. This ceramic material contained oxides of thallium, barium, calcium, and copper.[26] Other researchers using thallium materials have obtained similar results, and all researchers pointed out that additional element substitutions in these systems may produce superconductivity at even higher temperatures. Current (lows-temperature) superconductors, principally alloys of the metals niobium and titanium, become superconductors when chilled to a liquid-helium temperature of about 4 K (−269° C). This expensive chilling process has so far limited applications to a few electronic devices for defense, industry, and medicine. The new thallium-base superconductors are at research stage, and practical applications are a few years into the future.

TABLE 22

U.S. IMPORTS FOR CONSUMPTION OF THALLIUM, BY COUNTRY

Country	Compounds			Unwrought and waste and scrap	
	Gross weight (pounds)	Content[1] (pounds)	Value	Gross weight (pounds)	Value
1987:					
Belgium-Luxembourg[2]	237	190	$16,670	1,151	$23,731
France	220	176	4,573	—	—
Germany, Federal Republic of	485	388	20,929	—	—
United Kingdom	11	9	2,450	1,034	20,756
Total	**953**	**763**	**44,622**	**2,185**	**44,487**
1988:					
Belgium[2]	552	442	36,955	674	38,409
Germany, Federal Republic of	169	135	10,898	—	—
Japan	385	308	11,372	—	—
Total	**1,106**	**885**	**59,225**	**674**	**38,409**

[1] Estimated by the Bureau of Mines.
[2] For 1987 Belgium and Luxembourg combined, data not available to separate; 1988 data for Belgium only.
Source: Bureau of the Census.

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[1] Prepared by J. Roger Loebenstein, Physical scientist.

[2] Great Falls (MT) Tribune. Fine of $1.6 Million Levied Against East Helena Smelter. Apr. 20, 1988, pp. 1A, 2A.

Montana (Butte) Standard. ASARCO Cleanup Area Extended. Mar. 7, 1988.

[3] ———. Area Arsenic: Experts Unsure of the Danger. May 30, 1988, pp. 1, 3.

[4] ———. Rising Mine Water. Sept. 5, 1988.

[5] Simpson, R. Last Homes Bought At Mill Creek. Montana (Butte) Standard. Aug. 17, 1988.

[6] Metals Week. V. 59, No. 7, Feb. 15, 1988, p. 2.

[7] Lasers & Optronics. AlGaAs/GaAs Solar Cells Reach 20-Percent Efficiency. V. 7, No. 1, Jan. 1988, p. 10.

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[9] Prepared by Robert G. Reese, Jr., Physical scientist.

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