Pyrite processing market studies: final report. v. 4

[s.l.]: [s.n.], [s.d.]

https://digital.library.wisc.edu/1711.dl/JNTBRJXOIJFTE8G

PYRITE PROCESSING MARKET STUDIES

FINAL REPORT

November 1979

COMMODITIES RESEARCH UNIT LIMITED
26 Red Lion Square
London WCIR 4RL
Tel: 01-242-9462; Telex: 264008
and
33 West 54th Street
New York
New York, 10019
Tel: 212-765-9600; Telex: 236971

PYRITE PROCESSING MARKET STUDIES

CONTENTS

CONTENTS

SUMMARY OF CONCLUSIONS

SUMMARY OF CONCLUSIONS

This report has been prepared by Commodities Research Unit for Davy McKee Project 2489 for use by Exxon Minerals Company, USA. The purpose of CRU's report was to provide a preliminary evaluation of the market situation for certain products associated with the processing of by-product pyrite from Exxon's proposed operations near Crandon, Wisconsin. The materials covered were:-

Potential products to be marketed

- iron pyrite concentrate
- iron pellets
- sulphur
- sulphuric acid
- phosphoric acid
- gypsum
- diammonium phosphate

Potential products to be purchased for manufacturing operations

- ammonia
- phosphate rock

The conclusions of our analysis concerning the prospects for marketing or purchasing these materials are summarised in turn below. Our overall conclusions concerning the market viability of by-product operations and guidance for further investigation then follow.

A. INDIVIDUAL PRODUCT MARKETS

1. Pyrite Concentrates

With just a few exceptions, the pyrite roasting industry in North America has disappeared in the course of the century because of competition from cheaper sulphur sources. CRU has identified only two possible customers for substantial amounts of Exxon's pyrite:

Copper Range Co. (White Pine, Michigan) and
Cities Service Co. (Copperhill, Tennessee).

Copper Range now buys about 23,000 tpa of pyrite from Noranda, Quebec for use in its copper smelter. Cities Services, which operates the only pyrite roasting facility in the US, theoretically has the ability to take all of Exxon's pyrite concentrates if they curtail their own mining of pyrite. Both companies have expressed interest in Exxon's material, but emphasize that they would have to study further the specifications, shipping and handling problems, and overall economics of using Exxon's concentrates. We would expect the netback to Exxon from sales to these companies to be very low, if anything at all.

2. Iron Pellets

CRU forecasts that US consumption of iron pellets will expand fairly rapidly in the future, but through most of the 1980's existing pellet capacity in North America will be sufficient to meet demand. Beyond this period additional supply would have to come from new US capacity or imports (which should be easily available). The prospects for substantial real price increases are not good because of plentiful North American supply in the short to medium term and the influence of large, low cost foreign supplies in the long term. However, if the US steel industry wants to avoid increasing dependence on foreign pellets, the domestic price would have to rise in the 1990's to the level necessary to justify new US pellet capacity.

Our research indicates that the quality of Exxon's pellets would be perfectly acceptable for general blast furnace use, and the quantity (180,000 tpa) is so small in relation to the total market that there should be no problem in selling them.

Customers could be any number of integrated steel works on the Great Lakes or Midwestern river system, to which Exxon would have easy access. The current posted pellet price, $.655/LTU ($42/tonne of Exxon's pellets) should be a fair approximation of future prices in constant 1979 dollars.

CRU would not recommend the production of reduced pellets by Exxon because of potential market development and quality problems and the small scale of the operation, though in general the US market for reduced pellets should be quite strong. In the opinion of industry experts the small scale of Exxon's output would also make the production of oxide pellets uneconomical, but we must leave it to the forthcoming engineering analysis to prove or disprove this contention.

3. Sulphur

The United States sulphur market is expected to remain tight in the 1980's until non conventional sources[1] of sulphur become available in the early 1990's. The market for brimstone in the remaining years of the decade is good, and it is CRU's opinion that given the expected development in sulphur prices and the gradual demise of the Frasch industry Exxon should have little problem in disposing of its limited quantity of sulphur. Two possibilities present themselves:-

(i) Exxon can market the product directly - a number of sulphur burning plants have been identified which should be interested in the purchase of local elemental sulphur. Allied at East St. Louis and Du Pont at Wurtland Kentucky are both adjacent to molten sulphur terminals. In the event of these two purchasers having obtained alternative sources or indeed opted to purchase merchant sulphuric acid there is scope for sales to a number of other acid producers in Illinois, Indiana and Ohio.

(1) Abatement sulphur, coal processing, oil shales and tar sands.

(ii) Exxon Chemical Co is a major recovered sulphur producer and marketer. Perhaps Exxon Minerals Co's sulphur production could be absorbed into the Chemical Company's sulphur sales.

The price outlook in the 1980's depends upon the ability of the Frasch producers to increase output, therefore, market prices are forecast to remain in line with Frasch production costs. The price range anticipated by 1985 is put at between $70-$80 (1978$) per tonne ex terminal. In view of the expected increase in recovered sulphur and by-product acid supply, prices in the post 1985 period are not expected to maintain their strong upward trend.

4. Sulphuric Acid

The sulphuric acid market is not expected to be in short supply in the remaining years of the decade. The impact of by-product acid does however depend upon the development and introduction of abatement by-product acid, and its interface with the virgin producers using Frasch and recovered sulphur. Given this situation, and the expected excess capacity in the future, CRU estimates that market prices in the 1980's and 1990's will reach $37.50 (1978$).

The options are open to Exxon for the sale of its by-product sulphuric acid production. The first option would be direct sales to a number of virgin acid producers, who given the availability of competitively priced by-product acid may cease production in favour of purchased sulphuric acid. The potential purchasers identified by CRU are:- Minnesota Mining and Manufacturing at Copley, Ohio, Du Pont at Cleveland, Ohio, and North Bend, Ohio, National Distillers at Dubuque, Ia., Mobil at Depue, Ill. and WR Grace at Joplin, Mo. In addition, the local East Central States market could absorb up to a further 100,000 tonnes H_2SO_4 in a wide range of industrial end uses. The other option would be sales to merchants, in which an agreed quantity of acid would be moved by a sulphuric acid broker. A case in point is CIL, which moves smelter acid for a number of Canadian and US by-product producers and will have the facilities to handle all Exxon's production. There are a number of other companies actively involved in retailing smelter acid on behalf of producers identified in the report. The main advantage of disposing of smelter acid in this manner is the guaranteed outlet and saving in distribution costs.

Exxon's sulphuric acid will be by-product material and such production cannot be guaranteed nor the producer run the risk of jeopardizing metal production because of sulphuric acid disposal problems. It is CRU's recommendation that the Exxon effect the disposal of the sulphuric acid through the existing brokers in the market place. Sale of sulphuric acid via brokers would inevitably command a price well below that in the prevailing market. A net back on sulphuric acid sales via brokers is estimated to be in the order of $15 per tonne.

5. Phosphoric Acid

The majority of the phosphoric acid production of the United States is used captively by producers, with only little merchant acid moved on the domestic market. The main market for phosphoric acid remains phosphate fertilizer, accounting for 85 per cent of consumption. Although the phosphoric acid market is currently buoyant and expected to remain so, it is not recommended that Exxon pursue the possibility of marketing merchant phosphoric acid.

No potential customers for phosphoric acid were recognised in either the Green Bay or Evansville location. The only market prospects identified were the possibility of persuading a number of existing producers to close captive units in favour of purchased acid. However, this possibility is considered unlikely, in view of the cost of transportation of phosphate rock from Florida/North Carolina to Green Bay or Evansville. It was CRU's opinion that given only the advantage of by product sulphuric acid, Exxon could not sell merchant phosphoric acid at the prevailing market rates. Furthermore, the production of phosphoric acid leads to an additional by-product problem - phosphogypsum. The conclusion regarding the market for gypsum are discussed later. It is therefore recommended that Exxon's involvement in phosphoric acid be confined to its production as a captive intermediate for downstream diammonium phosphate production.

6. Diammonium Phosphate

Undoubtedly, the US domestic market for diammonium phosphate will continue its upward trend for the remainder of the century. Consumption of diamonium phosphate is forecast to increase at a rate of 2 per cent over the next 20 years.

In terms of the market for Exxon's production, the cornbelt market offers considerable potential for diammonium phosphate. Marketing in the region is effected through four main channels.

(1) Cooperatives - which are largely producer/distributor. However, major cooperatives and affiliates handle sales of other companies' production.

(2) Major fertilizer producers - retail diammonium phosphate through their own distribution network and through state agents. Most fertilizer producers have invested heavily in distribution systems.

(3) Distribution companies - normally retail a range of producers' diammonium phosphate on the agency basis.

(4) Bulk blenders - there are currently 7,000 bulk blenders operating in the US. These purchase through the above channels.

As Exxon Minerals Company has no fertilizer distribution or marketing system, it is CRU's recommendation that in the unlikely event of diammonium phosphate production being economically feasible, the output be offered to the major cooperative groups and the bulk blenders. Diammonium phosphate prices by 1990 are forecast to be in the range of $220 per tonne (1977 $) f.o.b. Tampa and $270 per tonne (1977 $) delivered in the Mid West.

7. Gypsum

US requirements for gypsum are supplied by enormous, virtually inexhaustible, low cost reserves of natural gypsum. Furthermore, Michigan, Iowa and Indiana are among the major producing States, which means that supply in the area of Exxon's facility is especially plentiful.

By-product gypsum, because of its chemical and physical characteristics, cannot be used for the major gypsum markets (wallboard, plaster and cement) without further reprocessing. In the US, such reprocessing is not done because of the easy availability and low cost of natural gypsum. Thus, vast quantities of by-product gypsum are dumped each year by phosphoric acid producers.

Currently, the only market for by-product gypsum in the US is for agricultural use, amounting to 500,000-600,000 tpa, almost all consumed in California and the South Atlantic States. Exxon's only chance for sales would be to the South Atlantic region, if shipping costs were low enough to compete with Florida and North Carolina supplies. In any event, Exxon could not hope to sell any significant fraction of the 750,000 tpa that they would produce. The few companies that now sell by-product gypsum receive $8-10/tonne at their plant.

8. Summary of Prices

The forecasts presented in this report are intended to serve only as an indication of the likely price trends based upon the expected development of supply and demand. They cannot be interpreted as reflecting production costs, as clearly given the cyclical nature of the industries considered, at various times production costs will exceed the prevailing market price.

For the major products analysed in the report, the following prices are forecast - 1978 US$.

Iron Pellets	:	\$42 per tonne delivered lower lake ports.
Sulphur	:	\$75-80 per tonne fob Port Sulphur.
Sulphuric acid	:	\$40 per tonne cif Mid West - \$15 net back.
Diammonium phosphate	:	\$300 per tonne delivered Mid West.
Phosphate rock	:	\$30-32 per tonne fob Tampa.

B. GENERAL CONCLUSIONS

The findings of the previous sections can be summarised as follows to indicate the option which, on marketing grounds, we consider to have the best potential for further consideration.

1. In the opinion of industry experts that we interviewed, none of the by-product possibilities examined in this report offer the potential of an economic return on investment during the forecast period, if viewed strictly as commercial manufacturing and marketing project.

2. In this situation, the possibility of selling pyrite concentrates to Cities Service Co. should be pursued as a first priority, since, providing an acceptable price could be negotiated, this would permit the removal of the material with minimal unremunerative capital investment by Exxon.

3. As a second priority the possibility of manufacture of sulphuric acid for sale to one or two major long-term contract buyers, or to a broker as Canadian Industries Limited, should be evaluated. The disposal of this material under large long-term contracts offers a better prospect than an attempt to enter the market more directly as a supplier of sulphuric acid in competition with chemical companies.

4. The prospects for the sale of elemental sulphur are favourable in view of the relatively small tonnage to be produced. Two options are open, firstly direct sales to existing acid producers; secondly negotiate with Exxon Chemical Co. to dispose of the tonnage. In either event, the disposal of 134,000 tonnes S in a tight market should not pose problems.

5. The prospects for the sale of diammonium phosphate at either of the proposed locationsare good. However, it is CRU's opinion that the economics of diammonium phosphate production are not sufficiently good to warrant the investment in production facilities and the complexities of purchasing and shipping ammonia and phosphate rock inputs (even though these materials may be available at attractive prices in the forecast period) and the disposal of by-product gypsum.

6. The results of our research, as reported above, clearly suggest that the prospects for sale of Exxon's by-product gypsum would be very poor. Exxon's material, produced in a geographic region with virtually unlimited sources of natural gypsum, would be unusable for any but agricultural applications without further processing. Judging by the absence of such processing elsewhere, there is no chance that the value added in upgrading the gypsum would equal the processing cost.

INTRODUCTION

INTRODUCTION

This report was prepared by Commodities Research Unit Ltd. for Davy McKee Project 2489 for use by Exxon Minerals Company, USA in conncection with the possibility and viability of developing deposits of zinc, copper and lead sulphides near Crandon, Wisconsin.

The purpose of the report was to provide a preliminary evaluation of the market situation in the period to 2000 for certain products associated with the manufacture and marketing of by-product materials from Exxon's proposed operations. Exxon's operations would involve the generation of by-product iron pyrite and a number of potential uses for this material have been evaluated in this study. Materials required to be marketed as outputs of various processes, or purchased as inputs, have been considered. The various processes involved and the materials examined in this report were as follows:

Processes	Products Covered	
	to be marketed	to be purchased
a. By-product production of iron pyrite	pyrite concentrates	
b. Manufacture of iron pellets using pyrite	iron pellets	
c. Manufacture of elemental sulphur using pyrite	sulphur	
d. Manufacture of sulphuric acid using pyrite	sulphuric acid	
e. Manufacture of phosphoric acid using sulphuric acid	phosphoric acid gypsum	phosphate rock
f. Manufacture of diammonium phosphate fertilizer using phosphoric acid	DAP fertilizer	ammonia

In the Chapters which follow the market situation for each of the major products to be purchased or marketed from the above processes is discussed with special reference to the opportunities open in the US market for an operation based at Green Bay, Wisconsin or Evansville, Indiana. The scale of operations considered was that determined from information provided by Davy McKee.

In view of the short time available for the study the method involved the combination of existing CRU analysis of the markets for the various iron, chemical and fertilizer products with a limited programme of field research in the US market to investigate the specific opportunities available to operations based in the given locations. The level of analysis provided is therefore intended to provide a sufficient basis for judgement of the overall commercial viability of proceeding in certain directions with by-product manufacture and to set the priorities for further consideration of the details of any by-product ventures.

After this Introduction the report is organised in the following manner. Chapters 1 to VIII presents in detail our analysis and conclusions concerning the market situation for each of the products covered. In each Chapter the basic information concerning the current and prospective US market for the material is presented, forecasts of future US consumption and production are derived and reviewed and the specific market opportunities associated with Exxon's potential operations are identified. Conclusions concerning the viability of marketing particular products are derived as appropriate in each chapter. These conclusions are summarised and their implications for the priorities for further action are presented in the Summary of Conclusions section preceding this Introduction.

CHAPTER 1 : MARKETS FOR PYRITE CONCENTRATES

CHAPTER 1 : MARKETS FOR PYRITE CONCENTRATES

1. WORLD OVERVIEW

Pyrite once was the world's major source of sulfur, but its relative importance has declined in this century because of the development of the Frasch process for mining elemental sulfur, and perhaps more importantly, since WWII, because of production of by-product sulfur and sulfuric acid from non-ferrous metal smelters, natural gas and petroleum.

Nevertheless in Europe and Asia pyrite is still a significant, though generally declining source of sulfur. The USBM estimates that in 1975, of the total world sulfur production of almost 50 million tonnes, pyrite accounted for 10.2 million tonnes. The major processors of pyrite are the USSR, Spain, China, Japan and Italy. These countries have plentiful local sources of pyrite and there is no chance that it would be economical to ship pyrite to them from the US.

With a few exceptions (see below), the pyrite roasting industry in North America has disappeared because of competition from cheaper sulfur sources. Moreover, industry experts are convinced that there is little chance of a reversal because of (a) almost no existing roasting facilities, (b) the high cost of pyrite roasting, (c) severe pollution problems (e.g. sulfur and particulate emissions), (d) probable future adequacy in North America of other by-product sulfur/sulfuric acid supplies, much of which will solve rather than create pollution problems.

2. NORTH AMERICAN PRODUCERS

Pyrite occurs very commonly in mineral deposits with sulfide mineralization, and many North American mines separate waste pyrite from their ores. In almost all cases they have no use for this material and dump it at the mine site. Table 1 shows the amount of pyrite that has been processed in the US since 1950.

In the US, only one company today processes the pyrite it mines. This is Cities Service at its copper/zinc/pyrite mine at Copperhill, Tennessee. Copperhill is a very old and unusual operation, whose economics have depended as much on the output of by-products as on copper. Besides roughly 10,000 tpa of 52 per cent zinc concentrates, the major by-products have been sulfuric acid and iron oxide pellets derived from processing pyrite.

The iron circuit at Copperhill apparently never performed up to standard and, in any event, is an inherently expensive, energy-intensive process. Increased fuel prices have finally made this product too expensive to compete with conventional iron ore sources despite the proximity (about 100 miles) to customers in Birmingham, Alabama. As a result the iron circuit which once produced approximately 800,000 tpa of 63 per cent Fe pellets, was shut down in early 1979. Currently, Copperhill still roasts 3,000 tpd (approx. one million tpa) of pyrite solely for production of sulfuric acid, and virtually all the iron slag is stored.

Small quantities of by-product pyrite are sold from two other US mines to small distributors who in turn dry and size the material for sale to several very small markets. The Climax (Colorado) mine of Climax Molybdenum Co. (AMAX) sells about 3,000 tpa in this way, reportedly for $22/tonne F.O.B.

Table 1 : US Production of Pyrite [1]

Year	000 tonnes
1950	946
1955	1,023
1960	1,032
1965	889
1970	859
1975	635
1977	420e

Note: 1. i.e. pyrite that was processed
e - CRU estimate based on reported sulfur content of products.
Source: USBM.

Climax, wet. In Arizona, Magma Copper Co. (Newmont) similarly sells about 7,000 tpa. In both cases the amount of pyrite sold is only a small fraction of the amount available at these mines. The main markets for this pyrite are the acidification of soil (especially in California and other parts of the Southwest where soils are basic) and for colouring of beer bottle glass. Based on our interviews, we estimate that the US market for pyrite in soil acidification is under 10,000 tpa, and for beer bottle glass is under 5,000 tpa. In any event, neither of these markets are available for Exxon's pyrite; soil acidification, because of the shipping distance to areas where it is needed; and beer bottle glass, because the pyrite must be +20 mesh so that it will not blow out the stack of the glass making furnace.

In Canada, roasting of pyrite is limited to two long existing facilities. Inco, at Copper Cliff, Ontario, actually roasts a nickel bearing pyrrhotite, with recovery of the nickel the main motivation for the process. Approximately 800,000 tpa of pyrrhotite containing over 1 per cent Ni is processed to make 5.3 million kg of nickel oxide, 630,000 t of iron oxide pellets, and sulfuric acid (actually produced by Canadian Industries, Ltd. in an adjacent facility).

Cominco, at Kimberly, B.C., roasts 250-300,000 tpa of pyrite and/or pyrrhotite from local mines, to make sulfuric acid which is used in phosphate fertilizer production. The remaining iron calcine is stockpiled.

The only other significant movement of pyrite in Canada is from Noranda, which ships about 23,000 tpa from the tailings pile of the former Horne Mine (shut down July 1976) at Noranda, Quebec. This material is sent to the White Pine Copper Smelter (Copper Range Co.) in Michigan at a price of $1/t plus freight (approx. $20/t.). White Pine, which mines a chalcocite-native copper ore is in the unusual position of having a deficiency of sulphur for its smelting process; thus the purchase of pyrite.

3. MARKETS FOR EXXON'S PYRITE

As no other company is likely to build a new pyrite roasting facility to use Exxon's concentrates, the only possible customers are companies within shipping range that already use pyrite in existing facilities. This narrows the list quickly to two prospects: White Pine and Copperhill, both of whom we contacted.

White Pine has an obvious interest in Exxon's pyrite because Crandon is closer than Noranda, Quebec and so the delivered cost might be less. Unfortunately, White Pine's total requirements represent less than 10 per cent of Exxon's projected output of pyrite concentrates.

White Pine gave us the following specifications for impurities in the pyrite they use:

Zn	< 2 per cent
Pb	< 3 per cent
As	< 1 per cent
Ni	< 250 ppm
Bi	< 100 ppm
Se	< 100 ppm

In the analysis of Exxon's material, only Bi and Se exceed the above limits, each being 160 ppm. White Pine is also concerned about their ability to handle Exxon's extremely fine material and about dust control problems that could result.

Copperhill represents the only prospect that theoretically could take all of Exxon's output of pyrite concentrates, and surprisingly we found that they have an interest in discussing the idea. For various reasons, Copperhill might like to have the option of mining at a lower rate while still operating the pyrite facility at a high rate. This could be accomplished by bringing in pyrite from outside.

Copperhill did not express any immediate misgivings about the specifications of Exxon's material, but the decision to pursue this idea would certainly have to be based on detailed economic analysis taking accounting of shipping costs, handling problems, chemical composition, etc., as well as a policy decision by Cities Service to curtail their own mining.

CHAPTER II : MARKETS FOR IRON PELLETS

CHAPTER II : MARKETS FOR IRON PELLETS

This section analyses the prospects for the successful production and marketing of iron pellets in the United States in the period to 1990. The section begins with a review of the main recent trends in the world market for iron ore and identifies the role of iron pellets within the total market. The prospects for iron ore demand and supply in the USA are then analysed, placing US developments in their proper international context. The position of iron pellets within the future market for iron products is then considered and the section concludes with an assessment of the competitive position of the pellets which might be produced from the client's mineral project.

1. RECENT TRENDS IN THE INTERNATIONAL IRON ORE MARKET

1.1 Demand for Iron Ore

The great bulk of iron ore (over 90 per cent) is consumed in the production of steel. The remaining small amounts are consumed in the production of iron castings or in chemical uses. In the case of iron pellets these are overwhelmingly used in the production of steel. Hence, throughout this section we are concerned only with the market prospects for iron pellets for use in the manufacture of steel.

Worldwide steel production has shown substantial growth in the last twenty years and continues to expand in 1979. Table 1 shows the production of crude steel in major areas in the period 1960-1978. During this period crude steel production in non-Socialist countries increased at an annual average rate of 3.4 per cent per annum, while crude steel production in the USA increased by an average of 1.8 per cent per year. In the first

Table 1 : Crude Steel Production in Non-Socialist Countries, 1960-1978
(million tonnes and annual average percentage change)

	1960	1965	1970	1975	1978	annual growth 1960-1978
USA	90.1	119.3	119.3	105.8	124.3	1.8
EEC	98.1	113.9	138.1	125.6	132.6	2.5
Japan	22.1	41.2	93.3	102.3	102.1	8.9
Other	31.4	50.6	70.8	93.9	136.7	8.5
Total Non-Socialist	241.7	325.0	421.5	427.6	459.1	3.4

half of 1979 non-Socialist countries' production of crude steel is some 6 per cent ahead of 1978, while production in the USA is over 8 per cent ahead.

One principal factor underlying this pattern of development in the production of steel has been the slower growth of steel consumption in the USA (2.8 per cent per annum) than in Europe as a whole, in Japan and in the developing countries. This undoubtedly reflects the maturity of industrial development in the USA which has reached a stage of constant or declining consumption of steel per unit of real Gross Domestic Product. Other countries are still at a more steel-intensive period of development when additional national production takes the form of steel-containing items in large measure.

A further significant feature of the relatively slow growth of US steel production has been the long-standing tendency for the US steel industry to have very small participation in international markets and to devote its efforts almost exclusively to serving the domestic market. The principal reason for this was the relatively high cost of US-made commercial steels when delivered to the significant export markets of Europe or even substantial areas of Latin America. Steel exports from the USA have generally been well below 5 per cent of finished steel production. The prospects for exports have become even more difficult in recent years with the substantial growth of domestic steel production capacity in Latin America and the large surplus of capacity in Europe, leading to extremely competitive prices on the international market.

While exports of steel products from the USA have never been a major item boosting domestic production, the industry has had its output depressed in recent years by a large increase in imports. Table 2 shows the trend of finished steel imports in relation to shipments of finished steel from US producers and US domestic consumption for the period from 1960. This shows that the increase in imports took importers' market share from under 5 per cent in 1960 to over 18 per cent in 1978.

Table 2 : Apparent Consumption of Finished Steel, USA, 1960-1978 (million tonnes)

	1960	1965	1970	1975	1978
Net Shipments	64.5	84.1	82.4	72.5	88.8
Imports	3.0	9.4	12.1	10.9	19.2
Exports	2.7	2.3	6.4	2.7	2.2
Apparent Consumption	64.9	91.2	88.1	80.8	105.8
Import Share %	4.7	10.3	13.8	13.5	18.1

This is the main reason why shipments of finished steel products (increasing at the same 1.8 per cent per annum as crude steel production) did not keep pace with the growth of US consumption in this period. Import penetration was particularly high in 1977 and 1978 and protective measures were instituted by the Administration at the beginning of 1978 in the form of the "trigger price mechanism" to ensure that imports did not enter the US market at prices less than those consistent with the most competitive costs of production in the non-Socialist world. In the first half of 1979 US imports of steel products have been about 30 per cent below the 1978 level. This is attributable to the effects of the trigger price system and the threats of anti-dumping action by US producers, as well as by relatively buoyant conditions in other markets served by the major steel exporters. The fall in imports is a major reason for the strong trend of domestic steel production in the USA so far this year.

As will be discussed later in this section, iron ore in the form of pellets finds uses in more than one aspect of steel production. However, the major use is in the manufacture of pig iron in the blast furnace. Pig iron is then charged into the steel furnace and refined to produce steel. The production of pig iron is therefore a key indicator in the demand for all iron ore, including iron ore pellets. Table 3 below shows the production of pig iron in non-Socialist countries for the period 1960-1978 and Table 4 indicates the ratio between pig iron and steel production in the main producing regions.

Table 3 : Pig Iron Production in Non-Socialist Countries, 1960-1978
(million tonnes and annual average percentage change)

	1960	1965	1970	1975	1978	annual growth 1960-1978
USA	61.1	80.6	83.3	72.5	79.7	1.5
EEC	70.3	80.9	98.2	88.6	89.8	1.4
Japan	11.9	27.5	68.1	86.9	78.6	11.1
Other	23.2	36.4	48.2	62.6	71.5	6.5
Total Non-Socialist	166.5	225.4	297.8	310.6	319.6	3.7

The main factors underlying the movements of pig iron production are total steel production and the methods by which steel is produced. The major tendencies in the techniques of production have been the relative growth of electric furnace steel production in the EEC and, to a lesser extent, the USA and the converse trend in Japan. In the EEC and USA, countries where large-scale integrated steel production has existed for many years, the trend in the development of new production capacity has favoured

Table 4 : Tonnes of Pig Iron Produced per Tonne of Crude Steel in Non-Socialist Countries, 1960-1978

	1960	1965	1970	1975	1978
USA	0.68	0.68	0.70	0.69	0.64
EEC	0.72	0.71	0.71	0.71	0.68
Japan	0.54	0.67	0.73	0.85	0.77
Other	0.74	0.72	0.68	0.67	0.52
Total Non-Socialist	0.69	0.69	0.71	0.73	0.70

the smaller scrap-based production unit using electric furnaces. It has been found that the price of scrap and the flexibility of this type of production, manufacturing mainly bar products for the construction and engineering industries, has made these units economic in times of fluctuating markets, such as have been experienced in the 1970's. Thus, an increasing proportion of steel production has come from electric furnace units causing the production of pig iron to increase more slowly than the total production of crude steel. In the case of Japan the massive growth of the steel industry since 1960 was based on the development of large-scale integrated works using blast furnace technology. In the Japanese case, long production runs of basic commercial steel products were required and the large-scale blast furnace route was the most economic.

These patterns of development in steel and pig iron production have naturally affected the growth of the market for iron ore. In total the iron content of iron ore consumed has moved closely in line with the production of pig iron, ie. growing over the period at a rate of some 3.7 per cent per annum in non-Socialist countries as a whole, but only 1.5 per cent per annum in the USA. The growth in total consumption of contained iron has been made up by different rates of consumption growth of different types of iron products, as shown in Table 5 below. Information on the consumption of iron in the various types of iron products is not generally available, but our estimates below are believed accurate for the main market areas.

Table 5 : CRU Estimates of the Consumption of Iron by Type of Iron Product (million tonnes gross weight)

	1967	1974	1975	1976	1977	1978
USA						
Lump ore	32.5	37.3	21.4	16.0	15.2	14.4
Sinter	48.5	39.1	32.0	33.1	31.9	32.3
Pellets	40.0	69.6	63.3	75.5	69.7	78.8
Total	121.0	145.0	116.7	111.3	116.8	125.5
EEC						
Lump ore	38.2	50.6	36.8	28.7	24.2	n.a.
Sinter	62.0	139.2	120.4	129.0	117.5	n.a.
Pellets	4.6	8.0	8.3	9.0	9.0	n.a.
Total	104.8	197.8	165.5	166.7	150.7	n.a.
Japan						
Lump ore	21.7	16.0	15.1	10.0	9.0	8.4
Sinter	35.0	110.4	108.8	111.9	111.8	96.4
Pellets	7.9	18.1	16.9	17.4	16.0	16.4
Total	64.6	144.5	140.8	139.3	136.8	121.2

The table shows that in each major consuming area the importance of lump ore as a feed for the steel industry has been substantially reduced in absolute terms. Only in the USA, on the other hand, have pellets become a major source of iron units. In both the EEC and Japan sinter is by far the main source of iron units in the manufacture of pig iron, although the relative importance of pellets is increasing slowly in these areas. In other producing countries, particularly newer producers able to adopt the latest technology, pellets form a more significant proportion of the iron feed.

The decline of lump ore as a feed for the blast furnace results from two mutually reinforcing tendencies common in all market areas. On the one hand the quality of natural ores has been falling such that lump ores (direct shipping ores) have become less available. At the same time efforts to improve the quality and economy of iron production have required closer control of the iron content and physical characteristics of the blast furnace charge. Hence, the agglomerated products sinter and pellets have become the most important form of product used. Sinter is generally manufactured by steel producers at the blast furnace site because the product breaks up during transport. Pellets are generally manufactured at the mine site and transported to the blast furnace location.

1.2 Supply of Iron Ore

1.2.1 Types of Iron Ore Product

Iron is one of the world's most abundant minerals and concentrations of iron in quantities sufficient for economic extraction have been found in many countries. Iron occurs in numerous mineral combinations, but the principal iron minerals which are exploited as iron ore are hematite, goethite and magnetite, although numerous variants are also exploited. The critical aspect of the mineral is not its precise chemical form (within broad limits) but the iron content, the proximity to the surface and its physical characteristics (whether it is hard or soft, friable or lumpy). The presence of impurities in the ore is also of particular importance because in either insufficient or excessive quantities they affect the economics of processing at the iron- and steel-making stages. In the history of the iron and steel industry major breakthroughs occurred when processes were developed to cope with iron ores containing impurities, particularly phosphorus.

Table 6 below lists the major iron minerals, together with an indication of their theoretical iron content.

Table 6 : Principal Iron Minerals Exploited as Iron Ore

Mineral	Composition	Iron Content (%) Before Ignition	After Ignition
Native iron	Fe	100.0	100.0
Hematite	Fe_2O_3	69.9	69.9
Goethite	Fe_2O_3, H_2O	62.9	70.0
Magnetite	Fe_3O_4	72.4	72.4
Siderite	$FeCO_3$	48.2	70.0
Pyrite	FeS_2	46.5	70.0
Chamosite	$(Mg, Fe, Al)_6$ $(Si, Al)_4$ O_{14} $(OH)_8$	33-42$\pm$	33-42

Source: United Nations, Survey of World Iron Ore Resources, 1970 and Economic Aspects of Iron Ore Preparation, 1966

Naturally occurring pure iron is a mineralogical curiosity only, but the iron content of other iron deposits is of crucial importance in determining the economics of exploitation. Although after ignition in the iron-making process most ores have a similar iron content, the economics of the iron-making process is determined by the iron content of ore before ignition, as well as by the physical characteristics of the iron products charged.

The products of the iron ore industry are, as noted earlier, overwhelmingly consumed in the steel industry and pass through the stage of iron making, generally in a blast furnace. Hence the dominant feature determining the nature of the products of the iron ore industry is the requirements of the steel industry. Several elements of the product specification are important:

a. Lump Ores

For direct charging to a blast furnace the traditional feed for a long period was lump ore. This product required little treatment at the mine site beyond crushing and the demand for the product naturally favoured ores with both a high iron content and the lumpy characteristics which would give them the necessary structural strength to be efficient blast furnace feed. Such ores would also transport well without breaking down to fines. Iron ores with these characteristics are increasingly difficult to obtain and the importance of lump ore as a feed for the steel industry has accordingly diminished as techniques have been developed to permit the use of different qualities of ore.

b. Sinter Feed

The feed for sinter plants (as intermediate stage between iron ore and the blast furnace in which iron ore is mixed with coke and subject to heat over a grate) is a finer grade of ore in physical terms and is obtained either by crushing run-of-mine ore to a lower mesh or is more often the product of beneficiating lower-grade iron ores which cannot be accepted by the iron and steel industry in a run-of-mine state.

Direct shipping ore (i.e. ore that is shipped to consumers without any upgrading apart from crushing) has declined substantially in importance as a product of the iron ore industry, as noted in our discussion of consumption. This results from a combination of falling availability of lump ore and a requirement by the iron and steel industry for grades of feed which are uniform in quality. As sinter plants make use of coke breeze (a product of the process of manufacturing metallurgical coke) and because sinter deteriorates when transported over long distance, the manufacture of sinter has been very heavily concentrated adjacent to blast furnaces in steel-producing countries. The product of the iron ore industry has therefore been sinter feed, a finely crushed product generally 1-6mm. in particle size.

c. Pellet Feed and Pellets

Although sinter offers a relatively uniform grade of iron feed to the blast furnace, it is of irregular size. A further form of intermediate processing of iron is therefore the manufacture of iron pellets, generally containing 60-70 per cent iron. Pellets are manufactured by moistening iron with a clay mineral such as bentonite to form the pellet shape, then heating the green pellet over a grate or in a kiln. This results in a product of very uniform quality and size (generally 7-16mm. in diameter) which has great structural strength, permitting the avoidance of clogging in the blast furnace.

Pellets were originally developed to use ores which were too fine for sintering, but their advantages, despite higher costs, have led to rapid growth such that ores which would otherwise have been used for sintering are now processed by further crushing (to 1mm. or less particle size) and concentration into higher grade feed. Because they can be transported long distances without deterioration pellets are generally produced at or relatively close to the point of iron ore extraction.

d. Direct Reduction Feed

As noted above, a trend in the steel industry in the last 20 years has been the movement to steel production in electric furnaces. These offer advantages of flexibility of operation, relatively small scale of units and high control of steel quality which it is difficult to achieve in large plants based on other processes. In developed countries the iron content of electric furnaces is generally supplied by scrap steel. The advantages of small size of production units together with the independence of the process from coke and hence scarce metallurgical coal, has also made the electric furnace steel-making process attractive to developing countries. Because these countries often lack an adequate stock of scrap steel to use as feed for such plants, attention has been turned to the development of iron feed from processes other than the blast furnace which requires a large scale of operation to achieve maximum economy. This has led to the development of the direct reduction process for iron, in which iron ore, usually in the form of pellets, is mixed with various reducing agents such as coal or other minerals and subjected to heat, often supplied by natural gas. A number of proprietary processes for direct reduction are in use and the iron product of the process ("sponge iron") generally contains 92-96 per cent iron.

The feed for direct reduction plants required from the iron ore industry is high quality pellets of 67-70 per cent iron.

1.2.2 The Structure of the Industry

The iron ore industry developed initially largely in the industrialised steel-producing countries and the degree of self-sufficiency (at least on a regional basis, particularly in Europe) was high. Thus in 1955 85 per cent of iron ore was produced in Europe, the USA and Canada. The development of Japan as a major steel producer (without iron ore reserves of any size) and the depletion of good ore reserves in Europe, together with the discovery of very large, high grade iron deposits in many countries, particularly Canada, Australia and Brazil) has led to a substantial change in the geographical distribution and structure of the industry.

In the USA the steel industry supplied a large proportion of its own requirements from captive mines, mainly in Minnesota. In the 1950's the discovery of large deposits of much higher grade in Canada (particularly in the Quebec-Labrador region) led to involvement by U.S. steel companies in the development of these resources. With this major development and continued expansion of domestic output, the US and Canadian steel industries are still very largely self-sufficient in iron ore supply. While there are major independent iron ore companies in the United States (particularly the Hanna Mining Co., Pickands Mather & Co., and Cleveland-Cliffs Iron Co.) US and Canadian steel companies have a high degree of involvement in iron ore mining and pellet plant ventures, such that arm's length transactions in iron ore and pellets in the North American market may account for less than 30 per cent of the market.

In Europe the steel industry has had ownership ties with the local ore producers, but as these have diminished substantially in importance (apart from Sweden) the industry has relied upon imports from Sweden, West Africa and, to an increasing extent Latin America. In the case of West Africa European steel companies had major interests in mines in Liberia and Mauritania, but these have been diminished by increased state participation in the mining industry which supplies the major part of these countries foreign exchange. Ownership ties are similarly limited in Latin America and the major part of Europe's iron ore imports are therefore at arm's length. The traditional pattern of purchase of European iron ores was the annual contract, but the development of large new mines has led to an increase in the importance of longer-term commitments in tonnage terms, with prices renegotiated annually.

The Japanese have developed the world's second largest steel production without significant indigenous iron resources. Their industry has been based on long-term contracts negotiated by trading houses with iron ore producers, particularly in Australia, Brazil, India and other developing countries. Each trading houses acts in turn on behalf of a number of steel producers. The Japanese have pioneered the multi-year contract containing tonnage provisions and this type of contract guaranteeing markets has been essential in raising finance for new iron ore ventures.

The result of this pattern of development has been a major shift in the focus of iron ore production from the steel-producing countries to new producers, particularly Australia and Brazil. The industry has seen a massive growth in international trade (from under one quarter of production being exported in 1955 to 44 per cent of production being exported in 1975). This development has gone in step with technical progress in the shipping and materials handling industries which have permitted both large ore-carrying vessels and the development of major port facilities to accommodate them and handle the tonnages of iron ore and pellets concerned.

1.2.3 Iron Ore Production 1960-1978

Table 7 presents statistics of iron ore production for the period 1960-1978. These show that between 1960 and 1976 iron ore production in the nine member countries of the EEC fell by approximately half, leaving only France, Sweden and Spain as significant iron ore producers in the whole of Western Europe. Iron ore production in the USA remained relatively constant, while production in Canada increased substantially to meet a major part of the growing needs of the US steel industry.

The major expansion of production during this period occurred in Australia and Brazil. India has also raised production substantially during the period, as have Liberia and South Africa.

Table 7 : Production of Iron Ore in Non-Socialist Countries, 1960-1978
(million tonnes gross weight)

	1960	1965	1970	1975	1978	total change 1960-1978
USA	90.2	88.8	91.3	81.4	82.1	-8.1
EEC	111.7	93.3	82.2	61.6	41.0	-70.7
Japan	2.9	2.5	1.6	0.9	0.6	-2.3
Australia	4.4	6.8	45.1	94.7	81.7	+77.3
Brazil	9.4	18.2	35.3	88.5	57.5	+48.1
Canada	19.6	34.2	47.5	44.7	40.4	+20.8
India	16.5	23.7	31.4	39.6	33.5	+17.0
South Africa	3.1	5.8	9.1	12.1	23.6	+20.5
Sweden	21.7	29.4	31.5	32.6	21.5	-0.2
Liberia	3.0	16.2	23.3	27.2	18.5	+15.5
Venezuela	19.8	17.5	22.1	24.1	14.0	-5.8
Mauritania	-	6.0	9.2	9.0	10.0	+10.0
Total Non-Socialist	348.8	409.5	515.3	603.4	483.5	+134.7

Source: UK Iron & Steel Statistics Bureau
Eisen und Stahl, Dusseldorf

As a result of the patterns of consumption discussed earlier, the development of iron ore production by type of product has been varied around the world. A high proportion of US and

Canadian mine production is further processed to the pellet stage, while much smaller proportions are processed to this stage in other major producing areas serving Japan (Brazil, Australia and India) and serving Europe (West Africa, Sweden and France).

As a result of the differing degrees of processing and the availability of natural ores of different qualities, the iron content of iron ore products produced in the major iron producing countries of the world varies. This is illustrated by estimates of the average iron content of iron ore products (which includes pellets) produced in major countries shown in Table 8.

Table 8 : Iron Content of Iron Ore Products of Major Non-Socialist Producers, 1960 and 1978 (percentage of contained iron)

	1960	1978
USA	50.0	61.2
France	32.9	29.1
Australia	56.8	62.6
Brazil	64.2	65.8
Canada	55.2	62.3
India	59.8	63.7
Sweden	60.0	64.0
Liberia	66.7	62.0
Venezuela	65.1	62.0

Source: UNCTAD and Eisen und Stahl, Dusseldorf

1.3 Market Balance and Prices

The iron ore industry is generally considered to have operated at effective full capacity in 1974 when 616m. tonnes were produced in non-Socialist countries. Production in 1978 was around 480m. tonnes, equivalent to 78 per cent of the 1974 capacity. Because of the growing demand in the years up to 1974 large expansions of capacity were committed in ore extraction and processing. These have been coming into production during the depressed years since 1974. As a result there is still very extensive worldwide over-capacity in iron ore production and also in the production of pellets. The iron ore industry in non-Socialist countries is estimated to have operated in 1978 at around 70 per cent of rated capacity and production will increase during 1979.

Throughout the 1960's and early 1970's developments in the technology of iron ore extraction and processing were such that the prices of iron ore showed relatively little change in absolute terms and fell substantially in relation to the prices of all goods and services, as shown in Table 9 . During 1978 market conditions were such that iron ore producers were not able to secure any significant increase in prices in absolute terms. Price negotiations for 1979 have generally resulted in an increase of approximately 8 per cent with no increase in tonnage shipped. As a result iron ore prices have continued to fall in real terms during the last two years.

Pellet prices in the international market have been particularly depressed during the last few years. This follows particularly from the surplus of steel production capacity in Japan and Europe, which has induced steel producers to run their existing sinter plants as much as possible to spread their capital charges and to avoid the purchase of pellets. Although they are not very large consumers of pellets, the slackness of demand from Japan and Europe has combined with large excess capacity to depress pellet prices even more than those of fines and lump ore.

Table 9 : Selected Iron Ore Prices, 1960-1977
(US dollars per tonne actual weight)

	Sweden (1)		Canada (2)		USA (3)		Liberia (4)	
	A	B	A	B	A	B	A	B
1960	11.50	13.37	-	-	11.42	13.28	-	-
1965	10.10	11.54	-	-	10.43	11.92	10.52	12.05
1970	9.30	9.30	11.88	11.88	10.63	10.63	12.54	12.54
1971	10.50	10.16	11.53	11.16	11.02	10.67	11.75	11.37
1972	10.80	10.72	11.18	11.09	11.02	10.93	11.22	11.13
1973	10.10	8.28	15.47	12.68	11.61	9.52	15.56	12.75
1974	12.80	8.83	17.15	11.38	13.68	9.43	18.14	12.51
1975	19.30	12.18	21.04	13.28	17.52	11.06	18.74	11.83
1976	16.10	9.71	20.17	12.17	19.09	11.51	18.50	11.16
1977	13.39	7.60	n.a.	n.a.	20.57	11.68	18.88	10.72

Notes A at historical prices
B = A deflated by US Wholesale Price Index, 1970=100

(1) Kiruna D, 60 per cent Fe, cif Rotterdam
(2) Lac Jeanne concentrate, c.65 per cent Fe, cif North Sea Ports
(3) Mesabi regular-unscreened 51.5 per cent Fe domestic/export price delivered lower lake ports
(4) Bong range concentrate c. 62 per cent Fe, cif North Sea Ports

Source: United Nations statistics and UNCTAD.

Table 10 : List Prices for US Iron Ore Pellets, 1974-1979
(dollars per metric tonne of contained iron)

Effective Date	Price	Effective Date	Price
August 1974	39.98	August 1976	52.26
February 1975	43.90	January 1977	54.62
September 1975	46.45	July 1978	57.69
February 1976	49.65	April 1979	64.46

Note: delivered at Lake Erie docks

2. RECENT TRENDS IN THE UNITED STATES MARKET

The section above discussed trends in the international market at some length because it is important to place developments in the USA in their international context, particularly with regard to future supply trends. In the last section some of the features of the US market were identified, and these are amplified further in this section.

2.1 Demand for Iron Pellets

As noted earlier, the demand for iron ore inputs in the USA has increased relatively slowly, at an average of approximately 1.5 per cent per annum between 1960 and 1978. The demand for iron pellets has increased much more rapidly during this period, from virtually nil in 1955 to an estimated 40m. tonnes in 1967 and 79m. tonnes in 1978. This follows from the demonstration in 1960 by Armco that an economic furnace burden was possible with a large proportion of pellets. This demonstration permitted the development of a product which could make use of the finely grained taconite ores of Michigan and Minnesota which had grain size and other properties unsuitable for use as sinter feed. The US production and consumption of pellets has therefore increased rapidly and consumption in pellet form is a far higher proportion of total iron consumption in the USA than in other major steel-making areas of the world.

Table 11 : CRU Estimates of Consumption of Iron Ore Products, United States, 1967-1978 (million tonnes gross weight)

	1967	1974	1975	1976	1977	1978
USA						
Lump Ore	32.5	37.3	21.4	16.0	15.2	14.4
Sinter	48.5	39.1	32.0	33.1	31.9	32.3
Pellets	40.0	68.6	63.3	75.5	69.7	78.8
Total	121.0	145.0	116.7	111.3	116.8	125.5

US iron ore demand has followed the growth of blast furnace iron production closely. The production of blast furnace iron is in turn dependent on trends in the production of steel by type of process. The growth of electric furnace steel production has been more rapid than that of blast furnace-based processes (open hearth and basic oxygen) and electric furnace steel production accounted for 23.5 per cent of crude steel production in 1978, compared to 8.4 per cent in 1960. The USA is the world's largest generator of steel scrap and the growth of electric furnace production has been based on the available supplies of scrap for its iron supply. The past rate of growth of electric steel production has been accomodated with relative ease by the available scrap supply and the US has been a major net exporter of steel scrap to other countries. In 1978 Open Hearth steel furnaces on average took 53 per cent of their iron inputs in the form of pig iron, the remainder as scrap, while Basic Oxygen furnaces took 72 per cent of their feed as pig iron. Hence the decline of the Open Hearth steelmaking system has caused pig iron consumption (and hence iron ore usage) to rise relatively more rapidly than the growth of total "blast furnace process" steel production shown in this table.

Table 12 : Production of Crude Steel by Process, United States, 1960-1978 (million tonnes)

	1960	1965	1970	1975	1978
Blast Furnace Processes					
Open Hearth	78.4	85.5	43.6	20.1	19.3
Bessemer	1.1	0.5	-	-	-
Basic Oxygen	3.0	20.8	57.5	65.1	75.7
Scrap-based Processes					
Electric	7.6	12.5	18.3	20.6	29.2
Total	90.1	119.3	119.3	105.8	124.3

The structure of the US iron ore market has been such that much of the demand has been directed to iron ore companies affiliated with the steel producers. In this sense the demand and supply for iron ore products have been closely connected, with both demand and supply factors determining the growth of pellet usage against a background of a slowly growing requirement for new iron units.

The relatively slack performance of steel demand in the USA in 1977, following the very poor year in 1975, set back iron ore demand substantially and its effect was felt on both existing units and on the plans for additional capacity. Iron ore consumption was strongly ahead in 1978 and remains very strong through the first half of 1979 (approximately 8 per cent above 1978 levels), but the experience of 1977 has introduced substantial caution into the iron ore market which is undoubtedly affecting decisions concerning the developments of future supply.

2.2 Supply of Iron Pellets

Table 13 below shows the production and imports of pellets to supply the US market. This shows that US production has fluctuated around a rising trend, while imports were steady at around 10m tonnes per year until 1976-1978. Extending the series back further would show that US production of pellets

Table 13 : Apparent Supply of Iron Pellets, USA, 1968-1978 (million tonnes gross weight)

	1968	1970	1975	1976	1977	1978
Production	49.3	56.3	62.3	62.5	42.8	65.0
Imports	10.1	10.5	11.5	16.1	17.2	16.6
Apparent Supply	59.4	66.9	73.8	78.6	60.1	81.6

was under 1m. tonnes in 1955, around 10m. tonnes in 1960 and rising steadily thereafter as new processing plant were opened through the 1960's and early 1970's.

The pattern of development of domestic supply can be traced in Table 18 which shows all operating pellet plants in non-Socialist countries and includes the US producers.[1] The US pelletising plants are heavily concentrated in a relatively small area and their principal links with the market are through shipping movements on the Great Lakes. Provided extensive rail hauls are not required the US pellet producers are at a substantial freight cost advantage over importers outside Canada.

Table 18 also shows the affiliation of the US pellet plants and indicates the structure of the market. The industry is dominated by two groups: the larger steel producers through fully integrated operations and a small number of US-based, but now international, independent iron ore producers, particularly The Cleveland-Cliffs Iron Company, The Hanna Mining Company and Pickands Mather & Company.

A further important feature of the US market is the extension of corporate links into the production of iron ore and pellets in Canada, such that a substantial part of Canadian production is essentially part of the US market for commercial purposes. Canada supplies the largest part of the imports into the USA from this type of affiliated operation. At the same time there has been some tendency for US mine and pellet plant development to be undertaken by Canadian companies with a view to exporting iron products to steel operations in Canada.

Other external suppliers to the US market have mainly been Venezuela and Brazil. These countries have extensive mine and pellet plant capacity (under US company control in Venezuela until nationalisation in 1975), but the current situation is that these sources are generally regarded as marginal suppliers to the normal sources from domestic and Canadian mines. The existence of regular supplies from these sources does provide an influence on pellet prices since this brings the US market into contact with the factors influencing the international iron ore and pellet markets.

---

(1) Table 18 is at the end of this Part of the report.

3. PROSPECTS FOR THE US MARKET FOR IRON PELLETS

The discussion in the previous section has identified a number of factors which are important in relation to the future trends in the US market for iron pellets. These can be summarised as follows:

- the importance of the growth of total steel consumption and domestic production for iron ore demand;
- the significance of trends in the processes of crude steel production for iron demand;
- the role of supply factors in determining the type of iron products consumed in the USA;
- the significance of imports of pellets into the US market and the potential impact of imports in the future;
- the significance of the structure of the industry where relatively few suppliers, some integrated with steel producers, dominate the market.

Each of these factors will affect the future market prospects for producers of iron pellets and they are considered in this section.

3.1 Future US Demand for Iron Pellets

3.1.1 Macro-economic Trends

In order to assess the future demand for iron pellets in the US market we have made use of more detailed forecasts of the consumption and production of crude steel in the USA developed in other CRU work. These forecasts are based on the underlying assumption that total economic activity (real gross domestic product) in the USA will increase at an annual average rate of some 2.8 per cent per annum in the period to 1990, with a slightly shifting emphasis in the distribution of total final expenditure towards investment and away from consumer and government current spending.

3.1.2 US Steel Consumption and Production

The table below shows our forecasts for the consumption of finished steel and production of crude steel in the period to 1990.

Table 14 : CRU Forecasts of US Steel Consumption and Production to 1990 (million tonnes)

	1975	1978	1980	1985	1990
Finished Steel					
Consumption	80.8	105.8	106.1	117.0	126.0
Exports	2.7	2.2	3.5	3.5	3.5
Imports	10.9	19.2	16.0	20.0	23.0
Production	72.5	88.8	94.6	100.5	106.5
Crude Steel					
Production	105.8	124.3	131.3	139.0	146.0

These forecasts imply that finished steel consumption will increase by an average of 1.5 per cent per annum over the period 1978-1990, while crude steel production will increase by an average of 1.4 per cent per annum. Imports are forecast to account for an increasing share of the US market, reaching some 22 per cent by 1990, but the forecast is based on the view that the US industry will remain relatively competitive in cost terms and will also continue to receive firm government support in resisting imports throughout the period.

Within the total production of steel we forecast a continuing shift in the method of production. Open hearth processes will decline to a low level of production in the forecast period, while the increase in steel production is shared between the basic oxygen system and electric furnace processes. Our forecasts with respect to the production of steel by process, which affects significantly the forecast of the amount of iron ore required, is shown in Table 15 .

Table 15 : CRU Forecasts of US Crude Steel Production by Process to 1990 (million tonnes)

	1975	1978	1980	1985	1990
Open Hearth	20.1	19.3	18.0	13.0	7.0
Basic Oxygen	65.1	75.7	80.5	88.5	95.2
Electric	20.6	29.2	32.8	37.5	43.8
Total	105.8	124.3	131.3	139.0	146.0

The forecasts embody the view that the US steel industry will be able to respond to the slow growth of consumption by an increase in production and, since production is already close to rated capacity in 1979, by an increase in productive capacity of substantial absolute proportions during the forecast period. This, in turn, reflects the view that the problems of steel industry profitability and availability of finance, restraints on investment through environmental pollution controls, etc. will be overcome in sufficient time to permit the necessary expansion of capacity, including the construction of at least one major new greenfield integrated steelworks in the 1980's. On balance we believe that the modest growth of capacity implied by our forecasts of production will be within the reach of the industry during the forecast period, so that the USA will not become excessively dependent on imports of basic steel products.

3.1.3 Demand for Iron Products

Each process for the production of steel requires iron in various forms. We forecast that the balance between iron units in the form of scrap and pig iron will not change significantly during the forecast period for the open hearth and basic oxygen processes. In the case of the electric furnace processes, the overwhelming source of iron at present is iron and steel scrap. In recent years there has been the significant development of direct-reduced iron as a source of iron units for electric furnaces, as mentioned earlier. This process has great attractions for countries without either large iron ore or steel scrap supplies and direct-reduced iron has the greatest potential as a feedstock for production of steel in such countries (eg. the Middle East and in smaller developing countries). Fears over the price of scrap have led electric furnace steel producers in industrial countries to show more interest in direct-reduced iron in recent years. There are at present a number of direct-reduction projects in operation in North America, as shown in Table 15 below, and major steel companies (eg. Bethlehem Steel) are known to be considering the establishment of new electric furnace capacity based on direct-reduced iron as a source of iron units.

Table 16 : Production Capacity for Direct-Reduced Iron, USA and Canada, 1978
('000 tonnes)

Company	Location	Capacity
USA		
Armco	Houston	330
Georgetown Ferreduction	Georgetown, S.C	400
Oregon Steel	Portland	300
Azcon	Rockwood, Tenn.	100
Canada		
Sidbec - Normines	Contrecoeur, P.Q.	1,050
Sudbury Metals	Sudbury, Ont.	260
Niagara Metals	Niagara, Ont.	30
Stelco	Bruce Lake, Ont.	350
Total		2,820

We forecast that direct reduction will become more significant as a source of iron units for the electric furnace producers of steel during the forecast period, providing up to 10m. tonnes of iron input by 1990 in the USA. As a result of the development of steel processes, the relative balance between pig and direct-reduced iron and scrap as a source of iron units for the US industry is forecast to alter during the period, and demand for iron arising from pig and DR iron is forecast to increase by an average of 1.8 per cent per annum. We believe that the implied forecast for scrap consumption (the alternative source of iron) is attainable within the available supplies of scrap in the US economy. Recent studies by the scrap industry have shown that there is a massive reserve of scrap iron and steel in the economy, and that this potential supply of scrap is responsive to relatively small increases in price.

As discussed earlier, the requirements for iron ore can be met in a variety of ways, of which pellets is one. Numerous factors are at work to influence the form of iron unit which will be demanded and many of these factors can be expected to exert the same influence as in the last few years. We therefore expect that lump ore will continue to fall as a proportion of the iron feed to the blast furnace, as the availability of high quality lump ores decreases further and iron-making technology stresses still more the close control of furnace burdens. The critical issue for the future is therefore the balance between sinter and pellets as a feed for blast furnaces. On the demand side, there are rival claims for the technical merits of sinter and pellets particularly the view in some parts of the steel industry that sinter is more economical of energy in the steel-making process. We therefore believe that sinter will continue to maintain an important position as a feed for blast furnaces. There are, however, decisive factors on the supply side which will reduce the potential for sinter.

The first of these is particular to the USA, namely the availability of the US fine-grained ores which are expensive to sinter but which can be made more economically into pellets. In other market areas, such as Japan or Europe which have to rely on imported materials and can therefore select from the total of the world's available ores, obtaining suitable ores for sintering is much easier and the role of sinter will remain more significant than in the USA. The second feature is the environmental pollution aspects of sinter production. Since sinter must be produced at the blast furnace site, the associated dust and gas emissions will present a problem to the construction of additional sinter plants and to the continued operation of old plants. These problems can be overcome but at a capital cost which will make sinter less attractive. The production of pellets, on the other hand, is invariably carried out at the mine site and the cost of overcoming pollution problems in less densely populated mining areas is likely to be considerably lower.

For these reasons we expect that pellets will continue to increase their share of iron feed for blast furnaces during the forecast period. In addition the expansion of the production of direct-reduced iron will provide a further demand for pellets, which constitute the feed for direct-reducing (sponge iron) plants. The pellets for this purpose are, however, of a higher quality than those for normal blast furnace feed.

The net result of these various trends is forecast to be a demand for iron ore, in terms of gross weight, as shown in Table 17 . In order to determine the gross weight of the products in question it is also necessary to consider the average iron content of iron ore products. As noted earlier this has been increasing steadily during the last 20 years, but we do not forecast any major increase in the near future. Some further upgrading of the iron content of sinter and pellets is forecast, raising the average iron content to 63.5-64 per cent from the present level of around 62.5 per cent by the end of the forecast period. Taking this factor into account yields the final forecast of iron pellet and other iron products demand in the US market in the period to 1990, as shown in Table 17.

Table 17 : CRU Forecasts of Demand for Iron Products to 1990, USA
(million tonnes gross weight)

	1975	1978	1980	1985	1990
Pig Iron Consumption					
steel-making	67.6	75.6	78.9	82.4	84.3
other uses	3.7	3.8	3.9	4.0	4.1
DR Iron Consumption	n.a.	n.a.	4.0	6.0	10.0
Form of Iron Product					
Lump Ore	21.4	14.4	9.9	8.6	6.2
Sinter	32.0	32.3	32.2	32.0	31.8
Pellets	63.3	78.8	90.1	99.0	109.5

These figures show the domestic US demand for pellets in the forecast period. A further source of demand for pellets is the potential for export. The development of iron ore properties in the USA by Canadian companies offers the only significant prospect for pellet exports from the USA. We forecast that these could amount to perhaps 2m. tonnes per year by the end of the forecast period. Thus the total demand for iron pellets is forecast to increase from the 1978 level of 79m. tonnes to some 111m. tonnes in 1990, an annual average rate of growth of 2.9 per cent per annum.

3.2 Future US Supply of Iron Pellets

In relation to the demand forecast above, this section considers the prospects for the supply of iron pellets in the USA. The various factors affecting future supply are considered in turn.

3.2.1 Reserves and Resources

Iron ore reserves and resources in the USA are continually increasing as a result of exploration and development. A study for the US Bureau of Mines of iron ore in Minnesota concluded that at break even (zero profitability) there were 47 billion long tons of reserves of all types on the Mesabi range, including 25 billion tons of magnetite taconite at a 90 per cent probability level. As calculated by the Bureau of Mines from information from the companies, economically mineable reserves are estimated at some 16 billion long tons in the Lake Superior region and a further 1 billion tons elsewhere in the USA. As mining proceeds these calculated reserves will undoubtedly at least keep pace with extraction for the foreseeable future. The absolute availability of iron ore reserves, particularly of the fine-grained and low-grade taconites, will not be a significant factor constraining the supply of iron ore in the USA, or the production of pellets, in the forecast period.

Resources of iron outside the USA are also very extensive. Economically extractable reserves are considered to be larger than those in the USA in Canada, Brazil and Australia and there are extensive reserves in many other countries.

3.2.2 Planned Production Capacity

Table 19[(1)] shows the current US production capacity for iron pellet production, totalling 88m. tonnes. A major influence on the market conditions for pellets will be the development of US pellet production capacity. The changes in production capacity will depend on the net balance of additions and closures.

A number of closures have been experienced in recent times. In 1977 Bethlehem Steel's Cornwall and Grace mines closed, along

(1) at the end of this Part.

with the Meramec mines and Pickands Mather's Hilton Mine. The Humboldt mine in Michigan exhausted its reserves, but the pellet plant is treating concentrates from the Republic mine of Marquette Iron Mining. Marmora ceased operations in 1978, while in March 1979 Cities Services' Copperhill plant closed and in April National Steel's Moose Mountain plant closed and will be idle for an indefinite period of time. The Pioneer and Steep Rock plants are scheduled to close permanently in August-September 1979. Some of these closures are temporary and do not reduce rated capacity. These temporary closures have come about because of the low level of capacity working in the US industry (production of 65m. tonnes utilising only 74 per cent of the available capacity).

Expansions of capacity are also under way on a significant scale. These result from decisions taken in the early 1970's when the demand for iron products was expected to be considerably higher than it has actually been. Major projects currently under way include the extra production from a second line at Sidbec-Normines in Canada, the first plant in North America to produce two grades of pellet, the latest grade being for direct-reduction. The Meramec mine of Bethlehem Steel was re-opened in May 1979 on a limited basis. Hibbing Taconite will complete expansion to 8m. tpy during 1979 while Tilden is scheduled to start up its 8m. tpy capacity operation later in 1979. Early in 1980 Empire's expansion to 8.1m. tpy will be started up.

This will take production capacity in the USA to an estimated 90m. tpy in 1980. Further potential expansions, particularly at the major Tilden project where long-term work on pollution control is under way, could boost capacity within the USA to over 100m. tpy by 1985.[1] Because of the slackness in the pellet market, no major completely new investment projects are under active consideration at present by the major iron ore producers. This means that there must be a lag between the

(1) see Table 19 for details.

completion of the present round of expansions in the early 1980's and the next round of expansions. Thus, major new projects initiated by the iron ore industry could not be in operation before 1985 and are not likely to come into production until the late 1980's.

In addition, as noted earlier, it is essential to consider a substantial part of Canadian capacity, typically around 20m tpy, as dedicated to serving the US market. Expansion plans in Canada are therefore also relevant to the US market position. Major iron ore companies are adopting a cautious approach to investing in Canada and no major iron projects are under active development at present. This results from market conditions, political uncertainty, particularly in Quebec, and the experience of iron ore companies of increasing operating difficulties in remote Canadian locations, especially concerning labour. Thus, no Canadian expansion is planned and the closure of small operations in the next few years is expected to reduce Canadian capacity in total to approximately 34m. tpy by 1985.

3.2.3 Supply from Outside North America

The capacity for pellet production outside North America is expanding rapidly and, unlike North American producers, iron ore operators in several countries have active programmes for the development of large additions to capacity. These projects are part of wider projects to develop iron ore resources. A review of the existing iron ore projects indicated that in total in non-Socialist countries close to 200m. tpy of additional iron ore production capacity was being planned between 1977 and 1985 of which over 85 per cent was outside the USA. Many of these projects will be delayed or cancelled as the market develops and it becomes apparent that they cannot be sustained. Nevertheless major integrated pellet producing operations are under construction in Brazil and Australia in particular and these will continue to completion. The development of these, and other smaller projects, was based on the view that the market was expanding rapidly in the major steel-producing areas. The experience of Japan, which has been attempting to reduce its commitments to iron products (withdrawal of Japanese orders led to the recent closure of a major pellet plant by Hamersley in Australia), has shown that this expectation will not be fulfilled in the near future. However, the second main feature of the development is the role of government in promoting the development of iron ore mining and processing. The main reason for such promotion, which is most significant in the developing countries, is to generate foreign exchange, promote local economic development or create employment. These are powerful factors which are likely to become stronger as a result of the oil shortage and the inflated import deficits of some countries. The development of raw material exports is one clear way in which oil importing countries can ensure an increase in their foreign exchange earnings.

We therefore expect that major projects to develop iron ore mining and processing to pellets will continue to receive significant priority in a number of developing countries such as Brazil and in other countries in need of foreign exchange (most particularly South Africa). Hence, we expect a continued increase in the capacity for pellet production in areas outside the USA, probably at a rate exceeding the growth of consumption. Part of this capacity will almost certainly be intended by the operators to supply the growing market in the USA. It is therefore certain that substantial quantities of pellets will be available to supply US consumption during the forecast period, offering US consumers the potential choice of alternative sources.

3.2.4 The Structure of the Industry

No significant changes are expected in the structure of the industry in the USA in the foreseeable future. Major steel producers appear willing to continue to provide their own sources of iron supply from captive operations. The profit record of the steel industry, and the requirement noted earlier for substantial investment in additional steel production capacity in the next ten years, could mean that some companies will not be able to devote extra finance to the development of additional iron mining and processing capacity. The larger independent iron ore mining companies might then take an increased share of investment, or steel producers could turn for an increased proportion of their requirements to imports. There is little doubt, however, that the US steel industry, and the Administration, will prefer to develop on the basis of one of the USA's great natural resources, iron ore, rather than to allow any significant proportion of steel production to depend on iron imported to North America. Security of supply and the political risk of most of the major iron ore importers except Canada will ensure that most of the additional supply of iron will come from North America, provided that the costs are competitive.

3.2.5 Production Costs

The largest single elements in the cost of iron ore pellets delivered to consumers from new projects are transport costs and capital charges (including profit). Other operating costs such as labour and fuel are significant, but the advantages which an operator can gain on these items are small compared to the penalties which he may suffer on transport or the cost of plant and infrastructure. For this reason we believe that the costs of iron ore pellet production in the USA will remain very competitive in the foreseeable future. Capital costs of mine and pellet plants are lower in the USA, possibly by as much as 30 per cent, compared to new producers because of the existence of infrastructure and the greater accessibility of sites. Similarly, the freight cost for shipment of iron ore products by the Great Lakes system places the US/Canadian producer at a continuous advantage relative to distant suppliers with a long ocean haul.

The history of the iron ore industry in recent years has been for the continuous reduction in the cost of iron ore production in relation to the cost of all goods and services. Even with the increased cost of energy, we expect that this will continue to be the case in North America. One reason for this is the technical development in production to substitute away from natural gas which has been the main fuel for pellet plants. Several projects are experimenting with the use of pulverised low-quality coal as a fuel for the pelletising unit and this appears likely to prove economic and shelter new pellet plants from the rapid rise in gas costs which is certain to occur. A further reason for the expected reduction in relative costs of production is that increases in scale of mining and processing are still considered possible in the industry. The scale of pellet plant, for instance, has increased sharply in recent years, and industry sources indicate that new units are not generally economic at under 4m. tpy capacity while natural ore projects are uneconomic below 10m. tpy.

We therefore expect that in real terms (ie. after allowing for the increase in the prices of all goods and services) the cost of production of iron ore pellets in the USA will not increase and is more likely to continue its past trend of a steady fall.

3.3 The Prospects for Market Conditions and New Investment

Our forecasts suggest that US consumption of iron pellets will expand relatively rapidly during the forecast period. At present there is substantial excess capacity in the pellet industry in North America. The growth in consumption (plus exports) can be expected to take up much of this slack during the early 1980's. If all consumption were to be met by US production there would be a need for additional capacity after 1985. However, when Canadian capacity is considered there remains little need for new capacity (beyond that already planned) well into the second half of the 1980's. In addition, it is our view that there will be substantial supplies of pellets from outside North America competing for a share of the US market throughout the 1980's.

Our overall view of the market prospects, therefore, is that there will be a continuing downward pressure on pellet prices in the US market for the next few years and probably continuing through most of the 1980's. Potential supply will be adequate to meet the growing demand such that producers will not be able to raise prices to the point at which high-cost new projects will be sustainable. Some new investment will occur in the US iron ore industry, because the costs of expansion of capacity in the USA will be among the lowest in the world, but the overall conditions facing the industry will not be such that high returns can be made from new iron processing operations which have to cover their full capital costs.

We therefore believe that the current caution of the major iron ore companies concerning future investment is correct. Major new projects do not appear justified even though the USA is a competitive location for investment in the light of production costs and business climate. Some further additions of US pellet capacity can be expected in the second half of the

1980's to ensure that domestic producers do not lose their share of the home market, but we expect that caution in investment and a generally easy supply of iron pellets will prevail at least into the second half of the 1980's.

The market for iron pellets is very large and, although the general market conditions may be unfavourable, it remains possible that individual operations may find conditions advantageous. Thus, while it may be difficult to finance and bring into production large increments of capacity such as a typical 4m. tpy unit, smaller operations may find marketing of their product easier and less depressing on prices. Similarly, particular qualities of pellet, or the need to recover only part of the capital cost of the total operation, could place an individual operator in a price or cost position untypical of the industry as a whole. Hence, while our overall assessment is that the market and price prospects for iron pellets are generally unfavourable, with prices being depressed below the full costs of new operations, and most likely falling in real terms over the next ten years, further investigation would be required to ascertain whether this position applies to the product of any particular company or process.

Our analysis has considered the balance of demand and supply in numercial terms only as far as 1990. Beyond that date it seems likely that consumption of steel in the USA will continue to increase at a slow rate, on average perhaps 1-1.5 per cent per annum. There will, therefore, be an attendant demand for iron ore increasing at approximately this rate to the year 2000. By the late 1980's it will be necessary for further major new production capacity for pellets to be established in the USA or Canada if the market demand for iron is not to be met from overseas projects. During this period prices can therefore be expected to move upwards in real terms to the point at which such major new investment becomes profitable. The precise timing or extent of such developments is not predictable at this stage because the market conditions of the late 1980's and 1990's will depend not only upon steel consumption in the USA, but upon the developments in iron ore mining and processing outside the USA during the 1980's. If there are large quantities of surplus pellet production capacity in areas such as Latin America and Africa, then international market prices will be such that US investment in pellet production will be delayed until the depressing impact of this surplus on pellet prices has passed. Alternatively, if many of the large overseas projects do not proceed as planned, the opportunities for investment in the USA may be better for the 1990's.

Our overall assessment of the prospects for the iron pellet market, however, is that it will be difficult for a new producer to enter the US market successfully in the foreseeable future and hope to recover the full cost of his capital plus a normal profit, unless there are special features of quality or production cost associated with his operations. The most promising area of investigation, assuming that the pellet product could be technically suitable, might be the production of the superior grade pellets required for direct reduction feed.

4. PROSPECTS FOR EXXON'S PELLETS

4.1 Specifications

The by-product iron oxide from Exxon's pyrites could be processed into 180,000 tpa of pellets with the following composition (as calculated by Davy-McKee[1]):

Fe	65.1%	Pb	0.01%
Fe_2O_3	93.0	Zn	0.01
SiO_2	3.28	S	0.02
Al_2O_3	0.78	As	0.03
CaO	1.47	Cl	0.02
MgO	0.83	P	< 0.02
Mn	0.03	K	< 0.01
Cu	0.02	Na	< 0.01

Our discussions with steel companies and other iron ore producers indicate that these would be considered good quality pellets. The iron content is quite high for US pellets and other components seem to fall within the range of normal practice. This is confirmed in Table 20, where the analysis of Exxon's pellets is listed above the reported analyses of most of the major types of US pellets produced in 1977.

(1) The specification has been improved substantially by Davy since the start of this study, when they thought the product would be much lower quality.

Table 20 : Analyses of US Iron Ore Pellets, 1977 (per cent)

	Fe	P	SiO_2	Mn	Al_2O_3
Exxon*	63.8	0.02	3.21	0.03	0.76
Empire-Cleve.-Cliffs	63.0	0.019	6.39	0.07	0.53
Marquette-Cleve.-Cliffs	63.4	0.051	5.00	0.07	0.76
Pioneer-Cleve.-Cliffs	59.6	0.057	7.87	0.34	2.81
Tilden-Cleve.-Cliffs	63.0	0.038	5.92	0.10	0.68
Groveland-Hanna	61.6	0.028	6.87	0.81	0.45
Aurora-Pick.Mather	62.5	0.015	6.00	0.20	0.37
Eveleth Taconite	64.6	0.013	5.32	0.09	0.37
Hibbing-Pick. Mather	64.4	0.002	5.02	0.08	0.15
Minntac-U.S. Steel	63.4	0.014	5.74	0.16	
Minorca-Inland Steel	65.8	0.014	3.62	0.13	0.20
National Steel	63.9	0.008	5.19	0.10	0.16
Reserve Mining	60.4	0.04	8.64	0.37	0.54
Bethlehem-Morgantown, Pa.	65.1	0.008	3.37	0.10	1.12
Pea Ridge, Miss.-Meramec	67.6	0.075	1.88	0.03	0.30
Pilot Knob, Mo.-Hanna	64.7	0.011	4.58	0.12	0.81

	CaO	MgO	S	Moist.
Exxon	1.44	0.81	0.02	2.00
Empire-Cleve.-Cliffs			0.001	2.31
Marquette-Cleve.-Cliffs			0.001	2.38
Pioneer-Cleve.-Cliffs			0.001	2.06
Tilden-Cleve.Cliffs			0.001	2.68
Groveland-Hanna	0.94	0.62	0.002	2.51
Aurora-Pick. Mather	0.44	0.44	0.004	3.25
Eveleth Taconite	0.37	0.41	0.002	1.16
Hibbing-Pick.Mather	0.13	0.19	0.001	2.09
Minntac-U.S. Steel				2.59
Minorca-Inland Steel	0.50	0.45		
National Steel	0.23	0.37	0.003	2.47
Reserve Mining	0.42	0.65		2.95
Bethlehem-Morgantown, Pa.	0.31	1.90	0.008	-
Pea Ridge, Miss.-Meramel	0.24	0.16		0.15
Pilot Knob, Mo.-Hanna	0.10	0.09	0.003	2.07

* Note: Analysis adjusted to assumed 2 per cent moisture.
Source: American Iron Ore Association.

4.2 Markets

While it does not come under CRU's charter to judge the total economic viability of the ideas being studied, we should report that in the opinion of industry experts to whom we talked the size of this pellet operation would be far below an economic scale. As we mentioned previously, the prevailing industry opinion is that 4 million tpa is now the minimum economic size for a new conventional pellet plant. Davy's engineering/ economic work in phase II of this project presumably will tell whether or not the same is true for the particular situation involved here.

On the other hand, the small output of the proposed facility makes it hard to imagine any problem in finding a market for the pellets as blast furnace feed. In 1978, the US and Canada produced 122 million tonnes of iron ore and the supply of pellets to the US steel industry amounted to 82 million tonnes. The destination of the majority of these pellets is to blast furnaces around the Great Lakes, to which Exxon's pellets would also have easy access. Under these circumstances, and also considering the good quality of the pellets, Exxon should have no difficulty slipping its 180,000 tonnes into the market at close to the prevailing market price. The customers could be any number of integrated steel companies situated on the Great Lakes or Midwestern river system. Table 21 is a list of US and Canadian integrated steel companies and their capacities, compiled in 1978 by the Institute for Iron and Steel Studies. Approximately 75 per cent of the capacity listed is on the Great Lakes or river systems.

4.3 Pellet Prices

The history of posted prices for iron ore pellets at lower Great Lake ports is shown in Table 22. We understand that the posted price is sometimes just a starting point for negotiations

Table 21 : Integrated Steel Companies

CANADA

Company and Plant Locations	Raw Steel Capacity Net Tons
ALGOMA STEEL CORP., LTD	4,000,000
Sault Ste. Marie, Ont	
DOMINION FOUNDRIES & STEEL LTD	3,750,000
Hamilton, Ont	
STEEL COMPANY OF CANADA	7,600,000
Contrecoeur, Que	250,000
Edmonton, Alta	250,000
Hamilton, Ont	5,800,000
Nanticoke, Ont.	1,300,000
SYDNEY STEEL CORP LTD	1,125,000
Sydney, N.S	
Canada Integrated Steelmakers Raw Steel Plant Capacity, Total	16,475,000

UNITED STATES

Company and Plant Locations	Raw Steel Capacity Net Tons
ALAN WOOD STEEL COMPANY	Inactive
Conshohocken, PA	
ARMCO STEEL CORPORATION	10,690,000
Ashland, KY	2,000,000
Baltimore, MD	230,000
Butler, PA	1,000,000
Houston, TX	1,500,000
Kansas City, MO	1,600,000
Marion, OH	200,000
Middletown, OH	3,800,000
Sand Springs, OK	300,000
Torrance, CA	60,000
BETHLEHEM STEEL CORP.	22,200,000
Bethlehem, PA	3,400,000
Burns Harbor, IN	5,300,000
Johnstown, PA	1,200,000
Lackawanna, NY	2,800,000
Los Angeles, CA	600,000
Seattle, WA	500,000
Sparrows Point, MD	7,000,000
Steelton, PA	1,400,000
C F & I STEEL CORPORATION	1,900,000
Pueblo, CO	
FORD MOTOR COMPANY	3,750,000
Dearborn, MI	
INLAND STEEL COMPANY	8,470,000
East Chicago, IN	
INTERLAKE INCORPORATED	1,380,000
Chicago, IL	900,000
Wilder, KY	480,000
JONES & LAUGHLIN STEEL CORP	9,065,000
Aliquippa, PA	3,840,000
Cleveland, OH	3,100,000
Pittsburgh, PA	1,800,000
Warren, MI	325,000
KAISER STEEL CORPORATION	3,600,000
Fontana, CA	
LONE STAR STEEL COMPANY	1,500,000
Lone Star, TX	
McLOUTH STEEL CORPORATION	2,400,000
Trenton, MI	
NATIONAL STEEL CORP	13,100,000
Granite City Steel Division	2,500,000
Granite City, IL	
Great Lakes Steel Division	6,600,000
Ecorse, MI	
Weirton Steel Division	4,000,000
Weirton, WV	
REPUBLIC STEEL CORP	13,100,000
Buffalo, NY	1,000,000
Canton, OH	1,500,000
Massillon, OH	
Cleveland, OH	4,400,000
Gadsden, AL	1,500,000
South Chicago, IL	2,000,000
Warren, OH	2,700,000
Youngstown, OH	
SHARON STEEL CORPORATION	1,560,000
Farrell, PA	
UNITED STATES STEEL CORP	41,140,000
Baytown, TX	2,000,000
Braddock, PA	2,500,000
Duquesne, PA	3,000,000
Fairfield, AL	3,500,000
Fairless Hills, PA	4,400,000
Gary, IN	8,000,000
Geneva, UT	2,750,000
Homestead, PA	4,000,000
Johnstown, PA	60,000
Lorain, OH	3,000,000
South Chicago, IL	5,250,000
Torrance, CA	180,000
Youngstown, OH	2,500,000
WHEELING PITTSBURGH STEEL CORPORATION	4,400,000
Monessen, PA	1,600,000
Steubenville, OH	2,800,000
WISCONSIN STEEL COMPANY	1,200,000
South Chicago, IL	
YOUNGSTOWN SHEET AND TUBE COMPANY	7,000,000
East Chicago, IN	5,500,000
Youngstown, OH	1,500,000
U.S. Integrated Steelmakers Raw Steel Plant Capacity, Total	146,455,000

between seller and buyer. Discounting has occurred, for example, during periods of especially slack markets, or for low quality pellets. Nevertheless, the trend of posted prices probably can be taken as reasonably representative of prices of good quality pellets.

Table 22 : Lake Superior Pellet Prices at Rail of Vessel Lower Lake Ports

Year	Date	Price per long ton unit
1962-69		$ .252
1970		.266
1971-72		.280
1973		.291
1974	1-1 to 3-25	.291
	3-25 to 4-26	.29884
	4-26 to 5-2	.31189
	5-2 to 6-24	.3550
	6-24 to 8-19	.3630
	8-19 to 12-30	.40619
	12-30 to 1-1-75	.44559
1975	1-1 to 2-7	.44559
	2-7 to 7-9	.452
	7-9 to 1-1-76	.472
1976	1-1 to 1-9	.472
	1-9 to 8-16	.5045
	8-16 to 1-1-77	.531
1977	1-1 to 1-7	.531
	1-7 to 1-1-78	.555
1978	1-1 to 3-21	.555
	3-21 to 9-6	.584
	9-6 to 1-1-79	.609
1979	1-1 to 4-4	.609
	4-4	.655

Source: Cleveland Cliffs Iron Company.

As we discussed in Chapter 3, the long term outlook for pellet prices is not especially favourable, and we would not expect to see sustained "real" price increases in the foreseeable future. This is because of the probable existence of more than ample North American pellet capacity during much of the 1980's, and beyond that period because of the depressing effects of large new foreign iron ore developments.

The current posted pellet price, $.655/L.T.U., translates to $42/tonne of Exxon's pellets. We think it would be a fair approximation to use this as the estimate for future prices in constant 1979 dollars.

4.4 Pre-reduced Pellets

In the course of this study, the question has been raised as to the desirability of converting Exxon's iron oxide pellets to pre-reduced pellets. Though we have forecast increased use of reduced pellets to supplement scrap in the feed to electric furnace steel plants, we think there are compelling reasons that rule against Exxon making this product.

One reason again is the small size of the operation, which would almost surely not be on an economic scale. Another reason is that it might take much more marketing effort to sell reduced pellets than to sell oxide pellets, because very few electric furnace operations in the US have used reduced pellets.

Finally, and perhaps decisively, though Exxon's oxide pellets are good quality for blast furnace feed, they are not nearly as suitable for direct reduction feed. Iron ore pellets that go to DR to make feed for electric furnaces usually are especially high grade, with low slagging impurities (which are difficult to remove from an electric furnace). The preferred analysis calls for greater than 66.5 per cent Fe and less than 3 per cent silica plus alumina. For example, Sidbec, at Contrecoeur, Quebec, the largest North American producer of DR pellets, has 2.9 per cent silica in its reduced pellets.

We have also contacted several iron foundry operators in Wisconsin to determine if foundries could represent a local market for reduced pellets. We discovered that (1) the tonnage output of most foundries is small (500 tpm is a good sized foundry), (2) foundries have no experience with DR pellets, and (3) among different foundries, the composition of the raw materials used varies tremendously, depending on the functional requirements of the end-products of the foundry. Our conclusion is that it could take a major marketing, educational and product development effort to create a market for Exxon's pellets in foundries.

In summary, for Exxon to produce DR pellets would seem to represent the expenditure of more money and effort to make a product that is relatively inferior in its market. If this facility were situated in a part of the world with only electric furnace steel mills, it might make some sense. Placed near the heart of the US blast furnace based steel industry, it seems to make no sense at all.

4.5 Other Iron Ore Markets

A relatively small amount of iron ore is used for purposes other than iron- and steelmaking. According to the USBM all other uses consume only about 400,000 tonnes (contained iron) annually in the U.S. Most of this quantity is used in cement and in heavy media coal washing.

The several hundred thousand tons per year of iron ore used in cement generally commands a lower price than normal iron ore for steelmaking. It is often off-grade material as the exact iron content is not critical. Uniformity of size distribution is important, however, as absolute control of the water content of the cement mix must be maintained. Moreover, sizes smaller than 100 mesh are not used because of mixing problems. We see no point in considering this market for Exxon's material.

Heavy media coal washing plants consume about 200,000 tons per year of iron ore, but the ore must be magnetite so that it can be recovered magnetically.

According to SRI, 65,000 tons of iron oxide was used in pigments in 1973. For this use there has been a strong trend away from the use of natural ores toward iron oxide manufactured from ferrous scrap. In many cases, the pigment manufacturer gets the scrap free or is actually paid to remove it from a by-product source. In the pigment application, there are strict limits on many impurities, including copper, lead and zinc, which Exxon's materials would exceed. It is interesting to note that though Cities Service has a subsidiary which is one of the major producers of iron oxide pigments, they do not use any of the iron cinder from Copperhill for pigments.

Other uses for iron ore not mentioned above are too small and specialized to be of interest here.

Table 18 : Iron Pellet Plants in Non-Socialist Countries, 1978

Country/company	Location	Make	Start-up	Capacity (m. tpy)	Raw materials	% Fe
ARGENTINA						
Sierra Grande	Punta Colorada		1975	2.0	M	67
AUSTRALIA						
Broken Hill Pty.	Whyalla, SA	AC	1968	1.5	H	65
Hamersley Iron	Dampier, WA	D/L	1968/74	3.1	H	63
Robe River	Cape Lambert		1972/75	5.0	L	63
Savage River	Port Latta, Tasmania	MR	1967	2.25	M	67
BELGIUM						
Forges de Clabecq	Clabecq		1969	0.45	B	
BRAZIL						
CVRD	Tubarao		1970	2.0	B	
	Tubarao		1972	3.0	B	
	Tubarao		1979	4.0	B	
	Minas Gerais		1978	4.0	H	66
	Minas Gerais		1978	4.0	H	66
Ferteco	Fabrica	L		2.5	M	
Itabrasco (CVRD-Finsider)	Tubarao		1976	3.0	B	
Nibrasco (CVRD Japanese Mills)	Tubarao		1977	6.0	B	
Hispanobras (CVRD-Spanish Mills)	Tubarao		1977	3.0	B	65
Samarco	Point Ubu		1977	5.0	H	65
CANADA						
Caland Ore Co. (Inland)	Atikokan, Ont.	D/L	1965	1.0	H	62
Carol Lake (IOC)	Labrador City, Nfld.		1963	5.5	H	65
			1967	4.0		
Consolidated Mining	Kimberley, BC		1960	0.3	B	67
Adams (Jones & Laughlin)	Kirkland Lake, Ont.		1964	1.25	M	65
Falconbridge Nickel Mines	Sudbury, Ont.		1969	0.33	P	90 (a)
Griffith Mine (Stelco)	Bruce Lake, Ont.	MR	1967	1.5	M	65
Hilton Mines	Shawville, Ont.	MR	1957	0.9	M	66
Inco	Copper Cliff, Ont.	D/L	1956	0.35	M	68
			1963	0.6		
Knob Lake (IOC)	Sept. Isles, Que		1973	6.0	H	65
Marmoraton (Bethlehem Steel)	Marmora, Ont.		1955	0.45	M	64
Moose Mountain (Hanna)	Capreol, Ont.	MR	1963	0.7	M	64
Sherman Mine (Dofasco)	Temagami, Ont.	AC	1968	1.05	M	65
Sidbec-Normines (Sidbec-BSC-US Steel)	Port Cartier, Que		1977	6.0		
Steep Rock	Steep Rock Lake, Ont.	D/L	1967	1.35	H	64
Wabush Mines	Point Noire, Que	D/L	1965/1972	6.0	H	65
CHILE						
Cap	Huasco		1977	3.5	M	65
FINLAND						
Rautaruukki	Otanmaki		1956	0.25	M	66
	Kokkola		1962	0.3		66
INDIA						
Chowgule & Co. Ltd.	Pale, Goa	L	1967/72	1.3	H	66
Mandovi Pellets	Shiroda, Goa	VA	1978	1.8		
Tata Iron & Steel	Naomundi		1972	1.0	H/L	65
ITALY						
Montecatini SpA	Follonica	HW/McK	1964	0.33	BP	65
JAPAN						
Kobe Steel	Nadahama	AC	1966	1.0	B	
Kobe Steel	Kakogawa		1970/73	4.0	B	
Nippon Steel	Tobata		1968	0.4	B	
Nippon Steel	Hirohata		1973	2.5	B	

Table 18 : Iron Pellet Plants in Non-Socialist Countries, 1978 (Continued)

Country/company	Location	Make	Start-up	Capacity (m. tpy)	Raw materials	% Fe
LIBERIA						
Bong Mining Co.	Bong range		1971/77	4.8	M/H	64
Lamco	Buchanan	D/L	1968	2.0	H	64
MEXICO						
Ahmsa	La Perla		1974	0.6	M/H	63
Fundidora	Monterrey		1976	1.5	B	
Hylsa	Las Encinas	L	1969	1.1	M/H	67
Pena Colorada	Manzanillo		1974	1.5	M	68
Sicartsa	Melchor Ocampo		1976	1.85	B	
MOROCCO						
Seferif	Nador		1972	0.85	M	65
NETHERLAND						
Estel Hoogovens	IJmuiden	L	1970	3.0	B	
NORWAY						
Norsk Jernwerk	Mo-i-Rana	HH	1964	0.6	M	66
Orkla Grube-Aktiebolag	Thamshavn		1967	0.24		
Sydvaranger	Kirkenes		1969/74	2.4	M	65
PERU						
Hierro-Peru	San Nicolas		1963/66/70	3.5	M	66
PHILIPPINES						
Philippine Iron Mines	Larap		1966	0.75	M	63
PORTUGAL						
Mineiro de Moncorvo	Moncorvo		1971	2.0	H	
Siderurgia Nacional	Seixal		1975	2.0		63
SPAIN						
Cia. Minera de Sierra Menera	Sierra Menera		1971	0.37	H	60
SWEDEN						
Granges	Grangesberg		1970	1.5(b)	M	60
	Strassa		1963/66	1.5	M	67
LKAB	Kiruna	HW/McK	1965	1.6	M	65
	Koskullskulle		1973/75	3.0	M	67
	Malmberget		1965/72	1.4	M	68
	Svappavaara	AC	1969	1.8	M	65
UK						
BSC	Redcar, Teesside		1978	3.0	B	
USA						
Atlantic City Ore Mine	Lander, Wyo		1963	1.5	H/M	62
Bethlehem Steel	Cornwall, Pa.		1959	0.7	M	64
	Morgantown, Pa.		1962	1.5	M	66
Butler Taconite (Hanna Mining)	Nashwauk, Minn	AC	1967	2.6	M	66
Empire Iron Mining (Cleveland Cliffs)	Palmer, Mich.	AC	1964/66	5.2	M	64
Eire Mining Co. (Pickands Mather)	Hoyt Lakes, Minn.	MR	1957/67	10.2	M	63
Eveleth Taconite	Eveleth, Minn.	AC	1966/76	6.0	M	65
Groveland Mining Co. (Hanna Mining)	Iron Mountain, Mich.	D/L	1963/68	2.1	H	62
Hibbing Taconite Co.	Hibbing, Minn		1976	5.4	M	65
Humboldt Mining Co. (Cleveland Cliffs)	Humboldt, Mich.	AC	1960	0.85	H	62
Jackson County Iron Co. (Inland Steel)	Black River Falls, Wis.	D/L	1969	0.75	M	65
Inland Steel Mining Co.	Minorca, Minn.			2.6		

Table 18 : Iron Pellet Plants in Non-Socialist Countries, 1978 (Continued)

Country/company	Location	Make	Start-up	Capacity (m. tpy)	Raw materials	% Fe
Kaiser Steel	Eagle Mountain, Cal.	D/L	1965	2.2	H	65
Marquette Iron Mining (Cleveland Cliffs)	Republic, Mich.	AC	1961	2.3	H	64
Meramec Mining Co.	Pea Ridge, Mo.		1964	1.8	M	66
Minntac (US Steel)	Mountain Iron, Minn.	AC	1967/72/76	18.8	M	65
National Steel Pellet Co. (Hanna Mining)	Keewatin, Minn.	MR	1967/75	6.0	M	66
Pilot Knob Pellet Co. (Hanna Mining)	Ironton, Mo.	D/L	1968	1.0	M	64
Pioneer Pellet Plant (Cleveland Cliffs)	Eagle Mills, Mich.	AC	1965	1.45	H/L	61
Reserve Mining Co.	Silver Bay, Minn.	McK	1954/59	10.5	M	63
Tilden Mining Co. (Cleveland Cliffs)	Ishpeming, Mich.		1974	4.0	H	65
YUGOSLAVIA						
Rudnici i Zelezara Skopje	Skopje		1968	0.6		47
VENEZUELA						
Ferrominera Orinoco	Puerto Ordaz		1982	3.3	H/L	64

Plant makers: AC - Allis Chalmers; D Dravo; H - Hitachi; HH Huntingdon Heberlein; HW Head Wrightson; L - Lurgi; McK - McKee; MR - Midland Ross; VA - Voest-Alpine.
Raw Materials: B - blend; H - hematite; L - limonite; M - magnetite.
(a) Incl. 1.5% Ni. (b) Cold bonded pellets.
Note: In most cases names between brackets are pellet plant managers.

Table 19 : Pellet Production Capacity, USA and Canada, 1978-1985 (million tonnes gross weight)

		1978	1981	1983	1985
USA					
Atlantic City Ore Mine	Lander, Wyo	1.5	1.5	1.5	1.5
Bethlehem Steel	Cornwall, Pa.	0.7	-	-	-
	Morgantown, Pa.	1.5	1.5	1.5	1.5
Butler Taconite (Hanna Mining)	Nashwauk, Minn	2.7	2.7	2.7	2.7
Empire Iron Mining (Cleveland-Cliffs)	Palmer, Mich.	5.2	8.0	8.0	8.0
Eire Mining Co. (Pickands) Mather)	Hoyt Lakes, Minn.	10.2	10.2	10.2	10.2
Eveleth Taconite	Eveleth, Minn.	6.0	6.0	6.0	6.0
Groveland Mining Co. (Hanna Mining)	Iron Mountain, Mich.	2.1	2.1	2.1	2.1
Hibbing Taconite Co.	Hibbing, Minn.	5.4	8.2	8.2	9.1
Humboldt Mining Co. (Cleveland Cliffs)	Humboldt, Mich.	0.85	0.85	0.85	0.85
Inland Steel Mining Co.	Minorca, Minn.	2.6	2.6	2.6	2.6
Jackson County Iron Co. (Inland Steel)	Black Rover	0.75	0.75	0.75	0.75
Kaiser Steel	Eagle Mountain, Calif.	2.2	2.2	2.2	2.2
Marquette Iron Mining (Cleveland Cliffs)	Republic, Mich.	2.3	2.3	2.3	2.3
Meramec Mining Co.	Pea Ridge, Mo.	1.8	1.8	1.8	1.8
Minntac (US Steel)	Mountain Iron, Minn.	18.8	18.8	18.8	18.8
National Steel Pellet Co. (Hanna Mining)	Keewatin, Minn.	6.0	6.0	6.0	6.0
Pilot Knob Pellet Co. (Hanna Mining)	Ironton, Mo.	1.0	1.0	1.0	1.0
Pioneer Pellet Plant (Cleveland Cliffs)	Eagle Mills, Mich.	1.45	1.45	1.45	1.45
Reserve Mining Co.	Silver Bay, Minn.	10.5	10.5	10.5	10.5
Tilden Mining Co. (Cleveland Cliffs)	Ishpeming, Mich.	4.0	8.0	8.0	8.0
	TOTAL	87.55	96.45	96.45	97.35
CANADA					
Caland Ore Co. (Inland)	Atikokan, Ont.	1.0	-	-	-
Carol Lake (IOC)	Labrador City, Nfld.	9.5	9.5	9.5	9.5
Consolidated Mining	Kimberley, BC	0.3	0.3	0.3	0.3
Adams (Jones & Laughlin)	Kirkland Lake, Ont.	1.25	1.25	1.25	1.25
Falconbridge Nickel Mines	Sudbury, Ont.	0.33	0.33	0.33	0.33
Griffith Mine (Stelco)	Bruce Lake, Ont.	1.5	1.5	1.5	1.5
Hilton Mines	Shawville, Ont.	0.9	-	-	-
Inco	Copper Cliff, Ont.	0.35	0.35	0.35	0.35
		0.6	0.6	0.6	0.6
Knob Lake (IOC)	Sept. Isles, Que.	6.0	6.0	6.0	6.0
Marmoraton (Bethlehem Steel)	Marmora, Ont.	0.45	-	-	-
Moose Mountain (Hanna)	Capreol, Ont.	0.7	0.7	0.7	0.7
Sherman Mine (Dofasco)	Temagami, Ont.	1.45	1.45	1.45	1.45
Sidbec-Normines (Sidbec-BSC-US Steel)	Port Cartier, Que.	6.0	6.0	6.0	6.0
Steep Rock	Steep Rock Lake, Ont.	1.4	-	-	-
Wabush Mines	Point Noire, Que	6.0	6.0	6.0	6.0
	TOTAL	38.23	34.48	34.48	34.48

CHAPTER III : MARKETS FOR SULPHUR

CHAPTER III : MARKETS FOR SULPHUR

I. GLOBAL OVERVIEW

1.1 Introduction

Sulphur is one of industry's most important and versatile raw materials. It finds application at some stage in nearly all industrial production, usually as its derivative sulphuric acid. Sulphur mainly occurs in the elemental form, metallic sulphides, sulphate minerals, in conjunction with liquid and gaseous hydrocarbons and most abundantly in coal.

To distinguish between the various forms in which world production of sulphur is realized, there are three terms we normally use to identify the sources:-

(1) Brimstone: applies solely to sulphur purchased in its elemental form. Brimstone is produced by three methods:

(a) Frasch - employs a process of hot water injection and liquid sulphur recovery.

(b) Native refined - employs conventional ore mining techniques followed by treatment in a beneficiation/ refinery plant.

(c) Recovered sulphur - occurs mainly at oil refineries and natural gas plants, where desulphurization units provide H_2S streams from which elemental sulphur is extracted

(2) Pyrite: the mining of pyrite ores to obtain iron pyrite, cupreus pyrite and pyrrhotite.

(3) Sulphur-in-other-forms (SOF) this residual category includes native sulphur ore used directly to make H_2SO_4, without prior refining to brimstone. SOF is used to

produce H_2SO_4, and can be produced from a variety of sources - SO_2 containing waste gases from smelters; gypsum or anhydrite; H_2S content of oil refinery or coke oven gases; oil refinery acid sludge; spent oxide, and ferrous sulphate.

Alternatively, SOF is used in other forms which do not go through the medium of sulphuric acid - gypsum used in ammonium sulphate production; liquid SO_2 production; spent oxides used in pulp production and unbeneficiated ore used in agricultural applications.

Total sulphur production i.e. the sum of these three groups is termed - sulphur-in-all-forms(SAF).

Table 1 : Development of SAF Production ('000 tonnes S)

	1960	1970	1975	1976	1977	1978
World Total	22300	41864	50947	51314	52695	54612
Western world		29439	34557	34148	34782	34916
Socialist world		12425	16390	17166	17913	19697
Brimstone	10200	22971	32414	31932	32786	34308
Western world		17755	24474	23736	24428	24531
Socialist world		5216	7940	8196	8358	9777
Pyrite	8100	11541	11004	10954	10946	11109
Western world		4839	4904	4654	4346	4279
Socialist world		6702	6100	6300	6600	6830
SOF	4000	7353	7530	8428	8963	9196
Western world		4983	5180	5758	6008	6106
Socialist world		2370	2350	2670	2955	3090

As can be seen from the above table, brimstone accounts for the major share of production - 63 per cent in 1978. The growth in brimstone production has been the major feature of the past 20 years. In 1970, brimstone acccounted for only 46 per cent of SAF, a mere 10 million tonnes. This has since more than trebled to 34 million tonnes. Pyrite production, although having increased in the 1960's, has remained fairly static in the 1970's with a slight downward trend in production arrested only in 1978. SOF output has also increased substantially with production more than doubling since 1960.

The growth area in the 1970's has been the Socialist world, as identified in Table 1 , which in 1970 accounted for only 30 per cent, by 1978 it had improved to 36 per cent. It is considered unlikely that the Socialist areas will overtake the Western world output. Within the Western world, the major producer is North America, which in 1978 produced 19.2 million tonnes, equivalent to 35 per cent of global output. West Europe was the second major Western world producer - output in 1978 totalled 7.7 million tonnes.

The Western world remains the major consumer; in 1978, the region accounted for almost 71 per cent of consumption, usage reaching a record level of 36.3 million tonnes, while the Socialist World recorded a consumption of 17.9 million tonnes. As in the case of production, North America accounts for the major share of consumption. In 1978 North American sulphur consumption reached record levels of 14.7 million tonnes S. Similarly, West European usage recorded new consumption heights of almost 11 million tonnes.

1.2 Current Situation and Outlook

During 1978 demand for sulphur continued its upward trend, due principally to the growth in the phosphate fertilizer industry. However, there was no matching growth in supply, and by mid year delivery schedules were falling behind, as the market tightened considerably in the second half of 1978.

In the Western world, output from non elemental sectors rose, due largely to a recovery in the non-ferrous metals smelting - contributing a 6 per cent increase to SOF supply. Given the improved market conditions, pyrite production increased by 2 per cent. Output of elemental sulphur remained unchanged as the increased production by recovered producers was cancelled out by the declining Frasch production in the US and Mexico. Frasch production declined in the area due to a combination of events - mining and processing difficulties and the closure of older mining operations. The market entered into a period of growing demand and tightening supply, which eventually manifested itself in higher prices - by the end of 1978 prices were renegotiated by +$10 per ton. This situation has improved little in 1979, with Iranian exports absent and Polish deliveries affected by bad weather and flooding. Looking ahead, Western world demand will increase as a result of the continuing growth of the fertilizer industry's requirements, particularly phosphoric acid and the more modest growth in industrial end uses. In spite of an allowance for increased imports from the Socialist world of up to 2.5 million tonnes by 1990 and the use of vatted stockpiles in Western Canada, it is evident that the Western world supply/demand balance will be tight until the 1990's unless sulphur resources are developed, which by today's standards are considered uneconomic.

Unfortunately, there has been no historical precedent for a sulphur shortage of the potential dimensions identified. Until recently, there have always been reserves of material available to voluntary producers when market developments have outstripped by-product sulphur supply. Thus it must be assumed that unless supplies of abatement sulphur or recovered from coal, oil shales etc become economic and enter the market, the growth in demand will slow down in all sectors as investment in sulphur using capacity slows, awaiting assurances of supply of sulphur at realistic prices. There are no structural changes in the pattern of demand anticipated, merely a deceleration in growth in response to market prices until new sources can be exploited.

2. THE UNITED STATES SULPHUR INDUSTRY

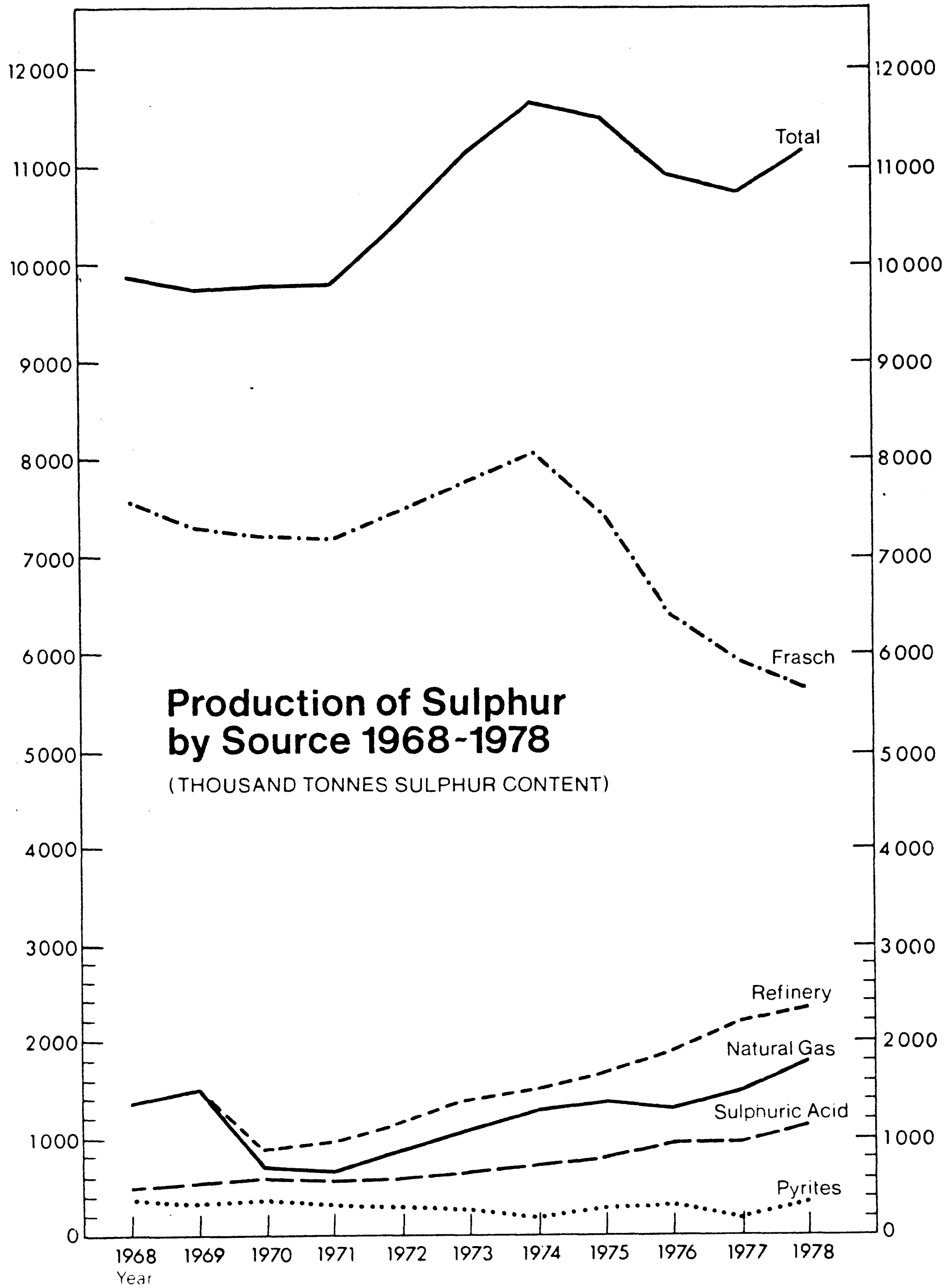
2.1 Introduction

The United States sulphur industry is the world's major producer. In 1978, domestic production of 11,168,000 tonnes S, represented 20 per cent of global production, while consumption of 12.6 million tonnes accounted for 23 per cent of world usage. Currently the Frasch sulphur sector accounts for the major output of sulphur, but as can be seen from the figure 1 Frasch usage has fallen steadily over the past 5 years, following a modest recovery in the early 1960's from its downward trend. The figure clearly illustrates how the increased production over the past two years has stemmed entirely from the output of recovered elemental sulphur and by-product sulphuric acid.

While production of sulphur has fluctuated considerably over the past 10 years, the fluctuations in the consumption of sulphur have been far less pronounced, with the trend moving upward, in spite of a slight fall in 1975. The United States remains a net importer of sulphur - out of the past 10 years, imports have exceeded exports on 7 occasions, indeed for the last four consecutive years. Mexican Frasch and Canadian recovered sulphur producers have played an increasing role in the US market - their combined exports to the US totalled 1,967,000 tonnes in 1978.

The salient developments of the United States industry over the past 25 years can be summarized in figure 2.

Figure 1



Production of Sulphur
by Source 1968-1978
(THOUSAND TONNES SULPHUR CONTENT)
Total
Frasch
Refinery
Natural Gas
Sulphuric Acid
Pyrites
12 000
11000
10 000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
Year

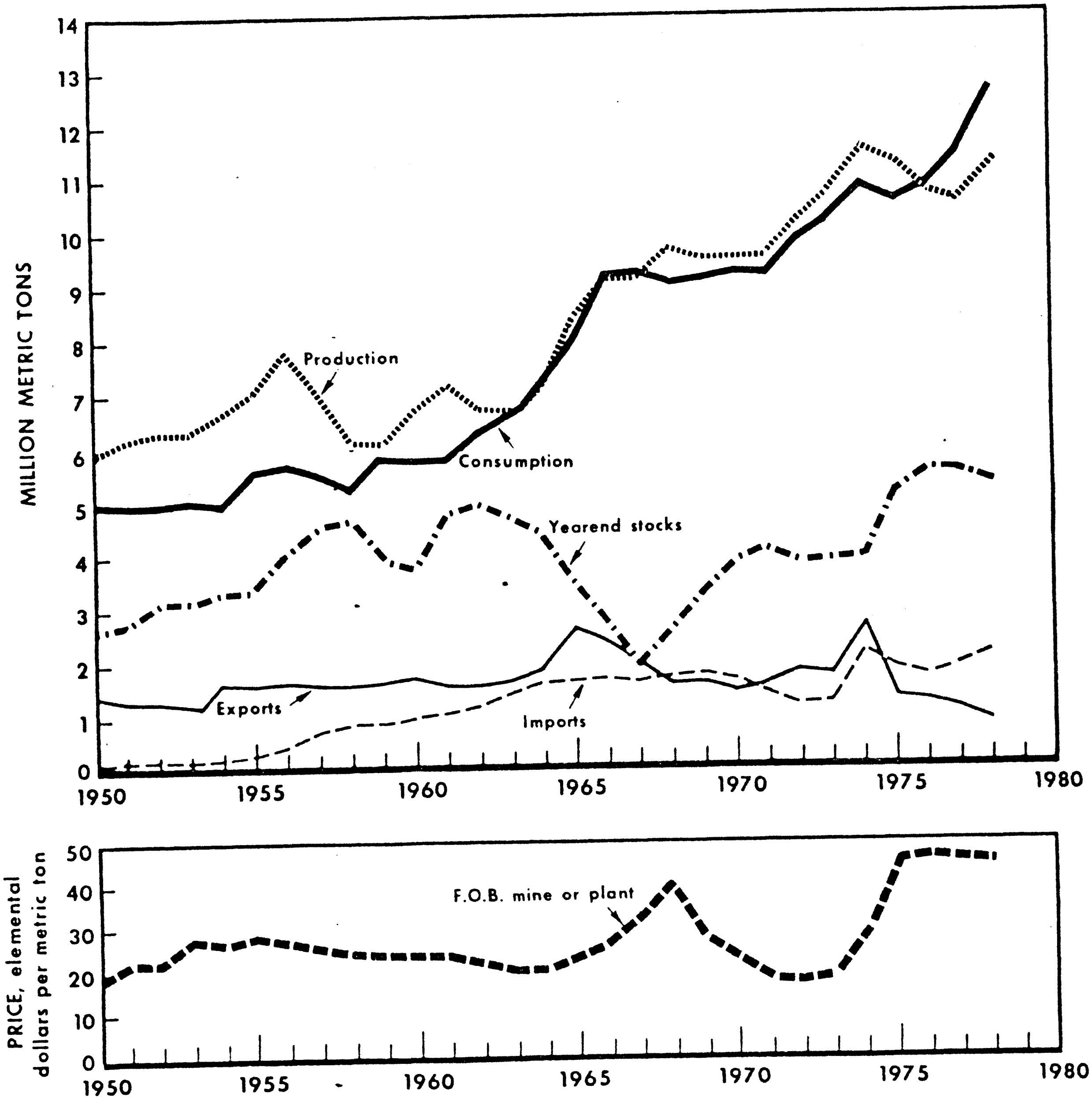


Figure 2 --Trends in the sulfur industry in the United States

2.2 Sulphur Supply

US production of sulphur in all forms totalled 11,168,000 tonnes S in 1978, a 4 per cent increase on the previous year.

Table 2 : Production of Sulphur in all Forms ('000 tonnes S)

	1966	1970	1976	1977	1978
TOTAL	9891	9710	10879	10727	11168
Frasch	7579	7196	6365	5915	5648
Recovered					
(1) Natural gas	1381	669	1298	1426	1752
(2) Refinery[1]		811	1890	2198	2303
By product H_2SO_4**	437	546	957	960	1103
Pyrites	368	344	291	169	301
Other forms[2]	126	144	78	59	61

Notes:
1. Includes a small quantity from coking operations.
2. Hydrogen sulphide and liquid sulphur dioxide.

** Further analysis of the by-product sulphuric acid is included in Chaper IV.

Source: USBM.

Frasch Sulphur

Frasch sulphur production is centred in Texas and Louisiana, where currently 8 mines are in operation.

Table 3 : US Frasch Sulphur Capacity (million tonnes S)

Location	Company	Capacity
Louisiana		
Garden Island	Freeport Sulphur Co.	1.00
Grand Isle	Freeport Sulphur Co.	1.30
Texas		
Comanche Creek	Texasgulf Inc.	0.20
Fort Stockton	Farmland Industries	0.05
Long Point	Jefferson Lake Sulphur Co.	0.20
Moss Bluff	Texasgulf Inc.	0.35
New Gulf	Texasgulf Inc.	1.20
Rustler Springs	Duval	2.50
TOTAL		6.80

Production of Frasch sulphur has declined from its peak of over 8 million tonnes S in 1974, to its present level of 5,648,000 tonnes S. The decline in production over the past four years has resulted from an interaction of the following factors:

(i) The closure of a number of mines with diminishing reserves, particularly on the Gulf Coast. During the past three years five frasch mines have ceased production - Lake Pelto and Grande Ecaille operated by Freeport Minerals Co. and Spindletop, Fannett and Bully Camp operated by Texasgulf. Commissioning of the Comanche Creek mine by Texasgulf has been insufficient to re-dress the balance.

(ii) The increased gas prices, so vital an element in production of Frasch sulphur.

Table 4 : Frasch Production by State ('000 tonnes)

	Texas	Louisiana	Total
1974	4667	3361	8028
1975	4208	3119	7327
1976	3838	2527	6365
1977	3454	2461	5915
1978	3720	1928	5648

Source: Mineral Industry Surveys Bureau of Mines

Recovered Elemental Sulphur

Production of recovered sulphur reached record levels of 4,055,000 tonnes S in 1978, a 12 per cent increase on the previous year. As a result of the decline in Frasch production, recovered sulphur accounted for 36 per cent of total domestic sulphur production.

Table 5 : Recovered Elemental Production ('000 tonnes)

	1970	1975	1976	1977	1978
Total recovered	1480	3017	3188	3624	4055
Natural gas	669	1364	1298	1426	1752
Petroleum refinery	811	1653	1890	2198	2303
Year end stocks		273	270	269	222

Source: Mineral Industry Survey.

Unlike the Frasch industry, which is characterized by a small number of producers and mines located in two States, the recovered sulphur industry is highly fragmented. In 1978 recovered sulphur was produced by 57 companies, operating 147 plants in 29 states. However, the majority of the operations are small scale and five major companies operating 37 plants accounted for 56 per cent of total recovered sulphur production in 1978. The five largest recovered elemental sulphur producers were Atlantic Richfield Co., Exxon Co. USA, Mallard Exploration Inc., Shell Oil Co., and Standard Oil Co. (Indiana).

Table 6 : Recovered Sulphur Production ('000 tonnes)

State	1977	1978
Alabama	284	405
California	507	443
Florida	332	341
Illinois	248	202
Indiana		71
Kansas	5	17
Louisiana	160	185
Michigan/Minnesota	74	79
Mississippi	294	493
New Jersey	130	120
New Mexico	58	64
Ohio	23	23
Oklahoma	10	9
Pennsylvania	83	74
Texas	1023	1107
Wisconsin	2	48
Wyoming	46	48
Others	343	379
Total *	3624	4062

Note: * may not add due to roundings.

Table 7 : Recovered Sulphur Capacity - by Source

(i) NATURAL GAS

Company	Location	Capacity '000 tonnes
Atlantic Richfield	Artesia N.M.	12
	Fashing Tex.	3
Cities Service Co.	Lehman Tex.	1
	Myrtle Spring Tex.	85
	Seminole Tex.	4
	Welch Tex.	1
Coastal States Gas Corp.	Corpus Christi Tex.	30
	Rock Springs Wyo.	24
Diamond Shamrock	Sunray Tex.	10
	Mt. Pleasant Tex.	10
	Regan Co. Tex.	1
Eagle-Picher Ind. Inc.	Miami Okla.	10
El Paso Natural Gas	Crane Tex.	25
	Goldsmith Tex.	20
	Odessa Tex.	10
Exxon Corp.	Flomaton Ala.	41
	Jay Fla.	264
	Jourdanton Tex.	6
	Sand Hills Tex.	7
Getty Oil Co.	Scroggins Tex.	82
	Teasfield Tex.	40
Gulf Oil Corp.	Como Tex.	9
	Fashing Tex.	16
	Monument NM	9
	Sand Hills Tex.	16
	Waddell Tex.	26
Intertex Gas Co.	Pecos Tex.	12
Mallard Exploration Inc.	Atmore Ala.	310
Marathon Oil Co.	Artesia NM	15
	Iraan Tex.	9
Northern Natural Gas. Co.	Hobbs NM	5
Peoples Gas Co.	Hercher Ill.	1
	Kermit Tex.	4
	Redwater Tex.	9
	St. Elmo Ill.	2
Phillips Petroleum Co.	Andrew Tex.	7
	Artesia NM	5
	Chatom Ala.	56
	Stamps Ark.	8
	Sweeny Tex.	15
Pioneer Corp.	Goldsmith Tex.	n.a.
	Madill Okla.	n.a.

Table 7 : Recovered Sulphur Capacity - by Source (continued)

(1) NATURAL GAS

Company	Location	Capacity '000 tonnes
R.J. Reynolds Indust. Inc.	Birthright Tex.	11
	Tioga N.D.	73
Shell Chem. Co.	Brandon Miss.	456
	Bryan's Mill Tex.	64
	Manistee Mich.	6
	Person Tex.	6
Standard Oil (Amoco Production)	Andrews Tex.	2
(Indiana)	Artesia NM	26
	Edgewood Tex.	126
	Goldsmith Tex.	12
	Powell Wyo.	49
	Riverton Wyo.	17
	Sundown Tex.	20
	Yantis Tex.	12
Texaco Inc.	Andrews Co. Tex.	2
	Burke County ND	1
	Ector Co. Tex.	1
	Eddy Co. NM	1
	Franklin Co. Tex.	15
	Hockley Co. Tex.	3
	Hopkins Co. Tex.	2
	Midland Co. Tex.	1
	Santa Rosa Co. Fla.	4
Texas Oil & Gas Co.	Cojanosa Tex.	9
	Harmoney Miss.	4
TransJeff Chem. Co.	Tilden Tex.	29
Westland Oil Dev. Corp.	Maud Field Tex.	2

(2) REFINERY

Company	Location	Capacity '000 tonnes
Amerada Hess Corp.	Purvis Miss.	12
American Petrofina Inc.	Port Arthur Tex.	36
	Big Spring Tex.	14
Ashland Oil Inc.	Ashland Ky.	49
	Canton Ohio.	16
	N. Tonawanda NY	16
	St. Paul Park Minn.	16
ARCO Chem.	Cherry Point Wash.	42
	Houston Tex.	123
	Philadelphia Pa.	49
	Wilmington Calif.	63
Charter Oil Co.	Houston Tex.	127
Clark Oil & Refining Corp.	Blue Island Ill.	3
Commonwealth Oil Refinery Co.	Ponce P.R.	20

Table 7 : Recovered Sulphur Capacity - by Source (continued)

(2) REFINERY

Company	Location	Capacity '000 tonnes
Continental Oil Co.	Denver, Colo.	6
	Paramount Calif.	18
Coulton Chemical Corp.	Oregon Ohio	160
	Cairo Ohio	54
Energy Co-operative Inc.	East Chicago Ind.	28
Esmark Inc.	Ardmore Okla.	20
Ethyl Corp.	Magnolia Ark.	18
Exxon Corp.	Baton Rouge La.	75
	Baytown Tex.	246
	Benicia Calif.	50
	Linden NJ	105
Farmland Industries Inc.	Coffeyville Kans.	2
Getty Oil Co.	Delaware City Del.	131
	El Dorado Kans.	42
Gulf Oil Corp.	Alliance La.	14
	Cincinnati Ohio	2
	Philadelphia Pa.	7
	Port Arthur Tex.	100
	Santa Fe Spring Calif.	8
	Toledo Ohio	4
Hunt Oil Co.	Tuscaloosa Ala	13
Koch Ind. Inc.	St. Paul Minn.	95
Little America Refining Co.	Sinclair Wyo.	9
Marathon Oil Co.	Detriot Mich.	13
	Garyville La.	88
	Robinson Ill.	10
Metal Corp.	Ferndale Wash.	4
	Joliet Ill.	70
	Paulsboro NJ	25
	Torrance Calif.	70
Monsanto	Avon Calif.	35
Montana Sulphur & Chem. Co.	East Buildings Mont.	37
Murphy Oil Corp.	Superior, Wisc.	5
Phillips Petroleum Co.	Borger Tex.	18
	Kansas City	8
Powerline Oil Co.	Sante Fe Springs Calif.	7
Shell Chem. Co.	Deer Park, Tex.	150
	Martinez, Tex.	36
	Norco La.	16
	Wilmington Calif.	15
	Wood River Ill.	100
Standard Oil Co.	El Segundo Calif.	235
	Perth Amboy NJ.	46

Table 7 : Recovered Sulphur Capacity - by Source (continued)

(2) REFINERY

Company	Location	Capacity '000 tonnes
	Richmond Calif.	200
	Salt Lake City Utah	4
	Pascagoula Miss.	57
	Sugar Creek Mo.	28
	Texas City Tex.	210
	Whiting Ind.	90
	Yorktown Va.	20
Standard Oil (Ohio)	Lima Ohio	12
	Marcus Hook	65
Sun Oil Co.	Duncan Okla.	12
	Toledo Ohio	16
	Yabucoa PR	12
Texaco Inc.	Lawrenceville Ill.	3
	Lockport Ill.	2
	Port Arthur Tex.	93
	Tulsa Okla.	4
	Westville NJ.	1
	Wilmington Calif.	40
Tosco Corp.	Bakersfield Calif.	-
Union Oil Co.	Arroyo Grande Calif.	26
	Lemont Ill.	109
	Rodeo Calif.	89
	Wilmington Calif.	80
Union Pacific Corp.	Corpus Christi Tex.	5

(3) COKING OPERATION

Company	Location	Capacity '000 tonnes
Bethlehem Steel	Bethlehem Pa.	n.a.
	Burns Harbour Ind.	n.a.
	Lackawana N.Y.	n.a.
	Sparrows Point ND.	n.a.
United States Steel Corp.	Clairton Pa.	2

(4) UTILITIES

Company	Location	Capacity '000 tonnes
NIPSCO	Mitchell Station Ind.	13
Public Service Co.	New Mexico	12

By-Product Sulphuric Acid

Sulphur contained in by-product sulphuric acid produced at copper, lead and zinc roasters and smelters during 1978 amounted to 10 per cent of the total domestic production of sulphur in all forms. It was produced by 12 companies at 24 plants in 13 States. The five largest acid plants accounted for 47 per cent of total output. The five largest producers of by-product sulphuric acid were American Smelting and Refining Co., Magma Copper Co., Kennecott Copper Corp., Phelps Dodge Corp., and St. Joe Minerals Corp. Together, their 15 plants produced 73 per cent of output in 1978.

Pyrite

Production of sulphur from pyrite increased to 301,000 tonnes S in 1978, the first time production has exceeded 300,000 tonnes since 1971. The increased production in 1978, almost double that of the previous year has resulted from the output of Cities Service Co.

Sulphur-in-other-forms. (SOF)

Sulphur recovered through the medium of smelted gas, sulphur dioxide and hydrogen sulphide remain relatively insignificant sources. In 1978 production from other forms totalled 61,000 tonnes, a marginal increase on the previous year.

2.3 Impact of Environmental Regulations on S Production

(a) Frasch - at the moment there are relatively few environmental problems associated with the Frasch sector. Major producing areas are isolated and molten S produced is distributed directly to the consumer thereby posing no environmental problem. Problems are however evident in the storage and distribution of elemental sulphur stored/moved in its dry form ie. vatted sulphur. Dust is the major hazard, but this is being overcome by the use of coating techniques. Of the total elemental sulphur distributed to sulphur burning sulphuric acid plants, it is estimated that 95 per cent is handled in the molten form.

(b) Recovered Sulphur Production

The emergence of recovered sulphur from natural gas over the past 20 years has been one of the major features of the sulphur market. The principal sources of recovered sulphur are the H_2S contaminants of sour natural gas and the organic S compounds in crude oil. Sulphur recovery is mainly in the elemental form. Its production has been stimulated by the increasing demand for low S fuel as an air pollution control measure. Recovered elemental sulphur accounted for 36 per cent of total domestic supply of sulphur in all forms in 1978.

(c) By product H_2SO_4 Production at Smelters

In the smelting of non ferrous sulphide ores, primarily copper, lead and zinc, the S is converted into SO_2 which can be recovered from the stack gases in the form of H_2SO_4. In view of the more remote locations of most non ferrous metal smelters, the pollution control laws allow intermittent controls for the lean streams of the SO_2 in the stack gases.

(d) H_2SO_4 Production in S-burning acid plants.
All H_2SO_4 plants, particularly the older generation, suffer problems in the control of the amount of pollutants in their tail gases as required under air pollution control laws. The SIP[1] standards in most states require the conversion efficiency of S to H_2SO_4 to be equal or greater than 99.7 per cent efficient. This means that the major portion of the existing plants must add a retrofit tail gas cleaning system in order to comply with air pollution control laws.

2.4 Sulphur Demand

For the third consecutive year, apparent consumption of sulphur in all forms exceeded domestic production. Apparent consumption of sulphur in all forms attained record levels of 12,600,000 tonnes S in 1978, an 8 per cent increase on the previous year.

Table 8 : Apparent Consumption of Sulphur ('000 tonnes S)

Apparent Consumption (1)	1968	1970	1976	1977	1978
Total (2)	9127	9375	10941	11657	12600
Frasch - Domestic	5026	5152	4737	4942	4909
Imports	797	548	743	781	993
Recovered Elemental - Domestic	1298	1495	3123	3518	4049
- Imports	843	1014	1012	1228	1185
By-product sulphuric acid	437	546	957	960	1103
Pyrite	510	476	291	169	301
Other forms	126	144	78	59	61

Source: USBM
Note: (1) Apparent Consumption = shipments + imports - exports.
(2) Total may not add due to rounding.

(1) State Implementation Plans (Emission regulation for sulphur oxides).

Table 9 : Consumption of Elemental Sulphur by End-Use ('000 tonnes S)

	1975	1976	1977	1978
Food	3	4	5	n.a.
Pulp and Paper	104	112	147	96
Synthetic rubber, cellulose fibres, plastics	131	86	65	n.a.
Agricultural chemicals	91	89	257	287
Paints and allied products, industrial organics	131	89	275	214
Petroleum refining/ coal products	123	85	111	108
Other Industrial Inorganic Chemicals	235	342	221	167
Rubber and miscellaneous plastics	2	10	n.a.	17
Sulphuric Acid				
Domestic sulphur	6796	7160	7435	7064
Imported sulphur	888	887	2162	2239
Unidentified	994	670	678	985
Exports	1260	1188	1044	898
TOTAL	10758	10722	12400	12075

Source: USDC.

Apparent sales of domestic Frasch sulphur declined marginally in 1978 by 33,000 tonnes S as producers' stocks were reduced by 165,000 tonnes. Recovered elemental sales were up by 531,000 tonnes to 4,088,000 tonnes S, a 15 per cent improvement on the previous year.

Over 83 per cent of the domestic shipments of sulphur was used for the production of sulphuric acid, the balance of up to 1 million tonnes S was used by a wide range of industries. The breakdown of elemental sulphur sold by end use is identified in Table 9 . (It can be seen from the table that of total elemental sulphur sales, 985,000 tonnes cannot be identified by end-use - but it is assumed that the majority of this tonnage is transformed into sulphuric acid).

Table 10 : Shipments of Sulphur in all forms ('000 tonnes S)

	1974	1975	1976	1977	1978
Shipments (1)					
Total	11513	10220	10476	10845	11289
Frasch	8025	6175	5954	6030	5636
Recovered elemental	2588	2947	3196	3627	4088
By-product sulphuric acid	664	779	957	960	1103
Pyrite	165	241	291	169	301
Other forms	71	76	78	59	61

Note: (1) Shipments = sold or used.
Source: USBM

In view of the diverse end uses of sulphur, it is proposed to examine the developments in demand on the basis of the following major categories.

(i) Agricultural Chemicals - in 1978, end use in the group totalled 272,000 tonnes, representing 2 per cent of the total sulphur usage. One of the major uses within this group is the direct application of sulphur as a soil conditioner.

Table 11 : Direct Application of Sulphur ('000 tonnes S)

1970	1974	1975	1976	1977	1978
26.4	59.1	47.0	85.9	41.3	110.0

Source: USDA

Historically usage has fluctuated considerably but substantial growth potential exists in the Pacific States region, notably California, which in 1978 applied almost 70,000 tonnes.

(ii) Pulp and Paper - consumption of sulphur by the pulp and paper industry was 293,000 tonnes S in 1978, in all forms. Of which 96,000 tonnes was elemental, the balance being sulphuric acid and sulphur dioxide. Historically, usage of elemental sulphur by the pulp and paper industry has been irregular, indeed until 1978, it appeared that the decline in recent years in the consumption of non-acid sulphur had been arrested.

(iii) Other End uses - totalled 506,000 tonnes S in 1978. The composition of demand is identified in Figure 3.

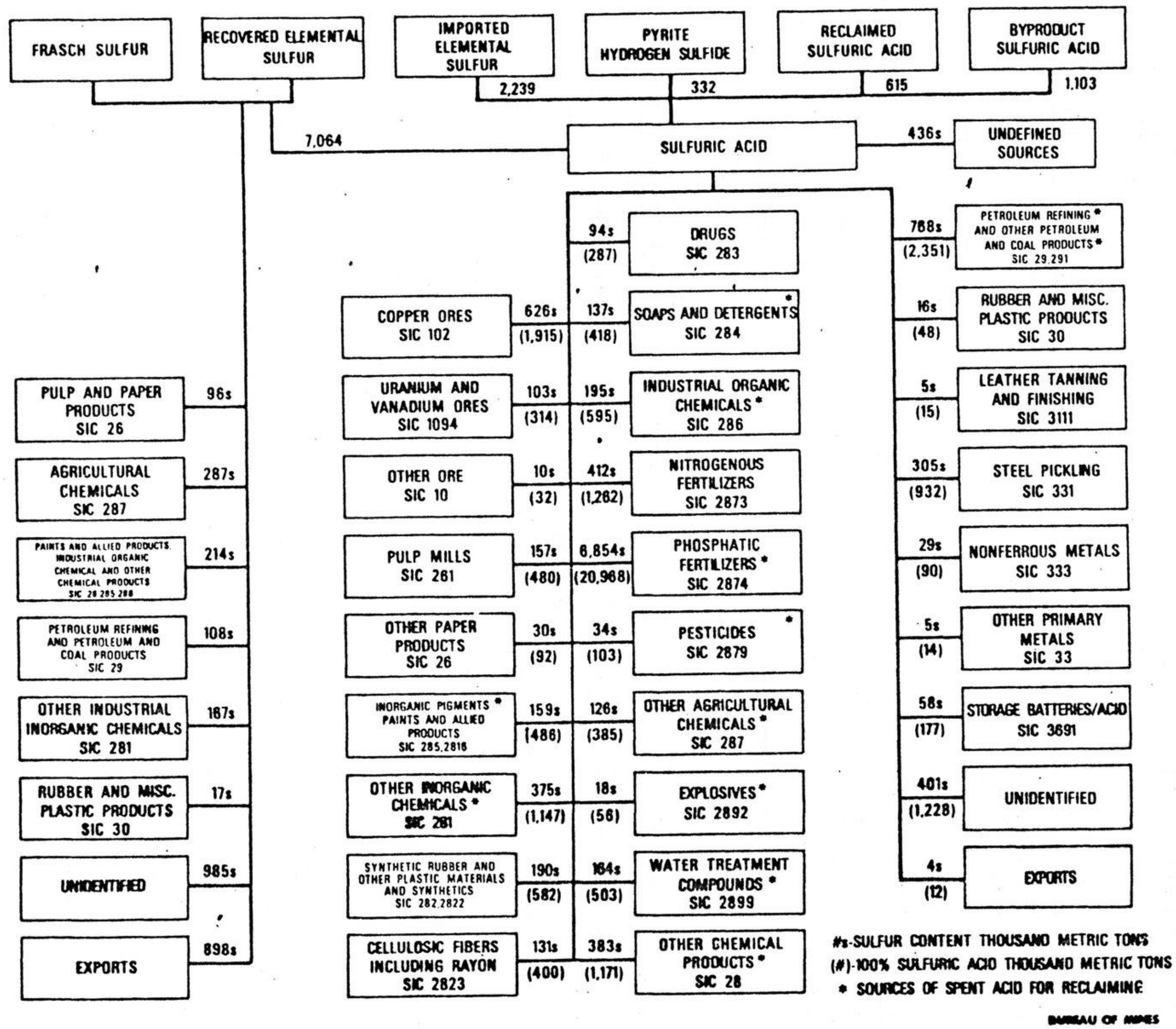


Figure 3 - Sulfur-sulfuric acid supply/end-use relationship
1978

(iv) Sulphuric Acid - the transformation into sulphuric acid is the major end use of sulphur. Of the total 12,075,000 tonnes of elemental sulphur consumed in 1978, sulphuric acid accounted for 9.3 million tonnes S. or 77 per cent of elemental sulphur usage. The phosphate fertilizer industry is the main ultimate end user of sulphuric acid. In terms of sulphur, the pattern of industrial usage in the past four years has developed as follows:

Table 12 : End Uses of Sulphur - Sulphuric Acid ('000 tonnes S)

	1975	1976	1977	1978
Total	9354	10038	11705	11978
Fertilizers total	5805	5979	6969	7383
Nitrogen	(164)	(146)	(235)	(419)
Phosphates	(5641)	(5838)	(6734)	(6964)
Petroleum Refining	610	600	780	780
Copper Ores	402	542	598	636
Inorganic Chemicals	282	232	653	381
Steel pickling	106	965	132	310
Others	2551	1730	2573	2486

Source: USBM.

As can be seen over 60 per cent of sulphur consumed is ultimately used by the fertilizer sector, principally for the production of phosphoric acid.

A more detailed discussion of the sulphuric acid industry can be found in Chaper IV "Sulphuric Acid".

2.5 Pricing Patterns

Any industry, in which a large share of the market is controlled by involuntary producers, whose industrial cycles do not coincide with that of the voluntary producers, is subject to unstable market conditions. The sulphur industry is a good example of such a pattern, with recovered sulphur prices historically acting as a depressant on the market.

An examination of the historical development of prices reveals a gradual decline in prices from the early days of the Korean war through 1963. The mid 1960's witnessed a firming of prices as demand recovered, particularly in the fertilizer sectors. However, by 1968 the peak prices had been reached and a gradual decline in prices followed under the impact of the Canadian and Mexican supplies on the domestic market, and the addition of Polish products on the international market. This fall in prices was finally arrested in 1972 by which time prices had reached an all time low.

Since 1972 there has been a gradual though intermittent recovery in surphur prices. The following price series illustrates the pattern and clearly identifies the price differential of the US Frasch, Mexican Frasch and Canadian recovered prices.

Table 13 : Mid Year Sulphur Prices (Current US$)

a) Export	1975	1976	1977	1978
U.S. Frasch (bright) fob Gulf Ports - per long ton	65	61-71	60-61	60-65
Mexican Frasch fob Coatzacoalcos per tonne	58	56-65	45-48	45-48
Canadian recovered (bright) fob Vancouver per long ton	60-65	38-42	35-38	35-41

Table 14 : Sulphur Domestic and Trade Price History ($ per tonne)

	Average unit value of Shipments fob mine/plant			Average unit value of Imports and Exports	
	Frasch	Recovered	Total	Imports	Exports
1956	26.92	n.a.	n.a.	n.a.	n.a.
1960	24.47	23.77	23.50	n.a.	n.a.
1965	23.06	21.33	22.82	18.50	24.89
1970	24.03	21.22	23.51	22.57	23.53
1971	17.78	17.70	17.75	19.88	18.46
1972	17.69	15.90	17.30	14.54	17.83
1973	18.92	15.70	18.13	12.26	19.69
1974	31.01	24.17	29.34	24.16	37.61
1975	49.37	35.57	44.91	36.76	54.20
1976	50.38	37.02	45.72	33.89	50.00
1977	48.88	36.91	44.38	32.43	47.90
1978	48.80	40.07	45.17	34.75	41.91

Source: USBM.

Table 14 presents a history of domestic prices. However because most sulphur is sold on negotiated contract prices, the terms of which are usually confidential, these prices serve only to identify the overall trend. Furthermore there are considerable regional price variations within the U.S. This arises because of (a) the freight aspect

(b) the competition from recovered sulphur - both Canadian and domestic US producers.

Table 15 : Current Prices at Selected Locations $ per tonne (molten sulphur)

Tampa	79-86
U.S. Gulf	69-74
U.S. West Coast	28
Pacific North West	42

2.6 Prevailing Commercial Arrangements

Sulphur is normally sold under long term contracts to major industrial consumers, on a delivered price basis at regional terminals. The terminal prices vary considerably with location, and contract prices are well below the list prices quoted in this study.

The recovered sulphur and by-product sulphuric acid producers have progressively obtained control of the markets in the Western and Central States. Canadian recovered sulphur sales have been confined to the Northern States. Penetration of the more southerly markets has been restricted by freight costs. The Mexican Frasch industry has remained competitive in Southern States. Expansions of the Mexican marketing area have been limited by the high freight element involved in reaching the inland markets. The Frasch producers, under pressure from recovered, by-product producers and imported sulphur, have found their market area gradually constricted to the Southern and Eastern States and the inland waterways.

Frasch producers normally ship molten sulphur by water from their mines or transhipment terminals on the Texas and Louisiana Gulf Coast to the marketing terminals. The basing point of the Gulf Coast Market is Port Sulphur, La. Marketing points are strategically located either on the inland waterway system or along the East coast adjacent to ports served by deepwater vessels. From the marketing terminal, molten sulphur is transported by barge, truck or rail directly to the point of consumption at the sulphur burning plant. A map of the locations of S terminals is presented in Figure 4.

Recovered sulphur is sold mainly by its producers, the oil and gas companies. As yet there has been little development of a merchant market for sulphur. This has stemmed from the reluctance of oil and gas producers to prejudice their oil and gas output by a build up of onsite liquid molten sulphur. Hence, the major producers have opted to market their own product:- Amoco Oil Co., Cities Services, Exxon Chemical Co Inc., Gulf Oil Corp., Mobil Oil Corp., Phillips Petroleum Co., Shell Oil Co., Standard Oil Co., and Texaco Inc.

2.7 Outlook

2.7.1 Supply

a) Frasch

In addition to the mining capacity currently in operation, Freeport Minerals owns two properties which, given appropriate economic conditions, could form the basis for future mining operations.

(i) Since the closure of Lake Pelto, the redundant equipment has been relocated to Caillou Island, where a relatively deep onshore dome has a potential capacity of 300,000 tpa S.

(ii) The offshore Caminada dome has been idle since 1969, following a sharp downturn in the market. The operation has been mothballed and is now on a standby basis. In view of the short operating life of the mine (13 months) it is difficult to determine its capacity. However, a future capacity of 500,000 tpa S is indicated.

In the absence of any new capacity developments, save the introduction of Caillou Island and the reactivation of Caminada, and the possible expansion of existing operations, the continued decline of the Frasch industry appears inevitable. A brief discussion of the cost structure of the industry will clearly illustrate why there is little chance of any expansion of the Frasch industry unless a significant technical break-through is achieved in energy saving. Of the costs of production, the cost of natural gas is crucial, and it is significant that many of the mines are fortunate to have contracts for long term supply of gas. For example, Freeport's Garden Island Bay dome gas supply is assured until 1989 though an intrastate contract, while Grand Isle supplies are contracted for 10 years with an intrastate gas company. This has ensured that for the most part gas supplies are available below $2 per mcf. The availability of gas at these prices is crucial to the older mines, where the hot water required to melt the sulphur has been increasing.

An indication of the future for those companies still in production can be gauged from the following estimates of gas consumption per tonne of sulphur produced.

Table 16 : Frasch Operations: Gas Consumption

Location	Gas Consumption mcf/tonne*
Louisiana	
Garden Island Bay	6.9
Garden Isle	3.8
Texas	
Long Point	9.1
Moss Bluff	9.0
New Gulf	7.6
Rustler Springs	5.0

Note: * 1,000 cubic ft. (approximates 1-million Btu.)

During the review period all of the above mines will see their consumption of gas per tonne of sulphur increase as the mines age. In projecting the future capacity of the above mines, two major factors dominate:

(i) The scale of the reserves.

(ii) The estimated gas consumption.

Based on these two factors, a knowledge of the historical performance of the operations, and consideration of the improvements in operating techniques, the following development of capacity is forecast:

Table 17 : Development of US Frasch Sulphur Capacity - 2000 ('000 tonnes)

Location	1978	1980	1985	1990	1995	2000
TOTAL	6800	6500	5700	5050	4200	3000
Louisiana						
Caillou Bay (1)	-	-	300	350	400	300
Caminada (2)	-	-	-	400	400	400
Garden Island Bay	1000	1000	800	800	600	400
Grand Isle	1300	1200	1000	800	800	600
Texas						
Comanche Creek (3)	200	300	500	500		
Fort Stockton (4)	50	-	-	-	-	-
Long Point (5)	200	200	-	-	-	-
Moss Bluff (6)	350	300	200	-	-	-
New Gulf	1200	1200	800	800	800	400
Rustler Springs (2)	2500	2300	2100	1600	1200	900

Notes:
(1) Expected to be commissioned by 1982.
(2) Status as yet undetermined.
(3) Has suffered considerable production problems. Original estimate of production of 400-600,000 tpa is not anticipated to be realized until the mid-1980's.
(4) Reported reserves are judged insufficient to sustain production into the 1980's.
(5) According to Hooker's IOK, economic reserves have only a 5 year life.
(6) Increased gas consumption will probably ensure closure by 1990.

It will have become evident from the preceding table that the US Frasch industry will continue its decline under the pressure from increased energy costs and involuntary producers. However, the very nature of production i.e. voluntary, makes it difficult to predict the level of output, in that production can be geared to match the prevailing market conditions. The capacity series outlined on Table 17 is intended to reflect the operating rates expected during the review period.

b) Recovered Elemental Sulphur - Natural Gas

In 1979 possibly more so than ever before, the forecast of recovered sulphur production from natural gas sources is dependent on political decisions.

The apparent decline in gas production evident in the early 1970's appears to have been arrested, and forecasts of production for the 1980's suggest a modest increase from the current production levels.

As mentioned earlier, the repercussions of the recent energy program are difficult to quantify, but in respect of the sulphur industry, it is generally considered that in the period up to 1985, output at existing sites will improve and that a significant number of new units will be developed in the post 1985 period. The net effect will be maintained sulphur production slightly in excess of existing levels.

Table 18 : U.S. Recovered Elemental Sulphur Production - Gas Based ('000 tonnes S)

	1979	1980	1985	1990	1995	2000
Production	1752	1800	2000	1800	1800	1800

c) Recovered Elemental Sulphur - petroleum refineries

The major expansion of sulphur recovery from petroleum refineries has resulted from two major causes:

(1) The imposition of strict legislation, on the prohibition of stack gas SO_2 emissions.

(2) The increasing importance of offshore oil supplies, which on the whole have a higher sulphur content than the sweeter domestic oils.

As a result of the current U.S. energy crisis, the most important factor in evaluating the future of refinery sulphur recovery is the importation of crude oil and of particular importance the level of high sulphur crudes. In a recent National Petroleum Refiners Association survey it was reported that the capacity utilization of refineries on the East coast was 97 per cent, with 85 per cent of capacity capable of handling the sour crudes. In 1978, domestic refinery production of residual oil totalled 611 million barrels with 50.5 per cent in the low sulphur range (ie. 1.0 per cent or less S content by weight). Imports of residual fuel oil during 1978 were 490.4 million barrels of which 54.7 per cent were classified as low sulphur content. For the sulphur producer it is of interest to note that on the West coast, the decrease in production of low sulphur residual has resulted in part from the increased use of high sulphur American crude.

The forecast of recovered sulphur production from petroleum refinery, by definition depends upon the quantity of crude refined and the proportion of crude and sweet oils. As clearly it is not without difficulties to forecast the domestic US oil demand, the base point from which recovered sulphur forecasts can be derived, the following series can only be presented as trends. Beyond 1990, it is impossible to identify the developments in the oil sector.

Table 19 : United States: Refinery Sulphur Developments

	Oil Demand million tonnes	Domestic Supply	Imports	Average S Dom. %	Average S imports %	Sulphur Throughput 000 tonnes	Recovered 000 tonnes	%
1976	725	455	304	0.75	1.00	6161	1885	30.6
1977	786	455	369	0.75	1.02	6846	2198	32.1
1978	816	478	338	0.76	1.06	7182	2303	32.1
1979	847	476	371	0.77	1.08	7673	2600	33.9
1980	878	474	404	0.78	1.12	8222	2870	34.9
1985	929	518	411	0.80	1.20	9077	3400	37.5
1990	964	536	428	0.83	1.30	10005	4000	40.0

d) Recovered Elemental Sulphur - Other Forms

Recovered sulphur, other than from natural gas processing or petroleum refineries is at the moment minimal. However, while operations in this area may be of only minor significance now, they are considered by certain sources to be areas of major potential.

These unconventional sources of recovered sulphur can be categorized as follows:

(1) Coal gasification
(2) Oil shales and tar sands
(3) Power plants

(1) Coal gasification - given the impetus provided by the recent energy policy to produce 1-1.5 million b/d of synthetic fuel from coal liquification and gasification by 1990 a substantial quantity of sulphur could be recovered. The recovery of the sulphur at the point of production would also enhance the chances of production resulting from the economies in pollution control At the moment however, there are no commercial operations in production, but tests are underway on both pilot and semi-industrial scale plants. Initially commercial operations will be limited by the high cost of these processes. Two demonstration plants to produce synthetic fuel will cost over $3.5 bn, while the fuel itself is forecast to cost between $27-$47 per barrel.

(2) Oil shales and tar sands - would appear to suffer the same disadvantages as coal gasification - notably technological and financial. Nevertheless, exploitation of tar sands and oil shales has been underway for considerable time at the Athabasca deposits in North East Alberta, where reserves are estimated at 1.7 bn tonnes S.[1] In the U.S., the largest deposits of oil shales are located on the borders of Utah, Colorado and Wyoming. Government proposals are to produce 0.5 millon b/d of fuel. The U.S. oil shales are generally thought to have a fairly low sulphur content and cannot be regarded as a major source of recovered sulphur. Sulphur recovery from oil shales is not expected before 1990, and is forecast to be in the order of 200,000 tpa S.

(3) Power plants - SO_2 emissions from coal fired power plants have not yet been recovered to any great extent. However, under pressure from the Environmental Protection Agency (EPA) power stations are becoming obliged to comply with clean air regulations. The question of the form in which the SO_2 emissions will be recovered remains. A recent publication[2] by the Tennessee Valley Authority and EPA has studied the relative trends of processes for cleaning up the SO_2 emissions. The conclusion is that the cost of recovery of elemental sulphur (by the Wellman Lord/ Allied process) was in excess of the cost of recovery of conventional sulphuric acid, even when the increased cost of distributing sulphuric acid was considered. Elemental sulphur is recovered from two utility companies, North Indiana Public Service Co. (NIPSCO) at Mitchell Station which currently recovers 60 tpd S, and Public Service Co. of New Mexico which produces 40 tpd S. Annual production from these two units is estimated to be 35,000 tpa S.

(1) Sulphur, Mineral Policy Series, Dept. of Energy, Minerals & Resources, Canada.
(2) "Potential Abatement Production and Marketing of By-product Sulphuric acid in the US" prepared for the US Environmental Protection Agency, Washington DC.

e) By-product Sulphuric Acid

By-product sulphuric acid production will increase from two main sources:

(1) Incremental smelter acid production.
(2) Recovery from SO_2 gas in the form of acid.

However, at present, the economics for significant recovery of acid from power plants is restrictive, although it is felt that this acid will become a strong force in the market by the end of the century. By the end of the century the combined production of acid from both sources is forecast to exceed 4 million tonnes S.

f) Pyrite

In the future, little growth is expected in this particular sector and there has been little interest in developing new pyrite burning facilities in the United States beyond the one existing unit.

g) Sulphur-in-other-forms (SOF)

In the remaining years of the century little growth in production of SOF is predicted. Output is estimated to be in the order of 100,000 tpa S by the end of the century.

Table 20 : United States: Sulphur Supply Forecast ('000 tonnes S)

	1978	1980	1985	1990	2000
TOTAL	11168	12823	13733	16600	23030
FRASCH	5648	6300	5700	5050	3000
RECOVERED	4055	4678	5478	8150	15400
(i) Natural gas	1752	1800	2000	1800	1200
(ii) Refinery	2303	2853	3403	4000	5500
(iii) Power plants	15	15	25	750	2000
(iv) Coal processing	5	5	50	1400	6200
(v) Oil shales/Tar Sands	-	-		200	500
BY PRODUCT H_2SO_4	1103*	1320	2200	3100	4200
PYRITE	301	275	275	200	200
OTHER FORMS	61	70	80	100	250

Notes: * excludes 613,000 tonnes of reclaimed H_2SO_4 from petroleum refining and coal products.

Reclaimed Sulphuric acid:

1980 700,000 tonnes
1985 850,000 tonnes
1990 950,000 tonnes
2000 1,600,000 tonnes

Source: CRU estimates.

2.7.2 Demand

On the basis of the phosphoric acid/phosphate fertilizer forecasts developed in later Chapters, and the continued growth in the industrial sectors, consumption of sulphur by the year 2000 is forecast to reach almost 24 million tonnes S.

Table 21 : United States Sulphur Demand ('000 tonnes S)

	1980	1985	1990	1995	2000
End Use	13513	15443	18360	21060	23780
Fertilizer	8128	9652	11760	13800	15800
Industrial	5385	5791	6600	7260	7986

As illustrated above, fertilizers will continue to be the main end users of sulphur via the medium of sulphuric acid. By 2000, consumption of sulphur by the industry is forecast to reach almost 16 million tonnes S. Of the total, the greater proportion will be used for the production of phosphoric acid, little growth is expected in consumption by singe superphosphate or ammonium sulphate producers. Indeed a fall in production is forecast, the majority of new phosphatic fertilizers will be produced by the phosphoric acid route.

In the industrial sector, the overall increase in demand is forecast to be in the order of 2.5 per cent per annum. The following growth rates by major end use are forecast.

(i) Via Sulphuric Acid

a. Petroleum refining — 0.5 per cent p.a.
b. Copper smelting — 4 per cent p.a.
c. Alcohols — 3 per cent

d.	Hydrofluoric acid	- 2 per cent p.a.
e.	Titanium dioxide	- 2 per cent p.a.
f.	Aluminium sulphate	1.5 per cent p.a.
g.	Cellulosics	1 per cent
h.	Uranium ore processing	10 per cent
i.	Iron & Steel pickling	- 1 per cent
j.	Surface active agents	1 per cent
k.	Batteries	1 per cent
l.	Others	- 1 per cent

(ii) <u>As elemental sulphur</u>

(a) Agricultural - historically usage has fluctuated considerably but substantial growth potential exists in the Pacific States, notably, California which in 1978 applied 70,000 tonnes S. As sulphur becomes a limiting factor in certain areas, strong growth in usage is predicted in spite of the higher price levels. By the end of the century usage could be in the order of 500,000 tonnes S.

(b) Pulp and Paper - it is anticipated that growth in demand for non-acid sulphur will not exceed 2 per cent per annum.

(c) Other End Uses - growth in the remainder of the century is not expected to exceed 2 per cent per annum.

2.7.3 Supply/Demand forecast

On the basis of the forecasts prepared from an assessment of the individual components of supply and demand, a continued imbalance into the 1990's appears inevitable. The shortfall in supply is expected to peak at 1.8 million tonnes S in the mid 1980's and decline through to the end of the century as new sources of sulphur become available. During this period, the U.S. industry will remain dependent upon imported sulphur from Canada, Mexico and Poland. Imported sulphur will mainly be in elemental form, although an increasing quantity will be in the form of by-product sulphuric acid imported from Canada.

However, the supply/demand balance is purely theoretical and the degree of actual imbalance depends upon the reactions of the voluntary producers and major end users to the prevailing level of prices. For instance, given a continued firming of prices, there is scope for the arrest of the decline in the Frasch industry. If new technology was introduced to economize on the energy cost, currently being evaluated by Duval, one could expect an additional 1.5 million tpa from the Rustler Springs mine. This would ease the supply/demand situation considerably in the 1980's.

Table 22 : United States: Sulphur Supply/Demand Balance ('000 tonnes S)

	1985	1990	2000
Supply	13773	16600	23050
Demand	15443	18360	23780
Surplus/(Deficit)	(1670)	(1760)	(730)

2.7.4 Price Outlook

After 1980, the critical factor will be the efficiency of the Frasch sulphur operations, coupled with the cost of energy particularly natural gas. During the period of tight supply which is expected to continue well into the 1980's, the introduction of new sources of sulphur should ease the situation and result in more modest prices albeit at higher levels. Prices in the 1980's and 1990's are expected to be maintained at higher levels as a reflection of increased production costs inspite of an easing supply situation. A fall in prices is not anticipated as this would effectively prohibit Frasch production, thereby reducing supply and triggering a realignment of prices.

It is expected that prices in 1978 $ will reach $70-80 per tonne exterminal Tampa. Prices for recovered product, which are normally discounted by upto $25 per tonne according to location, are expected to be more in line with Frasch prices particularly in East coast markets.

3. POTENTIAL MARKETS FOR EXXON'S SULPHUR

The major area of potential sales will be the existing sulphuric acid producers operating Frasch burning units. As illustrated in Figure 5, the majority of Frasch sulphur-burning plants are located in the Eastern half of the United States. Three concentrations are evident:

(1) Florida
(2) North East
(3) Mid West

The Florida market, in CRU's opinion should be the market of last resort and will remain the preserve of the Frasch producers and Gulf recovered producers. Exxon's recovered elemental sulphur from Green Bay or Evansville is unlikely to be competitive in view of the freight costs. Thus the two remaining areas are the North East - particularly New Jersey and Virginia and the Mid West-Illinois and Ohio.

The North East market is currently well served by the Gulf Frasch producers - (i) Texasgulf moving considerable quantities of sulphur through its Carteret NJ, Newall Pa, Norfolk Va and Morehead City NC molten sulphur terminals (ii) Duval operates terminals in the area at Norfolk Va and Wilmington NC. (iii) Freeport operates a terminal at Uncle Sam La.

Most sulphuric acid producers in the North East (with the exception of North Carolina which is served by Frasch producer operated terminals) are potential purchasers of recovered sulphur. These can be easily identified from the listing of sulphur burning acid producers in Table 23. The only constraint is likely to be the cost of freighting from Green Bay or Evansville to the Carteret and other New Jersey terminals. While the concentration of sulphuric acid producers in the Mid West is less dense than the North East, there is more scope to identify individual buyers. In the region there are two customer liquid sulphur terminals in operation, which are conveniently placed to serve the Evansville location.

(1) East St. Louis Ill. operated by Monsanto
(2) Wurtland Ky operated by Du Pont.

The East St. Louis terminal would be ideal for sales of sulphur to Allied Chemicals' plant at East St. Louis, where the annual sulphur requirement is 50,000 tonnes S. Products could be moved further up the Mississippi to Marseilles to serve the Illinois acid producers. A Green Bay location would also be favourably sited for potential sales to Illinois.

The Wurtland terminal unfortunately only serves Du Pont's acid plant at this location. The annual sulphur requirement of the plant is put at 60,000 tonnes S.

The Evansville location allows access to the Ohio River and the potential sales to Du Pont at Cleveland with an annual requirement of 56,000 tonnes and Minnesota Mining and Manufacturing at Copley with an annual requirement of 24,000 tonnes.

The list of potential buyers can be expanded to include Mobil at Depue Ill., National Distillers at Dubuque Ia., First Mississippi at Madison Ia., Du Pont at East Chicago Ind. and Stauffer at Hammond Ind. There seems adequate scope for sales of Exxon's 134,000 tonnes S to the above acid producers. There is however one possible constraint to the market - the impact of by-product acid either abatement or smelter. However, in view of the small sulphur tonnage produced by Exxon, this is not considered a major problem.

Table 23 : United States Sulphuric Acid Producers using Sulphur Feedstocks

Company	Location	Capacity ('000 tonnes)	Vulnerable	Comments
ALABAMA				
Reichold	Tuscaloosa	36	A	merchant acid.
Stauffer	Le Moyne	227	B	
ARKANSAS				
Allied	Helena	180	A	100% captive ferts.
Monsanto	El Dorado	104	C	merchant
Olin	Little Rock	80	A	merchant
CALIFORNIA				
Allied	Pittsburg	91		100% captive ferts.
Oxychem	Lathrop	213		100% captive ferts.
Valley Nitrogen	Helm	572		100% captive ferts.
COLORADO				
Union Carbide	Uravan	47		100% captive
FLORIDA				
Agrico	Donaldsonville Pierce	1082 1086		) 100% cap-) tive ferts.
Borden	Piney Point	535		100% captive ferts.
CF Industries	Bartow Plant City	1682 1429		) 100% cap-) tive ferts.
Englehard	Nichols	476		100% captive ferts.
Farmland	Green Bay	1138		100% captive ferts.
Gardinier	Tampa	1769		350,000 tonnes merchant
W.R. Grace	Bartow	1842		100% captive ferts.
IMCC	New Wales	1905		100% captive ferts.

Table 23 : United States Sulphuric Acid Producers using Sulphur Feedstocks (continued)

Company	Location	Capacity ('000 tonnes H_2SO_4)	Vulnerable	Comments
Oxychem	White Springs	1710		100% captive ferts.
Royster	Mulberry	425		100% captive ferts.
Swift	Bartow	190		100,000 tonnes merchant
USS Agri	Bartow	227		) 100% captive
	Ft Meade	444		) ferts.
GEORGIA				
American Cyanamid	Savannah	245	C	some merchant
Cities Services	Augusta	118	B	merchant
Columbia N	Moultrie	24	A	100% captive ferts.
Southern States Phosphates	Savannah	136	B	some merchant
IDAHO				
Beker	Conda	631		100% captive ferts.
Simplot	Pocatello	580		100% captive ferts.
ILLINOIS				
Allied	Chicago	145	C	116,000 tonnes = sulphur
American Cyanamid	Joliet	45	A	some merchant
Borden	Streater	32	A	100% captive
Mobil	Depue	380	B	320,000 tonnes merchant
Monsanto	Sauget	198	A	merchant
National Distillers	Tuscola	165	C	merchant
Swift	Calumet		A	100% merchant

Table 23 : United States Sulphuric Acid Producers using Sulphur Feedstocks (continued)

Company	Location	Capacity ('000 tonnes H_2SO_4)	Vulnerable	Comments
INDIANA				
Du Pont	East Chicago	340		
Stauffer	Hammond	272		some merchant
IOWA				
First Mississippi	Ft. Madison	474		100% captive ferts.
National Distillers	Dubuque	90	B	merchant
KENTUCKY				
Du Pont	Wurtland	192		
KANSAS				
National Distillers	Desoto	92	B	merchant
LOUISIANA				
Allied	Baton Rouge	91		
	Giesmar	454		100% captive ferts.
Beker	Taft	631		100% captive ferts.
Freeport	Uncle Sam	2032		100% captive ferts.
Olin	Shreveport	127		merchant
Stauffer	Baton Rouge	544		272,000 tonnes = sulphur
MAINE				
Delta Chem.	Searsport	63	C	40,000 tonnes merchant
MARYLAND				
Olin	Baltimore	318	C	merchant

Table 23 : United States Sulphuric Acid Producers using Sulphur Feedstocks (continued)

Company	Location	Capacity ('000 tonnes H_2SO_4)	Vulnerable	Comments
MASSACHUSETTS				
Monsanto	Everett	104	B	merchant
MICHIGAN				
Bay Chem	Bay City	32	A	merchant
MINNESOTA				
N. Ren Corp.	Pine Bend	91		70,000 tonnes sulphur
MISSISSIPPI				
Mississippi Chem Corp.	Pascagoula	943		400,000 tonnes merchant
MISSOURI				
W.R. Grace	Joplin	63	A	100% captive ferts.
NEW JERSEY				
American Cyanamid	Linden	218		
Du Pont	Gibbestown	100		
	Linden	295		
Essex Chem	Newark	180	C	some merchant
LJ & M La Place	Elmwood	91	B	merchant
NL Industries	Sayreville	544		100% captive
NEW MEXICO				
Climax	Monument	52		15,000 merchant
Kerr McGee	Grant	127		100% captive

Table 23 : United States Sulphuric Acid Producers using Sulphur Feedstocks (continued)

Company	Location	Capacity ('000 tonnes H_2SO_4)	Vulnerable	Comments
NEW YORK				
Allied	Buffalo	110		76,000 sulphur
Eastman Kodak	Rochester	4	A	100% captive
NORTH CAROLINA				
North East Chem	Wilmington	117	A	merchant
Swift	Wilmington	29	A	100% captive
Texasgulf	Lee Creek	1880		100% captive ferts.
USSAgri	Wilmington	41	C	100% captive ferts.
Wright Chem.	Riegelwood	60	B	merchant
OHIO				
American Cyanamid	Hamilton	82	B	
Coulton	Cairo	54		merchant
Du Pont	North Bend	159	B	
	Cleveland	195		
Minnesota Mining	Copley	68	B	merchant
OKLAHOMA				
Ozark	Tulsa	100		some merchant
PENNSYLVANIA				
Allied	Newell	163		100,000 tonnes - sulphur
S. CAROLINA				
WR Grace	Charleston	45		100% captive ferts.
TENNESSEE				
Ordnance	Tyner	77	A	captive

Table 23 : United States Sulphuric Acid Producers using Sulphur Feedstocks (continued)

Company	Location	Capacity ('000 tonnes H_2SO_4)	Vulnerable	Comments
TEXAS				
Du Pont	La Port	318		some merchant
Gulf Oil	Pt. Arthur	84		some merchant
Oxychem	Plainview	92	C	100% captive
Olin	Pasadena	453		100% captive ferts.
Stauffer	Ft. Worth	572)	C	some merchant
	Pasadena	408)		some merchant
VIRGINIA				
Allied	Front Royal	145)	B/C	
	Hopewell	218)		
Borden	Chesapeake	32	B	100% captive
Du Pont	Richmond	93	B	
Weaver Ferts	Norfolk	41	B	100% captive
W. VIRGINIA				
Allied	Nitro	127	B	
WYOMING				
Western Nuclear	Jeffery City	91		captive

Notes:
A. Plants considered as potential closures by 1985.
B. Plants considered as potential purchasers of by-product sulphuric available at competitive prices.
C. Plants consiered as possible purchasers of by-product and or recovered sulphur.

4. CONCLUSIONS

The current tight supply/demand position in the US sulphur market is expected to continue into the 1980's as identified in Table 22. Indeed, by 1990, on the basis of projected consumption rates the Western world is moving towards a 4 million tonnes S deficit. However, in view of the current price levels and expected developments, the bulk of hte shortfall will be met by increases from voluntary production, notably Frasch production in the United States and Mexico, increased imports of Polish sulphur and from remelted stockpiles of recovered sulphur in Canada.

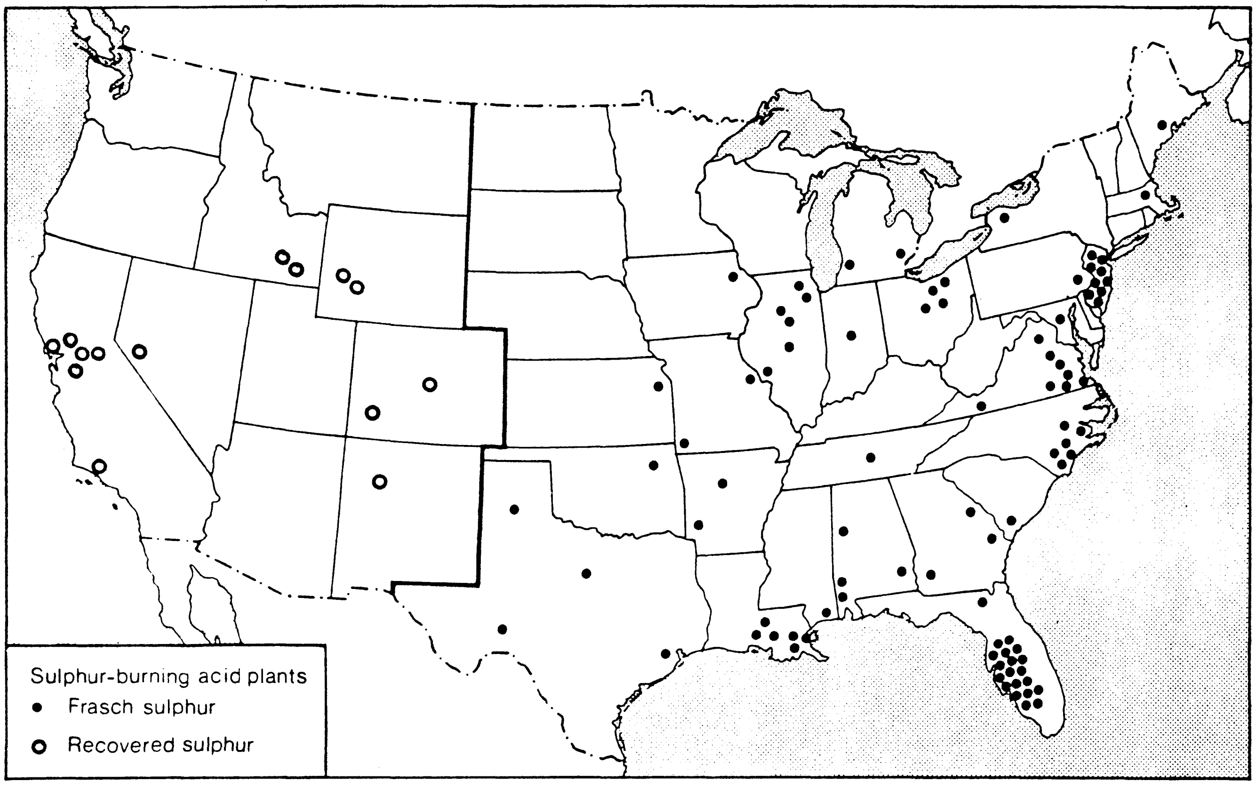
The development of this scenario and the continued upward trend in prices should result in Exxon having little difficulty in disposing of its meagre sulphur output. Prices in the 1990's are expected to reach between $70-80 (1978 $) per tonne ex terminal Tampa. There are however, considerable discounts offered by recovered producers over those of Frasch producers. Discounts are normally between $20-$25 per tonne according to location. Itis anticipated that given the tighter market conditions the discounts will be of more modest levels in 1980's particularly in the East Coast markets.

The market for Exxon sulphur will be the Mid West area, in view of the small quantity involved, it is considered unlikely that Exxon will have to secure more than a few purchasers.

Figure 4

Geographic distribution of sulphur terminals

Figure 5



Geographic distribution of sulphur-burning acid plants (1978)

APPENDIX A : THE MARKET FOR SULPHUR DIOXIDE

APPENDIX A : THE MARKET FOR SULPHUR DIOXIDE

1. INTRODUCTION

Sulphur dioxide, also known as sulphurous anhydride and sulphurous oxide is a colourless non-inflamable gas. It condenses at - 10°C at ordinary pressure to form a colourless liquid. Sulphur dioxide is produced by controlled burning of elemental sulphur or by roasting of metal sulphides. It is also recovered from stack gases.

2. SULPHUR DIOXIDE CAPACITY

There are 11 sulphur dioxide producers in the United States operating at 16 locations. Total domestic capacity has more than doubled since 1970 to over 265,000 tonnes.

Table 1 : Sulphur Dioxide Capacity ('000 tonnes)

1970	123
1973	128
1974	182
1975	182
1976	182
1977	189
1978	220
1979	265

Source: Mannesville Chemical Products

Table 2 : United States: Sulphur Dioxide Capacity ('000 tonnes)

Company	Location	Capacity
Ansul Co.	Marinette, Wis.	14
ASARCO	Tacoma, Wash.	45
Cities Service Co.	Copperhill, Tenn.	36
Essex Chemical Corp.	Newark, NJ	14
Industrial Chemicals Corp.	Penuelas, PR	2
National Distillers & Chem Corp.	Tuscola, Ill.	na
Olin Corp.	Curtis Bay, Md.	8
Scott Paper	Anacortes, Everett, Wash) Oconto Fall, La.)	*
Stauffer Chemical Corp.	Baton Rouge, La.	31
	Hammond, In.	9
	Houston, Tex.	31
	Martinez	18**
Virginia Chemicals Inc.	Bucks, Ala.	36
	Portsmouth, Va.	36
Witco Chemical Corp.	Trainer, Pa.	3

Note: * Captive production
** Project.

3. SULPHUR DIOXIDE PRODUCTION

During the 1970's production of sulphur dioxide grew at an annual average growth rate of 5 per cent. By 1978, production of sulphur dioxide had reached 149,680 tonnes.

Table 3 : U.S. Sulphur Dioxide Production ('000 tonnes)

1960	64.4
1965	91.6
1970	98.9
1973	99.8
1974	117.3
1975	132.4
1976	147.0
1977	138.8
1978	149.7

Source: USDC.

The growth in production in the mid 1970's resulted from the imposition of pollution control regulations. Whereas in the past by-product sulphur dioxide was discharged into the atmosphere the introduction of emission regulations resulted in a by-product sulphur dioxide problem. However, the availability of relatively cheap by-product sulphur dioxide in the market prompted a number of companies currently producing sulphur dioxide by sulphur burning to purchase by-product material.

4. SULPHUR DIOXIDE CONSUMPTION

Domestic demand has shown continued growth in the 1970's. In the current year the domestic US market is expected to exceed 200,000 tonnes.

Table 4 : U.S. Sulphur Dioxide Consumption ('000 tonnes)

1960	64
1965	92
1970	122
1973	150
1974	168
1975	174
1976	187
1977	192
1978	200

Source: Mannesville Chemical Reports.

Domestic demand has exceed production throughout the 1970's Canada, has remained the major source of imports.

The largest end use of liquid sulphur dioxide is in the manufacture of sodium hydrosulphate, produced by either the reaction of sodium formate or sodium hydroxide and sulphur dioxide. It is used as a reducing agent in vat dyeing and for pulp bleaching. Recent growth rates in this sector have averaged 6-7 per cent per annum. This has been due to. (1) The growth in the market for denim cotton which is vat dyed. (2) Its uses as a replacement for zinc hydrosulphate in ground wood bleaching, due to cost and the need to reduce zinc effluent.

The second major end use is the paper industry either for reduction of sodium chlorate to sodium dioxide or in the sulphate process. There has been little growth in this area as the use of the sulphate process is declining as pulp producers turn to the Kraft process which now accounts for 80 per cent of all wood pulp production.

The other major end use of liquid sulphur dioxide is in sugarbeet refining where it is used as a bleaching agent after lime treatment of the beet extract. Other uses are in the petroleum industry where it is used as a liquid solvent for extraction of aromatic compounds in lube oil manufacture.

Table 5 : End Use Pattern, 1977

Derivative	%
Total	100
Sodium hydrosulphate	40
Pulp and paper	20
Starch and sugar	10
Oil refining	5
Metal and ore refining	5
Caprolactam, detergents Sulphonations, food preservation and refridgeration	20

5. CONCLUSIONS

5.1 Future Developments

The future demand for liquid sulphur dioxide is forecast to be in the order of 5 per cent per annum. Strong growth in expected in dechlorination, inorganic chemicals and sugar end uses. The only exception to this upward trend will be in the sulphate pulping sector, in which usage will decline as sulphate pulpers switch from lime to magnesium oxide in the pulping process. Since by product calcium sulphate cannot be reused, magnesium sulphate can be decomposed to sulphur dioxide and both the magnesium and sulphur values recycled.

By-product sulphur dioxide availability is well in excess of demand, with producers having a number of options - conversion of sulphur dioxide to sulphur trioxide, sulphuric acid or back to elemental sulphur. Increasing amounts of sulphur dioxide will be recovered as sulphurous emission controls are implemented. The future supply/demand balance for sulphur dioxide will depend increasingly upon the market price covering the cost of recovery and purification.

5.2 The Market in Exxon's Region

In view of the small scale nature of the Mid West market, it is unlikely that demand in the area could sustain additional capacity. At the moment, the regional market is estimated to be in the order of 16,000 tpa. Of this Stauffer supply 10,000 tonnes from their nearby Hammond, Indiana plants.

It is CRU's opinion that the market is already served by existing suppliers and the incremental demand in the area does not merit investment in the industry where capacity utilisation is already low.

CHAPTER IV : MARKETS FOR SULPHURIC ACID

CHAPTER IV : MARKETS FOR SULPHURIC ACID

1. INTRODUCTION

86 per cent of the western world consumption of sulphur in all forms is destined for the manufacture of sulphuric acid. Sulphur for the manufacture of sulphuric acid is supplied in the form of brimstone, of sulphur in pyrite and of sulphur in other forms. In the latter category, the sulphur in the form of SO_2 in non-ferrous metal smelter gases is the largest single source of supply and the quantity in which it arises is not governed by sulphur demand but as a function of another industrial activity. Sulphuric acid manufactured from SO_2 in the exit gases at non-ferrous metal smelters is known as "fatal acid" ie. involuntary production.

The manufacture of sulphuric acid is predominantly integrated with its use. Throughout the world, the majority of manufacturers of fertilizers and of industrial products build a suitable sulphuric acid plant together with the manufacturing facilities of their chosen end-product, thus having vertically integrated installations.

The minority choose to depend on non-integrated sources of sulphuric acid supply. The degree of dependence varies from country to country and is a reflection of the complexity and sophistication of the respective heavy chemical industries and transportation systems.

Excluding the total dependence on imports of sulphuric acid in many under-developed countries, with negligibly small requirements of sulphuric acid, the highest degree of dependence on purchased sulphuric acid, i.e. supply sources outside the control of the sulphuric acid end-user, is in the USA. Approximately 34 per cent of the total sulphuric acid consumption in the USA is purchased by end-users from sulphuric acid manufacturers or from sulphuric acid merchants. In the case of manufacturers, the sulphuric acid for sale may represent the whole of their output or only a part which is surplus to their own requirements.

In Japan, the proportion of non-captive sulphuric acid consumed by end-users may well be even greater, but the definition of captive, integrated sulphuric acid supply and the dependence on purchased sulphuric acid is blurred. In Japan, the total structure of industry comprises a relatively small number of vast enterprises each of which is engaged in a wide variety of manufacturing activities. Thus within each of these industrial empires there is a substantial capability to produce sulphuric acid, especially smelter acid, which may then be marketed to end-users within the group or sold outside the group. There is also a strong emphasis on rationalisation and there is a significant incidence of "swapping" to avoid logistic problems and to minimise costs.

In Western Europe, the dependence on purchased supplies of sulphuric acid is about 11 per cent. The dependence is significant in Northwest Europe, notably in the highly industrialised region extending from the Ruhr in West Germany, through the Netherlands and Belgium into Northern France. It is also significant in a number of Mediterranean markets, where investment in sulphuric acid manufacturing facilities has lagged behind the evolution of sulphuric acid demand. The most notable examples are Turkey and Spain, the latter being a paradox as Spain possesses substantial sulphur resources in the form of pyrite.

In East Europe, there is some dependence on non-integrated sources of supply of sulphuric acid. Thus, quantities are railed from the USSR to end-users in a number of Comecon

Table 2 : H_2SO_4 Production by Sulphur Source
('000 tonnes 100 per cent H_2SO_4)

	NEW ACID				
	FROM NEW SULPHUR				
	Elemental S	H_2S	Smelter Gas	Pyrite	Total
1955	10,493	308	1,009	1,467	13,277
1960	11,180	599	1,074	1,547	14,400
1965	16,658	844	1,207	1,252	19,961
1970	20,531	611	1,668	1,134	23,944
1971	20,420	544	1,610	1,080	23,654
1972	22,633	499	1,696	807	25,635
1973	23,666	453	1,863	513	26,495
1974	26,034	408	2,033	392	28,867
1975	23,532	363	2,382	572	26,849
1976	23,643	318	2,928	690	27,579
1977	25,983	272	2,936	399	29,590
1978	na	na	na	na	na

	NEW ACID				
	FROM NEW SULPHUR				
	Total	Sludge Acids*	Total	Fortified Acids*	TOTAL ACID
1955	13,277	620	13,897	849	14,746
1960	14,400	1,099	15,499	724	16,223
1965	19,961	1,642	21,603	942	22,545
1970	23,944	1,694	25,638	1,148	26,786
1971	23,654	1,527	25,181	1,159	26,340
1972	25,635	1,561	27,196	1,091	28,287
1973	26,495	1,446	27,941	1,042	28,983
1974	28,867	1,453	30,320	684	31,004
1975	26,849	1,442	28,291	1,066	29,357
1976	27,579	1,451	29,030	1,181	30,211
1977	29,590	1,399	30,989	1,510	32,499
1978	na	na	34,720	933	35,653

Source: SRI

Note: * 1. Sludge acids ie. virgin acid produced by decomposition of spent acid from petroleum refining, sulphonation and petrochemical processes.
2. Recovered acids - brought back to strength by blending with new acid or oleum or concentrated and distilled.

countries, notably Czechoslovakia and Hungary, from Poland to GDR, Yugoslavia to Hungary and at times to Roumania. In addition, some of these countries eg. GDR and, until recently, Roumania depend on purchased sulphuric acid imported from West Europe.

As indicated above, the supply of sulphuric acid to non-integrated users may be effected by a manufacturer of sulphuric acid or by a sulphuric acid merchant. In order to fulfil his role as a credible, reliable and flexible source of supply the merchant is obliged to invest in infra-structure such as terminal facilities, storage and transportation, the latter extending in the case of international merchants to time of chartering or ownership of ocean tankers. As a corollary the merchant will as a rule, buy free-on-board/free-on-rail and sell cost and freight. This practice is probably the sulphuric acid merchant's greatest commercial strength.

In the closing months of 1978 the world supply of and demand for brimstone came into closer balance, with the result that market prices increased sharply, both for contracts and for spot deliveries. Both factors were reflected by sulphuric acid which became less readily available and increased in price. This study is thus being carried out at a time when, after a period of over 4 years of adequate or even excess supply and accompanying weak prices of brimstone, as well as of sulphuric acid, world markets have entered a period of short supply and rising prices.

2. UNITED STATES SULPHURIC ACID

2.1 Introduction

Sulphuric acid is the largest tonnage industrial chemical in the United States, production totalling 35,653,000 tonnes in 1978. Sulphuric acid is used in most industrial sectors but the phosphate fertilizer industry accounts for the major share - 60 per cent, the balance of consumption is spread between a wide range of industries - petroleum refining, 5 per cent; copper leaching 5 per cent, titanium dioxide, 3 per cent, hydrofluoric acid, 2 per cent, alcohols, 2 per cent; explosives, 2 per cent; aluminium sulphate, 2 per cent, ammonium sulphate 2 per cent iron and steel pickling, 2 per cent; cellulosics, 1 per cent, uranium milling, 2 per cent, surface active agents, 1 per cent, others, 12 per cent. In view of the wide range of end uses, sulphuric acid is often considered as an economic indicator. Sulphuric acid is particularly responsive to rapid changes in supply and demand largely because of the expense and difficulty of storing the product. Consequently inventories are kept at a minimum. Although buffered to some extent by the wide variety of outlets, in view of their relatively small individual market size, the fortunes of the sulphuric acid industry have been dependent upon phosphate fertilizers.

2.2 Sulphuric Acid Capacity

At the beginning of 1979, there were 73 companies producing sulphuric acid at 133 locations, with a total nameplate capacity of over 51,000,000 tonnes 100 per cent H_2SO_4.

Table 1 : U.S. Sulphuric Acid Capacity and operating rates ('000 tonnes pa 100 per cent H_2SO_4)

	Capacity	Operating rate %
1960	20475	76
1965	22755	95
1970	35380	73
1971	35712	71
1972	36529	74
1973	37338	75
1974	38570	79
1975	40882	69
1976	42072	69
1977	43327	72
1978	45560	77

Source: SRI

Of the above capacity, 81 per cent is produced from elemental sulphur feedstocks, 8 per cent from sludge acids, 8 per cent from smelter acids and 3 per cent from other sources - H_2S, pyrite etc.

Capacity is currently well in excess of production, from its peak operating rate of 95 per cent in the mid 1960's operating rates have since fluctuated between 69-80 per cent of total capacity. Prior to 1970 the typical operating level was generally 75-80 per cent. However several factors in the 70's have affected these rates: (i) A substantial incremental capacity has been introduced due to the construction of by-product acid plants particularly at copper smelters. Operating rates at such plants have generally been low as copper producers have invested in excess capacity so as not to inhibit metal production. (ii) The main market for sulphuric acid is the phosphate fertilizer sector, and consequently the operating rates in the acid sector have paralleled those of phosphate plants.

2.3 Sulphuric Acid Production

Total sulphuric acid production has grown from 14,746,370 tonnes 100 per cent H_2SO_4 to 35,912,000 between 1955 and 1978. Three marked phases can be identified. (1) the slow but steady growth over the period up to 1973, (2) the pre fertilizer price hike growth in 1974 and the consequent stagnation in 1975 and 1976, (3) over the past two years, spurred on by the growth in the phosphate fertilizer sector, output has increased by 5.7 million tonnes 100 per cent H_2SO_4.

As can be seen from Table 3, production of sulphuric acid by the contact process now dominates the industry. In 1955, of the 13.9 million tonnes of new acid production, 85 per cent was via the contact process; by 1976 (the last year for which chamber process production was recorded) this had increased to over 99 per cent - with only two chamber process plants remaining. The balance comprises fortified acid.

In terms of production by sulphur source, elemental sulphur accounts for the major share. In 1977, the burning of elemental sulphur by acid plants accounted for 88 per cent of total output of new acid. Of the remaining 12 per cent supplied by other sources, smelter gases accounted for 10 per cent (of which copper represented 7 per cent of the total) with H_2S and pyrite the remaining 2 per cent. There are several other small sources which have not been identified separately - SO_2, $FeSO_4$ and coke oven-gases.

Table 2 : H_2SO_4 Production by Sulphur Source
('000 tonnes 100 per cent H_2SO_4)

	NEW ACID				
	FROM NEW SULPHUR				
	Elemental S	H_2S	Smelter Gas	Pyrite	Total
1955	10,493	308	1,009	1,467	13,277
1960	11,180	599	1,074	1,547	14,400
1965	16,658	844	1,207	1,252	19,961
1970	20,531	611	1,668	1,134	23,944
1971	20,420	544	1,610	1,080	23,654
1972	22,633	499	1,696	807	25,635
1973	23,666	453	1,863	513	26,495
1974	26,034	408	2,033	392	28,867
1975	23,532	363	2,382	572	26,849
1976	23,643	318	2,928	690	27,579
1977	25,983	272	2,936	399	29,590
1978	na	na	na	na	na

	NEW ACID				
	FROM NEW SULPHUR				
	Total	Sludge Acids*	Total	Fortified Acids*	TOTAL ACID
1955	13,277	620	13,897	849	14,746
1960	14,400	1,099	15,499	724	16,223
1965	19,961	1,642	21,603	942	22,545
1970	23,944	1,694	25,638	1,148	26,786
1971	23,654	1,527	25,181	1,159	26,340
1972	25,635	1,561	27,196	1,091	28,287
1973	26,495	1,446	27,941	1,042	28,983
1974	28,867	1,453	30,320	684	31,004
1975	26,849	1,442	28,291	1,066	29,357
1976	27,579	1,451	29,030	1,181	30,211
1977	29,590	1,399	30,989	1,510	32,499
1978	na	na	34,720	933	35,653

Source: SRI

Note: * 1. Sludge acids ie. virgin acid produced by decomposition of spent acid from petroleum refining, sulphonation and petrochemical processes.
2. Recovered acids - brought back to strength by blending with new acid or oleum or concentrated and distilled.

Table 3 : H_2SO_4 Production by Process and by Strength ('tonnes 100 per cent H_2SO_4)

	BY PROCESS				BY STRENGTH*		
	Chamber	NEW Contact	Total	Fortified	100% H_2SO_4	Oleum (1)	TOTAL
1955	2,106	11,792	13,989	849	11,026	1,615	14,747
1960	1,706	13,794	15,500	724	12,850	1,667	16,224
1965	1,155	20,447	21,602	942	19,407	1,982	22,544
1970	291	25,346	25,637	1,148	23,807	2,686	26,785
1971	191	24,989	25,180	1,159	23,915	2,234	26,339
1972	130	27,198	27,328	1,091	25,799	2,362	28,419
1973	97	27,844	27,941	1,042	26,355	2,532	28,983
1974	119	30,202	30,321	676	28,482	4,314	30,997
1975	88	28,203	28,291	1,066	27,380	1,890	29,357
1976	73	28,956	29,029	1,181	28,282	1,513	30,210
1977	n.a.	n.a.	30,986	1,510	30,553	1,636	32,496
1978	n.a.	n.a.	34,720	933	n.a.	n.a.	35,653

Source: USDC
Note: * Contact only.

2.4 Sulphuric Acid Consumption

In 1978, consumption of sulphuric acid in the United States totalled 37 million tonnes 100 per cent H_2SO_4, a 9.5 per cent increase on the previous year.

The fertilizer industry has remained the major end user of sulphuric acid. In 1978, fertilizer production consumed over 24 million tonnes 100 per cent H_2SO_4 or 65 per cent of the total. The development of the fertilizer sector has been one

(1) Oleum or fuming sulphuric acid contains free SO_3 dissolved in the acid. Can be expressed in terms of percentage H_2SO_4 equivalent.

Table 4 : Consumption of Sulphuric Acid
('000 tonnes 100 per cent H_2SO_4)

	Fertilizer Materials	Petroleum refining	Copper	Alcohols	Titanium dioxide	Aluminium Sulphate	Cellulosics	U_3O_8 Processing
1960	6979	1542	n.a.	1570	1583	435	620	432
1965	11135	1987	n.a.	1888	1585	532	771	200
1970	14527	1993	726	1764	1577	591	625	234
1971	15247	1796	839	1340	1450	590	642	216
1972	17183	1837	998	1260	1427	651	660	239
1973	17652	1700	1043	1246	1403	681	624	263
1974	18568	1710	1088	1288	1340	693	592	256
1975	19935	1696	1225	838	1027	650	362	274
1976	20462	1706	1656	1062	1069	643	422	311
1977	23015	1646	1565	1033	855	643	441	356
1978	24149	1656	1814	1084	885	644	431	499

	Iron & Steel Pickling	Surface active agents	Batteries	Phenol	Hydro fluoric Acid	Others	Total
1960	973	n.a.	86	157	469	3180	17731
1965	871	316	104	128	628	3733	23876
1970	467	346	114	184	907	4410	28465
1971	404	318	123	90	930	3689	27674
1972	340	340	136	97	952	3582	29702
1973	390	334	139	105	1016	3684	30280
1974	363	336	136	91	1061	4912	32434
1975	254	320	122	69	872	2897	30542
1976	308	324	140	83	801	2743	31730
1977	308	281	172	94	775	2722	33906
1978	318	295	177	27	780	4368	37127

Source: SRI

of the main factors promoting the growth of sulphuric acid consumption. Usage by the fertilizer sector has increased by 350 per cent since 1960, when the industry accounted for only 39 per cent of usage.

It is significant to note that the major growth factor in the fertilizer sector has been the emergence of the phosphoric acid industry. As detailed in table 6 , consumption of sulphuric acid used in the production of phosphoric acid has increased from 3.3 million tonnes in 1960 to 21.8 million tonnes in 1978. The spectacular increase in the growth of consumption of phosphoric acid, has almost been matched by the decline of consumption in the production of single superphosphates.

Table 5 : Distribution of Sulphuric Acid by end use

	1960	1965	1970	1978
Total	100.0%	100.0%	100.0%	100.0%
of which				
Fertilizers	39.4	46.6	60.8	65.0
Petroleum refining	8.7	8.3	7.0	4.5
Copper	n.a.	n.a.	2.6	4.9
Alcohols	8.9	7.9	6.2	2.9
Titanium dioxide	8.9	6.6	5.5	2.4
Hydrofluoric acid	2.6	2.6	3.2	2.1
Aluminium sulphate	2.5	2.2	2.1	1.7
Others	29.0	25.8	12.6	16.5

Outside of the fertilizer sector, the second major area of usage is in copper leaching where usage in 1978 reached 1.8 million tonnes. The usage of sulphuric acid in petroleum refining has declined marginally over the years. In effect the petroleum refining industry is largely a recycling industry, with disappearance in one form or another negligible. The consumption of sulphuric acid by the other industries remains stable, although its consumption in the production of alcohols and titanium has declined.

Table 6 : Consumption of Sulphuric Acid by Fertilizers ('000 tonnes 100 per cent H_2SO_4)

Year	Phosphoric Acid	Single Super-phosphate	Ammonium Sulphate	Others	Total
1960	3306	2057	1308	308	6979
1965	7225	1808	1696	406	11135
1970	11581	1088	1472	386	14527
1971	12514	1017	1340	376	15247
1972	14410	1100	1293	380	17183
1973	14767	1005	1455	425	17652
1974	15433	1133	1506	496	18568
1975	17267	786	1467	415	19935
1976	18027	622	1406	407	20462
1977	20567	552	1477	419	23015
1978	21854	467	1420	408	24149

Source: SRI

Total shipments of sulphuric acid exceed the level of production in respect of deliveries of acid used in the oil refinery alkylation processes, steel pickling, nitric acid concentration etc. and then reshipped as "spent acid" for use in other sectors. The main source of so called "spent acid" is the oil refinery industry while its main uses are in the regeneration of concentrated sulphuric acid by burning waste acid in a sulphuric acid plant, purification by hydrolysis, concentration by evaporation or fortification by the addition of SO_3.

2.5 Pricing Patterns

Sulphuric acid prices are normally quoted list price ex works. Historically actual prices have been contracted at levels considerably below listed prices. Discounts are available for large accounts, contract customers and to match specific competition.

Table 8 : Sulphuric Acid List Price ($ per tonne)

	East Coast
1968	31.4
1970	31.4
1971	30.6
1972	30.6
1973	30.6
1974	37.0
1975	42.3
1976	42.3
1977	42.3
1978	48.3
1979	54.0

Note: In Mid 1979 list prices for other regions are as follows:

Gulf Coast	47.9
Midwest	51.4
West Coast	52.4

Source: Chemical Marketing Reporter.

In order to illustrate the discrepancy between list prices and actual prices, it is necessary to compare the prices quoted in Table 8, with the average shipment value recorded by the USDC.

Table 9 : U.S. Sulphuric Acid Shipment Value ($ per tonne)

	All Shipments	Interplant transfers (1)	Commercial Shipments
1955	17.44		
1960	n.a.		
1965	15.12		
1970	17.29		
1971	17.36		
1972	16.53		
1973	16.64	15.50	16.79
1974	21.20	20.66	21.23
1975	29.37	28.70	29.43
1976	28.07	27.09	29.07
1977	30.00	30.68	29.90
1978			

Source: USDC.
Note: (1) Company transfers from primary plant to downstream plant.

As can be seen, throughout the 1970's average shipment values have been well below the prevailing list prices. The sale price for larger transactions has in fact been below the average value of all shipments which has been boosted by the inclusion of all sales, oleum and other premium grades.

The price structure of the sulphuric acid industry is particularly complex as the market is dominated by two groups of producers with vastly differing sales considerations.

(1) Virgin producers ie. those operations based upon brimstone burning. Even within this group there are two distinct types of producers - (a) those based upon local recovered sulphur supplies and having less expensive feestocks. (b) those based upon Frasch sulphur - which itself is a voluntary production product. Virgin producers are voluntary acid manufactures, for whom acid is their primary sales product.

(2) Fatal acid producers - are involuntary producers - mainly smelters, for whom acid is a by-product disposal problem.

The situation has been one in which voluntary producers have been caught in a cost/price crisis. Faced with increasing sulphur prices, they have been forced to cut their prices in order to compete with smelter acid producers.

This is amply evidenced in Table 10, in which prices in Arizona reflect the abundance of smelter acid supplies. Historically the problem was less severe for virgin producers as sulphur supplies were relatively inexpensive and fatal acid producers tended to serve the local markets. However, as sulphur prices increased, and under the pressure of a buoyant copper market Mountain States smelters were forced to look further afield for markets to ensure disposal of their by-product acid. Because of their low "production cost", fatal acid producers were able to remain competitive over longer distances, and have been prepared to sell their product at prices substantially below those of virgin producers. In actual terms, Arizona smelters have been prepared to sell acid for as little as $6 per tonne fob to Nebraska and Kansas. Indeed in extreme cases, where smelters have had insufficient onsite storage, they have been prepared to move acid for as little as $3 per tonne rather than jeopardize metal production. As a result current smelter acid spot prices are in the order of $6-18 per tonne 100 per cent tanks Western works; $14-16 per tonne 100 per cent tanks Gulf and $7-18 per tonnes 100 per cent tanks New Mexico.

These spot market prices for smelter acid can be compared to list prices of $57-60.80 West Coast; $52.75-55.75 US Gulf; and 58.65 Mid West for Virgin acid.

The net result of the uneasy relationship between virgin and fatal acid producers has been major price cutting in the Mid West, where delivered prices have been in the range of $25-$48 per tonne. Indeed an indication of the degree of competition in the Mid West is that the largest customer in Illinois is able to secure its annual requirement at delivered costs of under $30 per tonne from a range of suppliers.

Table 10 : Sulfuric Acid Unit Shipment Value; Selected States[a] (Dollars Per Short Ton)

	Arizona	California	Florida	Illinois
1965	21.18	16.62	12.75	19.00
1970	14.15	18.49	15.92	19.51
1971	16.57	20.42	15.52	18.95
1972	16.26	22.72	13.93	19.60
1973	11.92	18.05	15.34	20.98
1974	12.71	23.52	21.16	36.26
1975	12.51	35.80	31.93	45.18
1976	10.36	34.83	30.91	38.31
1977	12.49	37.55	29.71	34.49

	Louisiana	New Jersey[b]	Pennsylvania	Texas[c]
1965	n.a.	20.64	17.93	16.17
1970	14.39	26.12	22.19	16.48
1971	15.73	25.08	26.84	16.45
1972	16.44	22.63	20.02	15.34
1973	17.58	24.05	20.77	14.97
1974	21.02	33.43	24.89	16.80
1975	37.46	38.16	32.52	31.27
1976	41.29	50.25	31.68	29.80
1977	43.95	47.80	31.21	31.37

Note: a. Data are for all shipments, interplant transfers and commercial.
b. Data for 1965-1974 include New York.
c. Data for 1965-1972 include Oklahoma.

Source: USDC.

2.6 Prevailing Commercial Arrangements

The situation up until the mid 1960's was that commercial sales accounted for approximately 50 per cent of US sulphuric acid deliveries. However, since this time, the trend has been steadily moving towards greater onsite usage and as a corollary a decline in the merchant sulphuric acid market. In 1977 of the total deliveries estimated at 32.9 million tonnes, 10 million tonnes were commercial sales and 1.1 million tonnes interplant transfers.

Table 11 : Development of U.S. Sulphuric Acid Deliveries ('000 tonnes 100 per cent H_2SO_4)

	Onsite Usage	Interplant Transfers	Commercial Sales	Total
1960	9,480	421	7,552	17,453
1965	12,248	1,116	10,505	23,869
1970	15,337	1,340	10,555	27,232
1971	15,633	1,226	9,612	26,471
1972	16,750	1,191	10,658	28,599
1973	17,326	997	10,949	29,272
1974	19,071	983	11,461	31,515
1975	20,521	900	9,430	30,851
1976	21,201	385	10,552	32,138
1977	21,798	1,114	9,993	32,905

Source: USDC.

Of the 30 per cent of deliveries which represent the merchant market, the greater proportion of these derive from the smelter producers. Marketing of by-product sulphuric acid is either handled directly by the producer, or in the case where no local market exists, production surpluses are handled by major chemicals companies.

The following list details some of the current arrangements between acid producers and their "sales agents".

(i) Allied - handles sales of acid for Bunker Hill's Kellogg, Idaho production. It is also responsible for the smelter acid sales for Climax Molybdenum's Fort Madison, Ia. and Langoth Pa. production and New Jersey Zinc's Palmerton NJ. acid production.

(ii) Stauffer sells a proportion of ASARCO's Tacoma, Wash. and Corpus Christi, Texas acid production.

(iii) Cities Services sells Jersey Miniere's, Clarskville, Tenn. acid output and Inspiration Consolidated Coppers' Arizona smelter acid.

(iv) Anamax/Philipp Bros. handles Magma Copper, Arizona smelter acid output.

(v) Canadian Industries Ltd. (CIL) handles smelter acid for a range of Canadian smelters, Anaconda Copper Co. and some of Kennecott Copper's.

(vi) Thompson Hayward act as agents for Mississippi Chemicals.

(vii) WR Grace handles a large proportion of Ozark - Mahoning acid production.

In addition to the above commercial arrangements a number of major producers market their product directly - American Cyanamid, ASARCO (which has a contract with Olin), Beker, Borden, Coulton Chemicals, Du Pont, Kennecott Copper, Monsanto, Olin and Stauffer.

2.7 Outlook

By the early 1980's the United States' sulphuric acid industry will commission an additional 3.1 million tonnes of capacity, thereby raising the total to 48,673,000 tonnes per annum H_2SO_4. Seven projects are currently in hand, 2 smelter and 5 brimstone. The above capacity will be more than adequate to cover incremental demand until 1983.

Demand for sulphuric acid is forecast to reach 64 million tonnes H_2SO_4 by 2000.

Table 12 : Development of Sulphuric Acid Demand

1985	42.3
1990	49.2
2000	64.0

The above demand forecast derives from an assessment of the requirements of the fertilizer and industrial end users.

The requirement of the United States industry cannot be considered outside the context of a North American market. Although there appears to be a slight tightening of the domestic US supply/demand balance by 1990, there is little possibility of this in reality in view of the substantial Canadian sulphuric acid surplus. In addition to the existing Canadian capacity of 4.36 million tonnes H_2SO_4, a further 2 million tonnes H_2SO_4 of capacity is proposed. The obvious market for this product will be the Northern US market.

In the 1990's, it is unlikely that the growth in demand will outstrip supply. The metals markets are expected to remain buoyant thereby increasing potential smelter acid supplies. Furthermore, an enormous potential exists in the form of abatement sulphuric acid from power stations. It is estimated that abatement sulphuric acid production potential is in the order of 25 million tpa H_2SO_4. The impact of abatement acid is not expected to be felt until the mid 1990's as the economics of recovery of acid from power plants are currently restrictive. However, it is expected that this acid will become a major force in the market in the 1990's.

3. MARKETS FOR EXXON'S SULPHURIC ACID

By the late 1980's, Exxon could have over 700,000 tonnes 100 per cent H_2SO_4 by-product acid for disposal. It is proposed to examine the markets for this acid on the following regional/state basis.

(1) North Central States:
Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Ohio and Wisconsin.

(2) South Central Region
- Alabama, Arkansas, Kentucky, Mississippi and Tennessee

(3) The South East
- Florida, Georgia and Louisiana

3.1 North Central States

3.1.1 Outline of the Industry

Illinois

The Illinois sulphuric acid market is generally considered to be one of the more complex of the North Central States. Capacity currently stands at 1,388,000 tonnes 100 per cent H_2SO_4, operated by eleven companies. Of these producers, six are based upon elemental sulphur, one on zinc smelting, one on $FeSO_4$ and the remaining companies on a combination of elemental sulphur and sludge acids. In terms of the acid end use, seven of the producers are phosphate fertilizer manufacturers, despite the long haul of phosphate rock from either the Florida or North Carolina producers. (However the twin economic pressures of long haul rock and purchased elemental sulphur have caused Beker to put their Marseilles unit on standby basis). The remaining producers all depend upon the prevailing merchant market for the disposal of their acid.

State sulphuric acid production has declined from its record production of over 1.5 million tonnes in 1965, to around 850,000 tonnes in the 1970's.

Table 12 : Illinois - Sulphuric Acid Production and Shipments ('000 tonnes 100 per cent H_2SO_4)

	Production	Shipments
1955	1134.4	760.0
1960	1229.8	608.7
1965	1546.1	499.3
1970	1021.9	699.4
1971	705.8	578.7
1972	660.9	592.4
1973	983.4	559.7
1974	876.8	426.7
1975	837.0	360.9
1976	830.1	527.3
1977	912.8	593.6
1978	814.3	n.a

Source: USDC

Shipments on the other hand have remained relatively stable over the years in comparison to production levels. In 1977, the last year for which shipment data is available, total shipments in Illinois were 593,600 tonnes. At the moment there are no significant imports from Canada into the region, although this state of affairs is viewed as temporary, following the construction of CIL's major terminal at Chicago in the 1980's. There is little domestic acid moved into the State. The merchant market in the State comprises a number of small to medium outlets, in addition to Olin's requirement of 300,000 tonnes pa for its phosphoric acid unit at Joliet. Olin's acid requirement is currently supplied by smelter acid from Arizona and Virgin acid from Freeport's Gulf operation.

Indiana

Sulphuric acid facilities are limited to two companies, Du Pont and Stauffer, with a combined capacity of 612,000 tonnes pa. Du Pont's operation is based entirely on elemental S, while Stauffer's production is split between elemental S and sludge. Both producers are located within the Chicago conurbation, with the marketing of their surplus output mainly as merchant product to the oil refining industry. Production data for Indiana have not always been available due to the limited number of producers. The following tables detail production data, when available. Figures in brackets are CRU estimates.

Table 13 : Indiana - Sulphuric Acid Production ('000 tonnes 100 per cent H_2SO_4)

1955	510.1
1960	440.3
1965	(700)
1970	(625)
1971	(575)
1972	619.6
1973	584.1
1974	474.4
1975	(400)
1976	(360)
1977	(380)
1978	(360)

Source: USDC, CRU estimates.

Both Du Pont and Stauffer produce sulphuric acid in accordance to their captive requirement from elemental S feedstock (mainly recovered sulphur from local refineries, in 1978 estimated State production from its three refineries was 75,000 tonnes S).

Iowa

The State boasts 3 acid producers - (i) First Mississippi Chemicals; an integrated fertilizer producer using captive sulphuric acid (thought to be on the verge of closure) based on elemental S feedstock (ii) National Distillers; a merchant acid producer based on elemental S feedstocks and (iii) Climax Molybdenum; merchant acid producer based upon smelter acid. As was the case with Indiana, production statistics are incomplete. The following table incorporates actual production data and CRU estimates.

Table 14 : Iowa - Production of Sulphuric Acid ('000 tonnes 100 per cent H_2SO4)

1955	(77)
1960	74.2
1965	74.7
1970	(320)
1971	(450)
1972	(550)
1973	(560)
1974	(580)
1975	(420)
1976	(300)
1977	(360)
1978	(300)

Source: USDC, CRU estimates.

Michigan

Michigan currently uses less than 180,000 tpa of sulphuric acid with steel-pickling and alum manufacture being major end uses. The market has contracted in size from over 300,000 tpa in the early and mid-1960's when a higher proportion of steel-picklers was based on sulphuric acid and when Michigan was a minor producer of superphosphate fertilizers. Imports of Canadian acid currently account for approximately half of the state's requirement, the balance coming from northern Ohio, from acid plants in the Chicago area and from Michigan's sole remaining producer, Bay Chemicals. Bay Chemicals operates a 14,000 tpa unit at Bay City using cheap sulphur from a nearby refinery.

Since 1976, the region has been supplied with acid imported from Canada. CIL has developed a market for around 20,000 tpa of direct sales out of its recently opened Detroit terminal. In 1977, CIL negotiated supply contracts for up to 45,000 tpa with Detroit Chemical and 18,000 tpa with American Cyanamid thereby including both companies to shut down production units.

The history of sulphuric acid output by producers in Michigan is shown in Table 15.

Table 15 : Michigan - Sulphuric Acid Production ('000 tonnes 100 per cent H_2SO_4)

1955	237
1960	294
1965	293
1970	153
1971	151
1972	120
1973	92
1974	88
1975	74
1976	(55)
1977	(32)
1978	(14)

Source: USDC, CRU estimates.

Minnesota

State capacity comprises N-Ren's plant at Pine Bend which is part based on sludge acid. Output from the plant is used mainly by oil refiners. Production history is unavailable but output is thought to be in the range 60-70,000 tonnes pa.

Missouri

Sulphuric acid is produced by 2 smelters and one elemental S based plant. Amax and St. Joe Minerals produce acid from lead smelting, which is marketed as merchant acid in the vicinity. St. Joe has the facility to move its products on the inland waterway.

Grace's plant at Joplin, was originally designed to feed the phosphoric acid plant. Production of acid is currently marketed as merchant product. The State's production of sulphuric acid is detailed below.

Table 16 : Missouri - Production of Sulphuric Acid ('000 tonnes 100 per cent H_2SO_4)

1955	(320)
1960	(320)
1965	(350)
1970	476.1
1971	455.3
1972	479.7
1973	495.7
1974	446.3
1975	394.2
1976	424.4
1977	332.9
1978	165.4

The reduction in production in 1978 is due to the closure of NL Industries 413,000 tonnes plant at St Louis.

Ohio

Ohio currently uses around 635,000 tpa of sulphuric acid. The market is divided with the northern industrial corridor between Cleveland and Toledo consuming around two-thirds of the state's total requirement and the balance of usage occurring in the areas of Cincinatti and Columbus. There is generally little interchange between these two marketing zones. As in Michigan, the market has declined since the 1960's again with the decline in usage by the steel industry and the cessation of superphosphate manufacture being the primary causes. In northern Ohio, the oil refining industry is a substantial consumer of sulphuric acid. In both areas, a significant proportion of acid production is based on brimstone although alkylation-waste-acid is used as a feedstock at a plant in Toledo and smelter gas acid is produced in Columbus. Small quantities of acid based on coke-oven H_2S are manufactured at Middletown.

Ohio currently has 8 sulphuric acid plants with total capacity of 772,000 tpa (Table 18). A major change in Ohio took place in 1973 when Allied Chemical shut its 200,000 tpa Cleveland plant when faced with the alternative of a major investment in pollution control equipment. Prior to the Allied closure a steady but modest reduction in the total size of the Ohio industry had followed successive closures of acid plants linked to manufacture of single superphosphate.

More recently, the Hamilton plant of American Cyanamid was scheduled to close at the end of 1978, to be replaced by acid from a new Cyanamid plant in Louisiana.

The closure of Allied's plant in 1973 actually left the State with a healthier fit between production and consumption, as Allied's competition had the capacity to supply the market previously supplied from the closed plant. A significant boost to CIL's sales also occurred at that time when Allied's customers had to examine alternative sources of supply. The actual history of H_2SO_4 production in Ohio is shown below.

Table 17 : Ohio - Sulphuric Acid Production ('000 tonnes 100 per cent H_2SO_4)

1955	676
1960	673
1965	639
1970	491
1971	433
1972	468
1973	508
1974	481
1975	542
1976	458
1977	493

Source: USDC.

Currently, we would estimate Ohio's acid production at about 550,000 tpa supplemented by imports of 50-60,000 tpa of Canadian acid sold by CIL out of its Cleveland distribution terminal.

Table 18 : Stucture of the Industry - North Central States ('000 tonnes 100 per cent H_2SO_4)

COMPANY	LOCATION	CAPACITY	FEEDSTOCKS	COMMENTS
ILLINOIS		1388		
Allied	Chicago	145	80% S, 20% Sl	
Amax Lead and Zinc	Sauget	112	100% Zn	103,000 tonnes merchant
American Cyanamid	Joliet	45	100% S	Some merchant
Beker*	Marseilles	190	100% S	190,000 tonnes merchant
Borden	Streator	32	100% S	Captive onsite
Mobil	Depue	380	100% S	57,000 tonnes merchant
Monsanto	Sauget	198	100% S	
National Distillers	Tuscola	165	90% S, 10% Sl	165,000 tonnes merchant
Pfizer Inc.	East St Louis	14	$FeSO_4$	Some merchant
Shell Oil	Wood River	77	10% S, 90% Sl	23,000 tonnes merchant
Swift	Calumet	30	100% S	30,000 tonnes merchant
INDIANA		612		
Du Pont	East Chicago	340	100% S	
Stauffer	Hammond	272	55% S, 45% Sl	Some merchant
IOWA		655		
First Mississippi	Fort Madison	474	100% S	Virtually all captive
National Distilers	Dubuque	90	100% S	90,000 tonnes merchant
Climax Molybdenum	Fort Madison	91	60% S, 40% Mo	91,000 tonnes merchant

(continued)

Table 18 : Structure of the Industry ('000 tonnes 100 per cent H_2SO_4) (continued)

COMPANY	LOCATION	CAPACITY	FEEDSTOCKS	COMMENTS
KANSAS		92		
National Distillers	De Soto	92	90% S, 10% Sl	92,000 tonnes merchant
MICHIGAN		32		
Bay Chems.	Bay City	32	100% S	
MINNESOTA		91		
N- Ren*	Pine Bend	91	70% S, 30% Sl	83,000 tonnes merchant
MISSOURI		194		
AMAX	Boss	54	100% Pb	54,000 tonnes merchant
WR Grace	Joplin	63	100% S	All captive
St Joe Minerals	Herculaneum	77	100%, Pb	23,000 tonnes merchant
OHIO		772		
American Cyanamid	Hamilton	82	100% S	Some merchant
ARMCO Inc.	Middleton	6	100% H_2S	
ASARCO	Columbus	45	100% Zn	45,000 tonnes merchant
Coulton Chem.	Cairo	54 163	100% S 15% S, 53% Sl 30% H_2S	217,000 tonnes merchant
Du Pont	Cleveland North Bend	195 159	100% S	
Minnesota Mining & Man. Co.	Copley	68	100% S	68,000 tonnes
REGION		3,639		

Notes: *Recovered Sulphur.

Key : S = elemental Sulphur.
Sl = Sludge Acid.

Table 19 : Production of New Sulphuric Acid by Area 1973-1978

	1973	1974	1975	1976	1977	1978
Northeast	*	*	1728.6	1579.8	1487.8	1635.6
New England	136.7 (1)	152.7 (1)	*	*	*	*
Pennsylvania	705.7	625.4	431.3	536.8	753.2	523.5
Middle Atlantic	2207.7	2128.6	*	*	*	*
New Jersey	*	*	1109.3	844.1	753.2	906.1
New York & New Jersey	1501.8	1503.2	*	*	*	*
Other	*	*	188.1 (7)	198.8 (7)	204.3 (7)	195.3 (7)
North Central	3423.6	3129.4	2805.0	2550.5	2621.3	2582.4
Illinois	983.3	876.8	836.9	830.1	912.8	814.1
Michigan	91.5	87.9	74.4	*	*	*
Missouri	495.7	*	394.2	424.4	332.9	165.4
Indiana	584.1	474.4	*	*	*	*
Ohio	508.4	524.8	542.2	457.7	493.2	505.7
Other	760.5 (2)	719.1 (2)	957.3 (3)	838.5 (3)	882.3 (3)	1097.1 (3)
South	18710.2	20563.4	19645.1	20514.9	22498.1	25281.4
Alabama	341.1	323.7	264.0	*	*	47.4
Arkansas	321.7	310.9	287.2	*	*	28.7
Florida	7760.1	8248.9	8831.7	9017.3	10502.7	12159.2
Georgia	457.3	478.6	375.9	425.1	439.7	449.2
Louisana	3398.6	3924.6	3864.7	4235.4	4507.0	4906.7
North Carolina	972.9	1359.6	*	*	*	82.6
Virginia	640.2	647.6	518.0	511.5	520.8	473.5
Texas & Oklahoma	2507.7	3002.7	1984.3	2056.4	2609.8	2911.4
Delaware & Maryland	638.1	608.5	432.6	*	*	119.7
Other	1672.4 (4)	1658.1 (4)	3086.5 (5)	4269.2 (6)	3918.8 (6)	3322.0 (5)

Note: (1) Includes Maine, Massachusetts and Rhode Island.
(2) Includes Wisconsin, Minnesota, Iowa and Kansas.
(3) Includes Wisconsin, Minnesota, Iowa, Kansas, Indiana and Michigan.
(4) Includes West Virginia, Kentucky, Tennessee, Mississippi and South Carolina.
(5) Includes (4) and North Carolina.
(6) Includes (4) and Alabama, Arkansas, North Carolina, Delaware and Maryland.
(7) Includes Maine, Massachusetts and New York.

* Denotes a change in regional composition.

3.2.2 Supply Outlook

Although the level of production and the market improved in 1977, this upturn was relatively short lived, with production falling in 1978 due to plant closures in Missouri and reductions of operating rates in Illinois.

The market in the North Central regional is expected to increase by the addition of about 300,000 tonnes by 1990, on the assumption that there are no new developments in phosphate fertilizer production. No additional capacity is designated for the region, although a number of operations could substantially increase output in the 1980's should demand merit. The most obvious example is Climax's operation at Fort Madison. In addition to potential supply expansions in the region, the area provides a particularly attractive market for smelter acid producers in the Western and Mountain States and Canadian by-product acid producers.

In their study, the EPA/TVA did not forecast any power plants to produce sulphuric acid in the North West Central region until the premium for clean fuels reached 50c/MBtu. At 50c/MBtu, three states would turn to production of acid - Illinois, where capacity was forecast to be 413,000 tonnes H_2SO_4 of power plant acid at three locations; Indiana, in which capacity was expected to reach 254,000 tonnes H_2SO_4 at two locations and Missouri, which is forecast to have 320,000 tonnes at three locations.

In the East North Central region, the EPA/TVA consider Michigan and Ohio to be the most likely sources of by-product sulphuric acid from power plants. On the basis of an EPA/TVA alternative

---

(1) Alternative clean fuel is defined by EPA/TVA as "the value assigned to premium price for fuel that will meet the sulphur oxide emission standard".

clean fuel of 35c/MBtu production levels of 390,000 tonnes in Michigan and 230,000 tonnes in Ohio are predicted.

3.1.3 Demand Outlook

The growth in market in the region is expected to derive from two main sources.

(i) Incremental consumption - in the region, there are no proposals to expand fertilizer production, hence the growth will be purely industrial. The growth rate in the period upto 1990 is expected to be approximately 2 per cent pa in view of the absence of any fertilizer expansions.

(ii) The closure of sulphuric acid plants burning elemental S - economics of production may enforce the closure of the regions sulphur burning plants.

None of the elemental S burning plants in the West Central States area, can be considered entirely secure in the longer term. For instance in Illinois, the plants of Borden, Cyanamid, Monsanto and Swift are all considered likely candidates for closure. Borden and Swift are considered particularly vulnerable as the acid is used in the production of single superphosphates. Mobil and National Distillers would be open to offers of cheap by-product acid in a period of sustained surplus, and American Cyanamid's plant at Joliet has been on the verge of closure for a number of years. Other vulnerable plants in the region are considered to be WR Grace at Joplin Mo. and National Distillers at Dubuque. Both plants are expected to succumb to pressure from by-product acid.

The market in Ohio depends upon the reaction of the three sulphur burning plants to the cost of compliance with clean air regulations. The plants in question are those of Du Pont at North Bend, and Cleveland and Minnesota Mining and Manufacturing at Copley. (It is of interest to note that Allied closed its Cleveland plant when faced with the alternative of pollution control investment). If supplies of by-product acid were available from either smelters or abatement sources these three plants could well close in the 1980's. In Michigan, the potential power plant acid identified by EPA/TVA would fill the local market.

3.1.4 Prospects for Sales of Exxon's Sulphuric Acid

The West North Central States market will remain particularly competitive in the coming years - three main groups of producers have a vested interest in the market.

(i) The Western States smelter acid producers, who are currently railing acid into the region - Utah and Montana are expected to move a considerable proportion of their surplus acid toward the region in the 1980's. However, in the 1990's and possibly even by the late 1980's increased local demand in the Western States should reduce the volume of acid railed to the North Central market.

(ii) Canadian by product smelter acid producers - as a result of the developments in the East Canadian smelting industry, by product acid supplies could increase by between 1.3-2.6 million tonnes by the mid 1980's. The following companies will have additional acid available - Falconbridge Nickel, Noranda, Texasgulf, INCO and Hudson Bay Mining and Smelting. This will be in addition to CIL's existing acid commitments.

(iii) The region's existing smelters are all expected to remain in production until at least the end of the century.

The main prospect for acid sales in the region would be an approach to the existing elemental S burning acid plants - the most vulnerable plants are: National Distillers at Dubuque, Iowa, and Mobil at Depue, Illinois. Other plants identified by EPA/TVA as potential users of by-product acid are Du Pont at its North Bend, and Cleveland plants, WR Grace at Joplin, and Minnesota Mining and Manufacturing at Copley.

3.2 South Central Region

The South Central region for the purposes of this report is defined as : Alabama, Arkansas, Kentucky, Mississippi, and Tennessee.

Sulphuric acid production data for any of the above South East States is unfortunately unavailable, as it is included under the "others" category by the USDC.

As detailed overleaf regional acid capacity currently stands at almost 3 million tonnes 100 per cent H_2SO_4, operated by 9 companies. Of the regional capacity 8 of the producers are based upon elemental sulphur, with Cities Services' acid production based upon pyrite.

The market potential in the area is limited, firstly it is not an area of particularly heavy industrial output, and consequently the growth in consumption of non-fertilizer end uses is minimal. Secondly there are no known fertilizer projects in the area which would necessitate additional sulphuric acid capacity. Thus any movement into this market will have to be through the closure of elemental S burning plants in favour of purchased sulphuric acid. Sulphuric acid producers currently burning sulphur, which are vulnerable to increased S costs and susceptible to offers of by product acid, are considered to be:-

(i) Reichold Chemicals at Tuscaloosa Ala., which uses acid for production of phenol. This plant was identified by EPA/TVA as likely to turn to by-product acid.

Table 20 : Structure of the Industry - South Central States ('000 tonnes 100 per cent H_2SO_4)

COMPANY	LOCATION	CAPACITY	RAW MATERIALS	COMMENTS
ALABAMA		263		
Reichold Chemicals	Tuscaloosa	36	100% S	Captive phenol production
Stauffer	Le Moyne	227	100% S	
ARKANSAS		336		
Allied	Helena	182	100% S	Captive
Monsanto	El Dorado	104	100% S	104,000 tonnes merchant
Ohio	Little Rock	80	100% S	80,000 tonnes merchant
KENTUCKY		182		
Du Pont	Wurtland	182	100% S	
MISSISSIPPI		943		
Mississippi Chem. Corp.	Pascogoula	943	100% S	566,000 tonnes fertilizers 377,000 tonnes merchant
TENNESSEE		1220		
Cities Services	Copperhill	1143	95% Pyrite 5% Cu	
Army Munitions	Tyner	77	100% S	
Jersey Miniere	Clarksville	136	100% Zn	136,000 tonnes merchant

(ii) Stauffer at Le Moyne Ala. - currently uses elemental sulphur for production of acid. This plant was also identified by EPA/TVA as likely to cease production and purchase acid.

Of the other plants, production is either based upon recovered sulphur or pyrite and they produce merchant product. The elemental S based merchant acid producers may elect to cease production and re-sell by-product acid.

The above market appears somewhat limited by comparison with the North Central area. This market development is constrained further by the potential for abatement sulphuric acid production. The three states of Alabama, Kentucky and Tennessee are considered to be prime candidates for the potential production of abatement acid. According to the EPA/TVA study the following potential production levels are forecast:-

Alabama	62,436	tonnes 100 per cent H_2SO_4
Kentucky	570,040	tonnes 100 per cent H_2SO_4
Tennessee	519,203	tonnes 100 per cent H_2SO_4
TOTAL	1,151,679	

Potential production of this magnitude would cleary swamp the limited local market of these states, where capacity is currently put at 1,668,000 tonnes 100 per cent H_2SO_4.

3.2.1 Prospects for sales of Exxon's Sulphuric Acid

It is considered unlikely that the regional market could absorb the whole of the proposed 700,000 tonnes of acid to be produced by Exxon. As suggested earlier, market potential is limited, the only scope being the closure of captive acid plants using elemental sulphur. In the event of by-product abatement acid being unavailable, an approach to Stauffer (NB Stauffer already handles substantial quantities of merchant smelter acid - swap deal could possibly be arranged) and Reichold Chemicals, which has a limited requirement, is recommended.

3.3 The Southern East

The whole of the Florida sulphuric acid industry, the capacity of which currently stands at 14.18 million tonnes 100 per cent H_2SO_4, is based upon elemental sulphur plants. Virtually all of the sulphuric acid production in the state is used captively, with only a small proportion of product moved as merchant acid. The dependence upon elemental sulphur for the production of sulphuric acid is also pronounced in Louisiana, Georgia, and Mississippi. In Louisiana, of the 4,552,270 tonnes 100 per cent H_2SO_4 capacity over 4 million tonnes of capacity is based upon elemental sulphur. The balance is based upon sludge acid. In Georgia, all sulphuric production is based upon elemental sulphur. It is considered improbable that by-product sulphuric acid produced at either Green Bay or even Evansville could displace the Frasch or recovered sulphur producers in the region.

4. CONCLUSIONS

4.1 U.S. Industry

By the end of 1978, there were some 187 power plants in the United States thought to be out of compliance with the current applicable emissions regulations. The total level of SO_2 emissions from these plants equates to a sulphuric acid production of 15.87 million tonnes 100 per cent H_2SO_4. The total potential abatement by-product acid from this source would account for 45 per cent of total current acid production. However, as a number of plants would choose to purchase clean fuel, and others opt for limestone scrubbing, EPA/TVA project production of sulphuric acid at between 2,317,540 tonnes and 5,075,680 tonnes.

Having established the level of potential abatement acid production at between 2.3 and 5 million tonnes H_2SO_4, the other major source of supply will be smelter by-product acid. Capacity of smelter acid is estimated to be in the order 5.4 million tonnes with a further 500,000 tonnes to be commissioned in 1979. The balance of capacity comprises brimstone burning and sludge acid plants.

With this background and the expected increased movement of Canadian smelter acid into the United States there seems to be little alternative to a prolonged period of potential oversupply in the US/North American acid market. There is however, some potential for a slight easing of the situation.

(i) The reduction in brimstone burning capacity in the short term, as elemental sulphur prices continue to firm. However, the supply of recovered elemental sulphur is expected to become a major sulphur source by the 1980's and may mitigate extensive closures.

(ii) The closure of some acid plants in the face of compliance with emisison control regulations - as in the case of Allied, which closed its 200,000 tonnes H_2SO_4 Cleveland plant in 1973.

(iii) The failure of abatement acid production to reach the production levels anticipated by the EPA/TVA.

In view of the oversupply situation which is expected to continue well into the 1980's there will be little scope for producers to exert much upward pressure on prices. This will become more evident as by-product producers expand their share of the market. Inevitably this will act as a depressant to any price increases which may be proposed by the brimstone virgin acid producers in response to higher sulphur prices.

In an evaluation of the future sulphuric acid prices that would be expected by a potential producer, a number of important factors must be taken into consideration.

(1) Exxon's sulphuric acid will be involuntary and any sales/ marketing programme must consider that this material poses a by-product disposal problem, and eventually a potential production bottleneck. As detailed earlier, distress sales by Mountain States' smelters have been made to California markets for as little as \$3 per tonne fob as the necessity to dispose of the acid due to insufficent onsite storage has over-ridden all other factors. The philosophy that sulphuric acid is merely a by-product problem, should not however, deter the involuntary producer from attempting to obtain a high net back on the acid. However, it must be evaluated along side the potential bottleneck problems from failure to dispose of the acid.

(2) Potential disposal problems will undoubtedly arise from fluctuating levels of production as sulphuric acid production is dependent upon the vagaries of metal processing. It is therefore unlikely that any new smelter acid producer could expect any major consumer to pay near list prices for fatal acid, for which neither the composition nor production could be guaranteed.

(3) Competition from other acid producers - the expected weak market conditions will force fatal acid producers to accept lower net backs, because of their unfavourable locations, than virgin acid producers. Exxon's main competition will not come from virgin acid producers but from other fatal acid operations. As stated earlier, Mountain States' producers are prepared to accept net backs of only $6.00 per tonne as they are forced to seek markets as far afield as Nebraska and Kansas. The expansion of production in the Mountain States areas will undoubtedly force smelter producers to look to the Mid West market. The other major competitor will be the Canadian industry. Canadian fatal acid directed towards the Mid West will increase substantially as CIL expands its range of suppliers and develops its market penetration. Net backs on Canadian acid are estimated to be slightly higher in certain cases than those of the New Mexican and Arizona smelters. In Table 21 estimated net backs for Canadian fatal acid for delivery to the North Central region are presented.

Table 21 : Estimated Net backs for Canadian Fatal Acid (1979 $ per tonne)

	West North Central	East North Central
INCO	10	16
Noranda	5	11
Texasgulf	4	10

Exxon will be faced with a highly competitive market in the North Central States by the mid 1980's. In view of its position as a new supplier of fatal acid, it is CRU's opinion that Exxon cannot expect its potential net back to be related to the prevailing list prices or indeed to the net backs achieved by virgin acid producers.

In the present climate of price cutting in the North Central States area, prices are in the order of $35 per tonne delivered, inspite of list prices of $58 per tonne. In the future there will be a slight firming of prices as fatal acid suppliers attempt to improve their net backs by following the price rises posted by virgin producers. CRU estimates that the delivered price in the North Central States by 1990 will remain in the range $35-40 on the basis of 1978 constant $. For which Exxon can expect a netback in the order of $10-15 per tonne if the acid is sold through a broker, judging by net backs of Canadian smelters.

4.2 Potential Market for Exxon's Sulphuric Acid

The market of potential interest to Exxon's production of sulphuric acid can be identified as the North Central region; although some potential for movement of acid to the Gulf area exists, it depends entirely upon the freight element from Evansville to the major consuming centre in central Florida.

Two options are open to Exxon with regard to its sales of acid.

(1) Direct Sales - in the market review, a number of existing producers who may wish to cease production should competitively priced by-product be available were identified.

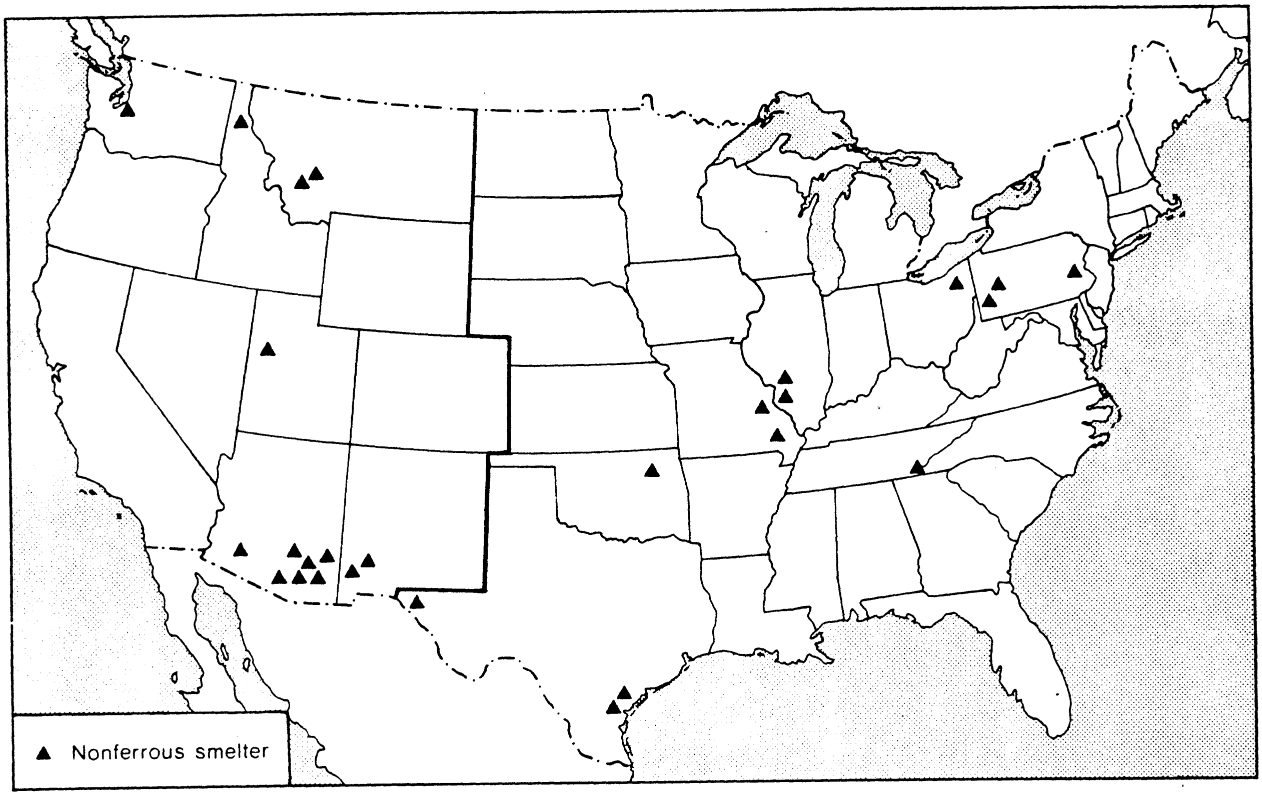
(i) In the East of the region - Minnesota Mining and Manufacturing at Copley and Du Pont at Cleveland could be susceptible to offers of acid supplies.

(ii) In the West of the region - National Distillers at Dubuque, Mobil at Depue, are potential purchasers, while the sulphur burning plants of Du Pont at North Bend and W.R. Grace at Joplinare considered vulnerable.

In addition to direct sales to major consumers, the existing merchant markets in the area could absorb up to 100,000 tonnes H_2SO_4 for the wide range of industrial end uses.

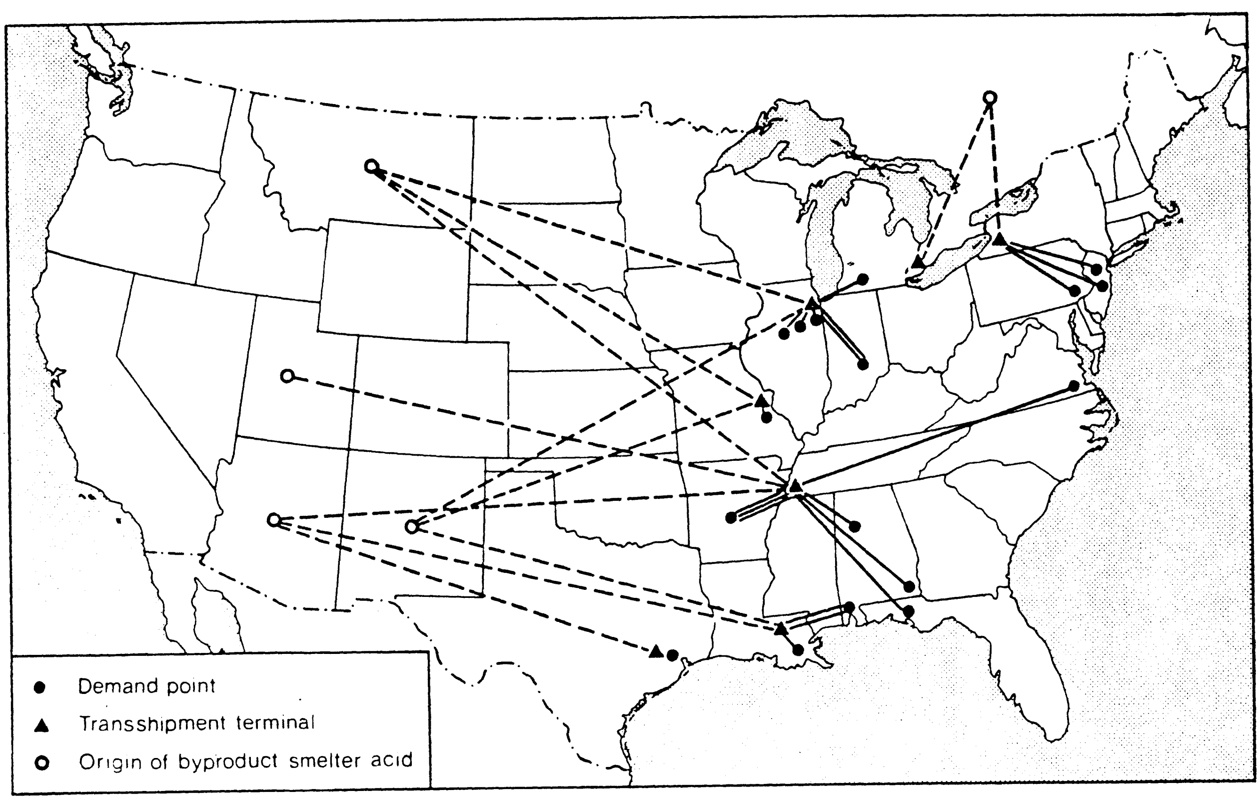
(2) Merchant Sales - the retailing of sulphuric acid requires a substantial investment in both storage and distribution facilities if a substantial proportion of sales are made to smaller consumers. An attractive alternative to handling sales internally, is to negotiate with a major sulphuric acid broker. The most obvious candidate is CIL, which in 1979 expects to move 1.3 million tonnes of sulphuric acid. By the early 1980's CIL expects to handle up to

Figure 1



Geographic distribution of smelter byproduct acid plants in 37 Eastern States and 11 Western States

Figure 2



Geographic distribution of assumed supply and demand for western and Canadian acid

1.7 million tonnes pa of sulphuric acid (excluding the output of Anaconda, with whom it is negotiating). In the longer term, they expect deliveries to reach 3 million tonnes.

The main advantage in dealing with a broker is the assured movement of the product, and the saving in distribution costs. In the case of CIL, contracts are normally of ten year duration, plus a one year introduction period, during which acid production will be irregular, and a two-three year run down period at the end. The arrangement usually operates as follows:

(i) The acid smelter invests in 6 weeks production storage equivalent, while CIL guarantees an equivalent storage, thereby assuring a 3 month total capacity.

(ii) The smelter, once the plant is operating normally, informs CIL of its expected production for the year, and sales are agreed on the basis of ± 10 per cent. Any deviation from this is costed on the basis of existing spot prices ie. (a) if the smelter exceeds the agreed figure his net back on the surplus tonnage reflects the current market price. (b) if production is below the agreed level, the smelter bears the cost of the CIL's incursion into the spot market to maintain its sales obligations. The wider the range of supplies CIL deals with the less severe will be the dislocation from any individual failing to meet his contracted volume.

It is CRU's recommendation that Exxon seek assistance in its marketing of sulphuric acid. Direct approaches to major consumers could be made to the existing producers identified above, and the balance of production be offered to CIL or a similar organization. The commercial arrangements section of the report listed the companies currently moving smelter acid. Details of CIL product specifications are reproduced overleaf.

APPENDIX "A"

To the Agreement made as of the 1st day of January, 1980 between C-I-L Chemicals, Inc. and

Qualify the SPECIFICATION ACID as loaded into CILCI's transportation equipment

Acid Strength (Commercial 66° Be Acid)	
On each shipment	Not less than 93.2 per cent, nor greater than 95.0 per cent by weight.
Iron (Fe)	
On each shipment	
- From 1st Acid Plant	50 ppm maximum
- From 2nd Acid Plant	35 ppm maximum
Sulphur Dioxide (SO_2)	
On each shipment	50 ppm maximum
Colour	
On each shipment	40 Hazen units maximum
Appearance	
On each shipment	No visible suspended particles
Mercury (Hg)	
On each shipment	3 ppm maximum
Average of 4 consecutive monthly composite samples	1 ppm maximum
Total oxides of nitrogen including nitrates expressed as nitrate	
On each shipment	5 ppm maximum
Average of 4 consecutive composite samples	2 ppm maximum
Copper (Cu)	
On each shipment	5 ppm maximum
Monthly composite sample	2 ppm maximum
Annual average analysis of monthly composite samples	1 ppm maximum

APPENDIX "A" (Continued)

Zinc (Zn)

On each shipment	5 ppm maximum
Monthly composite sample	2 ppm maximum
Annual average analysis of monthly composite samples	1 ppm maximum

Nickel (Ni)

On each shipment	5 ppm maximum
Monthly composite sample	2 ppm maximum
Annual average analysis of monthly composite samples	1 ppm maximum

Lead (Pb)

On each shipment	5 ppm maximum
Monthly composite sample	2 ppm maximum
Annual average analysis of monthly composite samples	1 ppm maximum

Arsenic (As)

On each shipment	1 ppm maximum
Monthly composite sample	0.1 ppm maximum

Note: With respect to each of the contaminants identified herein, where a more liberal specification is provided for samples taken in respect of individual shipments of Specification Acid than for composite samples representing all shipments of such Acid during certain periods, it is understood that the more liberal specification shall continue to apply to samples from individual shipments until the composite samples indicate non-compliance with the more exacting specification. In such event, however, the more exacting specification shall apply and continue to apply to samples taken from individual shipments until the composite samples have met the more exacting specifications during the period or periods covered by such composite samples.

APPENDIX "B"

To the Agreement made as of the
1st day of January, 1980 between
C-I-L Chemicals, Inc. and

QUALITY OF START-UP ACID AS LOADED INTO CILCI's TRANSPORTATION EQUIPMENT

Acid Strength	Not less than 93.2 per cent by weight
Sulphur Dioxide (SO_2)	50 ppm maximum
Chlorides	50 ppm maximum
Metallic Impurities other than Mercury (Hg)	Up to 10 times the limits allowed in Appendix "A"
Mercury (Hg)	3 ppm maximum
Colour and appearance	No specification
Total oxides of nitrogen including nitrates expressed as nitrate	200 ppm maximum

APPENDIX C : UNITED STATES SULPHURIC ACID CAPACITY

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
AMAX, INC. (cont.)			
AMAX Zinc Company, Inc., subsidiary			
Sauget, Illinois	124	100% Zn smelter gas	8% captive, 92% domestic merchant
Climax Molybdenum Company, division			
Fort Madison, Iowa	100	60% S, 40% Mo smelter gas	100% domestic merchant
Langeloth, Pennsylvania	83	40% S, 60% Mo smelter gas	100% domestic merchant
AMERICAN CYANAMID COMPANY			
Industrial Chemicals Division			
Hamilton, Ohio	90	100% S	Captive for alum and merchant
Joliet, Illinois	50	100% S	Captive for alum and merchant
Linden, New Jersey	240	100% S	Captive and merchant
New Orleans, Louisiana	528	100% S	Captive and merchant
Savannah, Georgia	270	100% S	Captive for TiO_2 and merchant
ARMCO INC.			
Middletown, Ohio	7	100% H_2S from coke-ovens	Captive for ammonium sulfate and merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
ALLIED CHEMICAL CORPORATION			
Anacortes, Washington	92	5% S, 90% sludge, 5% H_2S	n.a.
Baton Rouge, Louisiana	100	100% S	n.a.
Buffalo, New York	120	70% S, 30% sludge	n.a.
Chicago, Illinois	160	80% S, 20% sludge	n.a.
Elizabeth, New Jersey	200	10% S, 90% sludge	n.a.
Front Royal, Virginia	160	100% S	n.a.
Geismar, Louisiana	500	100% S	≤100% captive for fertilizers
Helena, Arkansas	200	100% S	≤100% captive for fertilizers
Hopewell, Virginia	240	100% S	n.a.
Newell, Pennsylvania	180	60% S, 40% sludge	n.a.
Nitro, West Virginia	140	100% S	n.a.
North Claymont, Delaware	350	10% S, 80% sludge, 10% H_2S	n.a.
Pittsburg, California	100	100% S	n.a.
Richmond, California	150	5% S, 90% sludge, 5% H_2S	n.a.
AMAX, INC.			
Amax - Homestake Lead Tollers (Managed by AMAX Lead Company of Missouri, a subsidiary of AMAX, Inc.)			
Boss, Missouri	60	100% Pb smelter gas	100% domestic merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
ASARCO INCORPORATED			
Columbus, Ohio	50	100% Zn smelter gas	100% domestic merchant
Corpus Christi, Texas	70	100% Zn smelter gas	5% on-site, 95% domestic merchant
East Helena, Montana	105	100% Pb smelter gas	100% domestic merchant
El Paso, Texas	335	Cu and Pb smelter gas	9% captive, 91% domestic merchant
Hayden, Arizona	180	100% Cu smelter gas	10% captive, 90% domestic merchant
Tacoma, Washington	54	100% Cu smelter gas	6% on-site, 94% domestic merchant
ATLANTIC RICHFIELD COMPANY			
The Anaconda Copper Company, subsidiary			
Anaconda, Montana	200	100% Cu smelter gas	10% captive for Cu leaching, 90% merchant (uranium and fertilizers)
BEKER INDUSTRIES CORP.			
Conda, Idaho	700	100% S	100% on-site for fertilizers
Marseilles, Illinois	210	100% S	100% domestic merchant
Taft, Louisiana	700	100% S	100% on-site for fertilizers
BORDEN INCORPORATED INTERNATIONAL			
Borden Chemical Division Smith-Douglass			
Chesapeake, Virginia	35		
Piney Point, Florida	590	100% S	≤100% captive for fertilizers
Streator, Illinois	35		

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
C F INDUSTRIES, INC.			
Bartow Phosphate Complex			
Battow, Florida	1,855	100% S	100% on-site for fertilizers
Plant City Phosphate Complex			
Plant City, Florida	1,575	100% S	100% on-site for fertilizers
CITIES SERVICE COMPANY, INCORPORATED			
Columbian Division			
Monmouth Junction, New Jersey	35	SO_2 off-gas from production of iron oxide from iron sulfate	n.a.
North American Minerals Group			
Augusta, Georgia	130	100% S	n.a.
Copperhill, Tennessee	1,260	5% Cu smelter gas, 95% pyrites	n.a.
North American Petroleum Group			
Lake Charles, Louisiana	210	83% sludge, 17% H_2S	n.a.
CLIMAX CHEMICAL COMPANY			
Monument, New Mexico	54	100% S	70% captive (HCl and sodium sulfate), 30% domestic merchant
COLUMBIA NITROGEN CORPORATION			
Moultrie, Georgia	26	100% S	100% on-site for fertilizers

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
COMMONWEALTH OIL REFINING COMPANY			
Penuelas, Puerto Rico	39	88% sludge, 12% H_2S	97% on-site for alkylation and water treatment, 3% merchant
COULTON CHEMICAL CORPORATION			
Oregon, Ohio	180	15% S, 55% sludge, 30% H_2S	100% domestic merchant
Cairo Chemical Corporation, subsidiary			
Cairo, Ohio	60	100% S	100% domestic merchant
DELTA CHEMICAL CORPORATION			
Searsport, Maine	69	100% S	35% captive for aluminum sulfate and ammonium sulfate, 65% merchant
DIAMOND SHAMROCK CORPORATION			
Diamond Shamrock Oil and Gas Company			
Dumas, Texas	35	95% sludge, 5% H_2S	80% captive for alkylation, 20% domestic merchant
E. I. DU PONT DE NEMOURS & COMPANY, INC.			
Biochemicals Department			
La Porte, Texas	350	S and sludge	n.a.

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
E. I. DU PONT DE NEMOURS & COMPANY, INC. (cont.)			
Chemicals, Dyes and Pigments Department			
Burnside, Louisiana	510	S and sludge	n.a.
Cleveland, Ohio	215	100% S	n.a.
Deepwater, New Jersey	90	100% S	n.a.
East Chicago, Indiana	375	100% S	n.a.
Gibbstown, New Jersey	110	100% S	n.a.
Linden, New Jersey	325	100% S	n.a.
North Bend, Ohio	175	100% S	n.a.
Richmond, Virginia	95	100% S	n.a.
Wurtland, Kentucky	200	100% S	n.a.
EASTMAN KODAK COMPANY			
Eastman Organic Chemicals			
Rochester, New York	5	100% S	100% captive
ENGLEHARD MINERALS & CHEMICALS CORPORATION			
National Zinc Company, subsidiary			
Bartlesville, Oklahoma	96	100% Zn smelter gas	domestic merchant
Philipp Brothers Division Conserv (department of Phillips Brothers)			
Nichols, Florida	525	100% S	100% on-site for fertilizers

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
ESMARK, INC.			
Swift Agricultural Chemicals Corp., subsidiary			
Bartow, Florida	210	100% S	46% on-site for fertilizers, 54% domestic merchant
Calumet City, Illinois	33	100% S	100% domestic merchant
Dothan, Alabama	25	100% S	100% captive
Wilmington, North Carolina	32	100% S	84% on-site, 16% domestic merchant Plant is presently leased to local operators
ESSEX CHEMICAL CORPORATION			
Industrial Chemicals Division			
Newark, New Jersey	180	95% S, 5% SO_2 from flue-gas recovery system	Captive and merchant
FARMLAND INDUSTRIES, INC.			
Green Bay, Florida	1,254	100% S	100% on-site for fertilizers
FIRST MISSISSIPPI CORP.			
FIRSTMISS INC., subsidiary			
Fort Madison, Iowa	552	100% S	99% on-site for fertilizers, 1% domestic merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
FREEPORT MINERALS COMPANY			
Freeport Chemical Company, division			
Uncle Sam, Louisiana	2,240	100% S	99% on-site for fertilizers, 1% domestic merchant
GARDINER, INC.			
(owned by French financial and private interests)			
Tampa, Florida	1,950	100% S	80% on-site for fertilizers 20% merchant (domestic and export)
GEORGIA-PACIFIC CORPORATION			
Bellingham, Washington	22	100% S	57% captive, 43% domestic merchant
W. R. GRACE & CO.			
Agricultural Chemicals Group			
Bartow, Florida	910	100% S	≤100% on-site for fertilizers
Charleston, South Carolina	50		
Joplin, Missouri	70		
Bartow Chemical Products (joint venture with USS AGRI-CHEMICALS)			
Bartow, Florida	1,120		
GULF OIL CORPORATION			
Port Arthur, Texas	93	100% S	on-site for petroleum alkylation and domestic merchant

[redacted]

COMPANY AND LOCATION	CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
GULF RESOURCES & CHEMICAL CORPORATION			
The Bunker Hill Company, subsidiary			
Kellogg, Idaho	249	Zn and Pb smelter gases	1% on-site, 99% domestic merchant
GULF + WESTERN INDUSTRIES, INC.			
Gulf + Western Natural Resources Group			
New Jersey Zinc Division			
Palmerton, Pennsylvania	160	10% Zn smelter gas	1% captive, 99% domestic merchant
INDUSTRIAL CHEMICALS CORPORATION			
Penuelas, Puerto Rico	35	100% S	merchant
INSPIRATION CONSOLIDATED COPPER COMPANY			
Inspiration, Arizona	485	100% Cu smelter gas	68% on-site for copper leaching, 32% domestic merchant
INTERNATIONAL MINERALS & CHEMICAL CORPORATION			
New Wales Chemicals, Inc., subsidiary			
New Wales, Florida	2,100	100% S	100% captive for fertilizers

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
JERSEY MINIERE ZINC COMPANY			
(joint venture of UNION MINIERE [Belgium] and GULF + WESTERN INDUSTRIES, INC., Natural Resources Group)			
Clarksville, Tennessee	150	100% Zn smelter gas	Domestic merchant
KENNECOTT COPPER CORPORATION			
Metal Mining Division			
Chino Mines Division			
Hurley, New Mexico	150	100% Cu smelter gas	Merchant
Ray Mines Division			
Hayden, Arizona	280	100% Cu smelter gas	Captive and merchant
Utah Copper Division			
Salt Lake City, Utah	577	100% Cu smelter gas	Captive and merchant
KERR-McGEE CORPORATION			
Kerr-McGee Nuclear Corporation, subsidiary			
Grants, New Mexico	140	100% S	Captive for uranium milling
L. J. & M. LA PLACE COMPANY			
Elmwood, New Jersey	100	100% S	Domestic merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
MINNESOTA MINING AND MANUFACTURING COMPANY			
Chemical Resources Division			
Copley, Ohio	75	100% S	100% merchant
MISSISSIPPI CHEMICAL CORP.			
Pascagoula, Mississippi	1,040	100% S	60% on-site for fertilizers, 40% domestic merchant
MOBIL OIL CORPORATION			
Mobil Chemical Company, division			
Phosphorus Division			
Depue, Illinois	420	100% S	85% on-site for fertilizers, 15% domestic merchant
MONSANTO COMPANY			
Avon, California	135	Sludge and H_2S	50% captive, 50% domestic merchant; jointly owned with TOSCO CORPORATION
El Dorado, Arkansad	115	100% S	100% domestic merchant
Everett, Massachusetts	115	100% S	100% domestic merchant
Sauget, Illinois	218	100% S	some captive, rest domestic merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
NATIONAL DISTILLERS AND CHEMICAL CORPORATION			
U.S. Industrial Chemicals Company, division			
DeSoto, Kansas	102	90% S, 10% sludge	100% domestic merchant
Dubuque, Iowa	98	100% S	100% domestic merchant
Tuscola, Illinois	170	100% S	2% on-site, 98% domestic merchant
NEWMONT MINING CORPORATION			
Magma Copper Company, subsidiary			
San Manuel, Arizona	450	100% Cu smelter gas	1% on-site, 99% domestic merchant
N L INDUSTRIES, INC.			
Titanium Pigment Division			
Sayreville, New Jersey	600	100% S	Most captive, primarily for TiO_2; some merchant
NORTHEAST CHEMICAL COMPANY			
Wilmington, North Carolina	130	100% S	Domestic merchant
N-REN CORPORATION			
North Star Division			
Pine Bend, Minnesota	100	70% S, 30% sludge	10% captive for aluminum sulfate, 90% merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
OCCIDENTAL PETROLEUM CORPORATION			
Hooker Chemical Corporation, subsidiary			
Agricultural Products Group			
Agricultural Products East Division			
White Springs, Florida	1,884	100% S	100% captive for fertilizers
Agricultural Products West Division			
Lathrop, California	235	100% S	≤100% captive for fertilizers
OLIN CORPORATION			
Olin Chemicals Group			
Baltimore, Maryland	350	100% S	100% domestic merchant
Beaumont, Texas	210	52% sludge, 48% H_2S	100% domestic merchant
North Little Rock, Arkansas	88	100% S	100% domestic merchant
Pasadena, Texas	500	100% S	100% on-site for fertilizers
Shreveport, Louisiana	140	100% S	100% domestic merchant
PENNWALT CORPORATION			
Ozark-Mahoning Company, subsidiary			
Tulsa, Oklahoma	110	100% S	Captive and merchant (oil refining and fertilizers)

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
PFIZER INCORPORATED			
Minerals, Pigments & Metals Division			
Easton, Pennsylvania	15	SO_2 off-gas from production of iron oxide from iron sulfate	Captive (pigments) and merchant (steel pickling)
PHELPS DODGE CORPORATION			
Ajo, Arizona	100	100% Cu smelter gas	Captive, mostly for copper leaching, and merchant
Hidalgo, New Mexico	1,150		
Morenci, Arizona	600		
Western Nuclear, Inc. subsidiary			
Jeffrey City, Wyoming	35	100% S	Mostly captive for uranium milling, some merchant for petroleum refining
Riverton, Wyoming	75		
PRESSURE VESSEL SERVICE INC.			
Bay Chemical Co., subsidiary			
Bay City, Michigan	37	100% S	Merchant
REICHHOLD CHEMICALS, INC.			
Tuscaloosa, Alabama	40	100% S	100% domestic merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
RICHARDSON-MERRELL, INC.			
J. T. Baker Chemical Co., subsidiary			
Phillipsburg, New Jersey	7	n.a.	100% domestic merchant
RHOM AND HAAS COMPANY			
Rohm and Haas Texas, Inc., subsidiary			
Deer Park, Texas	700	8% S, 92% sludge acid from acrylic monomer production	95% on-site for acrylic monomer, 5% domestic merchant
ROYSTER COMPANY			
Mulberry, Florida	468	100% S	≤100% captive for fertilizers
ST. JOE MINERALS CORP.			
Herculaneum, Missouri	75	95% Pb smelter gas, 5% other stack gas	100% domestic merchant (fertilizers)
Monaca, Pennsylvania	321	100% Zn smelter gas	100% domestic merchant (mostly steel pickling)
SHELL CHEMICAL COMPANY			
(a division of Shell Oil Company)			
Wood River, Illinois	85	90% sludge, 10% S	70% captive (alkylation) 30% domestic merchant

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
J. R. SIMPLOT COMPANY			
Minerals and Chemicals Division			
Pocatello, Idaho	640	100% S	99% on-site for fertilizers, 1% domestic merchant
SOUTHERN STATES PHOSPHATE & FERTILIZER COMPANY			
Savannah, Georgia	150	100% S	Captive (normal superphosphates) and merchant
STANDARD OIL COMPANY OF CALIFORNIA			
Chevron U.S.A., Inc., subsidiary			
Barbers Point, Hawaii	32	85% sludge, 15% H_2S	85% on-site for alkylation, 15% domestic merchant
El Segundo, California	100	62% sludge, 38% H_2S	100% on-site
STANDARD OIL COMPANY (INDIANA)			
Amoco Oil Company, subsidiary			
Texas City, Texas	130	85% sludge, 15% H_2S	100% on-site for refining

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
STAUFFER CHEMICAL COMPANY			
Industrial Chemical Division			
Baton Rouge, Louisiana	600	50% S, 50% sludge	16% captive (on and off-site for aluminum sulfate and other chemicals) 30% merchant for refining, 54% merchant for other uses
Baytown, Texas	250	100% sludge	
Dominguez, California	212	23% S, 72% sludge, 5% H_2S	
Fort Worth, Texas	100	100% S	
Hammond, Indiana	300	55% S, 45% sludge	
Houston, Texas	1,250	70% S, 30% sludge	
Le Moyne, Alabama	250	100% S	
Matrinez, California	250	70% S, 30% sludge	
Pasadena, Texas	450	100% S	Captive (fertilizers) merchant (refining)
TEXASGULF INC.			
Aurora, North Carolina	2,072	100% S	100% on-site for fertilizer
UNION CARBIDE CORPORATION			
Metals Division			
Uravan, Colorado	52	100% S	Captive for uranium and vanadium milling
UNION OIL COMPANY OF CALIFORNIA			
Union Chemicals Division			
Wilmington, California	160	35% S, 35% sludge 30% H_2S	n.a.

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
UNITED STATES STEEL CORPORATION			
USS Agri-Chemicals, division			
Bartow, Florida	250		
Fort Meade, Florida	490	100% S	≤100% captive for fertilizers
Wilmington, North Carolina	50		
VALLEY NITROGEN PRODUCERS, INC.			
Helm, California	630	100% S	80% on-site for fertilizers, 20% domestic merchant
WEAVER FERTILIZER COMPANY, INC.			
Norfolk, Virginia	50	100% S	Captive (fertilizers) and merchant
WHEELING-PITTSBURGH STEEL CORPORATION			
East Steubenville, West Virginia	25	100% H_2S from coke ovens	Captive for ammonium sulfate
THE WILLIAMS COMPANIES			
Agrico Chemical Company, subsidiary			
Donaldsonville, Florida	1,200	100% S	≤100% captive for fertilizers
Pierce, Florida	1,200	100% S	≤100% captive for fertilizers

COMPANY AND LOCATION	TOTAL ANNUAL CAPACITY YEAR END - 1978 (1,000 Short Tons, 100% H_2SO_4)	RAW MATERIAL	DISTRIBUTION
WITCO CHEMICAL COMPANY			
Sonneborn Division			
Petrolia, Pennsylvania	53	31% S, 56% sludge, 13% SO_2 off-gases	80% captive (sulfonation) 20% merchant
WRIGHT CHEMICAL CORPORATION			
Riegelwood, North Carolina	66	100% S	100% domestic merchant
TOTAL	51,279		

CHAPTER V : PHOSPHATE FERTILIZERS

CHAPTER V : PHOSPHATE FERTILIZERS

1. GLOBAL OVERVIEW

1.1 Historical Review

In 1977/78 world production of phosphate fertilizers increased to 30,044,000 tonnes P_2O_5, an increase of over 10 million tonnes since 1969/70. The major areas of production are East Europe, notably the USSR, and North America, these two accounting for 53 per cent of global P_2O_5 production.

Table 1 : Distribution of Phosphate Production (percentages)

	1969/70	1977/78
World	100.0%*	100.0%*
West Europe	28.0	19.5
East Europe	24.3	28.8
Africa	3.8	3.6
North America	25.9	26.0
Latin America	1.8	4.7
Asia	10.3	13.3
Oceania	5.8	4.1

Note: * totals may not add due to rounding.

Since 1969/70, there has been relatively little change in the distribution of production. The major change has been the decline in West Europe, which has in fact seen production fall from its peak in 1970/71.

The industry in West Europe has stagnated in the 1970's as a result of two distinct factors:-

(1) The price increases of the mid 1970's made many farmers appreciate they were applying P_2O_5 at above optimal levels and consequently consumption fell, soon followed by production.

(2) The 1970's have witnessed a decline in West Europe's export potential - which has resulted in the closure of a number of export oriented plants based upon imported phosphate rock.

The industry has, however, shown signs of recovery. Spurred on by growth of demand, production has increased for the past 3 years but still lags behind the level of 1972/73.

The French phosphate industry remains the largest in West Europe - in 1977/78 output exceeded 1.5 million tonnes P_2O_5. Other major producers of significance were Belgium, West Germany and Spain, which produced 623,000 tonnes P_2O_5, 712,000 tonnes P_2O_5 and 600,000 tonnes P_2O_5 respectively in 1977/78.

East Europe, notably the USSR, has increased production by almost 4 million tonnes as a region. The USSR has in fact accounted for 2.65 million tonnes P_2O_5 of the additional output, in 1977/78 the Soviet industry producing 5.6 million tonnes P_2O_5. The USSR represents over 70 per cent of East European production, the balance being evenly distributed among other countries.

Table 2 : East European Phosphate Production 1969/70 and 1977/78 ('000 tonnes P_2O_5)

	1969/70	1977/78
Albania	19	25
Bulgaria	140	279
Czechoslovakia	289	389
GDR	395	403
Hungary	170	226
Poland	521	906
Roumania	221	520
Yugoslavia	189	237

For the first time African phosphate fertilizer production exceeded a million tonnes in 1977/78. Three countries - Morocco (185,000 tonnes P_2O_5), South Africa (400,000 tonnes P_2O_5) and Tunisia (249,000 tonnes P_2O_5) were responsible for 83 per cent of African production.

North American phosphate production has moved steadily upward in the 1970's to 7.8 million tonnes P_2O_5 (for a more detailed discussion see the review of the USA).

Two countries, Brazil and Mexico, dominate Latin American phosphate production. Mexican output has increased by almost 200 per cent to 282,000 tonnes P_2O_5 in 1977/78, while Brazilian production has increased from 114,000 tonnes P_2O_5 in 1969/70 to 1,009,000 tonnes P_2O_5 over the same period. The massive developments in Brazilian production were based until 1977/78 on imported phosphate rock.

Asian phosphate fertilizer production has almost doubled in the 1970's to 4 million tonnes P_2O_5 in 1977/78. On the basis of production estimates, China has been recognized as the major producer. In 1977/78 China's estimated production represented 40 per cent of Asian phosphate production. In addition to the PRC, there are three other producers of significance (i) Japan, where the market, based upon an historically strong demand, has sustained an industry producing almost 700,000 tonnes P_2O_5 in 1977/78. (ii) India, where the domestic industry has made considerable strides - output having increased almost threefold by 1977/78. (iii) South Korea, where as in India, production has increased markedly in the 1970's, output having trebled since the turn of the decade.

Oceania, largely through its production of single superphosphate has seen its production fluctuate between 800,000 and 1,200,000 tonnes P_2O_5 in the 1970's.

Following this review of production, it is also valuable to consider the pattern of fertilizer consumption, illustrated in Table 3.

Table 3 : Distribution of Phosphate Fertilizer Consumption 1969/70 and 1977/78

	1969/70	1977/78
World	100.0%*	100.0%*
West Europe	27.3	21.5
East Europe	24.0	29.9
Africa	3.0	3.4
North America	23.6	18.1
Latin America	4.3	7.4
Asia	12.0	15.7
Oceania	5.7	4.4

Note: * totals may not add due to rounding.

Following a decrease in consumption of almost 1 million tonnes P_2O_5 between 1972/73 and 1975/76, West European consumption has made a remarkable recovery in the past 2 years. France is the major market; in 1977/78 usage totalled 1.8 million tonnes P_2O_5. Other major consumers were West Germany 870,000 tonnes P_2O_5, Turkey 614,000 tonnes P_2O_5, Italy 520,000 tonnes P_2O_5 and Spain 500,000 tonnes P_2O_5.

While West European consumption has yet to regain its consumption level of 1972/73, neighbouring East Europe has seen usage increase annually throughout the 1970's. The pattern of consumption is very similar to that of production - USSR accounting for over 60 per cent of the market with a domestic "market" of over 5 million tonnes P_2O_5. Polish consumption in 1977/78 was 950,000 tonnes P_2O_5 with Czechoslovakia and Roumania using 500,000 tonnes P_2O_5.

African phosphate consumption continues to be at fairly low levels, by 1977/78, total usage was only 945,000 tonnes P_2O_5. South African usage in 1977/78 was 389,000 tonnes P_2O_5, the remaining countries using only marginally over 0.5 million tonnes P_2O_5.

As a result of a particularly wet fall season and severe winter, North American phosphate consumption fell in 1977/78 to the levels of the early 1970's at slightly over 5 million tonnes P_2O_5.

As with the case of production, Mexico and Brazil account for the major proportion of regional consumption of 2,084,000 tonnes P_2O_5 in 1977/78, Brazil used 1,411,000 tonnes P_2O_5 and Mexico 222,000 tonnes P_2O_5 - 78 per cent of Latin American consumption.

Asian phosphate consumption has risen steadily in the 1970's to 4.4 million tonnes P_2O_5 in 1977/78. As with production, China remains the largest market - estimated usage is put at 1.6 million tonnes P_2O_5 for 1977/78. Japanese consumption of phosphate has expanded, in spite of the cutback in rice acreage, to over 700,000 tonnes P_2O_5, while Indian phosphate usage has more than doubled from its early 1970's level to over three quarter of a million tonnes P_2O_5.

Oceania consumption has fluctuated markedly in response to both international prices and the changing government policy. This was particularly evident in 1975/76 when usage fell to 857,000 tonnes P_2O_5.

From the decline in consumption evident in 1974/75, the phosphate industry appears to have recovered its upward trend, although increases have been erratic. In 1976/77 the growth rate was 9.5 per cent, falling to only 2 per cent in 1977/78.

The expansion of both production and consumption has been fairly pronounced in the 1970's, the overall level of trade however, has exhibited only slight increases. This reflects the the growing movement towards self-sufficiency in phosphate fertilizers based on captive or imported rock.

Table 4 : Phosphate Fertilizer - Summary of Production and Consumption
('000 tonnes P_2O_5)

	1969/70	1972/73	1975/76	1976/77	1977/78
PRODUCTION					
West Europe	5598	6600	5236	5589	5859
East Europe	4863	6155	8003	8196	8639
Africa	757	992	910	935	1085
North America	5180	6348	6964	7352	7800
Latin America	356	693	962	1145	1429
Asia	2057	2657	3064	3457	4012
Oceania	1164	1605	828	1108	1220
WORLD	19975	25050	25930	27882	30044
CONSUMPTION					
West Europe	5483	6192	5297	5766	6035
East Europe	4828	6167	7769	8066	8398
Africa	601	729	842	936	945
North America	4746	5074	5241	5577	5091
Latin America	855	1530	1589	1975	2084
Asia	2409	3159	3559	4071	4417
Oceania	1154	1379	857	1146	1243
WORLD	20076	24230	25154	27537	28213

Source: BSC Statistical Supplement.

Table 5 : Phosphate Fertilizer Trade
('000 tonnes P_2O_5)

	1969/70	1972/73	1974/75	1975/76	1976/77
IMPORTS					
West Europe	1510	1511	1202	1363	1770
East Europe	267	438	455	316	343
Africa	191	153	130	173	222
North America	331	347	341	264	299
Latin America	606	722	933	728	721
Asia	600	701	1202	968	562
Oceania	13	25	15	12	45
WORLD	3518	3507	4278	3824	3962
EXPORTS					
West Europe	1504	1553	1806	1162	1389
East Europe	195	243	280	242	222
Africa	369	396	318	213	245
North America	1329	1631	1671	1811	2052
Latin America	93	74	39	24	53
Asia	149	211	218	155	106
Oceania	-	-	-	5	-
WORLD	3639	4108	4332	3612	4067

Source: BSC Statistical Supplement.

1.2 Outlook to 1990

World consumption of phosphate fertilizers has grown steadily at about 4 per cent per annum for the last five years. Demand growth was strongest in developing regions, notably South America and Africa. In North America and Western Europe the growth rate has been relatively slow at 2.7 and 3.6 per cent per annum, respectively. Recent trends in consumption and estimates for the future will now be considered in greater detail for each region.

1.2.1 Western Europe

In 1977/78 Western Europe consumed about 6 million tonnes P_2O_5 of phosphate fertilizer, just over 20 per cent of world demand. France was the largest market, taking 2 million tonnes P_2O_5 chiefly in the form of diammonium phosphate, followed by Germany and Turkey both consuming slightly over 0.9 million tonnes P_2O_5. Overall consumption in this region peaked in 1973/74 and subsequently fell as the price of phosphate rock rose. Since the material was very cheap in the early 1970's it tended to be overused and demand dropped considerably after the increase.

Future demand for phosphate fertilizers in Western Europe is expected to reach 7.3 million tonnes P_2O_5 by 1985, rising to 8 million tonnes P_2O_5 in 1990. This represents an average annual growth rate of 2.2 per cent per annum from 1977/78. The most significant area of growth will be Southern Europe, particularly Turkey which is expected to consume over 1 million tonnes P_2O_5 per annum by 1990.

Although growth of future demand will probably initially be met by increased local production, Western Europe will clearly become a net importer during the forecast period. However, major producers will continue to export, particularly within the

EEC. There is likely to be a marked growth in imports of concentrated products, from North America and North Africa. Diammonium phoshpate and triple superphosphate cannot now be incorporated readily into conventional European compound fertilizer manufacture. However in future, producers will need to take advantage of this relatively cheap source of phosphate, as an alternative to phosphate rock and phosphoric acid.

1.2.2 Eastern Europe

Demand for phosphate fertilizers has grown steadily in recent years at about 4 per cent per annum. Consumption was over 8 million tonnes P_2O_5 in 1977/78, the major consumers being the USSR, Poland and Roumania. There is still a considerable potential use for fertilizers and demand will probably continue to grow at a steady rate to about 15.5 million tonnes P_2O_5 by 1990. However, it is difficult to predict either the source or the type of phosphate to be supplied. The only significant exporter in Eastern Europe is Yugoslavia which supplies other Comecon countries, Poland is in a similar position but has a larger domestic market so only exports when there is a surplus. The Socialist bloc countries are expected to trade internally where possible, only going to the United States and North Africa for TSP. Thus there will be pressure to put in concentrated phosphate capacity, in place of existing single superphosphate plant, particularly as demand for the more concentrated product rises.

1.2.3 Africa

African demand has grown rapidly in recent years although it now only accounts for about 3 per cent of total world demand. The most significant consumers are South Africa, Egypt, Algeria and Morocco, and these with Nigeria and Ethiopia will be the areas of highest future growth. The overall growth rate for

Africa from 1977/78 to 1989/90 is expected to average 6 per cent per annum, bringing consumption to about 2 million tonnes P_2O_5 in 1990, just over double that of 1978.

North African producers aim almost entirely at the export market, producing bulk quantities of concentrated phosphate fertilizers which are unsuitable for domestic use. Production in Senegal, the Ivory Coast and South Africa is enough to meet their own demand and that of neighbouring states, but the rest of Africa is still dependent on imports from elsewhere. Being readily available for importation, high analysis products are emphasised.

1.2.4 North America

The use of phosphate fertilizers in North America is particularly well established - hence the recent relatively slow growth of consumption compared with developing countries. In 1977/78 North America accounted for about 18 per cent of world demand, consuming just over 5 million tonnes P_2O_5. Its market share is expected to remain unchanged throughout the 1980's, with an average annual growth rate of about 2 per cent reaching nearly 7.5 million tonnes P_2O_5 by 1990. Most of this demand will still be for triple superphosphate and diammonium phosphate, particularly as the importance of blending in fertilizer manufacture increases.

Supply comes entirely from domestic producers, and demand will probably be met by increased capacity utilisation. It is also likely that diammonium phosphate capacity will expand in the long term, maintaining North America's position as the largest producer. North America is of prime importance as an exporter of concentrated products, and plays a dominant role in determining the nature of the world market itself, treating it as an extension of the home market. Growth in other regions will therefore focus on TSP and particularly DAP, as North America's requirements are unlikely to change.

1.2.5 Latin America

Consumption in Latin America has grown rapidly in recent years, reaching just under 2 million tonnes P_2O_5 in 1977/78. Brazil is the main market for phosphate fertilizers accounting for about two thirds of demand, mostly in the form of diammonium phosphate. Growth is expected to remain at a high level throughout the 1980's, and by the early 1990's Latin America will consume about 5 million tonnes P_2O_5 per annum, about 10 per cent of world demand.

Although this region has significant phosphate rock resources of its own, mostly in Brazil, Mexico and Venezuela, they are not yet fully developed, so most countries are net importers. North America has a strong influence on the nature of demand and readily exports TSP and DAP to Latin America. DAP is emphasised, being granulated and blended with domestically produced nitrogen. In future most countries will try to minimize imports, but domestic capacity, even allowing for new plant, will be insufficient to meet growing demand. Possible exceptions will be Mexico and Venezuela which may attain self-sufficiency through local production. Mexico now exports some TSP, but this will probably cease as existing plant is converted to DAP production for domestic use.

1.2.6 Asia

Demand for phosphate fertilizers has risen steadily in the last few years, reaching 4.4 million tonnes P_2O_5 in 1977/78, about 15 per cent of the world market. However, Asia should be considered as four regions with distinct patterns of demand. The West (Middle-East) consumes very little phosphate fertilizer, and the expanding industry is chiefly export-orientated. In central Asia, particularly India, there is a rapidly increasing demand for fertilizers largely due to the development of agriculture. In 1977/78 consumption in India was 867,000 tonnes P_2O_5, 34 per cent greater than the previous year. Consumption in the Far East has grown relatively slowly in recent years as the market is a well developed one. The other main region is China, the largest single consumer in Asia and accounting for just over half the market, mainly in the form of TSP and DAP. Future demand in China, India and other parts of central Asia such as Thailand and the Philippines, will continue to grow rapidly, at about 7 per cent per annum, reaching over 10 million tonnes P_2O_5 by 1990.

Demand is now satisfied largely by local production and Chinese exports. However, future phosphate fertilizer capacity will be insufficient to meet demand particularly in developing Central Asia and imports will rise. A good deal of low analysis phosphate fertilizer is produced domestically especially in China, but production and use of TSP and particularly DAP will tend to increase. Imports of these products will also rise steadily.

1.2.7 Oceania

Consumption of fertilizers in Australia and New Zealand tends to be erratic, fluctuating from year to year, reflecting the agricultural economy. However, the overall trend is one of relatively slow growth as would be expected of a well developed region. In 1977/78 demand for phosphate fertilizers was slightly over 1 million tonnes P_2O_5, a very small percentage of the world market. Future growth is expected to show a similar pattern through the 1980's, reaching slightly over 1.5 million tonnes P_2O_5 in the early 1990's.

Traditionally, the market has been dominated by single superphosphate met entirely by local production. However, there is growing interest in DAP as an intermediate for fertilizer production, encouraging relatively cheap imports. However, in tonnage terms these will remain quite a small proportion of total supply. Increased domestic production of these concentrated products is also likely.

1.3 Outlook Beyond 1990

By the end of the century phosphate fertilizer consumption is forecast to reach 65.6 million tonnes P_2O_5. This modest forecast is based upon the assumptions that:-

(1) The residual value of phosphate fertilizers will prevent over-optimal applications.

(2) The failure of the developing world to achieve its potential. There is a considerable confusion between consumption forecasts , some of which are based upon needed food production to supply forecast population levels. The forecasts presented in this report reflect actual usage, while forecasts based on need rather than achievement overstate fertilizer growth prospects.

Table 6 : Development of Global Phosphate Fertilizer Consumption ('000 tonnes P_2O_5)

	1980	1985	1990	1995	2000	Avg. Annual growth rate 1980-2000
Total	33950	42450	49830	57495	65615	3.3%
West Europe	6500	7300	8000	8600	9000	1.6
East Europe	9800	13000	15500	17000	18750	3.3
Africa	1150	1600	2050	2555	3215	5.3
North America	6150	6800	7500	8280	8920	1.9
Latin America	2500	3750	4750	6060	7730	5.8
Asia	6500	8600	10500	13400	16300	4.7
Oceania	1350	1400	1530	1600	1700	1.2

Source: CRU estimates.

1.4 Supply/demand Situation

An examination of the post 1980's supply/demand balance for phosphate fertilizers indicates that if production is to match the growth in demand additional capacity will have to be commis-commissioned by the mid 1980's. On the basis of all known plants and projects, current capacity forecasts reveal a potential shortfall, starting by 1984-1985. It is too soon to draw too many conclusions from such developments apart from the main one, that if a repeat of the chaos of the early-mid 1970's is to be avoided, up to 10,000,000 tonnes of additional capacity is required. This additional capacity represents about thirty seven 1000 tpd P_2O_5 phosphate fertilizer units by 1990 (this excludes any replacement factor for existing units).

In the period post 1990, the assumption must be that given the available supplies of phosphate rock, there is no raw material constraint on the supply of phosphate fertilizers to the market. The only constraint may be the level of capital investment.

2. UNITED STATES - PHOSPHATE INDUSTRY

2.1 Introduction

The United States is the world's largest producer of phosphate products - rock, phosphoric acid and finished fertilizer products. In addition to being the major producer, the US is by far the largest exporter of phosphate products at all levels.

Domestic concentrated phosphate fertilizer production capacity is currently in the order of 6.5 million tonnes p.a. P_2O_5. As illustrated in the following table, ammonium phosphates account for the major share of capacity. Since a number of companies have "alternate production facilities" which allows ammonium phosphate or triple superphosphate production from the same plant, the capacity breakdown must be treated with some caution.

Table 7 : United States Concentrated Phosphate Fertilizer Capacity ('000 tonnes P_2O_5)

	1967	1972	1976	1978	1979
Total	4649	4544	6363	6563	6492
Triple superphosphate	2273	1766	2147	2214	2214
Ammonium phosphate	2376	2778	4126	4349	4278

Source : TVA

The apparent decrease in triple superphosphate capacity reflects the closure of a number of smaller obsolescent units in the late 1960's which were not fully replaced until the mid 1970's.

Production of phosphatic fertilizers by the US industry has increased by almost 40 per cent over the past 5 years and by 56 per cent over the past 10 years. Diammonium phosphate has accounted for an increasing proportion of total output - in 1978 DAP production accounted for 54 per cent of the total P_2O_5 production.

Table 8 : United States - Phosphate Fertilizer Production ('000 tonnes P_2O_5)

	1960	1965	1970	1976	1977	1978
Total	2409.3	3476.3	4170.3	5283.5	6077.0	6709.6
Single/Enriched Superphosphate	1152	1009.7	607.8	347.1	308.4	264.1
Triple Superphosphate	894.5	1329.9	1337.2	1446.9	1624.6	1658.7
Diammonium phosphate)	244.0	980.7	1897.8	2608.8	3134.2	3598.6
Other ammonium phosphate)				670.0	789.6	851.9
Other phosphatic ferts	118.8	156	327.5	210.7	220.2	336.3

Source: USDA

As can be seen from the above, the major growth products have been ammonium phosphate, and to a lesser extent triple superphosphate, which have expanded their share of production largely at the expense of single superphosphates. Production of single superphosphates has fallen to less than 25 per cent of its production level in 1960.

2.2 United States Supply/Demand Balance

As stated earlier the United States is the largest producer of phosphate products and has continued to be the world's largest exporter of rock, intermediate and finished fertilizer products.

The US industry has maintained its exportable surplus since the war. The following table of exports/imports clearly illustrates the massive trade balance in favour of finished P_2O_5 exports.

Table 9 : US Imports and Exports of P_2O_5 Products*
('000 tonnes P_2O_5)

	Imports	Exports
1951/52	35	117
1955/56	51	139
1960/61	61	216
1965/66	113	400
1970/71	256	815
1975/76	200	1973
1976/77	222	2269
1977/78	208	3003
1978/79**	202	3452

Notes: *Excludes phosphate rock
**Estimated
Source: Fertilizer Supply - USDA

The United States supply/demand situation is summarized overleaf in terms of net domestic supply, which illustrates the growth in both net domestic supply and the exportable surplus through the 1970's.

Consumption of phosphatic fertilizers has increased from 3,186,000 tonnes P_2O_5 in 1965 to a peak of over 5 million tonnes P_2O_5 in 1977, before declining to 4,626,000 tonnes P_2O_5 in 1978 following the poor fall season and bad spring weather.

Table 10 : United States - Phosphate Fertilizer Consumption
('000 tonnes P_2O_5)

	1965	1970	1975	1976	1977	1978
Total Phosphates	3186	4149	4088	4742	5107	4626
Single/enriched Superphosphate	na	71	102	116	109	152
Triple superphosphate	na	483	384	385	391	279
Mixtures (P_2O_5 content)	na	3365	3372	4012	4345	3940
Others	na	230	230	299	262	373

Source: USDA

Table 11 : United States - Phosphate Supply/Demand Balance ('000 tonnes P_2O_5)

	1970/71	1972/73	1975/76	1977/78	1978/79
Supply From Domestic Production					
Normal/enriched superphosphate	568	562	376	275	239
Triple super-phosphate	1326	1511	1508	1604	1607
Ammonium phosphate	2066	2453	3066	4216	4563
Others	1243	1267	1581	1475	2209
TOTAL	5204	5973	6531	7480	8681
Imports					
Triple super-phosphate	13	24	14	15	11
Ammonium phosphate	184	170	132	133	123
Others	60	89	54	60	68
TOTAL	257	283	200	208	202
Exports					
Normal super-phosphate	3	8	4	3	4
Triple super-phosphate	261	361	511	598	635
Ammonium phosphate	460	835	1103	1646	2140
Others	90	85	356	756	673
TOTAL	814	1289	1974	3003	3452
Net Domestic Supply	4646	4787	4757	4685	5368

Source: USDA

As illustrated above, by far the largest medium of phosphate consumption is through mixtures, which now account for 85 per cent.

Although consumption of mixtures is the main group - the majority of product is moved in the form of dry bulk of total fertilizer application (including N and K). Over 51 per cent is classified as dry bulk, 16 per cent dry bagged and 33 per cent fluid (which is largely nitrogenous solutions and liquid ammonium polyphosphates).

In the remaining years of the century there is little doubt that the United States will remain self sufficient in phosphate fertilizers, and maintain its role as the major phosphate fertilizer exporter.

Domestic demand for phosphate fertilizers is forecast to grow at a little under 2 per cent pa over the review period, with consumption reaching 8 million tonnes P_2O_5 by 2000. By this time, single superphosphate production will have virtually disappeared, except in areas where sulphur applications are required. The role of triple superphosphate is forecast to diminish in the future as the United States moves increasingly toward multinutrientfertilizers to supply the P_2O_5 based dressings. Thus the growth products are identified as; diammonium phosphates, particulary its use in bulk blends and in its own right as a finished fertilizer, and liquid polyphosphates, notably through the medium of the 10.34.0 base solution material.

On the supply side, current capacity will be inadequate to maintain export levels at their present levels, hence the slight fall expected through to 1985 which reflects the lack of investment apparent for the period 1980-1985. However, the exports of phosphoric acid are expected to increase. By 1985 the US phosphoric acid exports are forecast to increase to

750,000 tonnes P_2O_5. In the longer term, the supply/demand balance presented overleaf incorporates the expansion of domestic phosphate facilities in order to maintain and indeed expand the US's export potential for both phosphoric acid and finished solid phosphates.

Table 12 : United States Phosphate Fertilizer Supply/Demand Balance
('000 tonnes P_2O_5)

	1980	1985	1990	2000
Wet process phosphoric acid capacity	9350	10600	12000	13800-15200
Wet process phosphoric acid supply	9050	9850	11550	13070
Assumed exports	600	750	800	1000
Non-fertilizer end uses	350	400	450	500
Available phosphoric acid for fertilizers	8100	8700	10300	11570
Phosphate rock based fertilizers supply	700	600	500	430
Single superphosphate	200	150	100	100
Triple superphosphate	450	400	350	280
Others	50	50	50	50
TOTAL PHOSPHATE FERTILIZER SUPPLY	8800	9300	10800	12000
DEMAND - PHOSPHATE FERTILIZERS	5400	6150	6800	8000
SURPLUS IE. EXPORTS	3400	3150	4000	4000

Source: CRU estimates.

3. PHOSPHORIC ACID

3.1 Introduction

Phosphoric acid is the most important inorganic acid produced and consumed in the United States in terms of production value, and second to sulphuric acid in volume terms. The major end-use of phosphoric acids is in the production of phosphate fertilizers, which accounts for over 85 per cent of total consumption. Other uses in order of significance are livestock and poultry feeds, building and water treatment, food and beverages, direct acid treatment of metals, and fire control.

Its importance to the US phosphate industry is illustrated by the fact that it accounts for 60 per cent of total US phosphate rock production and 85 per cent of domestic phosphate rock consumption.

For the purposes of this report it is proposed to examine the salient developments of 54 per cent P_2O_5 wet process orthophosphoric acid ie. fertilizer grade acid as used in the production of diammonium phosphates.

3.2 Structure of the US Phosphoric Acid Industry

3.2.1 Capacity Developments

In 1978, phosphoric acid was produced by 24 companies at 32 locations throughout the US. Capacity currently stands at 8,841,000 tonnes pa P_2O_5, a 68 per cent increase since 1967.

Table 13 : United States - Wet Process Phosphoric Acid Capacity ('000 tonnes P_2O_5)

Company	1967	1970	1975	1976	1977	1978
TOTAL	5249	5342	7633	8185	8597	8705
Agrico	196	217	635	635	635	635
Allied	65	145	145	145	145	145
Beker	-	-	358	624	624	624
Borden	243	222	176	176	176	176
CF Industries	227	853	1225	1225	1225	1225
Englehard	-	-	136	136	136	154
Farmland	231	231	413	413	413	413
Fertilizer Co of Texas	-	-	-	-	48	48
First Mississippi Corp	-	172	172	172	172	172
Freeport	-	272	680	680	680	680
Gardinier	449	449	449	449	449	449
Grace	281	281	281	281	644	644
IMCC	454	-	544	680	680	771
Mississippi Chemical	145	145	220	220	220	220
Mobil	109	109	113	113	113	113
Occidental	516	420	565	565	565	565
Olin	305	305	333	333	333	333
Royster	29	122	122	122	122	122
Simplot	136	136	181	218	218	218
Stauffer	62	62	90	90	90	90
Texasgulf	313	313	46	622	622	622
USSAgri	250	250	250	250	250	250
Valley Nitrogen	36	36	36	36	36	36
Closed	1202	602	41	-	-	-

Source: TVA/SRI

3.2.2 Production of Phosphoric Acid

Production of wet process phosphoric acid has risen dramatically, to over 8 million tonnes pa by 1978. The incremental production from the industry has stemmed not only from expansions of capacity but also from a gradual improvement in utilization rates. In 1978, allowing for the unrecorded debottlenecking, capacity utilization rates were in excess of 90 per cent in wet acid plants. (Other sources such as IMCC have suggested that in 1978/79 shipments from the phosphoric acid industry were 100 per cent of capacity).

Table 14 : Wet Process Phosphoric Acid Production, USA, 1955-1978 ('000 tonnes P_2O_5)

1955	703
1960	1201
1965	2627
1970	4211
1971	4551
1972	5240
1973	5370
1974	5612
1975	6250
1976	6560
1977	7100
1978	8050

Source: USDC

The industry enjoyed a high capacity utilization rate in the early 1970's due to a combination of factors - the strengthening of prices and the shortfall in capacity - a consequence of the poor market in the 1960's and the disincentive to investment. Thus by 1973 operating rates were in excess of 80 per cent. However, two related factors caused reductions of utilization rates in the following years. A relaxation of price controls prompted an overinvestment in new capacity and consumption of

Table 15 : Total US Disappearance of Phosphoric Acid (Wet Process) ('000 tonnes P_2O_5)

	Fertilizers	Livestock and Poultry Feeds	Builders and Water Treatment	Other Industrial*	Total
1965	2289	na	na	327	2616
1970	3700	306	82	106	4194
1971	4119	308	86	93	4606
1972	4650	338	91	157	5236
1973	4825	311	91	201	5428
1974	4890	285	82	485	5742
1975	4950	273	68	782	6073
1976	5412	333	59	443	6247
1977	6256	311	59	43	6689
1978	7398	318	55	150	7921

Source: SRI, USDC and CRU estimates
*Includes variations in inventory.

finished phosphate fell in response to the mid 1970's price hike. Since 1976, demand has recovered, spurred on by the substantial increase in US exports of solid phosphate and consequently utilization rates have improved accordingly - to an estimated 90 per cent in 1978.

3.2.3 Phosphoric Acid Consumption

As stated in the introduction the phosphate fertilizer is the major user of phosphoric acid, In 1978 it is estimated that of total domestic disappearance - the fertilizer industry accounted for 93 per cent of wet process phosphoric acid (including up-grading into superphosphoric acid). Outside the fertilizer sector the second major consumer is the animal feed industry, which has an annual consumption of up to 338,000 tonnes P_2O_5 for the production of dicalcium phosphates. Other uses of significance are in building and water treatment.

Inevitably the changing pattern of the phosphate fertilizer industry has had a marked effect on the development of phosphoric acid usage, principally the demise of the single and enriched superphospate industry, the slow growth of triple superphosphate and the rapid emergence of ammonium phosphates both solid and liquid as the major P_2O_5 medium. The following table identifies the pattern of phosphoric acid consumption by fertilizer product.

Table 16 : Total US Phosphoric Acid Consumption ('000 tonnes P_2O_5)

Year	Triple Superphosphate	Ammonium Phosphate Solid	Ammonium Phosphate Liquid	Direct Acid	TOTAL
1965	1005	1182	200	19	2406
1970	1016	2337	472	37	3862
1971	1038	2693	529	31	4291
1972	1138	2998	581	29	4746
1973	1160	3111	585	35	4891
1974	1182	2810	615	29	4636
1975	1130	3250	567	27	4970
1976	1094	3664	631	23	5412
1977	1228	4301	663	30	6222
1978	1254	5378	736	30	7398

Source: USDC, SRI, TVA and CRU estimates.

3.2.4 Phosphoric Acid Exports

The historical development of wet process fertilizer grade phosphoric acid is difficult to trace, as export data prior to 1969 are not available, all grades being incorporated in "inorganic acids nec". From 1969-1973 exports of phosphoric acid were not identified by grade. However, it is estimated that of total acid exports in the period 1970-1973 approximately 30,000 tonnes pa P_2O_5 were fertilizer grade.

Table 17 : US Exports of Phosphoric Acid (Fertilizer Grade) ('000 tonnes P_2O_5)

1974/75	211.0
1975/76	281.9
1976/77	403.3
1977/78	681.3

Source: USDC

3.2.5 Structure of the Market

The disappearence of phosphoric acid falls into three major categories

(1) Captive onsite use
(2) Merchant sales within the fertilizer industry
(3) Non-fertilizer demand

As 93 per cent of production is used in fertilizers the first two sectors are clearly the main channels.

Of the US phosphate fertilizer producers producing triple superphosphate or diammonium phosphates, according to plant list details only three plants producing finished concentrated phosphates have a requirement for merchant acid.

(1) American Plant Food at Galena Tex. 27,000 tonnes P_2O_5
(2) Standard Oil Ft. Madison Iowa - has a total requirement of 54,000 tonnes P_2O_5
(3) Valley Nitrogen at Chandler Arizona - 14,000 tonnes P_2O_5.

Of the producers of phosphoric acid, it is estimated that only 7 of the 24 producers have substantial surplus tonnages (over 300,000 tonnes P_2O_5) available per year. Of these three companies dominate.

Freeport - has a contract with Agrico for the sale of 300,000 tonnes pa P_2O_5 until 1982. The balance of their production (non-tolled) is sold on the domestic and international merchant acid markets.

CF Industries - moves approximately 50 per cent of its Plant City production, 110,000 tonnes P_2O_5, as merchant acid.

Texasgulf - sells about 16 per cent of its Lee Creek production c.160,000 tonnes as merchant product in the domestic and international market (100,000 tonnes P_2O_5 is moved in the domestic market).

There is a substantial although unquantified tonnage of phosphoric acid moved to the blending/mixing tier of the industry. Estimates of consumption at this level have put disappearence at 300-400,000 tonnes P_2O_5 per year.

3.2.6 Historical Price Developments

In view of its "sole role" as an intermediate in the fertilizer industry, phosphoric acid prices have followed the pattern set by finished phosphate fertilizer products. The decline in prices through the late 1960's and early 1970's followed by a marked increase in 1974, though not as pronounced as the increases in finished phosphate prices.

The following table of prices, extracted from shipments information produced by the USDC, illustrates the cyclical developments.

Table 18: Wet Process Phosphoric Acid - Prices per short ton, 1955-1977 ($)

	Shipments and Interplant Transfers	Commercial Shipments Only
1955	124	
1960	109	110
1965	99	99
1970	85	83
1971	80	79
1972	79	79
1973	93	97
1974	147	139
1975	154	na
1976	165	na
1977	163	165

Source: USDC

1978 and 1979 witnessed a firming of prices, as the international phosphoric acid market tightened. Although one cannot directly compare the current ex Gulf price of $270 per ton with the values listed above, it seems to illustrate the turnaround in the phosphoric acid market over the past 18 months. Indeed, this trend is expected to continue into 1980, as Gulf prices in excess of $300 per ton are firmly expected.

3.3 The Longer Term Development of the Phosphoric Acid Industry

Existing capacity for phosphoric acid, at the beginning of 1979, totalled 8,841,000 tonnes P_2O_5, although in many cases plants have been debottlenecked and therefore operate in excess of nameplate capacity. A number of new projects are under consideration for the post 1980 period which will raise capacity to over 11 million tonnes by 1990. For the period 1990-2000 new developments in capacity can only be related to the growth in P_2O_5 demand and an assumed maintanance of exports of finished products.

The following capacities are forecast to be operational by 1990, all but one in Florida.

(1) Occidental Chemicals: a 350,000 tpa P_2O_5 wet process phosphoric acid unit will be commissioned by 1980 at Swift Creek, to enable Oxychem to comply with its SPA committment.

(2) Grace has announced, though not confirmed, its proposal to construct a 363,000 tpa P_2O_5 wet process acid project in the 1980's.

(3) USSAgri are considering a joint venture operation to replace their existing Fort Meade operation.

(4) Gardinier will expand its overall capacity following the addition of a 363,000 tpa P_2O_5 unit.

(5) Texasgulf is reviewing the addition of 310,000 tpa P_2O_5 acid capacity at Lee Creek N.C. in the 1980's.

(6) CF Industries are proposing to construct a 363,000 tpa P_2O_5 phosphoric acid unit at their new Hardee Co. site.

(7) Farmland Industries have a project under consideration for a 363,000 tpa P_2O_5 plant linked to their new mining operation.

(8) In addition to the new capacity, a number of companies are expanding capacity of their existing units - IMCC is debottlenecking its New Wales subsiduary at Mulberry to over 1,000,000 tpa P_2O_5. Agrico and CF Industries are debottlenecking existing capacity.

The above developments should result in the addition of over 1.5 million tonnes P_2O_5 of new capacity, and debottlenecking is seen as adding up to 1 million tonnes P_2O_5 of capacity.

Table 19 : Development of Phosphoric Acid Capacity/Production ('000 tonnes P_2O_5)

	1980	1985	1990	1995	2000
Capacity	9350	10600	11500	12500-13100	13800-15200
Production	9050	9850	10700	11550	13070

Source: CRU estimates.

In the period 1990-2000 capacity developments are expected to match demand developments which will be a growth rate of between 2.0-3.0 pa, with a slight easing in the level of utilization, as by 1995 a new generation of replacement units will be required as little further bottlenecking of existing units is envisaged after 1990.

The outlook for prices in the remainder of the century is difficult to predict, although one can draw conclusions from a number of developments, which suggest a continued upward trend in prices (inspite of cyclical fluctuations).

(i) Increased manufacturing costs due to environmental constraints (on new plants and expansions).

(ii) The reduction of available quantities of higher grade phosphate rock and the required process modifications and improvements.

3.4 Conclusions

While Exxon's primary interest in wet process orthophosphoric acid is for the production of diammonium phosphate, the possibility of producing merchant acid based upon purchased phosphate rock merits at least minor consideration.

The market for phosphoric acid has improved significantly of late, and in our opinion is likely to continue to improve into the 1980's. Of the United States production of 8,050,000 tonnes P_2O_5, approximately 400,000 tonnes P_2O_5 of acid were exported in 1978, and exports are forecast to reach 600,000 tonnes by 1980. Given the continued improvement in international spot prices (US phosphoric acid exports are normally off season shipments) the United States will maintain its phosphoric acid exports at 750,000 tonnes P_2O_5 in the late 1980's.

While the export market will remain buoyant, although any price explosion will be contained by underutilized capacity in West Europe, little growth in the domestic merchant market is envisaged as the majority of additional capacity will be used captively by producers. The only growth in the domestic merchant market will be in granulation and fluid blends (although upgraded superphosphoric acid is more likely to be the major product).

Furthermore, of the total US triple superphosphate and ammonium phosphate producers, the majority of companies are self sufficient in phosphoric acid. On the basis of nominal capacity data, there are currently only three producers with a nameplate requirement - American Plant Food at Galena, Tex. Chevron at Fort Madison, Iowa and Valley Nitrogen at Chandler Arizona. There is however substantial tonnage moved between plants in order to maintain downstream production eg. Oxychem is currently purchasing acid to upgrade to superphosphoric acid as part of its Soviet contract.

There is a market for wet process phosphoric acid for non fertilizer uses - defluorinated phosphates, dicalcium phosphates and sodium phosphates - in 1978 usage in these industry totalled 305,000 tonnes P_2O_5. The market is fragmented with a number of small producers. The potential for a producer of acid based upon purchased phosphate rock is poor in the non fertilizer sector.

To summarize, the demand for wet process acid is largely served by captive producers, the only fertilizer market is the TSP/AP sector, which is largely self sufficient. Outside the sector are a wide range of smaller fragmented users which are currently served by existing phosphoric acid producers. The growth in the fertilizer acid market is not expected to generate a substantial incremental demand by these in the 1990's.

It is therefore recommended that Exxon's involvement in phosphoric acid be confined to its production as an intermediate for downstream production.

4. DIAMMONIUM PHOSPHATE

4.1 Domestic Overview

The United States is the world's major ammonium phosphate producer - in 1978 output totalled 4.45 million tonnes P_2O_5. Diammonium phosphate (18.46) is the main product, dominating US production of ammonium phosphates, in 1976 DAP production reached record levels of 3.6 million tonnes P_2O_5.

As the major ammonium phosphate producer the United States has played an ever increasing role in the world P_2O_5 market. Exports of US P_2O_5 in the past two years have exceeded 3 million tonnes P_2O_5 with ammonium phosphate exports exceeding 2 million tonnes P_2O_5 for the first time in 1978/79.

Table 20 : United States Phosphate Fertilizer Exports ('000 tonnes P_2O_5)

	1965	1970/71	1976/77	1977/78	1978/79
Total	353	765	2269	3003	3452
Normal superphosphate	15	5	1	3	4
Triple superphosphate	211	296	518	598	635
Ammonium phosphate	127	400	1258	1646	2140
Diammonium phosphates	n.a.	n.a.	1118	1475	n.a.
Other ammonium phosphates	n.a.	n.a.	140	171	n.a.
Others	-	64	464	756	673

Source: USDA

4.1.1 Market for diammonium phosphates

The market for diammonium phosphates is complex in that the product is used both as an intermediate for the use in bulk blending operations and as a finished fertilizer product. For the purposes of an examination of the market potential, we shall identify the salient developments of diammonium phosphates primary sales ie. the primary producer - dealer trades as reported by the USDA.

This data refers to the volume of non-captive fertilizer sales by primary producers to dealers and blenders prior to any mixing or blending operations. A significant but unquantified tonnage of diammonium phosphates is subsequently used in blends rather than as a direct application product.

4.1.1.1 primary sales

Consumption of diammonium phosphate has over the past 20 years emerged as the main grade of direct application mixed fertilizers.

Table 21 : Consumption of Mixed Fertilizers - by Main Grade ('000 tonnes)

Grades	1960	1970	1975	1976	1977	1978
Total Mixtures	19137	18975	18736	20827	21862	20068
18-46- 0	1131	1374	2027	2896	3255	2868
6-24-24	1110	929	623	957	964	832
10-10-10	799	752	1048	881	817	739
13-13-13	246	317	548	671	683	639
5-10-15	944	824	812	823	725	599

Source: USDA

Primary sales of diammonium phosphates accounts for approximately 42 per cent of production, the export sector and bulk blends accounting for the balance.

4.1.2 Regional Consumption of DAP

Over three quarters of total domestic direct application of diammonium phosphate is consumed in two regions, East North Central (Ohio, Indiana, Illinois, Michigan and Wisconsin) and West North Central (Minnesota, Iowa, Missouri, Dakotas, Nebraska and Kansas).

Table 22 : Distribution of Diammonium Phosphate Consumption ('000 tonnes)

	1968	1970	1975	1976	1977	1978
Total	1131	1374	2027	2896	3255	2868
East North Central	267	323	559	816	1027	888
West North Central	575	623	1019	1374	1429	1324
East South Central	n.a.	28	72	117	182	164
West South Central	128	157	109	229	215	149
Mountain States	106	145	161	213	225	200
Pacific States	28	26	52	70	84	72
Others	27	72	55	77	93	220

Source: TVA

4.1.3 Commercial Arrangements

Detailed information on the domestic distribution of diammonium phosphates is limited, the issue being complicated by diammonium phosphates' role as both intermediate and finished product. In a recent review by the USDA[(1)], over 50 per cent of ammonium phosphate sales were identified. The results of their investigation can be summarized by the following table.

Table 23 : Distribution of sales and transfers of ammonium phosphates (1) (per cent)

To own outlets		To controlled outlets		Sold to Brokers	Traded	Other Sales	
Used Captively	Used by Wholly own cos.	Co-operatives	Other			Co-operatives	Other
5	7.4	-	4.6	14.6	8.4	13.5	14.6

(Type of sale of outlet: To controlled outlets, Sold to Brokers, Traded, Other Sales)

Note: (1) based upon respondents data.

(1) "The manufacturing and marketing of nitrogen fertilizers in the US," USDA.

4.1.4 Domestic Prices

Inspite of significant improvements in the international market prices for diammonium phosphate, the domestic prices remain relatively depressed. This follows a three year period of relatively depressed prices at all levels. The development of diammonium phosphate prices is summarized in the following table and reveals the current price levels at some $30 per ton below those of 1975.

Table 24 : United States Domestic DAP prices by region* (average prices paid by farmers $ per short ton.)

	1970	1973	1975	1976	1977	1978
Illinois	95	115	220	180	186	185
Indiana	96	115	215	180	186	185
Iowa	98	125	220	180	186	185
Kentucky	n.a.	n.a.	215	175	182	n.a.
Minnesota	94	125	210	200	186	185
Nebraska	97	115	225	185	184	184
Ohio	90	115	215	170	186	185
Tennessee	n.a.	n.a.	225	200	182	n.a.
Wisconsin	100	115	220	215	186	185
US Average	95	119	216	177	187	187

*October 15th

Source: USDA

4.2 Market Potential

The main markets for Exxon's potential production of diammonium phosphate must be considered as the adjacent States at the two proposed locations.

4.2.1 Green Bay

The marketing area for diammonium phosphates produced in Wisconsin is considered to be the following States.

Table 25 : Green Bay - Marketing Area - Consumption by State ('000 tonnes)

		1968	1970	1975	1976	1977	1978
Total		815	681	1224	1752	1960	1808
Wisconsin	(ENC)	123	64	111	150	151	135
Iowa	(WNC)	132	149	317	451	433	478
Illinois	(ENC)	100	178	272	440	565	460
Indiana	(ENC)	175	32	65	96	131	112
Ohio	(ENC)	103	44	84	120	136	127
Minnesota	(WNC)	93	117	266	318	328	308
Nebraska	(WNC)	84	87	84	138	172	135
Michigan	(ENC)	5	10	25	39	44	53

Source: TVA

The local market for diammonium phosphates produced at a Green Bay location is currently in the order of 1.9 million tonnes. Consumption of diammonium phosphates in the region has increased almost three-fold in the 1970's although adverse weather conditions in 1978 limited further developments of usage.

The marketing area encompasses the US corn belt, particularly in the East North Central States where of the 61,136,000 acres harvested in 1978, 24,000,000 were under corn. Average P_2O_5 applications to the region's corn crop have been 78lbs/acre, with applications as high as 83lbs/acre in past years. In the areas sewn to corn in the West North Central region the average application is only 35lbs/acre with levels in Kansas as low as 9lbs/acre.

In terms of the development of the market in the region, limited growth can be expected because of the already high level of P_2O_5 fertilization and the large proportion of cropped area. Nevertheless, some growth is expected - in 1978, the cropped area was some 5 million acres below maximum levels and there is potential for increased application rates in the West North Central States. Incremental demand for the region as a whole is estimated to be in the order of 2 per cent pa for the remainder of the decade. However, this is totally dependent upon the continued attractive cost/value ratio of fertilizers and a strong international demand for US foodstuffs. On the basis of a 1.5-2 per cent annual increase, demand for diammonium phosphate is expected to rise to 2.5-2.7 million tonnes by 2000.

Existing and potential diammonium phosphate supply in the region is limited-

Illinois - in which Mobil operates a 218,000 tpa plant at Depue, and Beker which has facilities for 380,000 tpa at Marseilles currently idle.

Iowa - in which First Mississippi Chemicals owns a 380,000 tpa plant at Fort Madison.

Total diammonium phosphate capacity in the region is 973,000 tpa, including the idle Beker facilities. No new capacity is known to be scheduled for the area.

The market is currently served mainly by product from the Gulf coast which is moved to the corn belt and surrounding environs through the internal waterway system and by railcar. The potential for a new supplier clearly exists in that expected incremental demand over the present level could provide a market for diammonium production from Exxon's Green Bay plant. Furthermore, given Exxon's local position and since product could be moved during the ice free months into the area, Green Bay production is possibly well placed to displace Florida producers if production economics permit.

Table 26 : Distribution of Ammonium Phosphate Producers by Major DAP Markets

(1) REGION STATE	Ammonium phosphate facilities.
East North Central	
Illinois	Mobil - Depue - 100,000 tpa P_2O_5 DAP Beker Marseilles 79,000 tpa P_2O_5 DAP idle.
West North Central	
Iowa	First Mississippi Chemicals-175,000 tpa P_2O_5 DAP (plant is currently idle) Ft. Madison.
East South Central	
Alabama	TVA - (demonstration) USSAgri - Cherokee 90,000 tpa P_2O_5 NPK/DAP.
Mississippi	Mississippi Chem. Corp. - Pascagoula - 154,000 tpa (NPK).
West South Central	
Louisiana	Beker - 218,000 tpa P_2O_5 DAP plant at Taft. Brewster-435,000 tpa P_2O_5 DAP plants at Geismar and Luling. Agrico - 628,000 tpa MAP/DAP at Donaldsonville.
Texas	Ensearch (Nipak)-50,000 tpa P_2O_5 DAP at Kevens. Fertilizer Co. of Texas 25,000 tpa P_2O_5 DAP at Pasadena. Occidental -19,000 tpa P_2O_5 DAP/TSP plants at Plainview. Ohio - 233,000 tpa P_2O_5 DAP plant at Pasadena.
Mountain States	
Idaho	Beker-175,000 tpa DAP plant at Conda North Idaho Phosphate Co. - 20,000 tpa P_2O_5 MAP at Kellogg. Simplot-53,000 tpa P_2O_5 DAP plant at Pocattelo.

4.2.2 Evansville

In the event of the plant being located at Evansville the marketing area will encompass a number of States disclosed above. The additional States designated to be in an Evansville marketing area are Kentucky, where consumption of diammonium phosphate has increased five fold over the past 8 years to 91,000 tonnes in 1978 and Tennessee, where usage of a mere 6,000 tonnes in 1970 increased to peak of 75,000 tonnes in 1977 and stood at 69,000 tonnes in 1978.

The marketing potential of the Evansville plant is more favourable than of Green Bay in terms of its easy assess to the major consuming areas of the North West Central States - notably Iowa, Illinois, and Minnesota which used 1.5 million tonnes in 1978. There seems to be limited scope for development of a direct application diammonium phosphate market to the east or south of Evansville, the market being dominated by NPK mixtures. However, as the majority of mixtures are diammonium phosphate based, some possible but as yet unquantified (except by a detailed study) market may exist at a bulk blender/. mixer level.

The Evansville location offers considerable advantages over the Green Bay location in terms of access to the main Mid West markets. The main advantages lies in Evansville's proximity to the inland waterway system via which the bulk of the Mid West's supplies of diammonium phosphate is transported.

Although there are no existing or proposed diammonium phosphate producers in either Kentucky, or Tennessee, the major source of competitive suppliers will be from the large integrated Florida producers and major producers in Florida and Alabama. The Florida diammonium phosphate producers account for the majority of product consumed in the Mid West. The balance of supplies is produced by the Illinois and Iowa producers identified earlier.

4.3 Conclusions

Undoubtedly the US domestic market for diammonium phosphate will continue its upward trend for the remainder of the century. Consumption of diammonium phosphate is forecast to increase at an average annual growth rate of about 2 per cent over the next 20 years. This projection is based upon the following considerations.

(1) A continued displacement of single superphosphate, and the absence of any growth in triple superphosphate usage. Indeed in the period 1990-2000, domestic usage of triple superphosphate will decline, as the trend toward higher use of multi-nutrient fertilizers increases.

(2) The expansion of the dry bulk blend industry, this is one of the primary disappearance channels for diammonium phosphate.

(3) The usage of diammonium phosphate as a direct application fertilizer is expected to increase marginally, particularly at the expense of triple superphosphate.

In terms of the market for Exxon's production of diammonium phosphate, in the physical sense the mid west corn belt market offers potential for any producer, at competitive prices. At this juncture however it is of interest to consider how the mid west market is currently served.

Production facilities in the region are limited, as detailed earlier, there are only 3 producers with a combined capacity of 770,000 tonnes pa. The balance between local production and consumption is all moved by the Gulf producers.

Gulf production is moved by a combination of barge and rail. As can be seen from the map in sulphur section, the inland waterways system allows Gulf producers the potential to move product to Minnesota, Wisconsin, Iowa, Indiana, Illinois and Ohio. Product is then off-loaded to terminals/railheads for subsequent transport inland. In addition to barge transported product, considerable quantities are moved directly by rail, particularly in the South Eastern region.

The marketing structure/channels of distribution in the midwest/corn belt area include all possible modes. However, for the purpose of this analysis four main channels are indentified.

1. Cooperatives - there are at present three major primary producer/retailer coops in the USA manufacturing diammonium phosphate -

(a) CF Industries - formerly Central Farmers, is owned by 17 regional farm supply cooperatives in the US and 2 Canadian. CF Industries, through its highly sophisticated distribution network, markets fertilizers in 42 states throughout the US.CF Industries has a particularly well developed distribution system in the mid west.

(b) Farmland Industries - is owned by 2200 locally owned member associations, and markets fertilizers in 15 mid west states.

(c) Mississippi Chemicals - is arranged as a cooperative, with 20,000 members, retailing mainly in the south east.

In addition to retailing their own brand products, the above cooperatives also move other producers's diammonium phosphate.

There are a number of smaller cooperatives, which are not primary producers that operate on the distribution/bulk blending level. These include CENEX, Farm Bureaux, Land and Lakes, Midland Farmers, Tennessee Farmers and Western Coops.

It is estimated that 40 per cent of all fertilizers in the area are moved through the cooperative system.

2. Major Fertilizer Producers - outside of the cooperative producers, there are 18 producers with diammonium phosphate facilities. The individual marketing systems of some of the major producers are briefly discribed below.

(a) Agrico - markets its diammonium phosphate production through a series of major distribution centres.

(b) Allied - the Agricultural Division operates 40 terminals at various locations, while also moving product through independent dealerships.

(c) Beker - retails its diammonium phosphate via regional representatives.

(d) First Mississippi - handles domestic sales through one of its subsidaries.

(e) WR Grace-markets intermediates and finished fertilizers through 100,000 outlets, including its bulk blending operations.

(f) IMCC - manages domestic sales through its own State level agencies.

(g) Kaiser - sells to distributors and directly through co-owned retail outlets in the south east and mid west.

(h) Hooker - maintains mixing and warehousing facilities throughout the mid west and Great Lakes area.

(i) Olin - markets through its dry fertilizer distribution centre at Joliet.

(j) Royster - operates a wide distribution network - 2000 retail outlets. It owns a fleet of private railcars.

(k) Swift - operates at a major farm distribution centre level.

(l) USSAgri - operates numerous bulk blending operations, in addition to moving product through dealerships and agencies.

3. <u>Distribution Companies</u> - operate retailing chains throughout the mid west. The best example of this is Terra Chemicals/Riverside - which have combined into the major distribution company in the mid west.

4. <u>Bulk Blenders</u> - while the major primary producers operate their own bulk blending facilities, there is a whole range of companies buying diammonium phosphate for use in the production of dry mixtures, dried bulk and bagged. It is estimated by TVA that there are over 7000 bulk blenders in operation in the US. The major blenders in the market area are listed in Table 27 (this excludes primary diammonium phosphate producers'blending plants).

The main marketing centres in the corn belt are essentially the internal waterway terminals and major railheads. For product moving northward from the Gulf, the first major distribution point is St Louis, where product is transhipped by barge or rail to the Missouri and Kansas markets. Further north along the river system, product is transhipped at various points, Dubuque, Fort Madision and Minneapolis-St Paul. In Illinois, product is moved as far north as Joliet. Eastwards along the Ohio river, product is moved as far as Cincinnati for distribution to Ohio consumers.

As Exxon Minerals Company has no distribution or marketing system for phosphate fertilizers, it is recommended that in the unlikely event of diammonium phosphate fertilizer production being economically feasible at either a Green Bay or Evansville location, the output be offered to the major cooperative groups and to bulk blenders for subsequent retailing. The major problem likely to be encountered will be the economics of moving phosphate rock to Green Bay or Evansville, to be transformed into diammonium phosphate, and then to transport the finished fertilizer back along the internal system to the major distribution centres identified above. Even at the Evansville location, the local market in Southern Illinois, Indiana and Ohio offers little prospect as it is largely a poor crops area. In order to guarantee disposal of the product, it would have to be moved to the corn belt either back down the Ohio River, or by rail Westward. In either event it is unlikely that Exxon could achieve this at competitive prices. Transportation of phosphate rock to Wisconsin and backhaul of the finished product to the corn belt will effectly prevent Exxon from approaching the forecast prices projected below.

Although it is virtually impossible to forecast prices over the next 20 years, it is CRU's opinion that the trend in real terms will be upward. This is confirmed by a recent World Bank price forecast, which suggests that diammonium phosphate prices by 1990 are expected to reach $220 per tonne (1978$). The increase in price largely reflects the higher production costs of new plants commissioned to meet incremental demand. On the basis of $230 fob Tampa price by 1990, and a freight charge of up to $70 per tonne, delivered prices in the Mid West should be between $280-300 per tonne (1978$).

Table 27 : MAJOR BULK BLENDERS

Name	Location	Capacity
ILLINOIS		
Watseka Farmers Grain Co.	Watseka	7,000
Meiners Farm Service Inc.	Colfax	20,000
Effingham Equity	Effingham	7,700
Stockdale Fertilizer Co.	Morris	7,040
INDIANA		
Indiana Farm Bureau Co-op	Indianapolis	21,000
Jasper Co, F.B. Co-op	Ronsselaer	11,300
Chemicals Fertilizers Services Inc.	Vincennes	34,000
Crop Fertility Specialists Inc.	Winamac	13,000
IOWA		
Lanco Inc.	Mason City	15,500
Hebel Fertilizer & Chemical Inc.	Masson City	24,000
Miner Farm Supply Inc.	Perry	9,050
Farm Services Inc.	Vinton	9,200
Farmers Co-op Grain & Seed Co.	Lamoni	200,500
KENTUCKY		
Bluegrass Plant Foods	Danville	11,000
Burley Belt Chemical Co.	Ferguson	10,000
Burley Belt Chemical Co.	London	13,000
Glasgow Fertilizer Co. Inc.	Glasgow	18,000
Ohio Valley Fertilizer Inc.	Maysville	12,000
Southern States Co-op - Russellville	Russellville	19,000
Hutson Chemical Co. Inc.	Murray	26,995

Table 27 : MAJOR BULK BLENDERS (Continued)

Name	Location	Capacity
MICHIGAN		
Anderson Fertilizer Services Inc.	Owosso	20,000
MINNESOTA		
Farmers Co-op of Hanska	Hanska	21,400
Hastings Farmers Co-op	Hastings	13,800
NEBRASKA		
Sur-Gro Plant Food Co.	Falls City	12,500
Agricultural Services Inc.	Grand Island	9,000
OHIO		
Ohio Farmers Grain & Supply	Fostoria	18,000
Plant Life Services Inc.	Marion	12,300
The Andersons	Maumee	194,000
TENNESSEE		
Tennessee Farmers Co-operative	Lavergne	14,000
WISCONSIN		
Howard Johnson Enterprises Inc.	Viroqua	6,000
Midland Fertilizer Plant	Johnson Creek	5,800

CHAPTER VI : AVAILABILITY OF PHOSPHATE ROCK

CHAPTER VI : AVAILABILITY OF PHOSPHATE ROCK

1. PHOSPHATE ROCK OVERVIEW

The United States is the major producer of phosphate rock in the world, output in 1978 surpassing 50 million tonnes. The phosphate rock industry is concentrated in four major areas: Florida, North Carolina, Western States (Idaho, Montana, Utah and Wyoming) and Tennessee.

As can be seen from the following tables of worldwide production and capacity, the United States accounted for 41 per cent of total world phosphate rock production in 1977.

Table 1 : World Phosphate Rock Production and Exports, 1977 ('000 tonnes)

	Production	Exports
TOTAL	115966	49475
North America	47553	13967
of which - United States	47256	13967
South America	754	-
Europe	24343	5790
of which - USSR	24200	5790
Africa	29783	
of which - Algeria	1055	698
Morocco	17027	15791
Senegal	1869	1767
South Africa	2403	
Togo	2857	2886
Tunisia	3614	1898
Asia	11486	
Oceania	2047	2679

Source: USBM, British Sulphur Corp.

While the United States dominates production and capacity into the review period, the situation is slightly different in terms of reserves. Reserves in the US (as of 1978) are estimated at 2200 million tonnes with identified resources in the order of 8000 million tonnes. The status of the US industry vis-a-vis its reserve/resources position is illustrated in the following table.

Table 2 : Identified World Phosphate Reserves, 1977 (million tonnes)

	Reserves	Total Identified Resources
TOTAL	27000	67000
North America	2200	8100
of which United States	2200	8000
South America	450	950
Europe	1415	3445
of which USSR	1400	3400
Africa	22180	51450
of which Morocco	18000	40000
South Africa	3000	7000
Asia	660	1350
Oceania	100	2130

Source: USBM

The following pages examine, in detail, the development of the US phosphate rock sector in the period up to 2000.

2. UNITED STATES PHOSPHATE ROCK INDUSTRY

US phosphate rock production reached record levels in 1978, when output passed 50 million tonnes, a 6 per cent increase on the previous year. Total shipments were up by 1.3 million tonnes, to a record level of 48.8 million tonnes. However, the increased total shipment figure tended to mask the declining exports - which fell back marginally to 12.6 million tonnes.

Table 3 : Phosphate Rock Salient Statistics, USA, 1974-1978 ('000 tonnes)

	1974	1975	1976	1977	1978
Mine production (ore)	141353	170077	154278	166893	173429
Marketable production (concentrate)	41437	44276	44662	47256	50037
Shipments - Total	43931	42120	40522	47437	48774
Exports	12605	11131	9433	13230	12570

Source: USBM

While export shipments slipped, domestic disappearances were up by almost 6 per cent - consumption in phosphoric acid dominating and accounting for 29 million tonnes.

The Florida and North Carolina producers dominate the industry. In 1978 they accounted for 86 per cent of total marketable production. The table overleaf identifies the likely development of domestic phosphate rock capacity until the end of the century.

Table 4 : Development of US Phosphate Rock Capacity to 2000 (million tonnes material)

Company/Location	1980	1985	1990	1995	2000	Mineout date
FLORIDA						
Amax						
Manatee Co.	-	2.0	3.6	3.6	3.6	
Agrico						
Payne Creek	2.3	2.3	2.3	-	-	1990
Fort Green	3.6	3.6	-	-	-	
Boyette	-	1.0	3.6	3.6	3.6	
Borden						
Big Four	0.9	0.9	1.1	1.1	1.1	2000
Brewster						
Haynsworth	3.2	3.2	-	-	-	1989
Lonesome	2.5	2.5	2.5	2.5	-	1997
C.F.Industries						
Stuart	0.9	2.0	2.5	2.8	2.8	2000
Cardinier						
Ft Meade	1.8	1.8	1.8	1.8	1.8	2000
W.R.Grace						
Bonnie Lake	1.8	-	-	-	-	1981/2
Hookers Prairie	2.3	2.3	2.3	2.3	2.0	1995
Four Corners	-	2.0	2.5	2.5	2.5	2000
IMCC						
Clear Springs	2.3	2.3	-	-	-	1985
Kingsford	4.5	4.5	4.5	4.5	-	2000
Norlalyn	4.6	4.6	-	-	-	1987
Horse Creek (South Manatee)	-		7.5	8.0	8.0	
Mobil						
Fort Meade	2.9	2.9	2.9	-	-	1990
Nichols	1.3	1.3	1.3	-	-	1992
South Fort Meade	-	-	-	3.0	3.5	2005
Occidental						
Swift Creek	2.2	2.2	2.2	2.2	2.2)	1998
White Springs	2.5	2.5	2.5	2.5	2.5)	
Swift						
Silver City	1.9	1.9	-	-	-	1982
Watson	0.8	0.8	0.8			1990
Manatee	-	-	2.0	2.0	2.0	

Table 4 : Development of US Phosphate Rock Capacity to 2000 (million tonnes material) (continued)

Company/Location	1980	1985	1990	1995	2000	Mineout date
FLORIDA cont:						
Transammonia						
Mulberry	0.3	1.5	0.3	-	-	1990
USS Agri						
Fort Meade	1.8	1.8	1.8	1.8	-	1995
TOTAL FLORIDA	44.4	47.4	45.7	44.2	35.6*	
NORTH CAROLINA						
North Carolina Phosphates						
Washington	-	2.0	4.0	4.0	4.0	
Texasgulf						
Lee Creek	3.2	4.5	4.5	4.5	4.5	
TOTAL NORTH CAROLINA	3.2	6.5	8.5	8.5	8.5	
WESTERN STATES						
Beker Industries Corp.						
Conda	1.2	1.2	1.2	1.2	1.2	n.a.
Cominco						
Garrison	0.2	0.2	0.2	0.2	0.2	
Monsanto						
Henry/Soda Springs	1.0	1.0	1.0	1.0	1.0	
Simplot						
Conda	1.4	1.4	1.4	-	-	1990
Gay	2.0	2.0	2.0	-	-	1990
Stauffer						
Leefe	0.9	0.9	0.9	0.9	0.9	
Woolley Valley	0.6	0.6	0.6	0.6	0.6	
TOTAL WESTERN STATES	5.3	5.3	5.3	3.9	3.9	
TENNESSEE						
Monsanto						
Columbia	1.4	1.4	1.4	1.4	1.4	2000
Occidental (Hooker)						
Columbia	0.4	0.4	-	-	-	1985

Table 4 : Development of US Phosphate Rock Capacity to 2000 (million tonnes material) (continued)

Company/Location	1980	1985	1990	1995	2000	Mineout date
TENNESSEE cont:						
Stauffer						
Mt Pleasant	0.5	0.5	0.5	0.5	0.5	2000
TOTAL TENNESSEE	2.3	2.3	1.9	1.9	1.9	

Total US Phosphate Rock Capacity

	1980	1985	1990	1995	2000
Total	55.2	61.5	57.8	54.9	46.3*
Florida	44.4	49.4	45.7	44.2	35.6
North Carolina	3.2	[illegible].5	8.5	8.5	8.5
Western States	5.3	5.3	5.3	3.9	3.9
Tennessee	2.3	2.3	1.9	1.9	1.9

Source: USBM, TVA, Company reports, personal contacts and CRU estimates.

*The above table refers only to those mines or companies which have made firm plans to develop reserves in the 1980s. There are, however, a number of other tracts which are as yet undeveloped. These non-operating reserve holding companies are summarised below.

A. FLORIDA

A.1 Atlantic Richfield Co.

ARCO owns reserves on the southern Hillsborough border. While the area is deemed too small for commercial exploitation as a single operation, it is conveniently placed to provide additional reserves for the nearby Brewster Lonesome mine or for IMCC's recently acquired tract formerly owned by Farmland Industries.

A.2 Beker

In 1974, Beker acquired tracts in Manatee County with estimated reserves of up to 54 million tonnes with an average BPL content of 68 per cent. Plans have been well advanced to install a 2.7 million tpa beneficiation unit. The major problem preventing Beker from developing these reserves is procurement of the necessary investment - $50-100 million. However, once the move south in Florida develops and the cheaper ores are mined out, finance ought to be more forthcoming. It is therefore forecast that Beker's tract will be in production by 1985 at up to 3 million tpa.

A.3 Farmland Industries

Farmland owns 14,000 acres in Hardee County, and is in the process of gathering environmental data. It is not expected that Farmland Industries will be producing phosphate rock until the late 1980's.

A.4 First Mississippi Corp.

FMC own a small tract in southeast Hillsborough County. As was the case with ARCO's tract, adjacent tracts would have to be purchased to make exploitation viable.

A.5 Mississippi Chemicals Corp.

Mississippi Chemicals' environment study has been submitted for construction permits for its proposed 2.7 million tonnes pa mine in Hardee County. However, the combination of high matrix yardage and deep pit should preclude any further developments until the 1990s.

A.6 Noranda

The US subsidiary has acquired a controlling interest in the mineral rights on 3,500 acres in DeSoto County. Estimates of phosphate rock reserves are put at 27 million tonnes. In the event of these reserves being exploited, the phosphate rock would be used internally by Noranda at its Canadian phosphoric acid plants.

A.7 Stauffer

The company has no plans to develop its 23-27 million tonnes of reserves in Hardee County or 16-18 million tonnes in Manatee County.

A.8 Texaco

Texaco owns 32-36 million tonnes of reserves in Manatee County adjacent to Beker's property. A consolidated development of both properties may prove the most realistic development.

Table 5 : Florida - Potential Phosphate Rock Developments to 2000 (million tonnes)

Company	Reserves	Annual Capacity	Start up date
Beker	54	2.7	1985
Farmland Ind.	18	1.0	1985
Mississippi Chem.	50	2.7	1990
Noranda	27	1.8	1995
Stauffer	45	2.7	1995
Texaco	36	2.0	1995
Total	230	12.9	

Source: CRU estimates

B. NORTH CAROLINA

B.1. First Mississippi Chemicals

FMC owns reserves in Beaufort County along the Pamlico river totalling 68 million tonnes. According to a recent report(1) "the Pamlico river deposit appears to be capable of increasing its production under sufficient economic incentive to as much as 18 million tonnes p.a. This increase in production in North Carolina will occur when the demand is assured under the economic competition with Florida deposits".

Table 6 : North Carolina - Potential Phosphate Rock Developments to 2000 (million tonnes)

Company	Reserves	Annual Capacity	Start up date
First Mississippi Chemicals	75	over 10	1995

Source: CRU estimates.

(1) "Evaluation of the Phosphate Deposits of Georgia, North Carolina and South Carolina using the Minerals Availability System". Prepared by Zellars-Williams Inc.

2.1 Captive US Supplies

2.1.1 Borden

Borden operates a 1.1 million tpa mine at Big Four in Florida, with total reserves estimated at 22 million tonnes. The Big Four mine, commissioned in 1978 to replace the mined out Tenroc operation, has been beset with production problems which have restricted output to 800,000 tonnes p.a. Output from the mine can be considered as all captive, used in Borden's downstream, phosphoric acid, triple superphosphate and technical phosphate operations.

Annual Capacity	900,000 tpa	(62-66% BPL)
P_2O_5 Production	260,000	
Downstream requirements:	215,000 tpa P_2O_5	

In the absence of any new deposits being acquired by Borden during the review period, it will continue to use its supplies internally until the mine out date near 2000.

2.1.2 CF Industries

Mining operations began at Stuart, Hardee County, Florida, in late 1978, with plans to produce up to 1.5 mtpa of product. Capacity of the mine is scheduled to expand to up to 2.8 million tonnes pa by the end of 1980, but output is expected to be behind capacity developments, and production in the order of 2.5 million tonnes pa is forecast for the review period.

Output from the mine will be used to displace purchased rock, currently obtained from a range of companies including IMCC (the largest), Agrico and Mobil. Phosphate rock is used in the production of phosphoric acid at the company's Bonnie and Plant City locations.

Phosphate rock capacity	2.0-2.8 million tpa (68% BPL)
P_2O_5 production	620,000 - 870,000 tonnes
Downstream requirements	
Phosphoric acid total	1,578,000 tpa P_2O_5

Total downstream requirement for CF Industries' phosphoric acid units is currently 1.5 million tpa P_2O_5 by the beginning of the review period. With a maximum production of up to 2.8 million tpa of rock anticipated, it is evident that CF Industries will remain dependent upon purchased rock supplies.

2.1.3 Gardinier

Capacity of the Tencor mine has recently been expanded by the addition of new dragline facilities, but production of rock is not expected to exceed 1.8 million tpa. Phosphate rock production is used captively at the company's two phosphoric acid plants at Tampa. In addition to the captive Florida requirement, Gardinier moves quantities of rock to the French phosphate industry, thus rendering any surplus production purely theoretical.

Annual capacity	1,800,000 tonnes (68% BPL)
P_2O_5 production	560,000 tonnes
Downstream requirements	
Phosphoric acid (1985)	862,000 tonnes P_2O_5

Gardinier's nominal phosphate rock surplus is expected to disappear following commissioning of the replacement second stream in 1985.

2.1.4 Occidental

Oxychem operates two open pit mines and associated beneficiation plants in Florida. Production capacity for phosphate rock for the period 1979-1998 is expected to range from 3.2-4.6 million tonnes pa, depending upon the prevailing mining conditions. Currently approximately 50 per cent of phosphate rock produced by Oxychem is processed into phosphoric acid and its derivatives at White Springs. Total capacity of the facilities has been increased to 617,000 tonnes P_2O_5 following the addition of 90,000 tpa P_2O_5 in 1978.

Production of phosphate rock in 1978 is estimated to have been approximately 1.5 million tonnes, of which approximately 50 per cent was utilised by Oxychem in its White Springs operation. The balance of 1.62 million tonnes (including some inventory) was sold to third parties. Approximately 1.54 of this was exported, the balance of 80,000 tonnes was sold on the domestic market.

Oxychem's phosphate rock balance will change radically in the 1980s following the completion of its 350,000 tpa P_2O_5 phosphoric acid unit at White Springs. This unit, designed to boost Oxychem's production of superphosphoric acid to 700,000 tpa P_2O_5 to meet the contractual obligation under the Oxy Soviet agreement, should have a rock requirement of approximately 840,000 tpa which should theoretically remove Oxychem's export/surplus rock potential. The rationale behind this is that rock production from the recently reactivated Swift Creek mine is high cost and given necessity to produce superphosphoric acid, it is considered unlikely that Oxychem will elect to market rock from its high cost operation.

Annual capacity	3.2-4.6 million tonnes (69.5% BPL)
Production P_2O_5	1,008,000-1,450,000 tonnes
Downstream requirements	944,000 tonnes P_2O_5
Phosphoric acid total	967,000 tonnes P_2O_5
Triple superphosphate	27,000

As can be seen from the above table, on the basis of the lower production levels identified by Oxychem, little phosphate rock is expected to be available over and above Oxychem's captive requirements.

Occidental's phosphate rock operations in Tennessee operated through Hooker Chemical Corporation is largely self-contained, the output of approximately 400,000 tpa being used locally for the production of thermal phosphoric acid at Godwin, Tennessee. The Godwin thermal acid plant is expected to close in the early 1980's, with the eventual mine out out of the phosphate deposit calculated by 1985.

2.1.5 USSAgri

Mining at the Rockland mine is forecast to continue throughout the review period, at an annual capacity of 1.8 million tonnes pa. At the moment the operation provides phosphate for both Freeport and USS Agri in equal proportions. The 900,000 used by Freeport is used captively for production of phosphoric acid at Uncle Sam. USS Agri's allocation is used at the company's Bartow and Fort Meade phosphoric acid plants. Surplus production to the Bartow and Fort Meade requirements is used in USS Agri/ W.R. Grace joint venture phosphoric acid unit at Bartow.

2.1.6 Other Companies

With the exception of Texasgulf's operation at Lee Creek N.C., which produced about 2.7 million tonnes of rock, the remaining US producers in the Western States and Tennessee are relatively insignificant, with most output being used captively.

2.2 Free Phosphate Rock Supplies

2.2.1 Amax

Amax is currently examining the feasibility of producing 3.6 million tonnes pa. The decision to proceed beyond the study stage has yet to be made, but on the basis of their progress to date, it is the consultant's opinion that the mine will be in operation by the mid-1980s. There are no proposals as yet to use the phosphate rock captively, with Amax's intention that the rock be put into the market.

2.2.2 Agrico

Agrico's phosphate rock capacity is forecast to decline from its present level of 5.9 million tonnes pa to 3.6 million tonnes pa by 2000 following the mine out at Payne Creek and Fort Green and the compensatory introduction of the Boyette mine.

In 1978 Agrico produced 6,096,000 tonnes of rock, of which 3 million tonnes was used captively, 2.54 million tonnes sold to third parties and the balance added to the inventory. Agrico's captive downstream requirements are to its phosphoric acid units at South Pierce, Donaldsonville, and triple superphosphates. In addition, under its contract with Stauffer for the purchase of rock reserves in Hardee County, Agrico supply Stauffer's elemental phosphorous plant at Tarpon Springs, Fla.

Annual capacity	5.9-3.6 million tonnes (67% BPL)
P_2O_5 production	1,830,000 tonnes - 1,116,000
Downstream requirements	820,000 tpa P_2O_5
Phosphoric acid total	725,000 tpa P_2O_5
Triple superphosphate	95,000 tpa P_2O_5

Of the sales to third parties, three main contracts exist:
(i) Nam Hae Chemicals (South Korea), in which Agrico has a 25 per cent shareholding. A maximum of 850,000 tonnes pa of phosphate rock will be supplied at prevailing world prices under a ten year agreement.
(ii) Freeport - under a ten year agreement, which expires in 1982, Agrico has contracted a tolling arrangement. In 1978, Agrico moved 450,000 tonnes of phosphate rock to Freeport for acid production.
(iii) Gouldings (Eire), under the terms of its acquisition of Fitzwilton's holdings, entered into a long term agreement with Agrico providing for the purchase of its phosphate rock requirements.

The balance of Agrico's phosphate rock production is sold domestically to CF Industries and Farmland and exported via Phosrock.

2.2.3 Brewster Phosphates

Brewster Phosphates was formed as a reserve and operations consolidation venture between American Cyanamid and Kerr McGee. It encompasses phosphate rock production plus conversion into phosphoric acid. The current split of rock production is 75 per cent Cyanamid and 25 per cent Kerr McGee.

Production of the two mines in 1978 totalled 4.6 million tonnes, although capacity at Haynsworth and Lonesome are 5.7 million tonnes pa.

Of Brewster's phosphate rock production, approximately 1.4 million tonnes pa is tolled by Freeport for production of phosphoric acid for conversion to diammonium phosphate at Brewster's Luling and Geismar plants. The balance of 130,000 tonnes P_2O_5 of acid is used by Cyanamid and Kerr McGee in proportion to their shareholding. The remaining phosphate rock production, estimated at between 3.2 and 4.0 million tonnes pa is distributed to both shareholders. Kerr McGee uses approximately 50,000 tonnes pa at its three single superphosphate plants (either Brewster rock or swapped product), the remaining tonnage is disposed of on the spot market (Kerr McGee not being a member of Phosrock).

Cyanamid's captive requirements are for its dicalcium phosphate plants at Alden, Iowa; Hannibal, Mo.; and Weeping Water, Nebraska. The annual phosphate rock consumption at these three sites is approximately 60,000 tonnes P_2O_5. The remaining phosphate rock tonnage estimated to be 2.8 million tonnes is sold as merchant product - major purchaser is Allied.

Following the mine-out of the Haynsworth operation in 1989, Brewster's supplies of phosphate rock, as merchanted through Cyanamid and Kerr McGee, will be reduced accordingly.

2.2.4 W.R. Grace

The phosphate rock capacity of W.R. Grace should expand marginally in the 1980s following the introduction of the Four Corners mine. Present production capacity is approximately 4.6 million tonnes, of which 1.45 million tonnes are used internally by Grace for production of phosphoric acid and triple superphosphate at Bartow, and triple superphosphate at Joplin. The captive downstream requirement should be increased by the commissioning of a 363,000 tonnes pa phosphoric acid unit by 1983. This will, however, have a limited impact on the level of Grace's phosphate rock sales in view of the net increase in capacity following full production at Four Corners.

As the phosphate rock deposits at Hookers Prairie and Four Corners will not be mined out until the late 1990s, and Grace owns substantial tracts in North and South Manatee, the company will be in a position to both maintain and increase sales of phosphate rock.

2.2.5 International Minerals and Chemicals Corporation

IMCC is the largest phosphate rock producer in the US. In 1978 production totalled almost 12 million tonnes, almost 26 per cent of the total US output. In 1978, total shipments of rock are estimated to have been over 12 million tonnes from which the following breakdown can be derived:

Total shipments	12.11	million	tonnes
Total domestic	5.05	"	"
of which - to CF Industries	3.53	"	"
Total internal	3.36	"	"
of which - New Wales	3.00	"	"
IMC Canada	0.36	"	"
Total exports	3.70	"	"
of which - Japan	0.60	"	"

IMC will maintain its position as premier phosphate rock producer in the US, following the gradual move south in Florida as Clear Springs and Noralyn are replaced by the Horse Creek mine. IMC's internal requirement is likely to increase as its New Wales phosphoric acid capacity is expanded - up to 1,000,000 tonnes pa P_2O_5 will be achieved by the beginning of the review period.

2.2.6 Mobil

Production from the company's Fort Meade and Nichols mine will continue into the 1990s with mineouts forecast in 1990 and 1992 respectively. The reserves at South Fort Meade should be exploited by 1995 following the demise of Mobil's other reserves.

In the absence of any major downstream activities, other than Mobil's elemental phosphorus production which has an annual requirement of 200,000 tonnes of rock, the majority of phosphate rock is sold to domestic users, notably CF Industries, First Mississippi Chemicals and Olin, and exports. An annual surplus of 3 million tonnes pa is estimated for the duration of the review period.

2.2.7 Swift

Swift's production of phosphate rock is expected to decline in the 1980s following the mine out of Silver City by 1982 and the Watson mine in the late 1980s. It is expected that by the early 1980s Swift will have phased in production at its tract in Manatee County.

Swift's downstream requirement is nil following the closure of its thermal phosphoric acid units, all of the output from the mine being merchant product. However, almost 300,000 tonnes pa of rock is moved to Yong Nam Fertilizers of South Korea, in which Swift has a shareholding. The balance of production, estimated at between 1.7 million tonnes and 2.5 million tonnes, is available to the domestic and export market.

2.2.8 North Carolina Phosphates

NCP is a joint venture operation between Agrico and Kennecott Copper Co. Mining of the 272 million tonnes of reserves is expected to commence in 1983, with full production envisaged by the late 1980s. At the moment there are no firm plans in hand for either Kennecott or Agrico to build downstream units, therefore the conclusion must be that output will be sold as phosphate rock.

2.3 Foreign Supplies Available for US Consumption

While the balance between supply and demand for phosphate rock will tighten, and the export potential will decline, the advent of large scale phosphate rock imports into the United States is not envisioned in the review period. However, there has been a small but growing volume of phosphate rock imports into the US from Dutch Antilles, Mexico and Morocco.

Table 7 : U.S. Imports of Phosphate Rock 1978 ('000 tonnes)

Morocco	857
Netherlands Antilles	50
Others	1
Total	908

Source: USBM

Imports into the United States are expected to continue at a level of about one million tonnes pa in the review period. The majority of the product is likely to be of Moroccan origin, imported by Occidental Chemicals. The other possibility is the import of Peruvian product on the West Coast. Although Minero Peru's exploitation of its Bayovar deposits has been beset with problems, production is expected in the 1980s. The West Coast market, using smelter acid, would prove an ideal market for competitively priced phosphate rock.

2.4 Phosphate Rock Prices

Phosphate rock prices appear to be moving out of the doldrums which followed the heady days of the mid-1970s, when the Moroccan inspired price hike raised the annual average price from $6 per tonne in 1973 to $25 per tonne by 1975. As can be seen from the following table, until the price hike in the mid-1970s, phosphate rock prices had begun to slip steadily downward, to their nadir in 1972, when Morocco stepped in to realign prices to, in their view, more realistic levels.

Table 8 : Time Price Relationship for Phosphate Rock ($ per tonne fob - average annual price Sold or used by U.S. Producers)

	Actual	1977 constant
1954	6.15	14.56
1960	6.60	13.58
1965	7.16	13.61
1970	5.80	8.97
1971	5.80	8.54
1972	5.62	7.94
1973	6.24	8.33
1974	12.10	14.74
1975	25.35	28.17
1976	21.36	22.44
1977	17.39	17.39
1978	18.50	

Source : USBM

In 1978, the average value per tonne of marketable phosphate rock was calculated by the USBM as US$18.50 per tonne fob plant, as compared with the $21.36 and $17.39 reported in 1976 and 1977 respectively. The average price of domestic shipments was marginally below the average for total marketable production at $18.48 per tonne fob plant. In spite of the minimal increase from the previous year, $1 per tonne, disappearance of rock increased. The export prices over the past two years have seen a similar pattern, a substantial reduction from the inflated prices of 1975 to the relatively modest levels of 1977; however, spurred on by the recovery in the downstream market prices rock prices firmed in 1978 and 1979. In view of the currently healthy export market, it is of interest to consider the development of international prices, to which domestic prices have become more aligned.

Table 9 : Development of Phosphate Rock Export Prices ($ per tonne)

		1976	1977	1978	1979	Loading Basis
FLORIDA						
75% BPL	Listed	47.00	31.00	37.00	40.00	Fob Tampa
	Actual	36.40	29.30	31.32	34.37	"
72% BPL	Listed	43.00	28.50	34.00	37.00	"
	Actual	33.38	25.28	28.29	31.36	"
68% BPL	Listed	33.00	25.00	30.00	33.00	"
	Actual	28.30	22.25	23.25	26.31	"

Source: British Sulphur Corp.

Though we do not expect any shortage of phosphate rock supply in the period up to 2000, prices, in constant dollars, are expected to continue an upward trend reflecting the increased operating costs and capital charges which will inevitably stem from the exhaustion of lower cost reserves. According to figures published by Zellars Williams[1] (Figure 1), by the year

(1) Evaluation of the Phosphate Deposits of North Carolina using the Minerals Availability System.

2000 virtually all of the rock with production costs of less than $15/short ton (1977 $) will be mined out. The depletion of these low cost reserves, according to the report, will force producers into the next price level ($15-20/short ton) which would support production of over 45 million tonnes pa of rock for the rest of the century. As illustrated in the Figure 1 on the basis of production costs alone, upward pressure on prices will be inevitable. On the basis of the above costs and phosphate rock price forecasts elaborated by the World Bank, by 1995-2000 we envisage a domestic US phosphate rock price of $25-30 (1977 dollars) per tonne, which is equivalent to $27-32 per tonne in 1978 dollars.

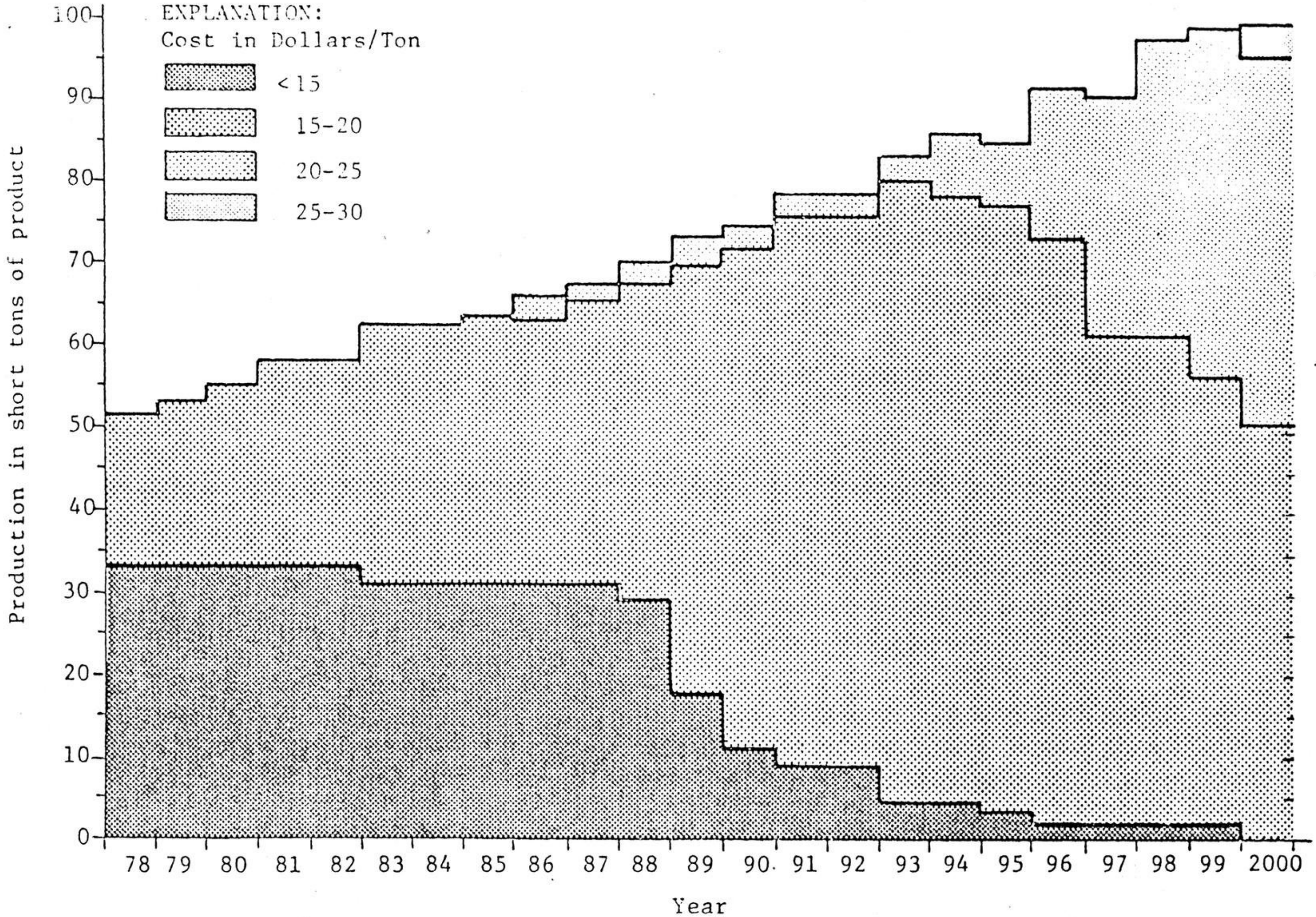


FIGURE 1. - Resource production cost for southeastern United States, constant 1977 dollars.

3. SOURCES OF SUPPLY

For the duration of the review period and indeed beyond, there will be ample supplies of phosphate rock available to serve the domestic US market, and afford the US a substantial, though decreasing, exportable surplus. As can be seen from Table 10, from the present export level of 15 million tonnes, a decline to 8 million tonnes is envisaged by the year 2000.

In terms of available supplies of phosphate rock, the two major areas with surplus will be Florida and North Carolina; the phosphate rock production of both the Western States and Tennessee is unlikely to be able to support much merchant rock over and above their captive requirements. Indeed, for the purposes of this study, the Florida/North Carolina deposits should provide more than adequate resources.

Companies which will have product available as detailed earlier are Amax - which will have up to 3.5 million tonnes pa from 1985 onwards; Agrico, who will have between 1-1.5 million tonnes pa available, depending upon the development of prices; Brewster Phosphates, who will have, via American Cyanamid and Kerr McGee, up to 3.00 million tonnes pa; W.R. Grace will have a potential 3.00 million tonnes pa available; International Minerals and Chemical Corp which, during the 1980s and 1990s, will have approximately 3.5 million tonnes pa over and above domestic commitments; Mobil and Swift between them have a potential merchant availability of up to 5 million tonnes pa available and, finally, North Carolina Phosphates mine should produce an estimated 4.0 million tonnes pa to put on the domestic/export market.

Table 10 : Phosphate Rock -United States Supply/Demand Balance ('000 tonnes)

	1978	1980	1985	1990	1995	2000
Phosphate Rock Production		53000	55500	55000	58000	59200
Demand		38560	42460	44830	47960	51860
Phosphoric Acid		31300	34500	36270	39000	42500
SSP		860	860	860	860	860
TSP		1900	2500	2900	3100	3350
Technical		4200	4300	4500	4700	4850
Direct application		300	300	300	300	300
Imports		1000	1000	1000	1000	1000
Export availability		15440	13540	11170	11040	8340

Source: CRU estimates.

CHAPTER VII : AVAILABILITY OF AMMONIA

CHAPTER VII : AVAILABILITY OF AMMONIA

1. GLOBAL OVERVIEW

Global ammonia capacity has almost doubled in the past ten years from 49 million tonnes N in 1969/70 to 96 million tonnes N in 1979/80. By the mid-1980s, on the basis of all known plants and projects, world capacity is expected to increase to 120 million tonnes.

Table 1 : Evolution of Ammonia Capacity ('000 tonnes N)

	1966/7	1970/1	1975/6	1980/1	1985/6	1990/1
WORLD	34504	53181	71022	100499	120468	134214
West Europe	9991	14118	14882	17155	18933	21489
East Europe	8015	13703	21962	31387	37296	42000
Africa	347	780	1228	3009	4180	4540
North America	9057	12528	14082	17238	19972	21670
Latin America	789	1310	2501	4505	8615	10854
Asia	5098	9019	14608	24353	30954	33125
Oceania	85	480	452	452	536	541

Source: British Sulphur Corp and CRU estimates

2. UNITED STATES AMMONIA INDUSTRY

US ammonia capacity currently stands at 15,493,000 tonnes N; indeed, actual operating capacity can be considered as substantially less, as the above total includes 2 million tonnes of capacity which is currently idle and given no improvement from the present market conditions is anticipated to remain idle. In addition to the idle capacity identified above, there is a further 2,117,000 tonnes N of capacity which can be classified as vulnerable and can be expected to cease production by the 1980s.

Table 2 : US Ammonia Capacity ('000 tonnes N)

	1970	1975	1976	1977	1978	1979
NH_3 Capacity	12457	13721	14200	16081	16434	15493

Source: TVA

The combination of increased gas costs and the low level of ammonia prices over the past two years has had a marked effect on production. Over the past two years in particular, capacity utilisation rates have declined from the mid-1970s levels of almost 90 per cent to a little over 80 per cent in 1978.

Table 3 : US Ammonia Production ('000 tonnes N)

1975	1976	1977	1978
12230	12471	12980	12669

Source: USDC.

By 1981, the present oversupply position is expected to reach its peak, before the market tightens into the late 1980s. This is evidenced by the fact that only two projects have been mentioned for the 1980s. As yet it appears that none has reached the detailed engineering stage save the coal-based Grace Ebasco project, which may be abandoned in favour of gasoline production.

It is expected that by 1985, given a tightening of the market, US domestic capacity will be expanded by the addition of up to 1.5 million tonnes N of capacity, either as reactivated units or new capacity.

Table 4 : Development of US Ammonia Capacity ('000 tonnes N)

	1980	1985	1990	2000
Nominal NH_3 Capacity	15,873	15,798	17,300	19,000

Source: CRU estimates.

The following tabulation identifies domestic US producers who have ammonia surplus to their captive downstream requirements. A proportion of this output will, however, be absorbed as direct application consumption.

Table 5 : US Ammonia Producers - With Merchant Potential

Company	Locations	Theoretical Surplus ('000 tonnes N)	Comments
Agrico	Verdigis, Okla.	1150	Expansion of UAN solutions could absorb any surplus NH_3
Allied		150	Quantities available from a range of plants
American Cyanamid	Fortier, La	c.300	
Amoco	Texas City, Tex	368	No captive down-stream
Chevron	Pascagoula, Fla	368	No captive down-stream
Union Oil (Collier)	Kenai, Alaska) Wilmington, Cal)	527	Logistics of Alaskan operation unfavour-able for Wisconsin operation
Cominco	Borger, Tex	230	No captive down-stream
Farmland Industries	Various	600	Major surpluses at Enid and Pierce
First Missis-sippi	Pascagoula, Fla) Fort Madison, Iow)	480	Pascagoula unit to be fully operational by 1980s
I.M.C.	Sterlington, La	350	Should have subs-tantial merchant potential once first plant reactivated

Source: CRU estimates.

In addition to the above, two cooperatives have "merchant" product available, but in most cases production is geared to the needs of members. However, an upturn in the market could tempt sales of surplus product to third parties.

As can be seen from the above table, there will be a limited number of US domestic producers who will be capable of supplying 125,000 tpa of merchant product in the 1980s, particularly as there appears to be an increasing trend toward the upgrading of ammonia into downstream products by erstwhile merchant suppliers. Nevertheless, there will be adequate product available well into the review period. However, it must be emphasised that there is a considerable body of opinion with the view that, in the US and indeed on a global basis, the supply/demand balance for nitrogen in the 1980s may be much tighter than is commonly predicted. Should this scenario develop, i.e. the expansion of capacity outside the US is not as substantial as was otherwise thought, the resulting interaction of supply/demand will force prices on the international market upward, thereby allowing a proportion of the otherwise idle capacity to be reactivated.

Regardless of which of these scenarios develops, it is unlikely that the US or, indeed, North America (for the purposes of an examination of the US ammonia supply, the Canadian production has no real alternative to the US market) will be able to avoid the inexorably increasing dependence upon imported ammonia.

The following table briefly examines the North American supply/demand balance for ammonia to 1990. As can be seen, even allowing for a continued flow of Canadian product into the US and an anticipated expansion in capacity, the import requirement for ammonia will approach 2.8 million tonnes N. by 1990.

Table 6 : North American Supply/Demand for Ammonia ('000 tonnes N)

	1980	1985	1990
Nameplate capacity*	17283	18500	21550
Forecast production	14700	16500	19400
Total ammonia demand	16000	19000	22200
Import requirement	1300	2500	2800

* excluded a number of idle plants expected to be closed by 1985 and 1990.
Source: CRU estimates.

Given the continued deficit situation in North America, the export potential of the major alternative foreign suppliers is reviewed in Section 3.

2.1 Ammonia Prices

Over the past five years, the Unites States nitrogen industry has seen its domestic prices fluctuate considerably as the cyclical supply/demand imbalances caused prices to weaken through to the early 1970's, and then move sharply upward in the mid 1970s. There has been some weakening of domestic prices over the past three years as illustrated in Tables 7 and 8.

In 1979, there has been a firming of international prices due to a number of unrelated incidents - notably the removal of Iranian product from the market, the call of force majeur by Pemex, the Soviet transportation problems, and the absence of spot market product in West Europe. By mid year the prices had weakened, but did not fall to the pre-crisis levels.

On the basis of available supply, little in the way of price escalation can be expected as nominal capacity is substantially in excess of requirement until the mid-1980s. However, in the period after 1985, the impact of increased feed stocks costs coupled with the downturn in capacity investment in the US and West Europe, could force prices upward until additional capacity is constructed or erstwhile idle capacity can be reactivated.

In the period after 1990, it is virtually impossible to identify the price pattern apart from noting that ammonia prices will have to be more closely related to feedstock costs, particularly natural gas. Even in the event of producers moving toward coal-based production, it is the consultant's opinion that prices will move steadily upward during the review period.

Table 7 : US Ammonia Prices
(average price paid by farmers $ per tonne)

	April 15	September 15
1964	126	122
1965	122	120
1966	119	116
1967	113	109
1968	91.4	85.6
1969	75.6	72.8
1970	75.0	76.8
1971	79.3	79.3
1972	80.8	80.8
1973	87.6	92.5
1974	183.0	229
1975	265	219**
1976	191	182**
1977	188*	177**
1978	177*	164**

* March 15

** October 15

Source: Agricultural Prices, Economics, Statistics & Cooperatives Service, USDA.

Table 8 : Ammonia: Value of Shipment and Interplant Transfers ($ per tonne f.o.b. plant)

Calendar year	Shipments and Interplant Transfers	Commercial Shipments only
1960	63.06	62.58
1964	61.74	61.06
1965	61.18	60.65
1966	57.61	56.65
1967	49.74	50.42
1968	37.82	38.88
1969	30.86	30.88
1970	30.69	31.08
1971	30.90	31.89
1972	32.08	32.76
1973	38.71	40.79
1974	87.65	94.56
1975	134.52	137.92
1976	97.03	96.67
1977	96.64	98.21

Source: The Fertilizer Supply, Agricultural, Stabilization and Conservation Service, USDA.

3. SOURCES OF SUPPLY

3.1 Imports

Imports of ammonia for fertilizer purposes have increased substantially in recent years, with the United States having been a net importer for the past five years.

Table 9 : US Ammonia Imports for Fertilizer ('000 tonnes N)

	1975/74	1975/76	1976/77	1977/78	1978/79
TOTAL*	446.9	572.0	720	785	1,570
of which					n.a.
Canada	111.5	98.3	365.4	404.5	
Mexico	3.7	10.8	32.7	90.9	
Trinidad	107.0	120.0	134.6	178.6	
Finland/USSR	-	13.3	-	97.9	
Netherlands	31.4	35.7	37.0	14.2	
UK	6.6	-	33.6	-	
Dutch Antilles	60.1	70.0	54.8	-	
Colombia	5.6	16.4	4.1	-	
Venezuela	11.9	68.4	26.9	-	
Iran	10.6	53.4	14.2	-	
Kuwait	12.8	18.0	14.3	-	
Others	85.7	67.7	2.4	-	

Source: USDC.

* May not add to independent rounding and conversion to tonnes N.

3.1.1 Canada

In recent years Canada had been the major supplier of merchant ammonia to the US market, exports peaking at 468,900 tonnes N in 1978. However, 1979 will see the first year of Soviet supremacy in the US market, when Russian exports are expected to approach 780,000 tonnes N as contracted under the Soviet Occidential Chemicals deal.

It is expected that in the period up to 1985, exports of Canadian ammonia will be maintained at a level of 400,000 tonnes N pa. Although there are no firm ammonia projects announced for Canada, it is considered probable that at least one large-scale ammonia project will be commissioned in the period up to 1990. The most likely candidate is identified as Alberta Gas and Chemicals, who have had an ammonia project slated for some considerable time. The other possibility is Sherritt Gordon, who had a proposal for a second unit; but following the escalation of costs and the downturn in the market, the project was abandoned. However, given that by the mid- to late-1980s the current surplus will be absorbed by the market, it is not unreasonable to include the Sherritt Gordon project in a longer term review of Canadian supply potential.

3.1.2 Mexico

In 1978, Mexico moved 316,400 tonnes N of ammonia into the US, and it is expected that in fertilizer year 1978/79 Mexico will have exported 400,000 tonnes N to the US market. By 1985 Pemex propose to increase ammonia capacity from its present level of 1,477,000 tpaN to 3,187,000 tpaN by the addition of five new plants, one of which is under construction. While these upstream developments will be associated with downstream projects developed by Fertimex, there will undoubtedly be an increase in available merchant ammonia over and above the growth in fertilizer needs and direct application. Fertimex plans at the moment centre on the Lazaro Cardenas ammonium nitrate project and two urea projects expected on stream by 1986. The additional ammonia requirement will be 1.0 million tonnes N of ammonia. Thus, by 1986 up to 800,000 tonnes N (allowing for a marked increase in direct application ammonia) will be available. In the period after 1985 based upon Pemex's development strategy in recent years, a new range of ammonia plants can be forecast for the period 1986-1990, from which one can assume an incremental export tonnage. Furthermore, as freight rates continue to increase, it is not unlikely that, contrary to Pemex's current strategy of having a wide marketing area, a greater proportion of export tonnage will find its way to the United States.

3.1.3 Trinidad

Exports from Trinidad have been effected from the Federations Chemicals (Grace) and also more recently from Trinidad Nitrogen's 296,000 tpa N plant at Point Lisas. In 1978, Trinidadian export to the US totalled 293,000 tonnes N. By 1985, following the successful commissioning of two plants in Trinidad, export potential for ammonia should be up to 700,000 tpa N on the basis of historical operating rates. As the two projects are both joint venture operations with the Government, it is not inconceivable that in the review period an additional unit will be constructed. In view of the close proximity to the lucrative Gulf market and the abundance of relatively inexpensive gas supplies, an expansion of Trinidad's ammonia capacity in the late 1980s is inevitable.

3.1.4 USSR

Although the Soviet Union has been an intermittent supplier of ammonia to the US, it was not until 1978 that the quantities involved attained any significance, when 300,000 tonnes of ammonia were imported under the first stage of the USSR-

Occidental Agreement. The following table sets forth the quantity of ammonia to be delivered under the agreement.

Table 10 : Soviet/Occidental Ammonia Deliveries ('000 tonnes)

	1979	Each year 1981-1982	Each year 1982-1987	Each year 1988-1997
Purchases from the USSR				
Pursuant to a 10 year agreement 1/	510	350	600	
Pursuant to a 20 year agreement 2/	440	1500	1500	1500
Total Ammonia	950	1850	2100	1500

1/ Occidental's purchases of ammonia under the 10 year agreement will be continued after 1987 at a rate of 600,000 tonnes pa if necessary to provide the USSR with an aggregate of US$800 million in sale proceeds from all ammonia purchases under such agreement. In addition, Occidental's purchases in any year may be increased by mutual agreement by up to 400,000 tonnes of ammonia if necessary to achieve the same result.

2/ The fertilizer agreements contemplate that the value of SPA sold by Occidental to the USSR over the 20 year period should not exceed the aggregate value of Occidental's purchases from the USSR of the ammonia purchased under the 20 year agreement and of potash and urea.

By mid-1979, Occidental had negotiated contracts with third parties for the sale of the following tonnages:

	1980	1981
	('000 tonnes)	
1. Ammonia quantities with respect to which purchase prices has been negotiated with the USSR	950	600
2. Minimum quantities with respect to which firm resale contracts have been negotiated with US purchasers	442	354
3. Maximum quantities available for resale to others or for internal use by Occidental	508	246

In order to maintain shipments at the agreed levels it will be necessary for the Soviets to increase their ammonia capacity during the next five year plan. An additional minimum of four plants are expected at Rossosh and at Togliatti - totalling 1.8 million tonnes pa of ammonia.

4. CONCLUSIONS

The US ammonia industry is currently in the middle of a recession with over 2 million tonnes N of capacity idle. The enforced closure of this capacity is the result of a cost/price squeeze. The two major factors involved in the crisis are as follows.

(1) Increased raw material costs - the U.S. ammonia industry is dependent upon natural gas feedstocks and since the escalation of gas prices a number of plants have been unable to operate competitively on the basis of current gas prices. Production of one tonne of ammonia requires approximately 40 mcf, of gas, at current prices of $2.5-$3.00 per mcf. The result is a feedstock cost of between $100 and $120 per tonne which is currently in excess of US Gulf prices. The only ammonia producers who have remained competitive have been those with evergreen or long term gas contracts at low prices.

(2) Low ammonia prices - the United States is the world's largest and most competitive merchant ammonia market. In 1979 for instance up to 1.6 million tonnes of ammonia was supplied by Canada, Mexico, Trinidad and the USSR. In most cases these suppliers were able to offer prices below the feedstock costs paid by a number of US producers. Furthermore, even in the lucrative cornbelt, imported ammonia was still more competitive than locally produced product.

There seems little respite from the cost/price squeeze in the early 1980's particularly as a number of major producers approach the end of their cheap gas contracts. However the present disequilibrium in the market and the disincentive to investment could lead to a tightening of the market by the middle 1980's. It remains to be seen how much of the short-fall will be filled by imported product and how much idle capacity can be reactivated.

In the event of the industry moving towards another cycle in the mid to late 1980's the inevitable result could be an escalation of prices. However, in view of the short lead up time to commissioning an ammonia plant, price forecasts in the 1990's are purely speculation.

Exxon's modest ammonia requirement is unlikely to impose any major constraint on the development of diammonium phosphate production. The supply of ammonia could easily be contracted via brokers or directly with overseas suppliers or from the remaining domestic producers operating on low price gas contracts.

Domestic producers with available tonnages, sufficient for Exxon's annual requirement are: Agrico, Allied, American Cyanamid, Amoco, Chevron, Cominco, Farmland Industries, First Mississippi, IMCC and Union Oil. Of the offshore producers, Trinidadian product is handled through Oxychem's subsidiary Interore while Pemex sells Mexican ammonia directly. Canadian product is normally handled by the individual companies; Canadian Fertilizers, Cominco, Cyanamid, Esso and Sherritt Gordon.

For the Evansville location, Exxon would be best served by large supplies from the inland waterway system. There are numerous ammonia terminals adjacent to the rivers. While at Green Bay - the most logical supply source would be via the two pipe line systems currently operated by Gulf Central Pipeline Co. and Mid-American Pipeline Co. (MAPCO). Both systens run pipelines well into the mid west. The list of terminals operated by the companies are presented in Table and the maps of the system presented in Figures 1 and 2.

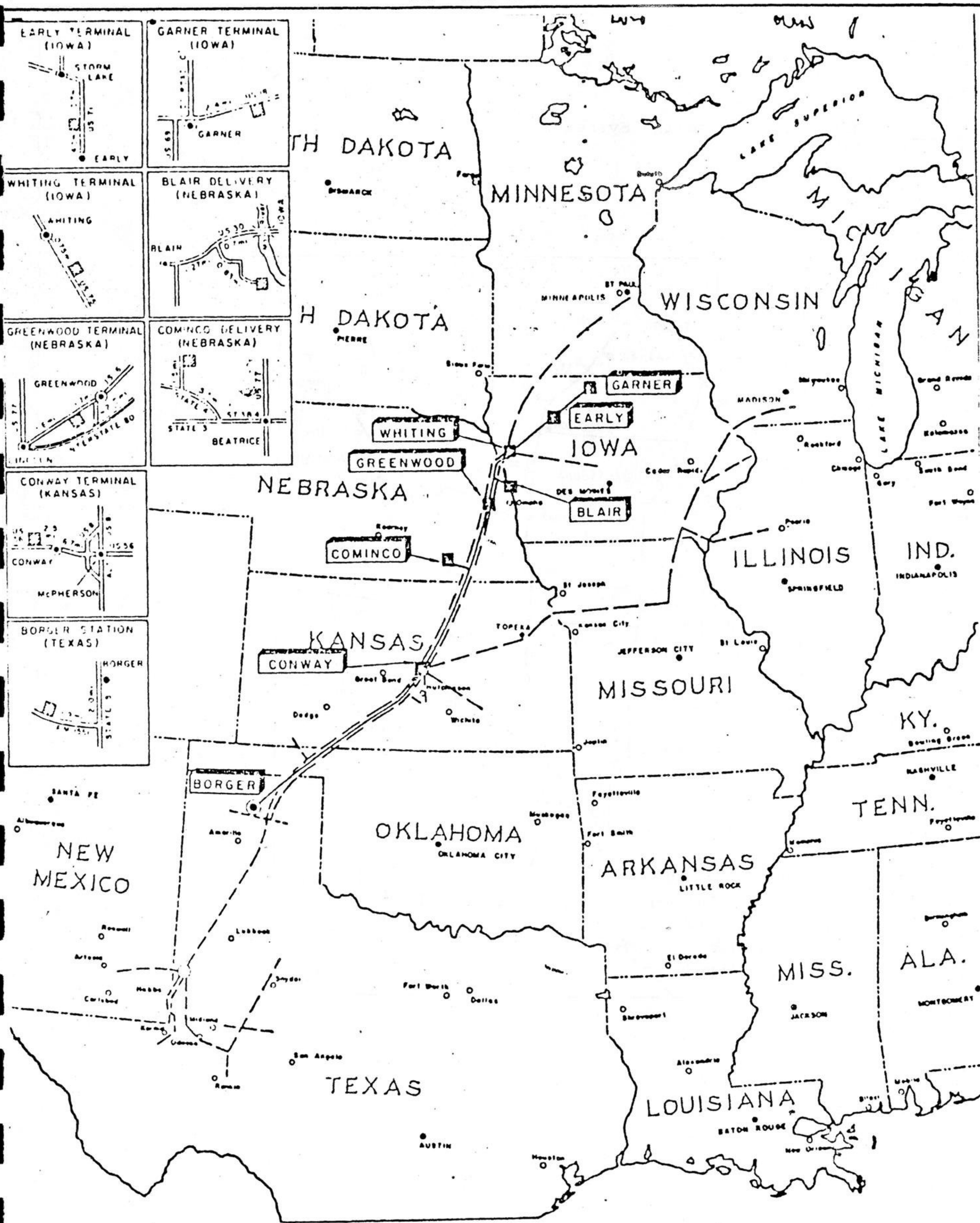


Figure 1 Mid-America Pipeline System

LEGEND

(●) AMMONIA PLANT LOCATION
DELIVERY POINT & TERMINAL
——— ANHYDROUS AMMONIA SYSTEM
– – – MID-AMERICA NATURAL GAS LIQUIDS SYSTEM

Figure 2 Gulf Central Pipeline System

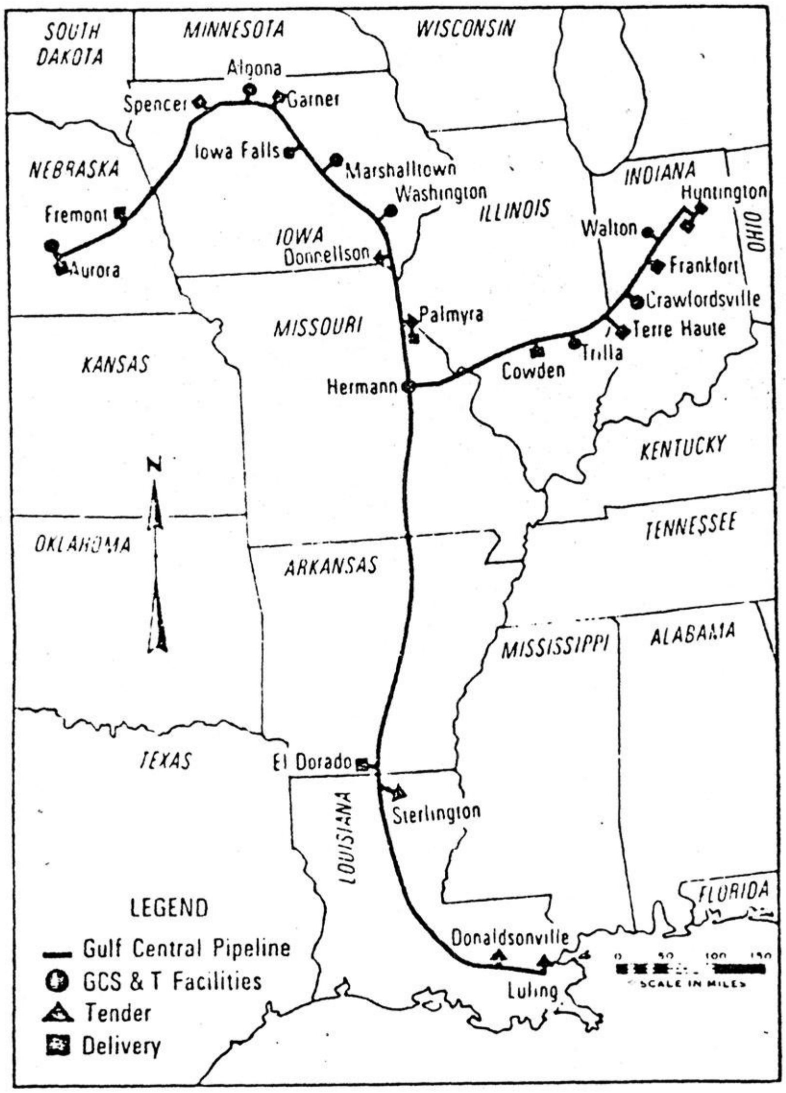


Table 11 : Ammonia Pipelines and Inland Terminal Locations

Company	Location	Capacity tonnes
GULF CENTRAL PIPELINE SYSTEM		
Monsanto	El Dorado, Ar.	15,000
Gulf Central	Hermann, Mo.	1,600
American Cyanamid	Hannibal, Mo.	27,000
C.F. Industries	Palmyra, Mo.	27,000
C.F. Industries	Cowden, Ill.	27,000
Gulf Central	Trilla, Ill.	800
C.F. Industries	Terre Haute, In.	27,000
Gulf Central	Cranfordsville, In.	27,000
C.F. Industries	Frankfort, In.	27,000
Gulf Central	Walton, In.	27,000
C.F. Industries	Huntington, In.	27,000
Amoco	Huntington, In.	27,000
Farmland	Washington, Ia.	27,000
Gulf Central	Marshalltown, Ia.	27,000
Gulf Central	Iowa Falls, Ia.	54,000
C.F. Industries	Garner, Ia.	54,000
Farmland	Garner, Ia.	27,000
Gulf Central	Algona, Ia.	27,000
CF Industries	Spencer, Ia.	54,000
Agrico	Blair, Neb.	77,000
C.F. Industries	Fremont, Neb.	18,000
C.F. Industries	Aurora, Neb.	14,000
Gulf Central	Aurora, Neb.	27,000
Gulf Central	Cherokee, Ia.	27,000
Gulf Central	David City, Neb.	27,000
MID AMERICAN PIPELINE SYSTEM		
MAPCO	Clay Centre, Ks.	130
Cominco	Conway, Ks.	130
Cominco	Greenwood, Neb.	3,200
Cominco	Whiting, Ia.	130
Agrico	Blair, Neb.	27,000
Cominco	Early, Ia.	39,000
Cominco	Garner, Ia.	78,000
Cominco	Beatrice, Neb.	18,000
Farmland	Garner, Ia.	27,000
Farmland	Sergeant Bluff, Ia.	27,000

Table 12 : United States Ammonia Storage Capacity (Coastal capacity)

Company	Location	Capacity (tons)
Agrico	Donaldsonville La.	22,500
Air Products	New Orleans, La.	30,000
Allied Chemicals	Geismar, La.	15,000
American Cyanamid	Avondale, La.	22,500
	Westego, La.	45,000
Amoco	Texas City, Tex.	20,000
Beker	Taft, La.	9,000
Borden	Geismar, La.	18,000
Chevron	Pascagoula, Miss.	2,700 x 2
CF Industries	Donaldsonville, La.	63,000
Du Pont	Beaumont, Tex.	18,000
Fertimex	Brownsville, Tex.	7,500
First Mississippi Chem.	Donaldsonville, La.	20,000
Gardinier	Helena	20,000
	Tampa, Fla.	10,000
W.R. Grace	Tampa, Fla.	45,000
	Wilmington, NC.	17,000
	Houston, Tex.	n.a.
Hooker	St. Helena River, Or.	n.a.
	Savannah, Ga.	n.a.
	Stockton, Calif.	20,000
Monsanto	Luling, La.	31,000
Olin	Lake Charles, La.	36,000
	Pasadena, Tex.	7,000
Royster	Tampa, Fl.	35,000
Shell Chemicals	Portland, Or.	27,000
Standard Oil	Pascagoula, Mass.	30,000
Swift	Beaumont, Tex.	2,000
Tenneco	Houston, Tex.	22,500
	Pasadena, Tex.	27,000
Texasgulf (1981)	Moorhead City	30,000
Triad Chemicals	Donaldsonville, La.	27,000

CHAPTER VIII : MARKET FOR GYPSUM

CHAPTER VIII : MARKET FOR GYPSUM

1. INTRODUCTION

Gypsum is a name loosely applied to several different forms of calcium sulfate, including the minerals selenite ($CaSO_4 . 2H_2O$) and anhydrite ($CaSO_4$), and calcined gypsum ($CaSO_4$, $\frac{1}{2}H_2O$) which is produced by heating selenite at about 350°F for over an hour. Technically, gypsum refers to the hydrated mineral, $CaSO_4 . 2H_2O$, which occurs naturally in very large deposits all over the world and is mined at extremely low cost to produce the great majority of gypsum products. Because of its widespread abundance and low cost, gypsum is usually not transported very far to market.

Large quantities of by-product gypsum result from various chemical processes, most notably the production of phosphoric acid. Without reprocessing, this material is unsuitable for most gypsum markets because of its chemical and physical characteristics. As the cost of reprocessing is high compared to the cost of natural gypsum, almost all by-product gypsum is dumped, except for a small amount that can be used directly in agriculture. The notable exception to this practice is Japan, which is one of the few countries without adequate reserves of natural gypsum. The Japanese have been in the forefront of nations utilizing by-product gypsum because otherwise they would have to rely largely on imports transported long distances at escalating costs.

2. UNITED STATES CONSUMPTION

2.1 Gypsum Markets and Consumption Trends

The most important market for gypsum is as a building material, for which calcined gypsum is used in wallboard or as plaster. These calcined gypsum markets usually account for over two-thirds of total US gypsum markets. In 1978, 14.4 million tonnes were used for board products (13.7), building (0.4) and industrial plaster (0.3).

Crude gypsum is used in portland cement to retard the setting of the concrete. This market took 3.6 million tonnes of un-calcined gypsum in 1978. In the same year 1.2 million tonnes, including both natural and by-product gypsum, were used in agriculture to neutralize soils and to provide sulfur (see section 2.2 below).

Other markets for gypsum are very small (127,000 tonnes in 1978). Ground white gypsum may be used as a filler in paint and paper and in toothpaste, yeast culture, face powder, varnish and rubber. Gypsum is sometimes added to oilwell drilling fluids to increase the calcium ion concentration, and small quantities of gypsum or anhydrite may be introduced into glass batches as a refining agent for bottle glass.

Table 1 shows the history of US gypsum consumption since 1965. While the average long-term growth of total gypsum consumption has been slightly over 2 per cent per annum, the trend is dominated by the cyclical pattern of construction markets. However, within the building applications there has been a relatively strong (though cyclical) uptrend in wallboard which is somewhat masked in the figures by a downtrend in the use of conventional plaster.

The USBM projects that the trend growth rate of US gypsum consumption will be about 2 per cent per annum to the end of the century. CRU has not done an independent analysis of future gypsum consumption growth because with any reasonable assumption about such growth there should be ample reserves of low cost natural gypsum to supply the market. Therefore, we believe that the high cost of reprocessing by-product gypsum will rule out its use in most gypsum applications, or to be more exact in all except agricultural where it is used today in modest quantities without reprocessing.

Table 1 : US Gypsum Consumption by End-Use 1965-1978, (thousand tonnes)

	Building & Industrial Plasters*	Cement Retarder	Agriculture	Other	Total
1965	10444	2859	1233	60	14595
1966	9147	3058	1125	73	13404
1967	8726	2861	1161	70	12818
1968	9696	3119	1259	98	14172
1969	10101	3142	998	106	14347
1970	9137	3046	730	88	13001
1971	11148	3071	1019	102	15341
1972	12896	3559	1039	112	17607
1973	13531	3762	1318	106	18717
1974	11647	3681	1516	112	16955
1975	9690	2942	1344	161	14138
1976	11469	3099	1555	221	16344
1977	13514	3762	1300	162	18738
1978	14443	3565	1236	127	19372
Average % growth rate 1965-78 (trend)**	3.0%	1.6%	1.9%	8.1%	2.6%

Note: * Includes wallboard and other prefabricated products
** Growth rate of least squares trend line.
Source: USBM.

2.2 Agricultural Market

As was shown in Table 1, over 1 million tpa of gypsum is used in agriculture in the US. In 1978, approximately 46 per cent of the material for this market was by-product gypsum from phosphoric acid plants.

In agriculture, gypsum performs as a soil conditioner, provides a source of available calcium and sulfate and helps retain organic nitrogen in the soil. It is used in areas where soils are deficient in sulfur, and can serve as a "land plaster" to help reclaim land that has been inundated by seawater or over-irrigated. Gypsum is applied to certain vegetable crops (especially potatoes and peanuts) where it enhances the fixing of nitrogen underground.

Because of the nature of its land, crops and irrigation practices, California is by far the largest market for agricultural gypsum. As shown in Table 2, the Pacific region accounted for 63 per cent of the US agricultural market in 1978. In California the major applications are for cotton and potato crops. The South Atlantic States are the only other large consuming region, representing another 27 per cent of the market. Here the main uses are for peanuts, other vegetables and perhaps cotton too. The regions closest to Wisconsin use relatively insignificant amounts of agricultural gypsum.

Table 2 : Gypsum used for agriculture in the US, 1978 ('000 tonnes)

Region	Quantity
New England	0.8
Middle Atlantic	13.0
E. North Central	14.3
W. North Central	20.9
So. Atlantic	333.9
E. South Central	8.1
W. South Central	11.5
Mountain	55.1
Pacific	775.8
Exports	3.0
Total	1236.3

2.3 Gypsum Price History

Crude gypsum is a very low value product. For 1978, the USBM reported an average price of $6.83/tonne (F.O.B. mine). Much value is added thereafter by calcining, production of prefabricated products, and transportation. In 1978, the average value of calcined gypsum was $25.57/tonne (F.O.B. Plant).

Table 3 shows the history of average crude gypsum prices as reported by the USBM. While the actual dollar price has increased over the period shown, the price in constant dollars has declined substantially since the 1950's, and in 1978 the price just managed to recover, in constant dollar terms, to what it was in 1970.

The average value of by-product gypsum sold, reported by the USBM at $8.86/tonne in 1977, seems to be somewhat higher than that of crude natural gypsum. This perhaps reflects the fact that in one of the major market areas for by-product gypsum, the Southeast, there are few nearby sources of natural gypsum.

Table 3 : Crude Gypsum Prices, 1955-1978
(dollars per tonne)

Year	Actual Price	Constant 1965 $ Price
1955	3.51	4.27
1960	4.00	4.29
1965	4.11	4.11
1970	4.10	3.34
1971	4.13	3.20
1972	4.33	3.22
1973	4.61	3.24
1974	4.86	3.11
1975	5.05	2.95
1976	5.51	3.06
1977	6.12	3.22
1978	6.83	3.34

3. UNITED STATES GYPSUM SUPPLY

3.1 Production History

In 1978, US mine production of crude gypsum was 13.1 million tonnes, which was a new annual record, surpassing the previous record year of 1973 by 6 per cent. In addition, 568,000 tonnes of by-product gypsum were used in agriculture during the year.

Imports of crude gypsum supply a significant share of the US market, almost all coming from Canada (primarily Nova Scotia) and Mexico. In 1978 imports were 7.2 million tonnes, 75.1 per cent from Canada and 19.5 per cent from Mexico. The Canadian gypsum supplies processing plants on the US East Coast which is the only large consuming region of the US without nearby gypsum deposits. Mexican gypsum is used mostly in California.

Table 4 shows the history of US gypsum supply.

Table 4 : US Gypsum Supply, 1965-1978
('000 tonnes)

Year	Mine Production	By-product gypsum used	Imports	Total
1965	9102	NR	5362	14464
1966	8752	NR	4971	13723
1967	8521	NR	4140	12661
1968	9088	NR	4966	14054
1969	8964	NR	5314	14278
1970	8660	NR	5559	14219
1971	9451	NR	5528	14979
1972	11184	253	7002	18439
1973	12300	292	6950	19542
1974	10885	420	6735	18040
1975	8846	335	4942	14123
1976	10868	520	5653	17041
1977	12165	513	6417	19095
1978	13065	568	7216	20849

Note: NR - not reported
Source: USBM.

3.2 Major Producers and Locations

In 1977, crude gypsum was produced by 42 companies at 69 mines in 22 States. In order of mine output, the leading States were Michigan, Texas, California, Iowa, Nevada and Oklahoma which produced more than one million short tons each and together account for 70 per cent of the total. Figure 1 shows the location of US mines and calcining plants. The notable point is that Exxon's property is virtually surrounded by major sources of gypsum in Michigan, Iowa and Indiana. This is confirmed by the reported production in nearby States shown in Table 5.

Table 5 : Crude Gypsum Mined by State, 1977
('000 tonnes)

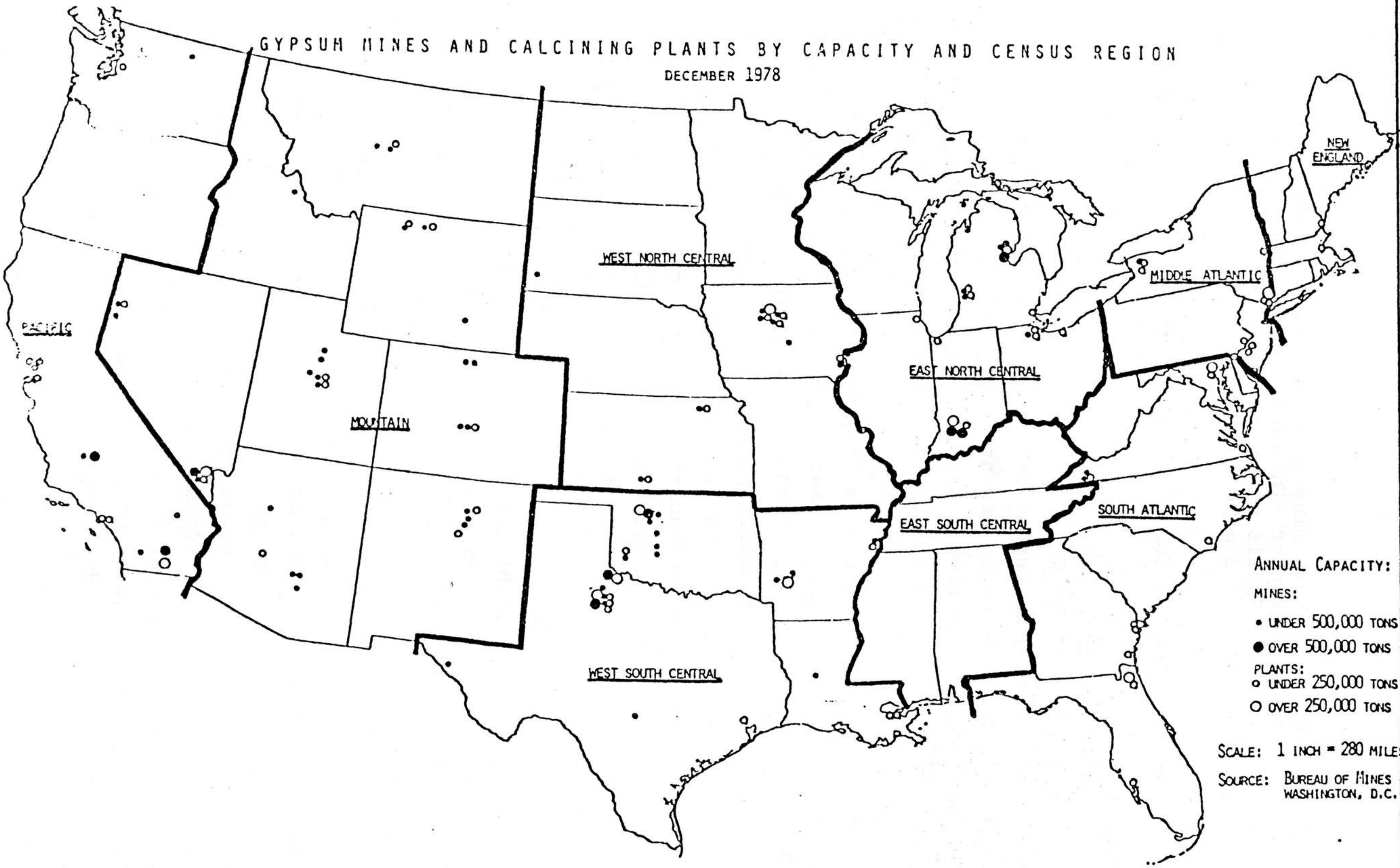
States	Quantity
Michigan	1745
Iowa	1445
Indiana, New York, Ohio, Virginia	1349
Arkansas, Kansas, Louisiana	1024

The leading gypsum mining companies are United States Gypsum Co. (12 mines), National Gypsum Co. and Georgia Pacific Corp. (6 mines each), Celotex Div. of Jim Walter Corp. (4 mines), The Flintkote Co. (3 mines) and H.M. Holloway Inc. (1 mine). These six companies produced 71 per cent of total US crude gypsum in 1977.

In order of total output, the leading individual mines are:

1. U.S. Gypsum's Plaster City mine in Imperial County, Calif.
2. National Gypsum's Tawas mine in Iosco County, Mich.
3. U.S. Gypsum's Alabaster mine in Iosco County, Mich.
4. U.S. Gypsum's Shoals mine in Martin County, Ind.
5. H.M. Holloway's Lost Hills mine in Kern County, Calif.
6. Pacific Coast Building Products' Las Vegas mine in Clark County, Nev.

Figure 1


GYPSUM MINES AND CALCINING PLANTS BY CAPACITY AND CENSUS REGION
DECEMBER 1978
PACIFIC
MOUNTAIN
WEST NORTH CENTRAL
WEST SOUTH CENTRAL
EAST NORTH CENTRAL
EAST SOUTH CENTRAL
SOUTH ATLANTIC
MIDDLE ATLANTIC
NEW ENGLAND
ANNUAL CAPACITY:
MINES:
UNDER 500,000 TONS
OVER 500,000 TONS
PLANTS:
UNDER 250,000 TONS
OVER 250,000 TONS
SCALE: 1 INCH = 280 MILES
SOURCE: BUREAU OF MINES WASHINGTON, D.C.

297

7. U.S. Gypsum's Southard mine in Blain County, Okla.
8. U.S. Gypsum's Sweetwater mine in Nolan County, Texas.
9. National Gypsum's Shoals mine in Martin County, Ind.
10. Georgia-Pacific's Acme mine in Hardeman County, Tex.

These 10 mines accounted for 45 per cent of the total in 1977.

3.3 Reserves/Resources

Domestic and foreign resources and reserves of gypsum are enormous and seem adequate far into the indefinite future. World reserves are conservatively estimated by the USBM at 1.8 billion tonnes, of which the US has 320 million tonnes.

In the US, the largest gypsum resources are centered near three main areas, the Great Lakes area, California and the Texas - Oklahoma area. In Michigan, a continuous belt of gypsum bearing rocks underlies parts of Kent, Iosco, Mackinac, Ionia, Saginaw, and Eaton Counties. These resources of gypsum are practically inexhaustible. Also in the upper mid-west, there are large deposits in Iowa and Indiana. In Webster County, Iowa, an area of 70 square miles is underlain by gypsum beds up to 30 feet thick.

Thus there is no possibility of exhaustion of natural gypsum supplies in the area of Exxon's facility.

3.4 By-product Gypsum

By-product gypsum is obtained mainly in the production of wet process phosphoric acid, but also in the production of hydro-fluoric acid and certain other chemicals. Impure by-product gypsum also results from the currently favoured process for limestone scrubbing of SO_2 from power plant stack gases. If existing and/or future coal fired power plants are required to install scrubbers, large quantities of waste gypsum would result, almost all of which would be dumped.

In the most common phosphoric acid process, 4 to 5 tonnes of by-product gypsum are produced for each tonne of P_2O_5. This means that over 30 million tonnes of by-product gypsum are produced each year, much more than the total US consumption of natural gypsum. Except for the 500-600,000 tonnes of by-product gypsum used in agriculture, all of this material is dumped.

There are many characteristics of by-product gypsum that make it unsuitable for use in the main outlets for natural gypsum at a competitive price. The chief disadvantages are (1) impurities such as flourine, residual phosphoric or sulfuric acid, uranium, radium (raising fears of radioactivity from wallboard) and many others depending on the phosphate rock feedstock, and (2) the morphology of the crystals. In competition with abundant, low cost natural gypsum it has not been economically feasible in the US to process by-product into a more usable product. While some day lack of land for waste gypsum disposal and environmental pressures might force alternative disposition of this material, no one believes this will happen quickly.

Most of the by-product gypsum used in agriculture is sold in California, by Occidental Petroleum Corp., Allied Chemical Corp., Valley Nitrogen Producers Inc., and California Industrial Minerals Co. Sales of by-product gypsum in other States are reported by Occidental Petroleum in Florida, Miles Laboratories in Indiana, Texasgulf in North Carolina, and Allied Chemical in West Virginia.

4. CONCLUSIONS

The results of our research, as reported above, clearly suggest that the prospects for sale of Exxon's by-product gypsum would be very poor. Exxon's material, produced in a geographic region with virtually unlimited sources of natural gypsum, would be unusable for any but agricultural applications without further processing. Judging by the absence of such processing elsewhere, there is no chance that the value added in upgrading the gypsum would equal the processing cost.

This leaves agriculture as the only potential market for Exxon's gypsum, but the closest region with significant agricultural consumption is the South Atlantic, which is surely out of range of a Great Lakes plant but perhaps within the realm of possibility (though not likely) from a lower Ohio River site. In any event, we do not think that sales, even to the South Atlantic region, could be more than several tens of thousands of tonnes, which would hardly make a dent in the 750,000 tpa available.