LIBRARIES
UNIVERSITY OF WISCONSIN–MADISON

Wisconsin engineer. Vol. 75, No. 5 February 1971

Madison, Wisconsin: Wisconsin Engineering Journal Association, [s.d.]

https://digital.library.wisc.edu/1711.dl/7P3DBZ6M5SIJV8I

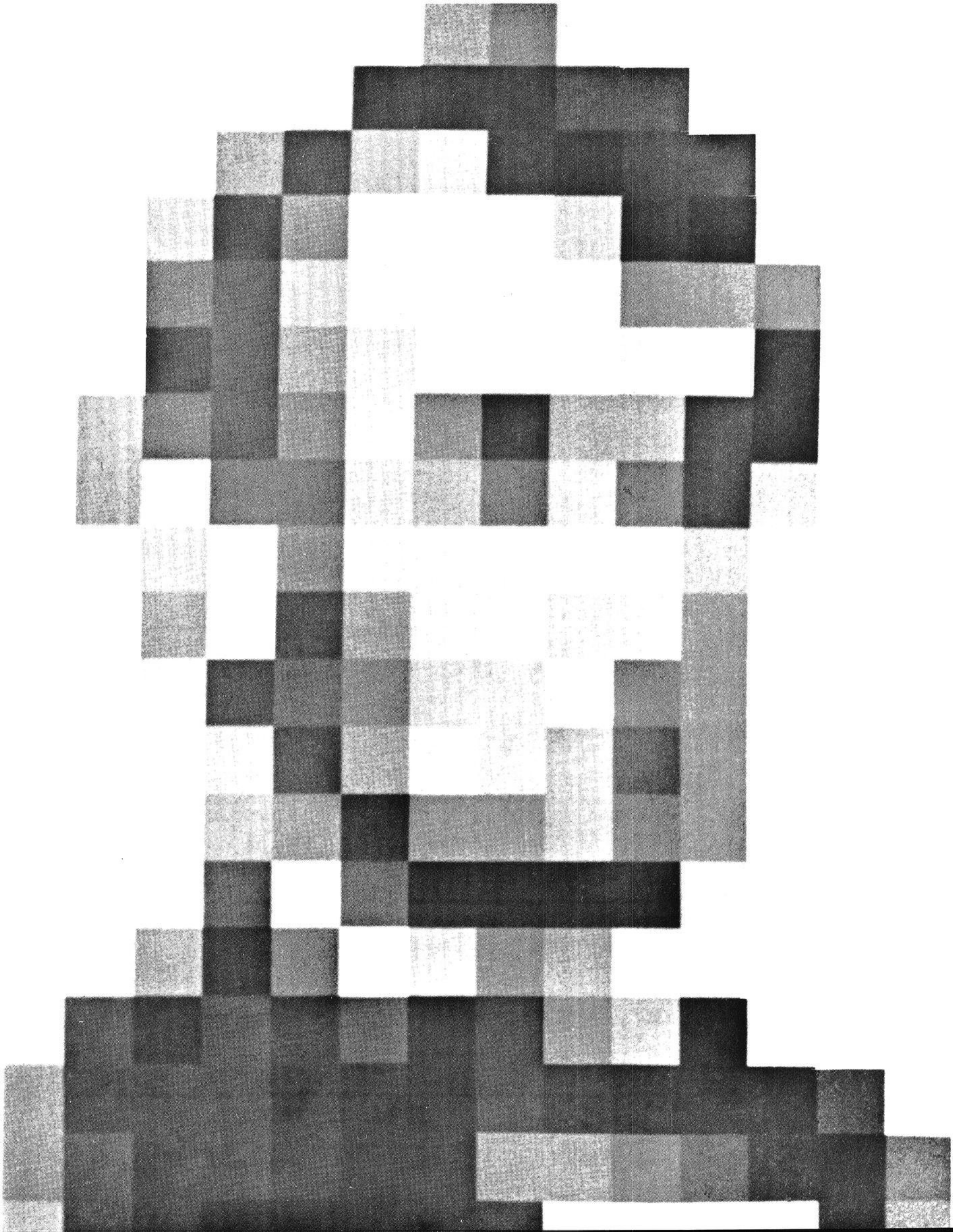
http://rightsstatements.org/vocab/InC/1.0/

The libraries provide public access to a wide range of material, including online exhibits, digitized collections, archival finding aids, our catalog, online articles, and a growing range of materials in many media.

When possible, we provide rights information in catalog records, finding aids, and other metadata that accompanies collections or items. However, it is always the user's obligation to evaluate copyright and rights issues in light of their own use.

VOL. 75, NO. 5 35 CENTS FEBRUARY, 1971

wisconsin engineer

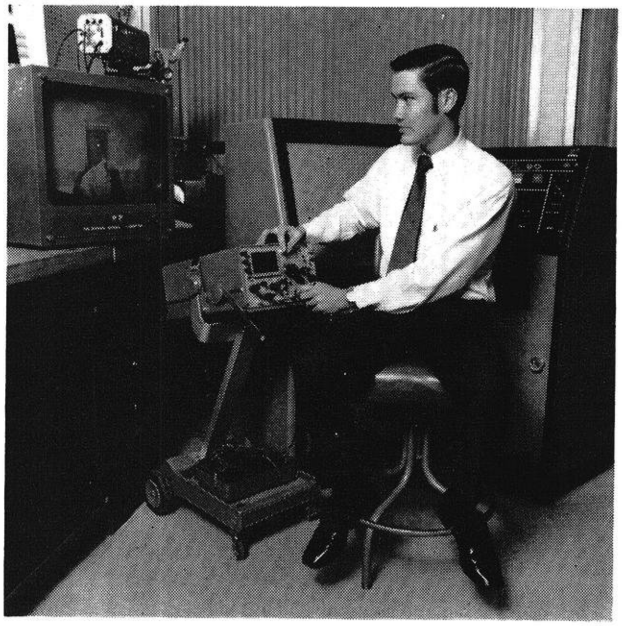


"They encourage us to look for original solutions to problems. This sparks inventiveness."

Bill Greiner, Western Electric

Bill Greiner's problem: shaving 10-14 seconds off one operation in the manufacture of integrated circuits, while reducing error factor below .001 inch.

Bill is a staff member at Western Electric's Engineering Research Center, working primarily with the handling and testing of integrated circuits.



Bill came to Western Electric in 1968 after receiving his MS from MIT. He earned his BS in Mechanical Engineering at Yale.

"My work here has given me a better appreciation of the problems in manufacturing," said Bill. His automatic TV system for the alignment of integrated circuits is a good example.

At one phase of the manufacturing process, operators must correct alignment of integrated circuits by hand—a job that took up to fifteen seconds, and was accurate to only .001 inch in x and y, and to one degree in rotary.

What Bill did, essentially, was design and build a small dedicated computer that completely automates the process. An operator can push a button to align the integrated circuits automatically. A TV camera enlarges the image in silhouette form, scans the pattern, and feeds the voltage signal into Bill's computer. The computer calculates the position measurements and triggers a stepping table to correct the alignment.

The correction time is reduced to one second, the error factor to .00025 inch in x and y, and ½ degree in rotary.

Bill finds the challenge of electronics and logic design extremely stimulating. "We're not channeled: we have a chance to get involved in a variety of fields."

What does he find most satisfying about his job at Western Electric? "Well," said Bill, "I look for an amount of responsibility. And here I'm encouraged to take it."

Western Electric

An Equal Opportunity Employer

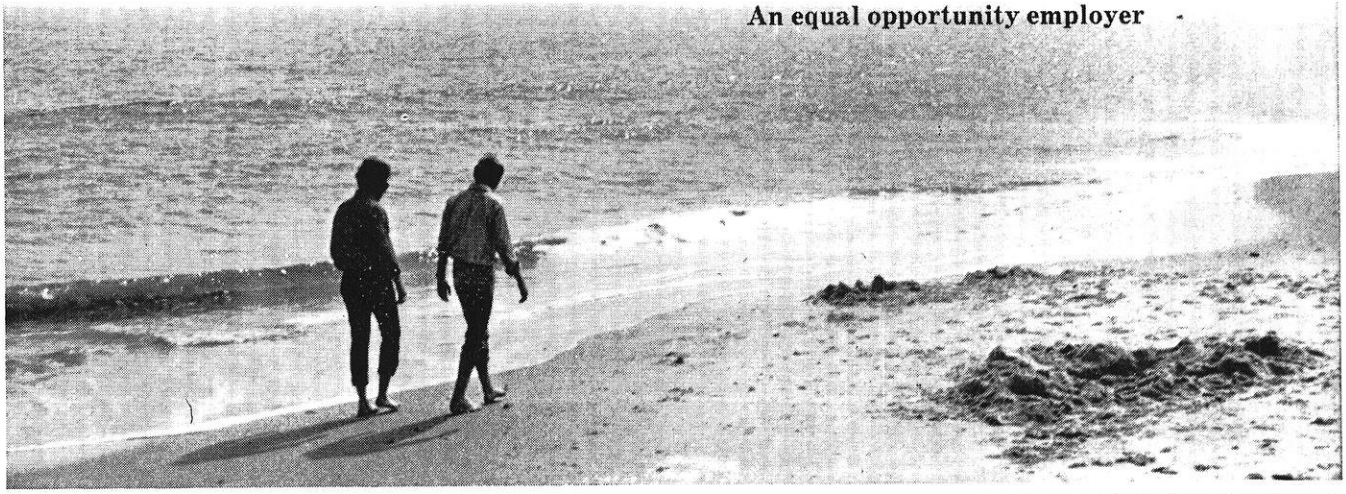
What I like about Celanese is the professional elbow room.

You had offers from other good companies. How did you come to pick Celanese?	There were a lot of reasons. One thing I liked—the recruiter I talked to was a Celanese project engineer, so he could tell me about the kinds of jobs I'd be working on.
How did you feel when you started?	Nervous! I was afraid of being stuck on one of those eternal company training programs. But at Celanese I was treated like a professional from the start. For a while, knowing that results were up to me was a little scary. But I found that when I needed help, it was right there.
You think that so much independence is a good thing?	It works. I think it's one reason why some basic ideas like epoxies, and an engineering resin—Celcon plastic—that's used to replace metals, and fibers like Fortrel polyester and Arnel triacetate all got their start at Celanese. A lot of new things are in the works, too. Right now I'm helping to scale up production of a composite material that will save weight in airplanes and rockets.
Expect to make a career with Celanese?	Who can say? All I know is I'm busy doing something worthwhile. I'm moving. I'm helping to make things happen.

Maybe Celanese is for you. If you have questions about how Celanese fits your plans for the future, have your placement office set up an interview. Or write to Dr. S. T. Clark, Celanese Corporation, 522 Fifth Avenue, New York, N.Y. 10036.

CELANESE®

An equal opportunity employer



ARNEL® AND CELCON® ARE TRADEMARKS OF CELANESE CORPORATION. FORTREL® IS A TRADEMARK OF FIBER INDUSTRIES, INC.

Can you cut costs without cutting corners?

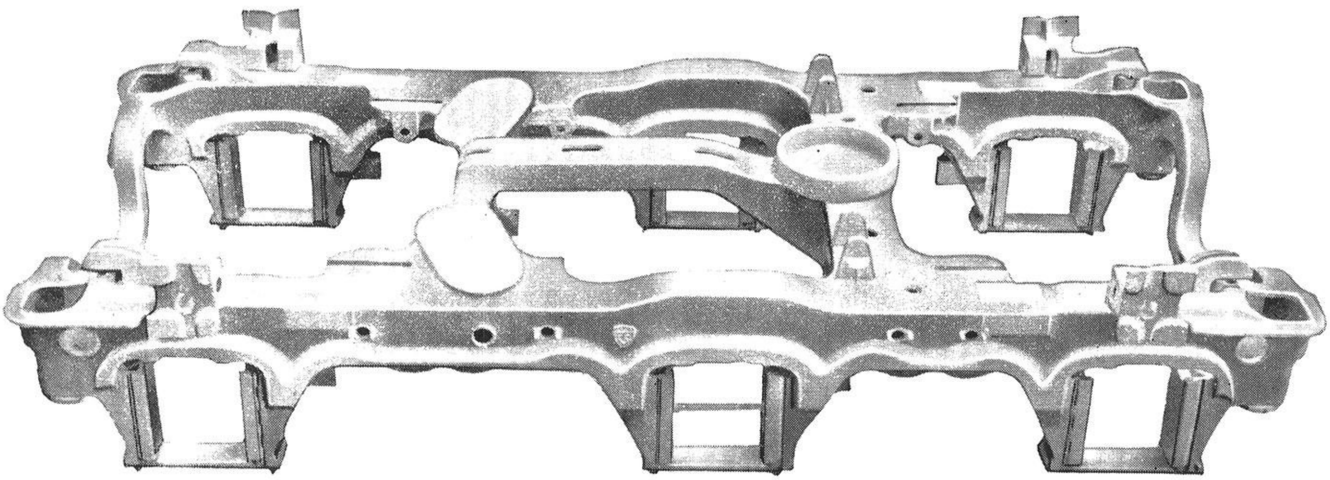
The designer of this six-wheel diesel locomotive truck frame did...that's why he chose *cast-steel.*

Using smooth fillets and fairings possible only with casting, he eliminated stress concentration caused by the corners and angles of wrought structures. To keep weight low without sacrificing strength, he varied section thickness, concentrating steel at the points of maximum stress.

And with *cast-steel* he got substantial savings in the bargain. One-piece construction eliminated assembly costs. Holes, slots and channels were cast-in directly. With the greater dimensional control inherent in casting, finishing costs on the 8 x 18 foot frame were cut to a minimum...Compare this with the tedious assembly, machining and finishing work that goes into a welded or bolted structure.

Want to know more about *cast-steel?* We're offering individual students free subscriptions to our quarterly publication "CASTEEL." . . . Clubs and other groups can obtain a sound film "Engineering Flexibility." Just write Steel Founders' Society of America, Westview Towers, 21010 Center Ridge Road, Rocky River, Ohio 44116.

STEEL FOUNDERS' SOCIETY OF AMERICA



Cast-Steel
for Engineering Flexibility

> *"We are drifting toward a catastrophe beyond comparison. We shall require a substantially new manner of thinking if mankind is to survive."* – **(Albert Einstein)**

CONTENTS:

wisconsin engineer

EDITORIAL STAFF

Dana Yarger	Editor
Ralph Berner	Associate Editor
Chris Pape	Staff
David Dornfeld	Staff
Carolyn Graff	Staff
Tom Freeman	Covers, Art Director
Scott Loomer	Photography

BUSINESS STAFF

Don Robinson	Business Manager
Jeff Crick	Assistant Business Manager
Stan Crick	Staff

BOARD OF ADVISORS

Prof. George R. Sell	Chairman
Assoc. Prof. Howard J. Schwebke	Faculty Advisor
Assoc. Prof. C. A. Ranous	Electrical Engineering
Asst. Prof. Raymond B. Esser	Mechanical Engineering
Asst. Prof. R. A. Moll	Minerals & Metals Engineering
Prof. Wayne K. Neill	Chemical Engineering
Prof. Charles G. Salmon	Civil Engineering
Asst. to Dean, Mrs. Hosman	Faculty Advisor

MEMBER OF ENGINEERING COLLEGE MAGAZINES ASSOCIATED

Chairman: DANIEL L. GRIFFEN, JR., Iowa State University, Ames, Iowa.
Publishers Representatives: LITTEL-MURRAY-BARNHILL, INC., 369 Lexington Avenue, New York, New York 10017.

* * * * * * * * * * * *

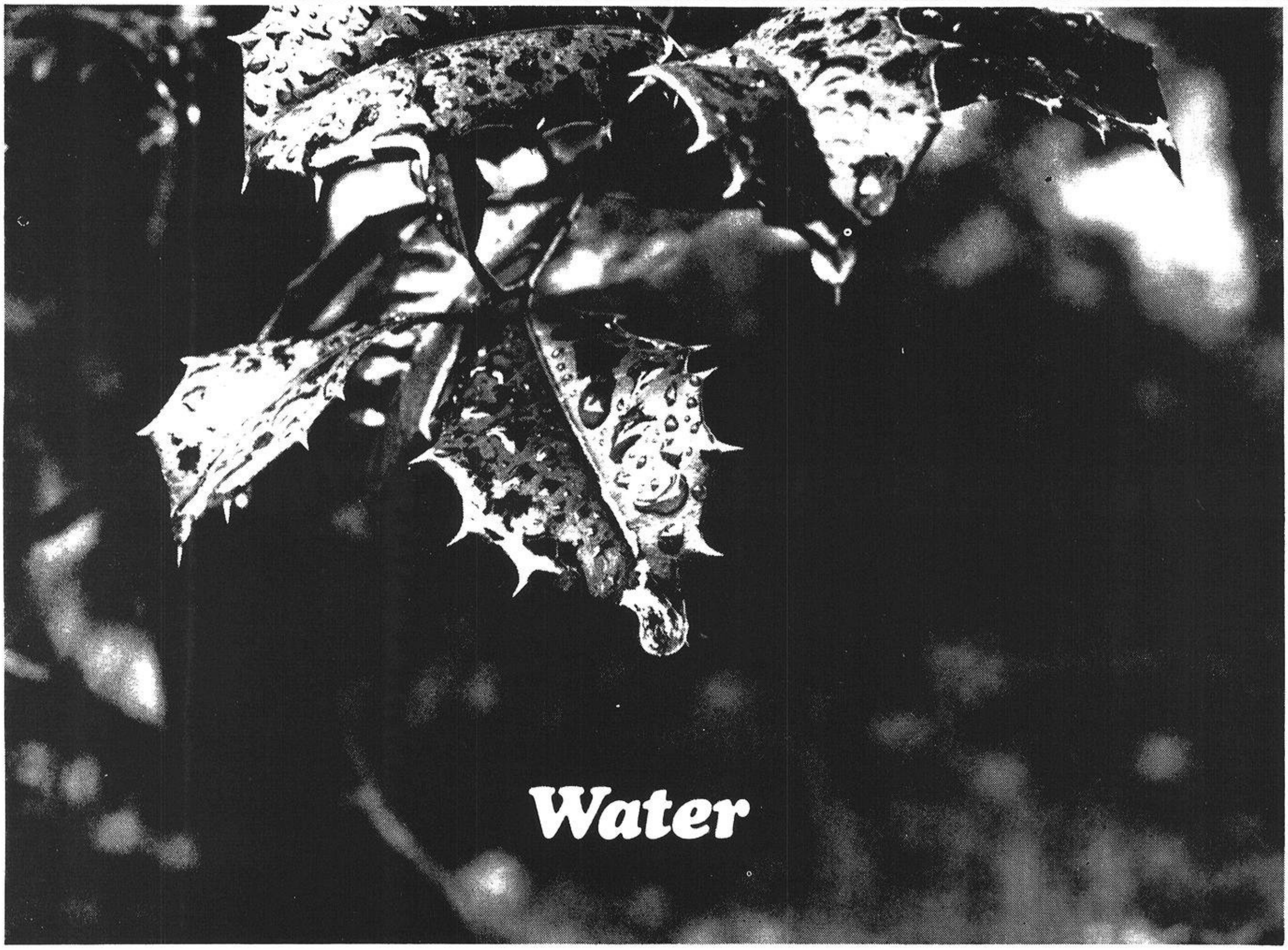
Second Class Postage Paid at Madison, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at a special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized Oct. 21, 1918.

Published monthly from October to May inclusive by the Wisconsin Engineering Journal Assn., Subscriptions: one year $2.00; two years $3.75; three years $5.25; four years $6.50. Single copies are 35 cents per copy. 308 Mechanical Engineering Bldg., Madison, Wis. 53706. Office Phone (608) 262-3494.

All rights reserved. Reproduction in whole or part without written permission is prohibited. Copyright applied for 1970.

ABOUT THE COVER:

COMPUTER CUBISM? – No, it's a well known face that has been precisely blurred by a computer. It's part of an experiment by Leon D. Harmon at Bell Laboratories to learn the least amount of visual information a picture may contain and still be recognizable. The picture is divided into about 200 squares, with each square rendered in an even tone from one of 16 intensities of gray. (If you still don't recognize the portrait, try looking at it from 15 feet or more, or while it's in motion, or while you're squinting, or with your eyeglasses removed.)



**Conserve it.
Respect it.**

Make a career out of it.

More people are deriving more benefits from our water resources than ever before in history. But today we are facing a new challenge: enhancing the quality of life by balancing the development of our water resources with the preservation of our natural environment. It is a big order, and it has to be filled.

That's where you come in. The Corps of Engineers needs engineers who are interested in the broad picture, who have a creative approach to today's problems, and who want to work with economists, planners, landscape-architects, biologists, and others to build a better quality of life. This is a chance for real involvement and achievement with an agency committed to meeting changing public needs—a chance to make it count.

Our challenges are not concerned solely with water resources. We are also applying all the techniques of modern technology to the improvement of our construction capability — systems analysis, computer technology, advanced materials research, and many more. As a Corps professional, you will face these challenges as a member of the largest engineering/construction organization in the world. Think about a career with us . . . and write today for full information.

Corps of Engineers

Department of the Army
Washington, D.C. 20314

An equal opportunity employer m/f

A Derivation of Man's Demise

Given An intelligent man
Who is only aware
Of Fortran IV
And the root mean square;
His Cartesian perception
By a function defined;
To external values
Voluntarily blind.

And: Consider a Prince,
A leader of the people,
Superficially righteous,
Accidently evil,
Who retains what he has
And gets what he can
By lying, and playing on
The passions of man.

Let: The former display
The technical skill
That enables the latter
To efficiently kill.

Let: Man's ethics be smothered
By his mechanical flair
To make death and carnage
Long-distance affairs.

Let: Those who protest
And in agony view
This hideous strength
Remain weak and few.

Mankind will die
Leaving nothing behind
But an epitaph of Fossils
To tell future minds:

Then: "Here lies a species
That failed to arrive
At the level of morality
It required to survive.

1)Anon.; Cornell Univ., Jan. 1971.

TO THE

UNDERGRADUATE

BY C. L. DEAN

(This Article Was Written in 1905; Read It and See How/If Engineering Education Has Changed)

When I consented to write an article for the WISCONSIN ENGINEER, I did not anticipate the difficulty I have experienced in choosing a proper subject. But of the number of things that a graduate might write about, I decided that some practical advice to the undergraduate would perhaps be as acceptable as anything. In treating of the work of under-graduates, one is dealing with a delicate subject for I may say something that will conflict with the ideas and practice of men engaged in teaching the theory and practice of engineering work. I may also criticise some parts of the present engineering education, but these criticisms refer to the education in general, and apply to no particular institution of learning, for all have faults in common.

But from whatever criticism I may offer, I do not mean to discourage the young man who is desirous of becoming an engineer, and of availing himself of the opportunity to obtain an engineering education. For any young man, intending to become an engineer, would make a serious mistake if he did not avail himself of the advantages of an engineering school, and such a mistake would greatly influence his future success as an engineer. But years of practice have shown that some parts of our present engineering education could be much improved, and upon these parts I may offer some criticisms.

But however great the advantages of an engineering education may be, the importance of that education should not be overestimated. If the student believes that it is thymost important of an engineer's qualifications, and that it alone will insure success, the sooner he abolishes that idea the better. Many a graduate has gone out with the idea that his education was the only necessary qualification for an engineer, but he found that in order to use his education to advantage, several years of practical experience were necessary.

The education he has secured will be of little use to him, unless he has the ability to use it. In many cases our higher education has this fault: It makes the student overestimate the importance of his college education, and it makes him think that it is the most important of an engineer's qualifications, and that it alone will insure his success. As previously stated, it is his ability to use his education that brings him success, and his ability to use it, depends upon whether it has been supplemented by several years of practical experience.

I would say that the qualifications necessary for an engineer were good common sense and judgement, education, experience and confidence. Practical experience is a supplement to education, for it gives that which an education cannot give, gives the engineer confidence in himself, and commands the confidence of those who may employ him. Without this confidence the young engineer cannot expect to be placed in positions of trust and responsibility. I might take a practical example, and as such, mention the special railway apprentice.Why is it that so few of our many college graduates take up this work? Simply because they will have to spend three or four years gaining their practical experience after graduating, and this the most of our graduates refuse to do. If men are to be educated in the railway profession, or any other branch of engineering, they must be taught that several years of practical experience are necessary in addition to their theoretical training. At the present time men graduate in the engineering profession, just as they do in medicine and law. But what conclusion do you come to when you compare the graduate in law and medicine with the graduate in engineering? Have you ever stopped to think that there are greater difficulties encountered in making a special educational course applicable to the engineering profession than to any other? When a young man graduates in law or medicine, he has learned enough of his profession to begin work in a tentative fashion; he is able to make a decent living from what he has learned. A young man graduating from the engineering courses is not likely to be acceptable for any position except a low one, which few of our college graduates would care to accept. So much of success in engineering work depends upon practical experience, that special training must necessarily be of little use unless experience in doing actual work is added to it.

A young doctor or lawyer may walk on the edge of starvation for the first year or two, but he is not required to do uncongenial labor. A graduate in the principles of engineering science, in spite of the high title he may receive from a university, must begin work as an apprentice, and his education in many cases tends to unfit him for the hard work to be done. The tendency for higher education is to fit men for being officers rather than workmen, and the training tends to make them think that experience in the ranks is unnecessary. Special college training will make a man more useful in engineering work, if he goes through the same practical experience as all successful engineers have to undergo; but unless he is willing to do this, his education will be of little use to him.

Graduates of engineering schools are rapidly coming to the front in engineering work at the present day, but those who are succeeding are the men who are not afraid to don overalls and learn the details of the trade after they have graduated from college. Most of our engineering graduates refuse to do this, and they drop into minor positions, as draftsmen and clerks, and are rarely qualified for the higher positions.

Within a short time many of you will have completed your education and as you look back, you may ask yourself this question: What have I accomplished during my four years' course? The answer to this question can best be given by the graduate himself, for he alone knows whether he has applied himself earnestly enough to warrant the confidence necessarily due the successful engineer. As to the future, you may ask yourself this question: What position am I capable of filling, and what salary should accompany that position? The anwer to this question depends upon what your employer thinks you ought to know, and what your services are worth, more than upon what the graduate thinks he knows, and what his services are worth. You will find the men in charge of our large manufacturing plants, or men in charge of any work that pertains to engineering, divided into two classes, which we may call, the college-bred man, who has had the advantages of a college education, and the self-made man, who has not had any educational advantages, but has gained his position by hard work and costly experiments. The college-bred man has had the same advantages that you have, consequently he has had very little difficulty in understanding the college man when he applies for a position. He knows how to manage the graduate, and under his management you will stand a better chance for advancement than apder the self-made man. When you apply for a position under the self-made man, the first question he asks is: What practical experience have you had, and where was it obtained? In the majority of cases the graduate has obtained his practical experience at some university, and is immediately told that if he wants to begin work at the bottom and work up, he can do so by starting in as a special apprentice, and gain sufficient practical knowledge to make his advancement profitable to himself and his employer. This is due to the fact that the self-made man has gained his position by hard work, or in the manner just mentioned, and it is very hard to convince such men that other methods may be employed to reach the desired end. He does not understand, that the college man, due to his special training, can learn more readily, and hence his promotion be more rapid. But in the end the methods used by the self-made man are that best for the young engineer in beginning his career.

In regard to the young engineer's salary, many people have the erroneous idea that a college graduate should draw a large salary immediately upon graduation, and this thought is entertained by many of our graduates. In other words, they seem to think that a college man ought to be paid according to what he knows. They forget the fact that a man's salary depends not upon his great amount of knowledge, but upon the practical application of the same. A schoolmate of mine once made the statement, "That if he did not receive fifteen hundred dollars for his first year's work after graduating, he would consider his four years of college wasted." He received a much smaller amount to start with, and if you were to ask him now about the matter, he will not tell you that his four years' of college training was a waste of time. This same idea prevails among the undergraduates of all our institutions, and the sooner we instruct them differently, the better it will be for all concerned.

When the student enters college he is told that in order to become an engineer a knowledge of French or German is necessary. The plea generally made for the study of the modern languages in our engineering schools is, that many of the best engineering works are in those languages. But you will find that there is very little in either language that will be of any practical value to you as engineers. If an article or treatise of merit does appear in French or German, it is soon translated into English, and there are already more good books on engineering in the English language than you can find time to read. And finally, not one student in fifty learns a modern language with sufficient thoroughness to translate correctly a technical article. The study of the dead language clings to our institutions too rigidly. Most of the time spent by engineering students in the study of languages is totally wasted. In the first place, only enough is learned to pass the examinations, and if it should be well learned, there is no use for it. My experience has been that the time devoted to studying French and German, or any other language except English, could be used to better advantage in studying something more practical. Men who are today engaged in the teaching of engineering and who have made it their life work, will strongly advocate the study of languages for the engineer, while our most prominent engineers who have been engaged in actual practice for 20 or 30 years, and many of them are college men, say that the time spent in the study of languages is totally wasted, and should be replaced by something of a more practical nature. It is for you to decide who is the better judge in this matter, those who are teaching in our engineering schools, or the men who are in actual practice and have to apply their education in a practical manner. For my part I cannot help but agree with the engineer in practice.

Instead of spending valuable time on these languages, why not give the students instructions in English, and make them masters of their own language? Of the large number of graduates, how many of them can spell correctly? How many of them can write a good business letter? Very few have had the right training along this line, and you would have ample proof of it if you were to look over a few examination papers or examine some of the applications for work sent in by college graduates. In the study of English for engineers, why not do away with the present methods, throw out the fad of studying old writers, their poetry and novels? It is engineering papers, books and specifications that the engineering students are likely to write after graduating, and not poetry and novels. In writing specifications the engineer cannot get too much practice during his college course. He should be taught to write and express himself clearly and emphatically. As examples, why not take up the works of some prominent engineer, selecting those written in good English, and study them. Our examples should necessarily be the work of some American engineer.

In addition to this I would suggest that the undergraduate make good use of the debating societies which are well founded in our institutions. The training received from debating, writing and reading papers will be of more value to you than you suppose. You will appreciate this fact when you have to put up a good talk to get your first contract.

There are many other things that

(Continued on page 13)

NDT*

*(NON-DESTRUCTIVE TESTING)

Although it existed in many recognized forms for years, nondestructive testing was formalized into a science under the impetus of World War II. The demand for quality and safety in aircraft and many other products, complex and simple, resulted in a steady growth. More recently, with the nation's aerospace and oceanographic programs, this growth in NDT has been astounding.

NDT has burgeoned because it had to. The engineers, scientists and technicians in nondestructive testing have no choice — they have to be good and make good. This is a materials age and the increasingly exquisite demands technology makes on materials, both common and exotic, can only be met if their performance can be assured by testing nondestructively. The discipline has been hustling for more than a quarter of a century and the men within it find they now must hustle more than ever.

Some Definitions

First, a few definitions. To say that nondestructive testing is testing without destroying is an oversimplification but a true one, even if it does use the words of the term in defining it. NDT can be as simple as egg candling or as complex as checking on man-made meteors by flash radiography to test the durability of space suits.

Harold S. Berger, a physicist at Argonne National Laboratory, describes a nondestructive test as "an examination of an object." The purpose of the test may be to detect internal or external flaws, to measure thickness, to determine material structure or composition, or to measure or detect any of the object's or the material's properties.

Warren McGonnagle and Ford Park give this estimation in **International Science and Technology**:

"nondestructive testing is the use of physical methods for evaluating materials without impairing their usefulness. It plays an important role in a number of industrial manufacturing areas: flaw detection, process improvement, control and monitoring, measurement of mechanical properties, as well as changes in them."

These definitions were framed five or six years ago and, although they are exact and explain what NDT is, they are already showing their age. Nondestructive testing is going farther in many directions: back to assessing the quality of the raw materials and ores from which objects are made (the latter definition only hints at this); far, far forward to predict incipient failure — that is detecting the gradual disarrangement of molecules in time to predict failure of a part in so many hours or days. It has had to thrust itself boldly by necessity into the field of design, where it is just now making itself felt.

If there is nondestructive testing, there also must be destructive testing, but this is a mode that because of cost and uncertainty of results is in decline as NDT undergoes furious growth. For example, a destructive test on castings may saw up and break up every 10th or 100th casting. The reasoning goes that if these are without serious flaw so are the other 9 or 99. But it is doubtful if NASA would be willing to fire a rocket or a commercial airline would be willing to send up a plane if either contained a component so tested.

World War II saw a spurt in the use of more sophisticated materials and metals. The thrust into space saw an even greater surge to exotic — and extremely expensive — materials. As the cost of basic material grew, the cost of destructive testing became prohibitive. So, at great expense you either had nothing left at the end of your test, or you weren't sure of the reliability of the items you had not tested. It is easy to see why NDT was thrust to the center of the stage and told to be good, to be very, very good.

Many Methods of NDT

Mr. Berger points out that in spite of the many different kinds of nondestructive tests, all methods have five basic elements in common:

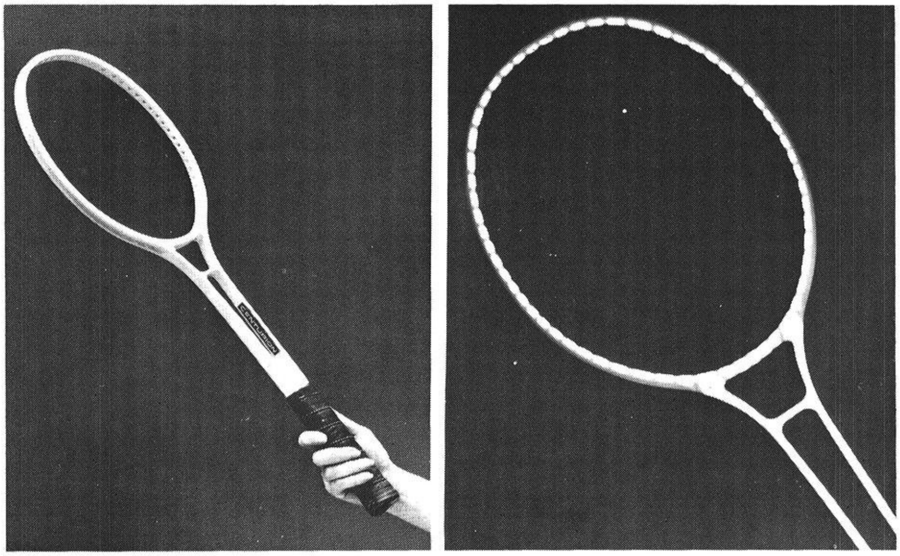
1. A source of energy is needed which provides some probing medium that can be used to inspect the item under test.
2. The probing medium must change as a result of discontinuities or variations within the object being tested.
3. A detector capable of revealing the changes in the probing medium is required.
4. A means of indicating or recording the signals from the detector is necessary.
5. A method of interpreting these indications must be provided.

The basic form of inspection is visual and the basic tool is the human eye, a versatile instrument capable of discerning gross flaws and capable, too, of reading indications from film or instruments which the eye cannot see. These instruments depend on various forms of energy to wrest the secrets hidden in materials and objects, among them: penetrating electromagnetic radiation, sound, ultrasound, chemicals, electricity, magnetic forces, light and heat, or temperature changes.

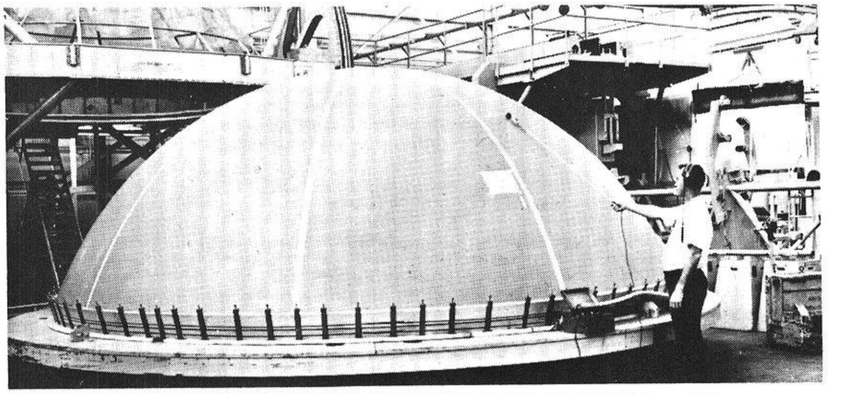
These energies have been harnessed into formal modalities, each of which fulfill Mr. Berger's five points. Following are brief descriptions of NDT regularly used in industry today (Researchers are constantly devising new techniques in the laboratory to meet new testing problems and a few of these advanced methods will be touched on later):

(Continued on page 12)

NDT — *Pictorial*



AT LEFT is the Centurion, the new, one-piece, magnesium alloy tennis racket designed and nondestructively tested by aerospace methods. At right is a radiograph (x-ray) of the racket showing its sturdy, single-unit construction.



SONIC "GROWLER" SEARCHES FOR VOIDS IN BONDING – The common bulkhead of Satern stage S-IVB which is 22-feet in diameter, is subjected to a nondestructive test using a sonic "growler" developed by McDonnell Douglas to search out voids in the bonding.

G = good
F = fair
P = poor
☐ = unsuitable

1 — Fluoroscopy suitable only for thin sections.
2 — If beam is parallel to cracks.
3 — Special thickness gages available.
4 — Size of defect found depends on thickness of section.
5 — Defects must be open to a surface to be located with penetrants.

Our thanks to Krautkramer Ultrasonics, Inc., and Magnaflux Corp. for their help in revising this chart.

NONDESTRUCTIVE TEST METHODS GENERAL SUITABILITY COMPARISON CHART

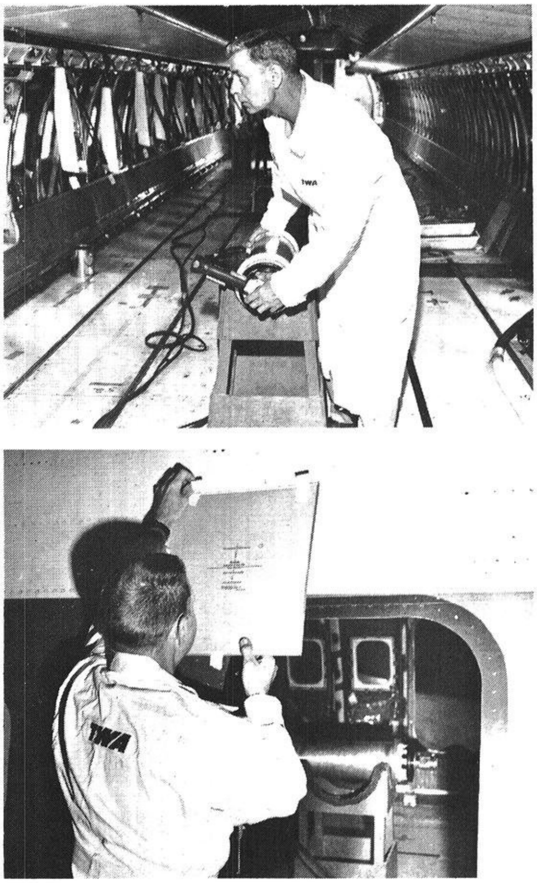
MAGNETIC (OR HEAVY) METALS

			GENERAL						SHEET AND PLATE			BARS AND TUBES				CASTINGS					FORGINGS					WELDS					PROCESSING		IN SERVICE				
																										WITH BEAD		WITHOUT BEAD									
			MINUTE SURFACE CRACKS	DEEPER SURFACE CRACKS	INTERNAL CRACKS	INTERNAL VOIDS	THICKNESS	METALLURGICAL VARIATIONS	THICKNESS	LAMINATIONS	HOLES	SEAMS	CENTER PIPE	CUPPING (CHEVRONS)	INCLUSIONS	COLD SHUTS	SURFACE CRACKS	INTERNAL SHRINKAGE	HOLES/POROSITY	CORE SHIFT	LAPS	INCLUSIONS	INTERNAL BURSTS	INTERNAL FLAKES	CRACKS AND TEARS	INTERNAL CRACKS LACK OF FUSION AND PENETRATION	SLAG INCLUSION/POROSITY	INTERNAL CRACKS LACK OF FUSION AND PENETRATION	SLAG INCLUSIONS/POROSITY	SURFACE CRACKS	HEAT TREAT CRACKS	GRINDING CRACKS	FATIGUE CRACKS, HEAT CRACKS	STRESS CORROSION	BLISTERING	THINNING	CORROSION PITS
PENETRATING RADIATION[4]		X-RAY		F[2]	F[2]	G	F	F	G[3]		G	P	G	G	F	G	F[2]	G	G	G	F	F	F	F	F[2]	G[2]	G	G[2]	G	P	P		P	F	P	F	G
		FLUOROSCOPY[1]			P	F					G				F	F		F	F	F						F[2]	F	F[2]	F							P	P
		RADIUM AND RADIOISOTOPE		F[2]	F[2]	G	F	F	G[3]		G	P	F	F	F	G	F[2]	G	G	G			G		F[2]	G[2]	G	G[2]	G	P			P	P	P	F	P
ULTRASONIC AND SONIC	CONTACT PULSE REFLECTION	NORM. TO SURF. OVER ½"			G	G	G	F	G	G	G		G	G	F	F		G	F	G	F	G	G	G	G				G				G		G	G	P
		SEND AND RECEIVE			G	G	G	P			G		G	P	G	P	F	G	G	G	F	G	G	G	G				G				G	G	G	G	G
		ANGLE BEAM	P	G	G	G		P		F	F	G		G	G	F		F	P		G	G	G	F	G	G	P	G	F	P	F	P	G				P
		SURFACE WAVE	G	G								F									F									P	F	G	F	F			
	IMMERSION PULSE REFLECTION	NORM. TO SURF.			G	G	G	F	G	G	G		G	F	G	F		G	F	G	F	G	G	G	G				F								
		ANGLE BEAM	P	G	G	G				F	F	G		G	G	F	F	F	F		G	G	G	F	G	F	F	G	F	G	F	P	G				
		THROUGH TRANSMISSION			F	G		F		G			P	P				F	P				F	P		F	F								F		
		RESONANCE			P	P	G	P	G	G									P	G															G	G	P
		METER THICKNESS GAGE (under 3")					G		G	G										G															G	G	F
		SONIC and MECHANICAL VIBRATION		P				G									P	P							P												
MAGNETIC PARTICLE	A.C.	WET	G	G						F		G	P		G	G	G				G	F			G	F		F		G	G	G	G	G			
		DRY	F	G						F		G				G	G				G	F	F	F	G	F		F		G	G	G	G	F			P
	D.C.	WET	G	G	P					G		G	P		G	G	G	F			G	G	F	F	G	F		F		G	G	G	G	G			
		DRY	F	G	F	P				G		G		P		G	G	F	P		G	F	F	F	G	G	G	G	G	G	G	G	G	F			P
ELECTRO-MAGNETICS		EDDY CURRENT	F	G			F	G	P			F				P	F	P		P	P				P		P		P	F	G	F				F	
		MAGNETIC PROPERTY ANALYSIS	P	F	P	P	F	G	F			G	F	F	P	P	F	P	P	P	P	P	F	P	P		P		P	P	G	F	F			P	
		LEAKAGE FIELD PICKUP	F	G	F						P	G		P	P	P	F		P		F	P	P	P	F		F		F	G	G	F	G				
		D.C. CONDUCTION	F	F	P	P	F	P	F	P	P	F		P			F			P	F				F					F	F	F	F	F		F	
PENETRANTS[5]		VISIBLE DYE PENETRANT	F	G						F	P	G	F		G	G	G		G		G				G					G	G	G	G	G			F
		FLUORESCENT DYE PENETRANT	G	G						F	P	G	F		G	G	G		G		G				G					G	G	G	G	G			F

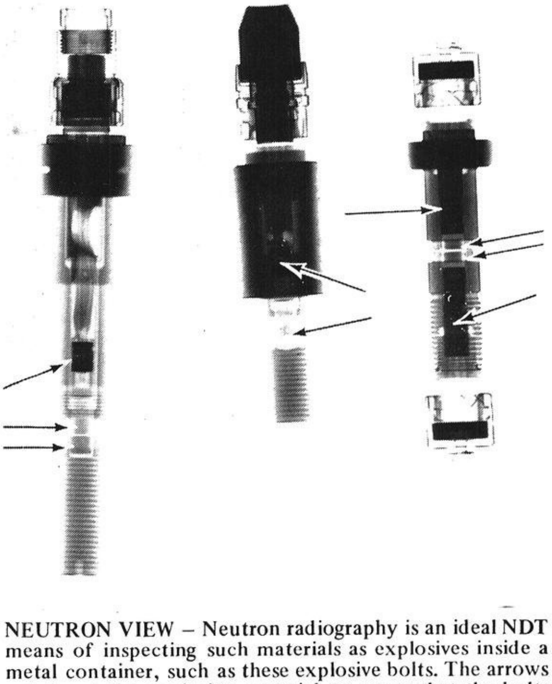
WHY THIS CHART

In February 1968, we ran a version of this chart as a supplement to our special report on NDT. It was no different from the one compiled in 1959 by Carl Betz of Magnaflux. Since our article appeared, we've received suggestions and contributions from several readers recommending we update the chart.

A few words of caution: ratings are subjective at best. These (good, fair, poor, unsuitable) are no different. A host of variables attends any inspection process, variables that could turn a fair rating into a good one or vice versa. An explanation as to why the distinction between "poor" and "unsuitable." Unsuitable means don't use the process. Poor implies a temptation to use the process, that it will give satisfactory results. The rating suggests you use the process but that you do at your own risk.



INSIDE OUT – Top: An x-ray machine is set up inside a TWA Boeing 707 cabin to "shoot" 14" by 17" films of emergency exit framing. Bottom: Film is placed at the emergency exit framing outside the cabin on the fuselage skin surface. Note x-ray machine inside cabin.



NEUTRON VIEW – Neutron radiography is an ideal NDT means of inspecting such materials as explosives inside a metal container, such as these explosive bolts. The arrows point out the explosive material to prove that the bolts are properly armed to do their job and that there are no flaws or separations in their containers.

If you are a senior...

1971

PRATT & WHITNEY AIRC
DEPENDABLE ENGI

could be the most
important year
of your life.

As you contemplate one of the most important decisions of your life, you will want to remember this: it is not just "a job" you are seeking—it should be the beginning of a career. And if it is to be successful, both you and your employer must need and want each other.

To help you with your decision, we invite you to consider the opportunities at Pratt & Whitney Aircraft. Currently, our engineers and scientists are exploring the ever-broadening avenues of energy conversion for every environment . . . all opening up new avenues of exploration in every field of aerospace, marine and industrial power application. The technical staff working on these programs, backed by Management's determination to provide the best and most advanced facilities and scientific apparatus, has already given the Company a firm foothold in the current land, sea, air and space programs so vital to our country's future.

We select our engineers and scientists carefully. Motivate them well. Give them the equipment and facilities only a leader can provide. Offer them company-paid, graduate-education opportunities. Encourage them to push into fields that have not been explored before. Keep them reaching for a little bit more responsibility than they can manage. Reward them well when they *do* manage it.

Your degree can be a B.S., M.S., or Ph.D. in: MECHANICAL ENGINEERING • AERONAUTICAL ENGINEERING • ENGINEERING SCIENCE • ENGINEERING MECHANICS.

If your degree is in another field, consult your college placement officer—or write Mr. Len Black, Engineering Department, Pratt & Whitney Aircraft, East Hartford, Connecticut 06108.

ratt & Whitney Aircraft

T HARTFORD AND MIDDLETOWN, CONNECTICUT

DIVISION OF UNITED AIRCRAFT CORPORATION

An Equal Opportunity Employer

Radiography Penetrating electromagnetic radiation, the most firmly established and popular form of NDT, employs x-rays or gamma rays to penetrate an object or material to detect any flaws within it. After the exposure, development of the film and interpretation, the radiograph can be permanently stored as a record of the test.

Radiography can be classified by its sources: x-rays are produced by machines, in other words are manmade; gamma rays are produced by radioactive material, such as cobalt-60. X-radiation and gamma radiation are short-wavelenght electromagnetic rays capable of passing through relatively large thicknesses of material.

X-rays have wave lengths ranging from 1/10.000 to 1/10.000.000 that of visible light and it is this shortness of wavelength which permits them to penetrate material. They are produced when electrons traveling at high speed strike matter. In the usual type x-ray tube, an incandescent filament supplies the electrons at high speed to the anode, or target, usually tungsten. As the electrons are suddenly stopped at or near the target, x-rays are generated. Voltages now in use may run from 4 kilovolts for the highly specialized laboratory unit to 30,000 kilovolts which may be produced by betatrons and linear accelerators.

The betatron and linear accelerator do not need the high voltage input but presently can carry the useful x-ray energy level to 30 million electron volts. Since the advent of atomic energy, neutrons from nuclear reactors are being used for radiographic NDT. However, neutrons have different absorption characteristics than x-rays. For instance, heavy elements such as lead, bismuth and uranium are practically transparent to thermal neutrons whereas they absorb x-radiation strongly. Conversely, hydrogen, lithium, boron and other light elements strongly absorb thermal neutrons but allow x-rays to pass freely. It is easy with neutron radiography to record on film a candle and its flame through a lead brick, or to record the height of a column of water in a lead tube. The neutrons penetrate lead but are strongly absorbed by hydrogenous materials.

Gamma rays are similar in their characteristic to x-rays and are distinguished by their source, rather than by their nature. Radium has been in use for many years, but cobalt-60 and iridium-192, both radioisotopes, are the most popular sources today. Others include thullium-170 and cesium-137. Recently researchers have been investigating the abilities of californium-252 as a radioactive source of neutrons, but it is a rare and expensive source, costing nearly $1 billion per gram.

Flaw detection can be accomplished because radiation entering the specimen is absorbed less by the flaw than by the rest of the specimen. This shows up on the developed film as a dark area, revealing the presence, location and general shape of the flaw.

Fluoroscopy, image intensification, motion picture units and television chains have been adapted as sophisticated additions to radiography.

Ultrasonics – Sound waves ranging from 250,000 to 25 million cycles per second, far above those audible by the human ear, are employed in ultrasonic testing, the fastest-growing NDT modality. These electronically-produced sound waves are relatively weak and are not to be confused with those used in ultrasonic vibratory techniques such as machining, cleaning or deburring.

High frequency sound, like audible sound, does not transmit well through air and in testing, oil or a column of water is used as a couplant. Ultrasonic equipment has a sound transmitter, a receiver, an amplifying system for the received signal and a means for presenting the signal, usually an oscilloscope. Thus, along the way, sound energy is translated into electrical energy for display and interpretive purposes. The system is related to the sonar submarine detector system where the signal bounces off a submerged object and returns.

Ultrasonic flaw-detection equipment shows how thick a part is and if and where it has an internal flaw. It can accomplish this by any of three methods; pulse-echo, through-transmission and resonance.

The pulse-echo system employs a piezoelectric crystal which throbs like an ultrasonic drum when high frequency alternating current is applied to it. (Piezoelectric crystals expand from current in one direction and contract when polarity is reversed). The pulse-echo ultrasound striking an object registers a blip on the oscilloscope as it meets the surface and is reflected; a portion of the sound travels on through the object to the opposite surface and another blip is registered as the sound bounces back. The space between the two blips represents the thickness of material and can be calculated. A flaw anywhere in the sound's path will register another blip between the original two.

In through-transmission, two piezoelectric crystals are used one as a transmitter and the other as a receiver. The crystals are coupled to the part being inspected as in the pulse-echo method, with water or oil, and the results are read on an oscilloscope but in a different way because the information is different.

In the immersion method of ultrasonic testing, both the part and the crystal or crystals are submerged in liquid, usually water. This method adapts well to production in aircraft, aircraft turbine and missile industries where large part-runs are encountered and there is a demand for flexibility because of the many different types of parts.

Penetrants – Radiography and ultrasonics can detect internal flaws in material but various forms of the penetrant method are employed to reveal surface cracks. It is basically an old method going back to the "whiting" technique, which involved chalk dust and water, but has been refined and sophisticated so that it is a widely used and effective testing tool in industry today.

Penetrants are used to find surface defects in connection with welding, forging, grinding, fatigue, shrinking, etc. A part to be inspected is thoroughly cleaned and then painted, dipped or sprayed with a penetrating chemical. After a suitable time, during which the penetrant enters any defects, the penetrant is washed off or removed from the surface and a developer applied. The developer brings to the surface the penetrant entrapped in the defect. The part is then inspected.

There are two main types of penetrant inspection: (1) dye penetrant which contains a visible dye, ususlly red; the defects show up as red lines or dots against a white developer background: (2) fluorescent penetrant which fluoresces brilliantly under black light; defects appear as fluorescent lights or dots against a nonfluorescent background.

Magnetic Particles – This is only one of three NDT tests in use today which uses the principle of magnetics to detect flaws. Iron filings or particles are distributed evenly over the surface to be tested. These can be dry or in a carrying liquid. The particles are attracted to defects at or just beneath the surface because of the local variations in the magnectic field that such defects produce. In some cases, the particles are coated with fluorescent material and subjected to black light. Both direct and alternating currents are used for magnetizing, and the part is demagnetized after inspection.

Eddy Currents – This NDT method employs the principle of magnetic induction. When a coil carrying a high frequency alternating current is brought into the vicinity of an electrical conductor, eddy or induced currents are generated in the conductor. By Lenz's law, there is a magnetic field associated with the induced currents. Flaws, as well as variations in mechanical, chemical or physical properties, cause resistivity changes in the specimen. These affect the eddy currents and consequently, the magnetic field induced in the specimen. Detection and measurement of distortions in this magnetic field form the basis of the test.

Two general types of probe are employed in this test: the encircling coil which completely surrounds the specimen and interrogates a volume of material determined by the coil geometry; and the point probe, which interrogates only a volume of material beneath it that is essentially equal to its cross section times a depth of penetration.

Other Modalities – Infrared and thermal NDT techniques, which depend upon heat as an indicator, are gaining increasing acceptance. Cholesteric crystals, which are in this category, are able to detect a change in temperature in less than one-fifth of a second and find flaws measuring less than one-thousandth of an inch. Acoustic emission, the measurement of sound (as differentiated from ultrasound), has had some fairly spectacular results in detecting incipient failure, that is sounding the alarm and predicting a material or a part will fail in the near future. Holography – lensless photography producing three-dimensional images – combined with laser interferometry is emerging as a widely applicable method. More new modalities and more sophisticated and refined variations of established modalities are appearing every year.

The foregoing only lightly touched on the various NDT methods and are far from being complete or in depth. For more complete and technical information.

A Science for All Seasons

One of the fascinating attractions about nondestructive testing is that it embraces nearly all the physical sciences and technologies. It demands knowledge of physics and chemistry. It is at home in the laboratory and in the industrial plant. Its involvement is wherever men are at work in the air, on or below the surface of the sea and on land. It applies its varied techniques in a myriad industries, among them: aerospace, aircraft, automotive, casting and forging, chemical and petroleum, construction, electronics, food processing, marine and oceanographic, materials joining, metals, nuclear, ordnance, railroad and utilities.

By concentrating on flaw detection and classification at every state of manufacture from raw material, through design and the various production stages to the final product **AND** its maintenance, NDT has saved untold lives and incalculable millions of dollars.

Our day-to-day life with its dependence on sophisticated machines all around us and vehicles in in the air, in space, on the ground and at sea, would not have been possible without NDT. Paraphrasing the old saying, if nondestructive testing were not in existence, it would have been necessary to invent it.

|***|

UNDERGRADUATE (from page 7)

might be said to help the undergraduate, but space and time will not permit my mentioning them at this time. But before closing let me impress upon you afew important facts. Get over that idea which still prevails to a certain extent in our institutions, that you must study just enough to pass your examinations. By following this practice you are the looser, not your instructor. Remember that your instructors are your friends after graduating as well as wherein college, and do not hesitate to apply to them for advice at any time. They can very often help you in starting right, and will willingly help you over any obstacles you may encounter. If you have an opportunity to take a post-graduate course, by all means take advantage of the opportunity, and you will not regret the time spent. I should advise going to some other good engineering school for your post-graduate work, in order that youay meet new instructors, and where your surroundings will be of a different nature than those you have become accustomed to during your four years' course. By all means become a good draftsman. Even if you do not take up this part of the work as your profession, you will find constant use for it in any branch of engineering work. Spend your vacations in doing actual engineering work. Do not take into consideration the money value of this work, for it is the experience you are after. Remeber that in England young men have to pay large sums just for the privilege of working for several years with prominent engineers. Our graduates are to be congratulated on the fact, that they are at least able to get their expense, and in most cases more when they start out.

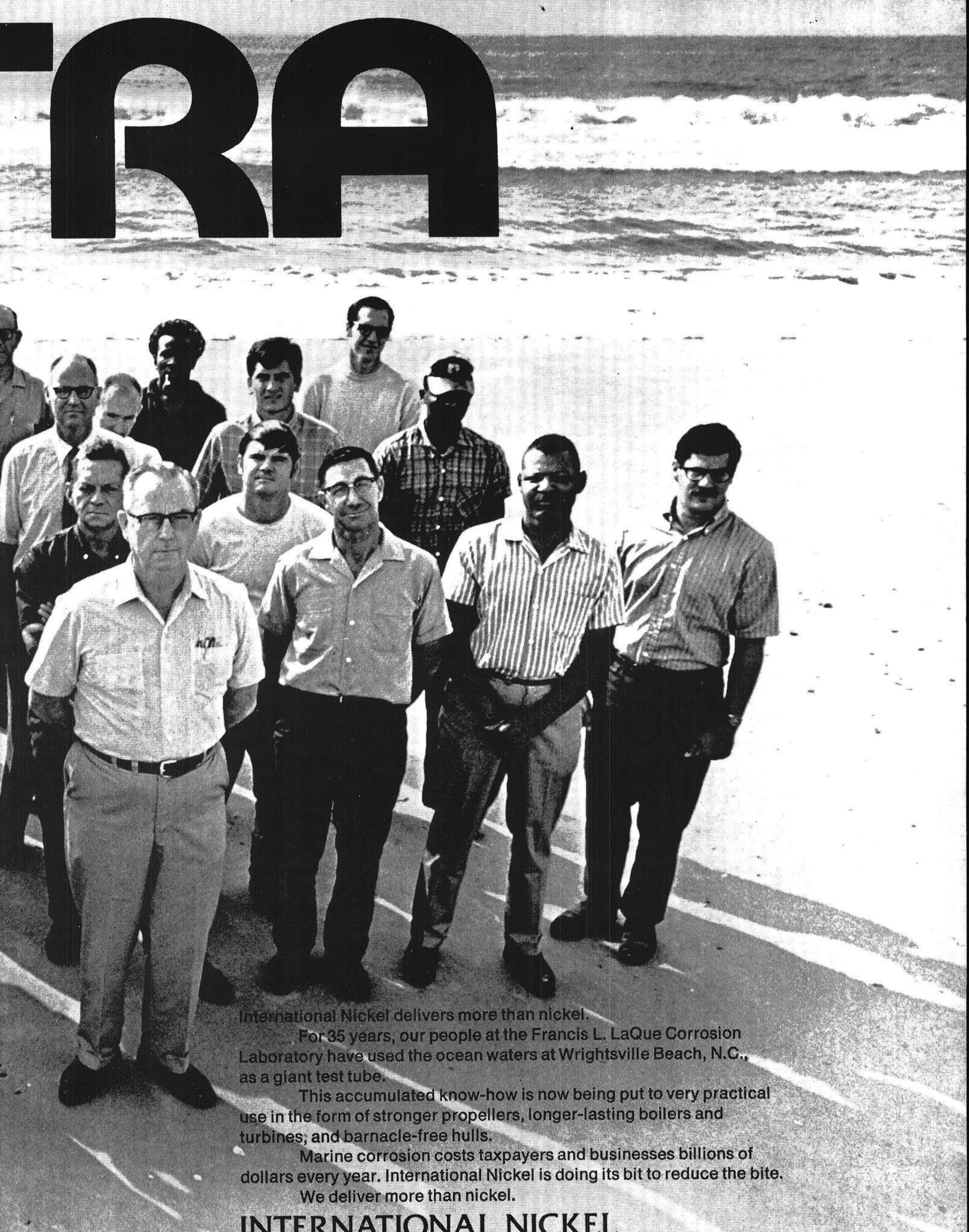
To sum up some of the things previously mentioned: Do not over estimate your education, and think it is the highest qualification necessary to the engineer. Do not get the idea that practical experience in the ranks is not necessary, and remember that you can not expect to command a large salary til you have added several years of successful practical experience to your theoretical training. Keep in mind that you will have to deal with many and different men, and that you will have to study very carefully their ways, in order to gain your end. Keep in mind what I have said about the study of modern languages, and determine for yourself whether the statements I have made are correct. Take special training in your English even at some sacrifice, and be able to write and express youself clearly.

Let me advise you, above all things, to cultivate a liking for your occupation. You will find that the longer you are engaged in engineering work, the more interesting it becomes. While it becomes more interesting, your problems will become more difficult, but I know of no greater satisfaction than the successful carrying out of a difficult problem, whether it be in theory or actual construction.

The young engineer of to-day is fitted to take up a variety of positions. He can not be proficient in all, so each much choose his specialty. But whatever position the graduate may choose, it is hoped that by diligent application he may soon rise to a position of trust and responsibility, and thus reflect credit upon his Alma Mater.

|***|


EXT



International Nickel delivers more than nickel.

For 35 years, our people at the Francis L. LaQue Corrosion Laboratory have used the ocean waters at Wrightsville Beach, N.C., as a giant test tube.

This accumulated know-how is now being put to very practical use in the form of stronger propellers, longer-lasting boilers and turbines, and barnacle-free hulls.

Marine corrosion costs taxpayers and businesses billions of dollars every year. International Nickel is doing its bit to reduce the bite.

We deliver more than nickel.

INTERNATIONAL NICKEL

The International Nickel Company, Inc., One New York Plaza, New York, N.Y. 10004. District Offices in Chicago, Cleveland, Dayton, Detroit, Hartford, Houston, Los Angeles, New York, Pittsburgh, Washington & Wilmington.


DRUG INFO CENTER OPEN
420 LAKE ST.
263-1737
71 ARMSTRONG

CONVERSION — NOISREVNOC FACTORS

★ ★ ★ ★ ★

(worth saving by the meticulous engineer)

Multiply	*By*	*To Get*
Abamperes	10	amperes
Abamperes	$3x10^{10}$	statamperes
abamperes per sq cm	64.52	amperes per sq inch
abampere-turns	10	ampere-turns
abampere-turns	12.57	gilberts
abampere-turns per cm	25.40	ampere-turns per inch
abcoulombs	10	coulombs
abcoulombs	$3x10^{10}$	statcoulombs
abcoulombs per sq cm	64.52	coulombs per sq in
abfarads	10^{9}	farads
abfarads	10^{15}	microfarads
abfarads	$9x10^{20}$	statfarads
abhenries	10^{-9}	henries
abhenries	10^{-6}	millihenries
abhenries	$1/9x10^{-20}$	stathenries
abmhos per cm cube	$1.662x10^{2}$	mhos per mil foot
abmhos per cm cube	10^{3}	megmhos per cm cube
abohms	10^{-15}	megohms
abohms	10^{-3}	microhoms
abohms	10^{-9}	ohms
abohms	$1/9x10^{-20}$	statohms
abohms per cm cube	10^{-3}	microhms per cm cube
abohms per cm cube	$6.015x10^{-6}$	ohms per mil foot
abvolts	$1/3x10^{-10}$	statvolts
abvolts	10^{-8}	volts
acres	43,560	square feet
acres	4047	square meters
acres	$1.562x10^{-3}$	square miles
acres	5645.38	square yards
acres	4840	square varas
acre-feet	43,560	cubic feet
acre-feet	$3.259x10^{5}$	gallons
amperes	1/10	abamperes
amperes	$3x10^{9}$	statamperes
amperes per sq cm	6.453	amperes per sq inch
amperes per sq inch	0.01550	abamperes per sq cm
amperes per sq inch	0.1550	amperes per sq cm
amperes per sq inch	$4.650x10^{8}$	statamperes per sq cm
ampere-turns	1/10	abampere-turns
ampere-turns	1.257	gilberts
ampere-turns per cm	2.540	ampere-turns per in
ampere-turns per inch	0.03937	abampere-turns per cm
ampere-turns per inch	0.3937	ampere-turns per cm
ampere-turns per inch	0.4950	gilberts per cm
ares	0.02471	acres
ares	100	square meters
atmospheres	76.0	cms of mercury
atmospheres	29.92	inches of mercury
atmospheres	33.90	feet of water
atmospheres	10,333	kg per sq meter
atmospheres	14.70	pounds per sq inch
atmospheres	1.058	tons per sq foot
Bars	$9.870x10^{-7}$	atmospheres
Bars	1	dynes per sq cm
Bars	0.01020	kg per square meter
Bars	$2.089x10^{-3}$	pounds per sq foot
Bars	$1.450x10^{-5}$	pounds per sq inch
board-feet	144	cubic inches
British thermal units	0.2530	kilogram-calories
British thermal units	777.5	foot-pounds
British thermal units	$3.927x10^{-4}$	harsepower-hours
British thermal units	1054	joules
British thermal units	107.5	kilogram-meters
British thermal units	$2.928x10^{-4}$	kilowatt-hours
Btu per min	12.96	foot-pounds per sec
Btu per min	0.02356	horsepower
Btu per min	0.01757	kilowatts
Btu per min	17.57	watts
Btu per sq ft per min	0.1220	watts per square inch
bushels	1.244	cubic feet
bushels	2150	cubic inches
bushels	0.03524	cubic meters
bushels	4	pecks
bushels	64	pints (dry)
bushels	32	quarts (dry)
Centares	1	square meters
centigrams	0.01	grams
centiliters	0.01	liters
centimeters	0.3937	inches
centimeters	0.01	meters
centimeters	393.7	mils
centimeters	10	millimeters
centimeter-dynes	$1.020x10^{-3}$	centimeter-grams
centimeter-dynes	$1.020x10^{-8}$	meter-kilograms
centimeter-dynes	$7.376x10^{-8}$	pound-feet
centimeter-grams	980.7	centimeter-dynes
centimeter-grams	10^{-5}	meter-kilograms
centimeter-grams	$7.233x10^{-5}$	pound-feet
centimeters of mercury	0.01316	atmospheres
centimeters of mercury	0.4461	feet of water
centimeters of mercury	136.0	kg per square meter
centimeters of mercury	27.85	pounds per sq foot
centimeters of mercury	0.1934	pounds per sq inch
centimeters per second	1.969	feet per minute
centimeters per second	0.03281	feet per second
centimeters per second	0.036	kilometers per hour
centimeters per second	0.6	meters per minute
centimeters per second	0.02237	miles per hour
centimeters per second	$3.728x10^{-4}$	miles per minute
cm per sec per sec	0.03281	feet per sec per sec
cm per sec per sec	0.036	km per hour per sec
cm per sec per sec	0.02237	miles per hour per sec
circular mils	$5.067x10^{-6}$	square centimeters
circular mils	$7.854x10^{-7}$	square inches
circular mils	0.7854	square mils
cords	128	cubic feet
coulombs	1/10	abcoulombs
coulombs	$3x10^{9}$	statcoulombs
coulombs per sq inch	0.01550	abcoulombs per sq cm
coulombs per sq inch	0.1550	coulombs per sq cm
coulombs per sq inch	$4.650x10^{8}$	statcoulombs per sq cm
cubic centimeters	$3.531x10^{-5}$	cubic feet
cubic centimeters	$6.10x10^{-2}$	cubic inches
cubic centimeters	10^{-6}	cubic meters
cubic centimeters	$1.308x10^{-6}$	cubic yards
cubic centimeters	$2.642x10^{-4}$	gallons
cubic centimeters	10^{-3}	liters
cubic centimeters	$2.113x10^{-3}$	pints (liq)
cubic centimeters	$1.057x10^{-3}$	quarts (liq)
cubic feet	$2.832x10^{4}$	cubic cms
cubic feet	1728	cubic inches
cubic feet	0.02832	cubic meters
cubic feet	0.03704	cubic yards
cubic feet	7.481	gallons
cubic feet	28.32	liters
cubic feet	59.84	pints (liq)
cubic feet	29.92	quarts (liq)
cubic feet per minute	472.0	cubic cm per sec
cubic feet per minute	0.1247	gallons per sec
cubic feet per minute	0.4720	liters per second
cubic feet per minute	62.4	lb of water per min
cubic inches	16.39	cubic centimeters
cubic inches	$5.787x10^{-4}$	cubic feet
cubic inches	$1.639x10^{-5}$	cubic meters
cubic inches	$2.143x10^{-5}$	cubic yards
cubic inches	$4.329x10^{-3}$	gallons
cubic inches	$1.639x10^{-2}$	liters
cubic inches	0.03463	pints (liq)
cubic inches	0.01732	quarts (liq)
cubic meters	10^{6}	cubic centimeter
cubic meters	35.31	cubic feet
cubic meters	61,023	cubic inches
cubic meters	1.308	cubic yards
cubic meters	264.2	gallons
cubic meters	10^{3}	liters
cubic meters	2113	pints (liq)
cubic meters	1057	quarts (liq)
cubic yards	$7.646x10^{5}$	cubic centimeters
cubic yards	27	cubic feet
cubic yards	46,656	cubic inches
cubic yards	0.7646	cubic meters
cubic yards	202.0	gallons
cubic yards	764.6	liters
cubic yards	1616	pints (liq)
cubic yards	807.9	quarts (liq)
cubic yards per minute	0.45	cubic feet per second
cubic yards per minute	3.367	gallons per second
cubic yards per minute	12.74	liters per second
Days	24	hours
Days	1440	minutes
Days	86,400	seconds
decigrams	0.1	grams
deciliters	0.1	liters
decimeters	0.1	meters
degrees (angle)	60	minutes
degrees (angle)	0.01745	radians
degrees (angle)	3600	seconds
degrees per second	0.01745	radians per second
degrees per second	0.1667	revolutions per min
degrees per second	0.002778	revolutions per sec
dekagrams	10	grams
dekaliters	10	liters
dekameters	10	meters
drams	1.772	grams
drams	0.0625	ounces
dynes	$1.020x10^{-3}$	grams
dynes	$7.233x10^{-5}$	poundals
dynes	$2.248x10^{-6}$	pounds
dynes per square cm	1	bars
Ergs	$9.486x10^{-11}$	British thermal units
Ergs	1	dyne-centimeters
Ergs	$7.376x10^{-8}$	foot-pounds
Ergs	$1.020x10^{-3}$	gram-centimeters
Ergs	10^{-7}	joules
Ergs	$2.390x10^{-11}$	kilogram-calories
Ergs	$1.020x10^{-8}$	kilogram-meters
ergs per second	$5.692x10^{-9}$	Btu per minute
ergs per second	$4.426x10^{-6}$	foot-pounds per min
ergs per second	$7.376x10^{-8}$	foot-pounds per sec
ergs per second	$1.341x10^{-10}$	horsepower
ergs per second	$1.434x10^{-9}$	kg-calories per min
ergs per second	10^{-10}	kilowatts
Farads	10^{-9}	abfarads
Farads	10^{6}	microfarads
Farads	$9x10^{11}$	statfarads
fathoms	6	feet
feet	30.48	centimeters
feet	12	inches
feet	0.3048	meters
feet	.36	varas
feet	1/3	yards
feet of water	0.02950	atmospheres
feet of water	0.8826	inches of mercury
feet of water	304.8	kg per square meter
feet of water	32.43	pounds per sq ft
feet of water	0.4335	pounds per sq inch
feet per minute	0.5080	centimeters per sec
feet per minute	0.01667	feet per sec
feet per minute	0.01829	kilometers per hour
feet per minute	0.3048	meters per minute
feet per minute	0.01136	miles per hour
feet per second	30.48	centimeters per sec
feet per second	1.097	kilometers per hour

Multiply	By	To Get
feet per second	18.29	meters per minute
feet per second	0.6818	miles per hour
feet per second	0.01136	miles per minute
feet per 100 feet	1	per cent grade
feet per sec per sec	30.48	cm per sec per sec
feet per sec per sec	1.097	km per hr per sec
feet per sec per sec	0.3048	meters per sec per sec
feet per sec per sec	0.6818	miles per hr per sec
foot-pounds	1.286x10^{-3}	British thermal units
foot-pounds	1.356x10^{7}	ergs
foot-pounds	5.050x10^{-7}	horsepower-hours
foot-pounds	1.356	joules
foot-pounds	3.241x10^{-4}	kilogram-calories
foot-pounds	0.1383	kilogram-meters
foot-pounds	1.286x10	kilowatt-hours
foot-pounds per minute	3.766x10^{-7}	Btu per minute
foot-pounds per minute	0.01667	foot-pounds per sec
foot-pounds per minute	3.030x10^{-5}	horsepower
foot-pounds per minute	3.241x10^{-4}	kg-calories per minute
foot-pounds per minute	2.260x10^{-5}	kilowatts
foot-pounds per second	7.717x10^{-2}	Btu per minute
foot-pounds per second	1.818x10^{-3}	horsepower
foot-pounds per second	1.945x10^{-2}	kg-calories per min
foot-pounds per second	1.356x10^{-3}	kilowatts
furlongs	40	rods
Gallons	3785	cubic centimeters
Gallons	0.1337	cubic feet
Gallons	231	cubic inches
Gallons	3.785x10^{-3}	cubic meters
Gallons	4.951x10^{-3}	cubic yards
Gallons	3.785	liters
Gallons	8	pints (liq)
Gallons	4	quarts (liq)
gallons per minute	2.228x10^{-3}	cubic feet per second
gallons per minute	0.06308	liters per second
gausses	6.452	lines per square inch
gilberts	0.07958	abampere-turns
gilberts	0.7958	ampere-turns
gilberts per centimeter	2.021	ampere-turns per inch
gills	0.1183	liters
gills	0.25	pints (liq)
grains (troy)	1	grains (av)
grains (troy)	0.06480	grams
grains (troy)	0.04167	pennyweights (troy)
grams	980.7	dynes
grams	15.43	grains (troy)
grams	10^{-3}	kilograms
grams	10^{3}	milligrams
grams	0.03527	ounces
grams	0.03215	ounces (troy)
grams	0.07093	poundals
grams	2.205x10^{-3}	pounds
gram-calories	3.968x10^{-3}	British thermal units
gram-centimeters	9.302x10^{-8}	British thermal units
gram-centimeters	980.7	ergs
gram-centimeters	7.233x10^{-5}	foot-pounds
gram-centimeters	9.807x10^{-5}	joules
gram-centimeters	2.344x10^{-8}	kilogram-calories
gram-centimeters	10^{-5}	kilogram-meters
grams per cm	5.600x10^{-3}	pounds per inch
grams per cu cm	62.43	pounds per cubic foot
grams per cu cm	0.03613	pounds per cubic inch
grams per cu cm	3.405x10^{-7}	pounds per mil-foot
Hectares	2.471	acres
Hectares	1.076x10^{5}	square feet
hectograms	100	grams
hectoliters	100	liters
hectometers	100	meters
hectowatts	100	watts
hemispheres (sol. angle)	0.5	sphere
hemispheres (sol. angle)	4	spherical right angles
hemispheres (sol. angle)	6.283	steradians
henries	10^{9}	abhenries
henries	10^{3}	millihenries
henries	1/9x10^{-11}	stathenries
horsepower	42.44	Btu per min
horsepower	33,000	foot-pounds per min
horsepower	550	foot-pounds per sec
horsepower	1.014	horsepower (metric)
horsepower	10.70	kg-calories per min
horsepower	0.7457	kilowatts
horsepower	745.7	watts
horsepower (boiler)	33,520	Btu per hour
horsepower (boiler)	9.804	kilowatts
horsepower-hours	2547	British thermal units
horsepower-hours	1.98x10^{6}	foot-pounds
horsepower-hours	2.684x10^{6}	joules
horsepower-hours	641.7	kilogram-calories
horsepower-hours	2.737x10^{5}	kilogram-meters
horsepower-hours	0.7457	kilowatt-hours
hours	60	minutes
hours	3600	seconds
Inches	2.540	centimeters
Inches	10^{3}	mils
Inches	.03	varas
Inches of mercury	0.03342	atmospheres
Inches of mercury	1.133	feet of water
Inches of mercury	345.3	kg per square meter
Inches of mercury	70.73	pounds per square ft
Inches of mercury	0.4912	pounds per square in.
Inches of water	0.002458	atmospheres
Inches of water	0.07355	inches of mercury
Inches of water	25.40	kg per square meter
Inches of water	0.5781	ounces per square in.
Inches of water	5.204	pounds per square ft
Inches of water	0.03613	pounds per square in.
Joules	9.486x10^{-4}	British thermal units
Joules	10^{7}	ergs
Joules	0.7376	foot-pounds
Joules	2.390x10^{-4}	kilogram-meters
Joules	0.1020	kilogram-calories
Joules	2.778x10^{-4}	watt-hours
Kilograms	980,665	dynes
Kilograms	10^{3}	grams
Kilograms	70.93	poundals
Kilograms	2.2046	pounds
Kilograms	1.102x10^{-3}	tons (short)
kilogram-calories	3.968	British thermal units
kilogram-calories	3086	foot-pounds
kilogram-calories	1.558x10^{-3}	horsepower-hours
kilogram-calories	4183	joules
kilogram-calories	426.6	kilogram-meters
kilogram-calories	1.162x10^{-3}	kilowatt-hours
kg-calories per min	51.43	foot-pounds per sec
kg-calories per min	0.09351	horsepower
kg-calories per min	0.06972	kilowatts
kgs-cms. squared	2.373x10^{-3}	pounds-feet squared
kgs-cms. squared	0.3417	pounds-inches squared
kilogram-meters	9.302x10^{-3}	British thermal units
kilogram-meters	9.807x10^{7}	ergs
kilogram-meters	7.233	foot-pounds
kilogram-meters	9.807	joules
kilogram-meters	2.344x10^{-3}	kilogram-calories
kilogram-meters	2.724x10^{-6}	kilowatt-hours
kgs per cubic meter	10^{-3}	grams per cubic cm
kgs per cubic meter	0.06243	pounds per cubic foot
kgs per cubic meter	3.613x10^{-5}	pounds per cubic inch
kgs per cubic meter	3.405x10^{-10}	pounds per mil-foot
kgs per meter	0.6720	pounds per foot
kgs per square meter	9.678x10^{-5}	atmospheres
kgs per square meter	98.07	bars
kgs per square meter	3.281x10^{-3}	feet of water
kgs per square meter	2.896x10^{-3}	inches of mercury
kgs per square meter	0.2048	pounds per square ft
kgs per square meter	1.422x10^{-3}	pounds per square in
kgs per sq millimeter	10^{6}	kg per square meter
kilolines	10^{3}	maxwells
kiloliters	10^{3}	liters
kilometers	10^{5}	centimeters
kilometers	3281	feet
kilometers	10^{3}	meters
kilometers	0.6214	miles
kilometers	1093.6	yards
kilometers per hour	27.78	centimeters per sec
kilometers per hour	54.68	feet per minute
kilometers per hour	0.9113	feet per second
kilometers per hour	0.5396	knots
kilometers per hour	16.67	meters per minute
kilometers per hour	0.6214	miles per hour
kms per hour per sec	27.78	cm per sec per sec
kms per hour per sec	0.9113	ft per sec per sec
kms per hour per sec	0.2778	meters per sec per sec
kms per hour per sec	0.6214	miles per hr per sec
[illegible]	3.968	British thermal units
[illegible]	3086	foot-pounds
[illegible]	1.558x10^{-3}	horsepower-hours
[illegible]	4183	joules
[illegible]	426.6	kilogram-meters
kilometers per min	60	kilometers per hour
kilowatts	56.92	Btu per min
kilowatts	4.425x10^{4}	foot-pounds per min
kilowatts	737.6	foot-pounds per sec
kilowatts	1.341	horsepower
kilowatts	14.34	kg-calories per min
kilowatts	10^{3}	watts
kilowatt-hours	3415	British thermal units
kilowatt-hours	2.655x10^{6}	foot-pounds
kilowatt-hours	1.341	horsepower-hours
kilowatt-hours	3.6x10^{6}	joules
kilowatt-hours	860.5	kilogram-calories
kilowatt-hours	3.67x10^{5}	kilogram-meters
knots	6080	feet per hr
knots	1.853	kilometers per hr
knots	1.152	miles per hr
knots	2027	yards per hr
Lines per square cm	1	gaus
lines per square inch	0.1550	gaus
links (engineer's)	12	inches
links (surveyor's)	7.92	inches
liters	10^{3}	cubic centimeters
liters	0.03531	cubic feet
liters	61.02	cubic inches
liters	10^{-3}	cubic meters
liters	1.308x10^{-3}	cubic yards
liters	0.2642	gallons
liters	2.113	pints (liq)
liters	1.057	quarts (liq)
liters per minute	5.855x10^{-4}	cubic feet per second
liters per minute	4.403x10^{-3}	gallons per second
$\log_{10} N$	2.303	$\log_{10} N$
$\log_e N$ or $\ln N$	0.4343	$\log_e N$ or $\ln N$
lumens per sq ft	1	foot-candles
maxwells	10^{-3}	kilolines
megalines	10^{6}	maxwells
megmhos per cm cube	10^{-3}	abmhos per cm cube
megmhos per cm cube	2.540	megmhos per in. cube
megmhos per cm cube	0.1662	mhos per mil foot
megmhos per inch cube	0.3937	megmhos per cm cube
megohms	10^{6}	ohms
meters	100	centimeters
meters	3.2808	feet
meters	39.37	inches
meters	10^{-3}	kilometers
meters	10^{3}	millimeters
meters	1.0936	yards
meter-kilograms	9.807x10^{7}	centimeter-dynes
meter-kilograms	10^{5}	centimeter-grams
meter-kilograms	7.233	pound feet
meters per minute	1.667	centimeters per sec
meters per minute	3.281	feet per minute
meters per minute	0.05468	feet per second
meters per minute	0.06	kilometers per hour
meters per minute	0.03728	miles per hour
meters per second	1968	feet per minute
meters per second	3.284	feet per second
meters per second	6.0	kilometers per hour
meters per second	0.06	kilometers per min
meters per second	2.237	miles per hour
meters per second	0.03728	miles per min
meters per sec per sec	3.281	feet per sec per sec
meters per sec per sec	3.6	km per hour per sec
meters per sec per sec	2.237	miles per hr per sec
mhos per mil foot	6.015x10^{-3}	abmhos per cm cube
mhos per mil foot	6.015	megmhos per cm cube
mhos per mil foot	15.28	megmhos per in. cube
microfarads	10^{-15}	abfarads
microfarads	10^{-6}	farads
microfarads	9x10^{5}	statfarads
micrograms	10^{-6}	grams
microliters	10^{-6}	liters
microhms	10^{3}	abohms
microhms	10^{-12}	megohms
microhms	10^{-6}	ohms
microhms	1/9x10^{-17}	statohms
microhms per cm cube	10^{3}	abohms per cm cube
microhms per cm cube	0.3937	microhms per in. cube
microhms per cm cube	6.015	ohms per mil foot
microhms per inch cube	2.540	microhms per cm cube
microns	10^{-6}	meters
miles	1.609x10^{5}	centimeters
miles	5280	feet
miles	1.6093	kilometers
miles	1760	yards
miles	1900.8	varas
miles per hour	44.70	feet per minute
miles per hour	88	centimeters per sec
miles per hour	1.467	feet per second
miles per hour	1.6093	kilometers per hour
miles per hour	0.8684	knots
miles per hour	26.82	meters per minute
miles per hour per sec	44.70	cm per sec per sec
miles per hour per sec	1.467	feet per sec per sec
miles per hour per sec	1.6093	km per hour per sec
miles per hour per sec	0.4470	M per sec per sec
miles per minute	2682	centimeters per sec
miles per minute	88	feet per second
miles per minute	1.6093	kilometers per min
miles per minute	60	miles per hour
milligrams	10^{-3}	grams
millihenries	10^{6}	abhenries
millihenries	10^{-3}	henries
millihenries	1/9x10^{-14}	stathenries
milliliters	10^{-3}	liters
millimeters	0.1	centimeters
millimeters	0.03937	inches
millimeters	39.37	mils
mils	0.002540	centimeters
mils	10^{-3}	inches
miner's inches	1.5	cubic feet per min
minutes (angle)	2.909x10^{-4}	radian
minutes (angle)	60	seconds (angle)
months	30.42	days
months	730	hours
months	43,800	minutes
months	2.628x10^{6}	seconds
myriagrams	10	kilograms
myriameters	10	kilometers
myriawatts	10	kilowatts
Ohms	10^{9}	abohms
Ohms	10^{-6}	megohms
Ohms	10^{6}	microhms
Ohms	1/9x10^{-11}	statohms
ohms per mil foot	166.2	abohms per cm cube
ohms per mil foot	0.1662	microhms per cm cube
ohms per mil foot	0.06524	microhms per in. cube
ounces	8	drams
ounces	437.5	grains
ounces	28.35	grams
ounces	0.0625	pounds
ounces (fluid)	1.805	cubic inches
ounces (fluid)	0.02957	liters
ounces (troy)	480	grains (troy)
ounces (troy)	31.10	grams
ounces (troy)	20	pennyweights (troy)
ounces (troy)	0.08333	pounds (troy)
ounces per square inch	0.0625	pounds per sq inch
Pennyweights (troy)	24	grains (troy)
Pennyweights (troy)	1.555	grams
Pennyweights (troy)	0.05	ounces (troy)
perches (masonry)	24.75	cubic feet
pints (dry)	33.60	cubic inches
pints (liquid)	28.87	cubic inches
poundals	13,826	dynes
poundals	14.10	grams
poundals	0.03108	pounds
pounds	444,823	dynes
pounds	7000	grains
pounds	453.6	grams
pounds	16	ounces
pounds	32.17	poundals
pounds (troy)	0.8229	pounds (av)
pounds per cubic foot	1.356x10^{7}	centimeter-dynes
pound-feet	13,825	centimeter-grams
pound-feet	0.1383	meter-kilograms
pound-feet	421.3	kgs-cm squared
pounds-feet squared	144	pounds-inches squared
pounds-feet squared	2.926	kgs-cm squared
pounds-inches squared	6.945x10^{-3}	pounds-feet squared
pounds-inches squared	0.01602	cubic feet
pounds of water	27.68	cubic inches
pounds of water	0.1198	gallons
pounds of water	2.660x10^{-4}	cubic feet per sec
pounds of water per min	0.01602	grams per cubic cm
pounds per cubic foot	16.02	kg per cubic meter
pounds per cubic foot	5.787x10^{-4}	pounds per cubic inch
pounds per cubic foot	5.456x10^{-9}	pounds per mil foot
pounds per cubic inch	27.68	grams per cubic cm
pounds per cubic inch	2.768x10^{4}	kg per cubic meter
pounds per cubic inch	1728	pounds per cubic foot
pounds per cubic inch	9.425x10^{-6}	pounds per mil foot
pounds per foot	1.488	kg per meter
pounds per inch	178.6	gram per cm
pounds per mil foot	2.306x10^{6}	grams per cubic cm
pounds per square foot	0.01602	feet of water
pounds per square foot	4.882	kg per square meter
pounds per square foot	6.944x10^{-3}	pounds per sq inch
pounds per square inch	0.06804	atmospheres
pounds per square inch	2.307	feet of water
pounds per square inch	2.036	inches of mercury
pounds per square inch	703.1	kg per square meter
pounds per square inch	144	pounds per sq foot
Quadrants (angle)	90	degrees
Quadrants (angle)	5400	minutes
Quadrants (angle)	1.571	radians
quarts (dry)	67.20	cubic inches
quarts (liq)	57.75	cubic inches
quintals	100	pounds
quires	25	sheets
Radians	57.30	degrees
Radians	3438	minutes
Radians	0.637	quadrants
radians per second	57.30	degrees per second
radians per second	0.1592	revolutions per second
radians per second	9.549	revolutions per min
radians per sec per sec	573.0	revs per min per min
radians per sec per sec	9.549	revs per min per sec
radians per sec per sec	0.1592	revs per sec per sec
reams	500	sheets
revolutions	360	degrees
revolutions	4	quadrants
revolutions	6.283	radians
revolutions per minute	6	degrees per second
revolutions per minute	0.1047	radians per second
revolutions per minute	0.01667	revolutions per sec
revs per min per min	1.745x10^{-3}	rads per sec per seo
revs per min per min	0.01667	revs per min per sec
revs per min per min	2.778x10^{-4}	revs per sec per sec
revolutions per second	360	degrees per second
revolutions per second	6.283	radians per second
revolutions per second	60	revs per min
revs per sec per sec	6.283	rads per sec per sec
revs per sec per sec	3600	revs per min per min
revs per sec per sec	60	revs per min per sec
rods	16.5	feet
Seconds (angle)	4.848x10^{-6}	radians
spheres (solid angle)	12.57	steradians
spherical right angles	0.25	hemispheres
spherical right angles	0.125	spheres
spherical right angles	1.571	steradians
square centimeters	1.973x10^{5}	circular mils
square centimeters	1.076x10^{-3}	square feet
square centimeters	0.1550	square inches
square centimeters	10^{-4}	square meters
square centimeters	100	square millimeters
sq cm (cm sqd)	0.02402	sq inches (inches sqd)
square feet	2.296x10^{-5}	acres
square feet	929.0	square centimeters
square feet	144	square inches
square feet	0.09290	square meters
square feet	3.587x10^{-8}	square miles
square feet	.1296	square varas
square feet	1/9	square yards
sq feet (feed sqd)	2.074x10^{4}	sq inches (inches sqd)
square inches	1.273x10^{6}	circular mils
square inches	6.452	square centimeters
square inches	6.944x10^{-3}	square feet
square inches	10^{6}	square mils
square inches	645.2	square millimeters
sq inches (inches sqd)	41.62	sq cm (cm sqd)
sq inches (inches sqd)	4.823x10^{-5}	sq ft (feet sqd)
square kilometers	247.1	acres
square kilometers	10.76x10^{6}	square feet
square kilometers	10^{6}	square meters
square kilometers	0.3861	square miles
square kilometers	1.196x10^{6}	square yards
square meters	2.471x10^{-4}	acres
square meters	10.764	square feet
square meters	3.861x10^{-7}	square miles
square meters	1.196	square yards
square miles	640	acres
square miles	27.88x10^{6}	square feet
square miles	2.590	square kilometers
square miles	3,613,040.45	square varas
square miles	3.098x10^{6}	square yards
square millimeters	1.973x10^{3}	circular mils
square millimeters	0.01	square centimeters
square millimeters	1.550x10^{-3}	square inches
square mils	1.273	circular mils
square mils	6.452x10^{-6}	square centimeters
square mils	10^{-6}	square inches
square varas	.0001771	acres
square varas	7.716049	square feet
square varas	.0000002765	square miles
square varas	.857339	square yards
square yards	2.066x10^{-4}	acres
square yards	9	square feet
square yards	0.8361	square meters
square yards	3.228x10^{-7}	square miles
square yards	1.1664	square varas
statamperes	1/3x10^{-10}	abamperes
statamperes	1/3x10^{-9}	amperes
statcoulombs	1/3x10^{-10}	abcoulombs
statcoulombs	1/3x10^{-9}	coulombs
statfarads	1/9x10^{-20}	abfarads
statfarads	1/9x10^{-11}	farads
statfarads	1/9x10^{-5}	microfarads
stathenries	9x10^{20}	abhenries
stathenries	9x10^{11}	henries
stathenries	9x10^{14}	millihenries
statohms	9x10^{20}	abohms
statohms	9x10^{5}	megohms
statohms	9x10^{17}	microhms
statohms	9x10^{11}	ohms
statvolts	3x10^{10}	abvolts
statvolts	300	volts
steradians	0.1592	hemispheres
steradians	0.07958	spheres
steradians	0.6366	spherical right angles
steres	10^{3}	liters
Temp (degs C) + 273	1	abs temp (degs C)
Temp (degs C) + 17.8	1.8	temp (degs Fahr)
temp (degs F) + 460	1	abs temp (deg F)
temp (degs F) − 32	5/9	temp (degs Cent)
tons (long)	1016	kilograms
tons (long)	2240	pounds
tons (metric)	10^{3}	kilograms
tons (metric)	2205	pounds
tons (short)	907.2	kilograms
tons (short)	2000	pounds
tons (short) per sq ft	9765	kg per square meter
tons (short) per sq ft	13.89	pounds per sq inch
tons (short) per sq in	1.406x10^{6}	kg per square meter
tons (short) per sq in	2000	pounds per sq inch
Varas	2.7777	feet
Varas	33.3333	inches
Varas	.000526	miles
Varas	.9259	yards
volts	10^{8}	abvolts
volts	1/300	statvolts
volts per inch	3.937x10^{7}	abvolts per cm
volts per inch	1.312x10^{-3}	statvolts per cm
Watts	0.05692	Btu per min
Watts	10^{7}	ergs per second
Watts	44.26	foot-pounds per min
Watts	0.7376	foot-pounds per sec
Watts	1.341x10^{-3}	horsepower
Watts	0.01434	kg-calories per min
Watts	10^{-3}	kilowatts
watt-hours	3.415	British thermal units
watt-hours	2655	foot-pounds
watt-hours	1.341x10^{-3}	horsepower-hours
watt-hours	0.8605	kilogram-calories
watt-hours	367.2	kilogram-meters
watt-hours	10^{-3}	kilowatt-hours
webers	10^{8}	maxwells
weeks	168	hours
weeks	10,080	minutes
weeks	604,800	seconds
Yards	91.44	centimeters
Yards	[illegible]	[illegible]
Yards	36	inches
Yards	0.9144	meters
Yards	1.08	varas
years	365	days
[illegible]	8760	hours
[illegible]	366	days
[illegible]	8784	hours

Westinghouse the teacher?
the medic?
the builder?
the crime fighter?
the urban planner?
the ecologist?

Westinghouse Learning Corporation has launched a computerized teaching system that lets each child learn at his own rate.

Our studies for the Defense Department will lead to the "hospital of the '70s," and a level of efficiency and economy unknown today.

Houses? We're not talking about the thousands of units completed or under construction. We're talking about the new plant we're building to mass-produce modular houses.

Our computer-based information systems improve police efficiency, speed up court administration. We're marketing electronic security systems for homes and plants.

We've developed waste-disposal units for neighborhoods, sewage treatment plants for cities, a smokeless refuse plant that reclaims rather than destroys.

We're transforming 16 square miles of Florida into a new city. It's the bellwether for hundreds of thousands of acres, bought or leased, here and abroad.

The list goes on. Everything electrical, of course—from nuclear power plants to light bulbs. And aerospace, oceanography, broadcasting, rapid transit.

It all means that Westinghouse has openings for skilled engineers—electrical, mechanical, chemical, industrial. And we also offer job training for the unskilled as another step toward increasing productive employment for the disadvantaged people of our country. An equal opportunity employer.

You can be sure...if it's Westinghouse

S
Z U
P
L Z
E

(1.) A young man was once asked his age. He replied as follows: "My grandfather was sixty-five when I was born. Gramp's age when he died this year, on his birthday, was the square root of the year in which he was born added to the square root of a recent presidential election year." How old is this obnoxious young man?

* * * * * * * *

(2.) A railroad runs straight from Punkton to Junkville. Mainfield is on this line just half the the way between Punkton and Junkville. Hotberg is just as far from Punkton as it is from Mainfield and Mainfield is as far from Hotberg as it is from Junkville. If it is twenty miles from Punkton to Hotberg, how far is Hotberg from Junkville?

* * * * * * * *

(3.) A group of women bought a number of items at a bargain counter. All of the items sold for the same price and the total amount paid by the women was $2.03, exclusive of the tax. If each item cost more than 10 cents, how many women were in the group and what did each item cost?

* * * * * * * *

(4) Here is a question from the ancient philosophers to test your ability in logic. If half of 5 were 3, what would be a third of ten be?

* * * * * * * *

(5) A number of chickens and horses are standing in a barn. The total number of heads and wings equals the number of feet. What percentage of the total number of animals are horses?

(6) A locomotive watering tank is to be located alongside a straight section of railroad and supplied with water from two wells located on the same side of the railroad and located respectively 1 mile and 3 miles from the track. The distance between lines drawn through the two wells perpendicular to the railroad is 3 miles. What is the minimum total length of pipe required to connect the two wells to separate inlets on the watering tank?

* * * * * * * *

Next to an open window are two baskets. One contains an infinite number of balls numbered 1, 2, 3, etc.; the other one is empty. At 11:00 o'clock I take the ten balls numbered 1 to 10 from the full basket and place them in the empty basket. At 11:30 I throw one of these balls out the window. At 11:45 I take balls 11 to 20 from the first basket and place them in the second. At 11:52:30 I throw another ball from the second basket out the window. If I continue in like manner, how many balls will there be in the second basket at 12:00?

(a). 27
(b). 9
(c). 0
(d). An infinite number
(e). Any of the above
(f). None of the above

Answers:

(1) Only two recent years have simple square roots: 1849, whose square root is 43, and 1936, whose square root is 44. The sum of these roots is 87 which was gramp's age when he died. The young man is 87 –65 or 22.

[***]

The correct answer, of course, is (e). Absurd, you say. As an example, how can there be zero balls in the second basket? Note the following reasoning. If there are any balls left, one of them will carry a lowest number. You say, for example, the lowest number is 77. But the first time I threw out ball 1, the second time ball 2, and similarly the seventy-seventh time ball 77. No matter what lowest number you give me, I have thrown out that ball. Since there are no balls of lowest number left, there are no balls in the basket. The other answers may be proved by the interested, intelligent rader.

(6) The minimum total length of pipe required to connect the two wells to separate inlets on the watering tank is five miles. This is just an old max-min problem from first year calculus. Set up the expression for the total length, take the derivative, set it equal to zero, and solve for the unknown.

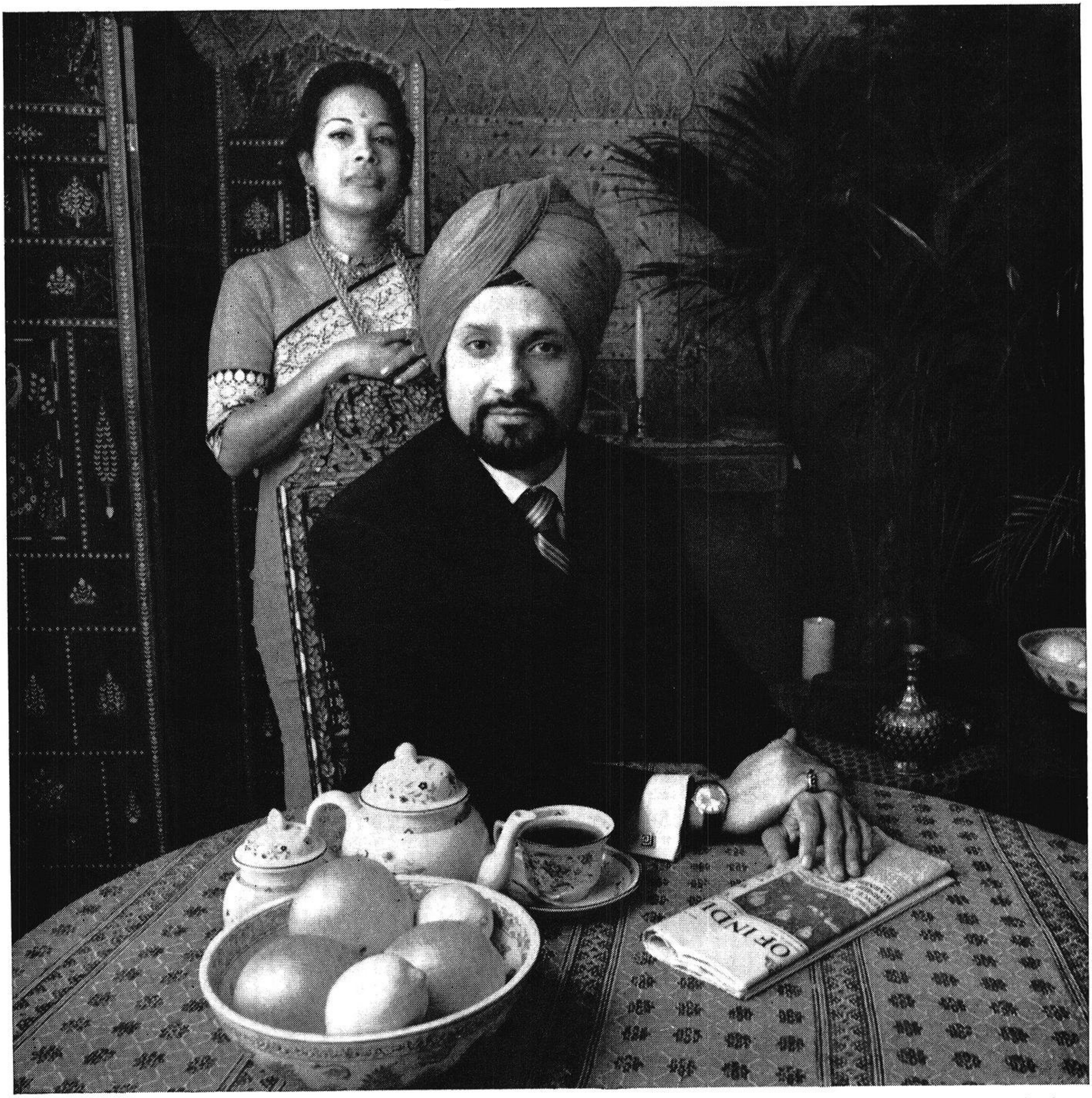
(5) Twenty-five per cent of the total number of animals are horses.

(4) Set up the proportion 5/2 : 10/3 x and solve for x. The argument is whatever factor causes 1/2 x 5 to give the result 3 must also be introduced into the product 1/3 x 10. This factor is expressed by the ratio.

(3) There must be 7 women, each paying 29c. This is because there are no numbers, other than 7 and 29, that will make 203 and since the price of each article is more than 10c, there cannot have been 29 women, each buying a 7c article.

(2) Since Hotberg is equidistant from Punkton and Mainfield, and since Mainfield is also equidistant from all the towns, Hotberg, Punkton, and Mainfield make an equilateral triangle, whose angles are therefore 60 degrees. But this makes the triangle joining Hotbert, Junkville, and Mainfield isosceles. Since the angle of this triangle at Mainfield is 120 degrees (180 degrees – 60 degrees), the other angles must be 30 degrees each. But this makes the triangle joining Hotberg, Punkton, and Junkville a right triangle, with its right angle at Hotberg. With the hypotenuse 40 miles and one side 20 miles, the other side must be about 34.6 miles.

When they look at us, they see a little of you.



When Union Carbide sends its people to Asia, Africa, South America and even Europe, they represent a country as well as a company.

So while we're out to make money abroad, we're also out to make friends abroad.

Sometimes, it's as simple as knowing local customs.

In Singapore, our Eveready battery plant has a cafeteria that serves three different menus. To meet the dietary, ethnic and religious needs of our Indian, Chinese and Malaysian employees.

Othertimes, making friends and making money is a little more complex.

To mine huge manganese deposits in Ghana, we built a whole town. From the ground up. Later, we put a plastics plant in Ghana. And then a battery plant. And made even more friends.

None of this is our newest idea. It's something Union Carbide discovered long before international business was fashionable.

And it's all quite simple.

Overseas, we're you.

UNION CARBIDE THE DISCOVERY COMPANY

For additional information on our activities, write to Union Carbide Corporation, 270 Park Avenue, New York, New York 10017. An equal opportunity employer.

An engineer can cut crime as well as any cop.

Maybe better.

Last year, murder was up 7%. Rape was up 17%. Robbery was up 14%.

It's getting to the point where a woman can't show her face on a dark street. And grown men are running scared. Sadly, crime has become a part of our everyday lives.

Where do we turn for help? To police, of course. But why not also to engineers?

Engineers at General Electric set out to develop a more efficient streetlight. And they came up with one of the most efficient crime fighters ever invented.

It's called the Lucalox® lamp. It puts twice as much light on a street as any other lamp without any extra operating cost. And wherever Lucalox has gone up, crime has gone down. By 50% or more in city after city.

But that's not all an engineer can do. He might design communications equipment that enables one patrolman to do the job of two. Or a complex of traffic monitors that puts twenty cops back on the beat. Or even a patrol car to do its special jobs in a better way.

It's sometimes hard for people to realize that engineers, with their technology, can solve social problems. But, in fact, some social problems can't be solved any other way.

So if you're an engineer who's bothered by social problems, you're in a unique position to help.

General Electric could use your help. We see more problems around us than we know how to solve. So what we need is more engineers.

GENERAL ELECTRIC

An equal opportunity employer