GENERAL ELECTRIC Review

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EVERETT S. LEE • EDITOR PAUL R. HEINMILLER • MANAGING EDITOR

COVER—While operations on steam turbine shells prior to final machining are taking place, the turbine-generator rotors are being balanced in another location before final assembly. The balancing operation is explained by L. P. Grobel in an article beginning on page 22. Cover picture is from an original painting by Ray Prohaska.

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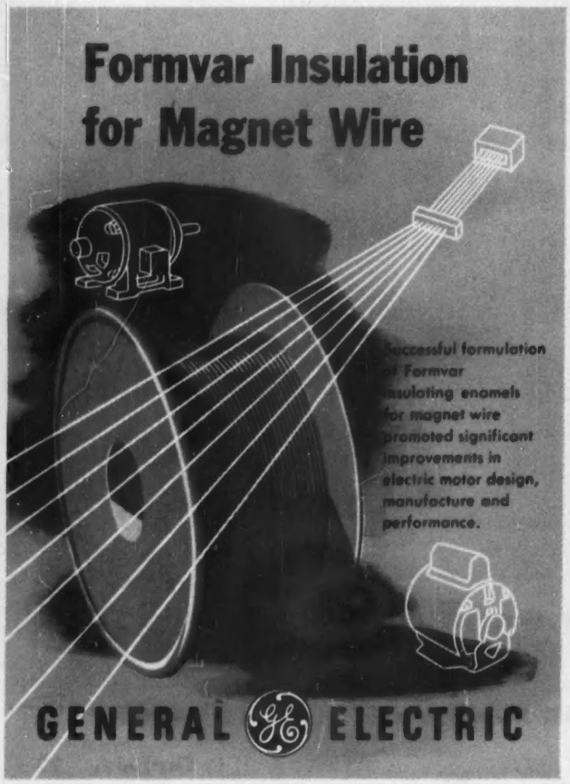
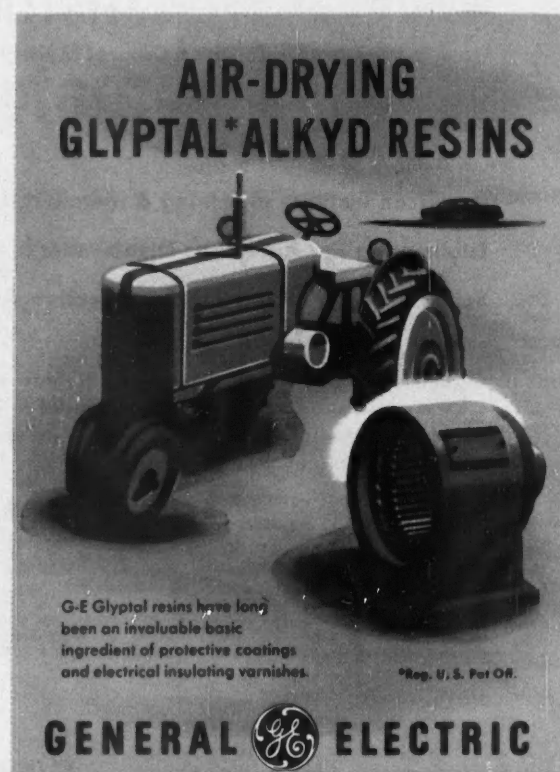
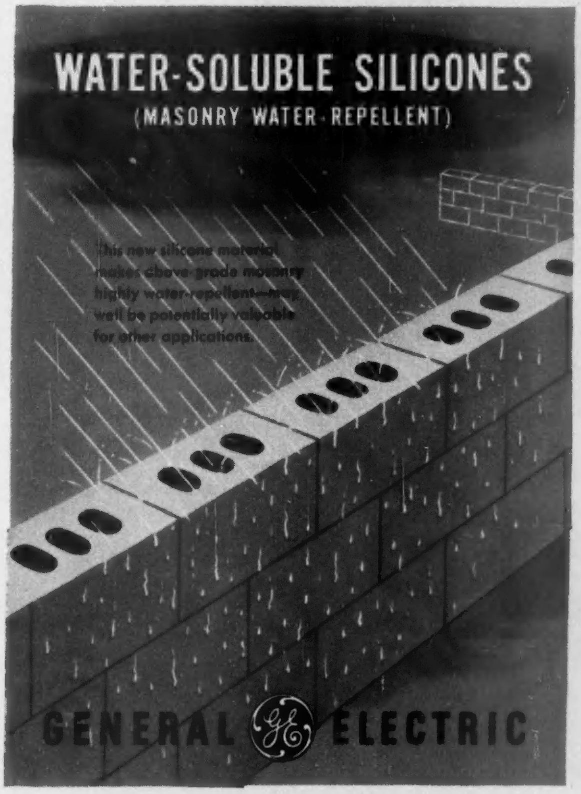
SOME IMPORTANT MILESTONES





OF G-E CHEMICAL PROGRESS



1878 75 1953
YEARS OF ELECTRICAL PROGRESS

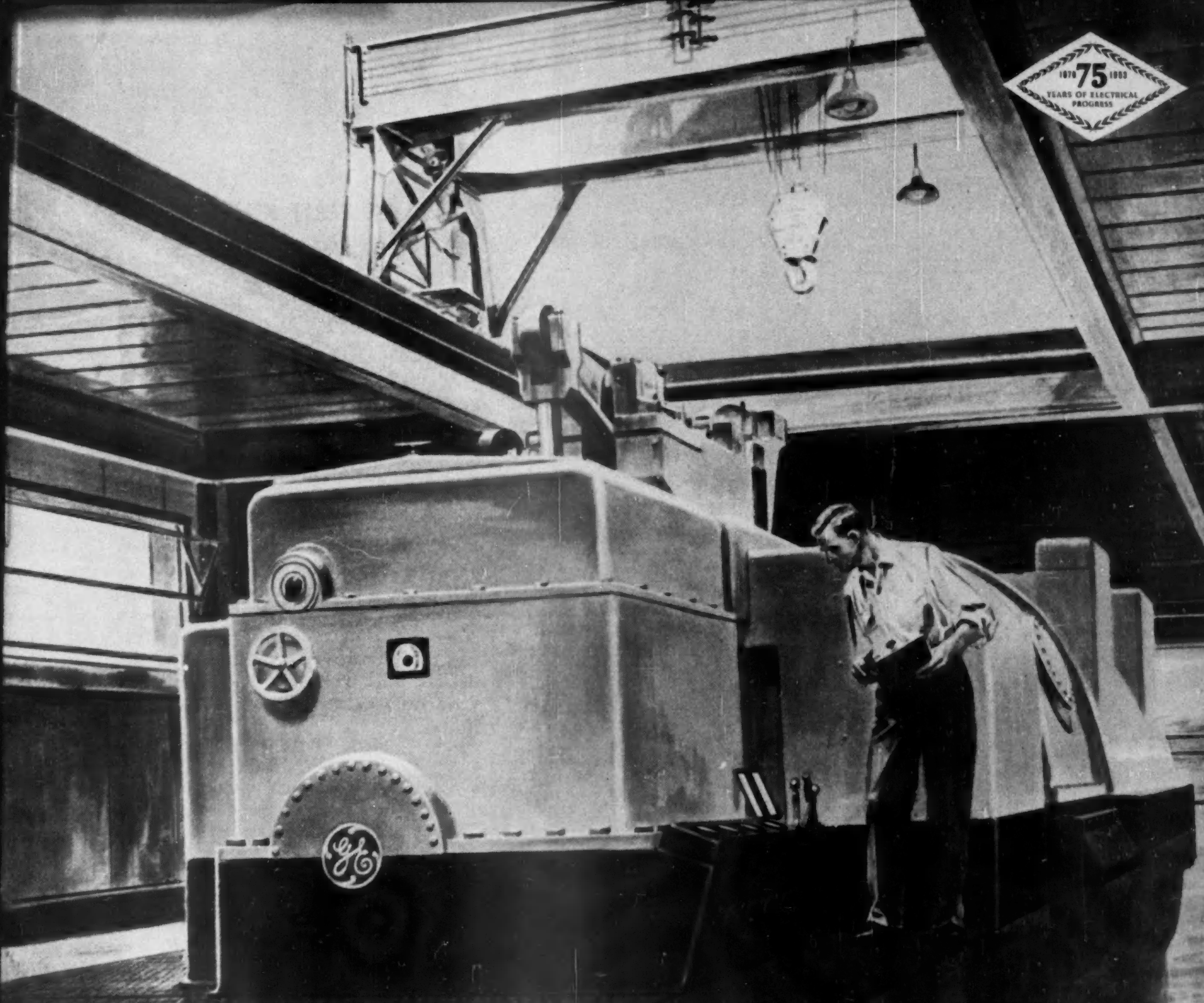
During much of General Electric's 75-year history, G-E *chemical* progress has made important contributions to the electrical and many other industries.

Here are some of the outstanding achievements of this chemical progress, pioneered for American business and industry by General Electric men and women and presented as evidence of our dedication to even greater progress and service in the future. *Chemical Division, General Electric Company, Pittsfield, Mass.*

Section 300—4E

You can put your confidence in—

GENERAL ELECTRIC



Stearns-Roger Manufacturing Co., Engineers and Constructors

ISAAC FERN KINNARD
1952 LAMME MEDALIST

" . . . for his outstanding contributions in design and developments in instrumentation and measurements"—AWARD CITATION

Mr. Kinnard was presented with the 25th annual Lamme award and medal last month at the AIEE Summer General Meeting, Atlantic City, NJ. He is Manager—Engineering, General Electric's Meter and Instrument Department, West Lynn, Mass. The purpose of the award is to recognize the AIEE member "who has shown meritorious achievement in the development of electrical apparatus or machinery." Founder of the medal was the late Benjamin G. Lamme, Chief Engineer of Westinghouse.

G-E Measurements Laboratory at West Lynn reflects the vision and achievement of Mr. Kinnard and his fellow engineers. These traits are typified by the medal's inscription: "The engineer views hopefully the hitherto unattainable."

THE PAST 40 YEARS—
AND THE NEXT

This month we welcome the new engineers as they come to us from the schools of our land. Many will be enrolled in the Test Engineering Program, an institution enriched with tradition, dating back to the earliest days of General Electric history. Our readers who are graduates of this program share the recollections of those days of their training as a common bond of fellowship. I have often said that Test is one touch of nature that makes us all kin.

This gives me an excuse to look back on my own period of Test training 40 years ago. It is interesting to compare conditions as they were then with conditions as they are now.

There were 160 of us who entered Test that year. Those were great days. The electrical industry was 35 years old, as we counted time in General Electric, for G-E chronology began that day in 1878 when the friends of Thomas A. Edison provided the money to form a company so that he could carry out his experiments to realize his dream of an incandescent electric lamp.

And engineers have brought their dreams to reality ever since. Even at that time long ago we inherited the results of their work of 35 years. Steam turbines for electricity generation had supplanted the steam engine; they were being built in sizes up to 20,000 kw. On water rate test we read steam pressures of 200 pounds and steam temperatures of 600 degrees. Today turbine-generator units rated higher than 300,000 kva are being planned. Steam conditions have been advanced to 2350 psig and 1100 F, and the electrical output per pound of coal has been increased threefold.

Hydroelectric generators were of 10,000 kva rating in 1913. The first of 12 large hydraulic turbine-driven generators delivered in 1952 is rated 73,684 kva and has a thrust bearing capable of supporting a four-million-pound load which is 33 percent greater than the heaviest thrust load previously carried.

The largest transformers of 1913 were 10,000 kva. At the turn of 1953 General Electric engineers were designing the most powerful transformers in the world, rated 300,000 kva; circuit breakers announced for the new 330,000-volt transmission lines will have 25,000,000-kva interrupting capacity. The limits of the engineer are boundless.

There was no electronics in 1913 as we know it today. Electron tubes were still in the Research Laboratory. Today they are made by the millions for radio sets in every home, for television sets on the way to being in every home, for the vast communication networks of our land, for industry, and for the defense of our country.

In 1913, homes had no electric refrigerators, no air conditioning; home appliances were few. During the year 1952 the total of refrigerators leaving the General Electric production line passed the 10-million mark; and electric ranges, dishwashers, food waste disposers, clothes washers and dryers, fans, irons and ironers, mixers, clocks, electric blankets, and air-conditioning equipments for heating and cooling were being produced in ever-increasing numbers.

The electrical industry is an engineer's and a scientist's industry. It requires the best of knowledge and experience to tame electricity and put it to use for mankind. A. L. Rohrer saw this when he early established the General Electric Test Course. And in 1913, Robert E. Doherty was beginning to dream of the Advanced Course in Engineering which he established in General Electric in 1923. Advanced study and training have since been extended into every engineering field within the Company. These years have seen a vast reservoir of engineering and scientific knowledge grow into being, the like of which exists nowhere else in industry.

In 1913 the business of General Electric Company amounted to \$106,477,438. In 1952 it was \$2,623,-888,000, a 25-fold growth in these past 40 years.

Our president, Ralph J. Cordiner, has said it is probable that in the next 10 years as much electric generating equipment will be built, sold and installed as has been built and installed in the industry's 75-year history. This means the electrical industry must be prepared to grow more than twice as fast as the remainder of the economy.

In the midst of this overwhelming production stands the engineer. And to the new engineers entering General Electric—and industry everywhere—our heartiest greetings. May they make the next 40 years to be even greater than the four decades just past.

Everett S. Lee

EDITOR

BUSY AIRPORTS SUCH AS NEW YORK'S INTERNATIONAL WILL ONE DAY SOLVE AIR TRAFFIC CONTROL PROBLEMS WITH COMPUTERS AND . .

DIGITAL DATA PROCESSING— A KEY TO TECHNICAL PROGRESS

By CHARLES R. WAYNE

Many achievements are attributed to the electronic digital computer. Newspapers and popular magazines tell the public how remarkably fast they solve highly complicated problems—problems that would take hundreds of mathematicians hundreds of years to solve. Science-fiction writers go one step further. They call the digital computer a "giant brain," picturing for the reader a future where all of man's complex problems are disposed of by merely pressing a button.

Neither group is completely right; neither group is completely wrong. For developments under way in the field of digital computers will improve many facets of our lives, now and in years to come. But essential to these developments is a tool of engineering called *digital data processing*—a name you'll hear frequently in the future.

What It Is

Digital data processing concerns itself with *any* kind of information or data in number form. This concept includes letters of the alphabet, too, since any 26 numbers can be assigned to represent them.

Processing may consist of: 1) storing numerically coded data for subsequent use, 2) performing algebraic operations upon it, 3) making decisions based upon it, 4) converting to other types of data, and 5) making use of data to accomplish some given purpose.

Unique features of information in digital form leading to its potentialities in many applications are . . .

- A number can be expressed as accurately as any problem requires.
- Numbers can be stored indefinitely in various devices, without loss of readability or accuracy.
- Complex ideas or processes expressed in words can be represented by code numbers.

But before going further into digital data processing, let's briefly look at the vehicle that uses it—the general-purpose computer, a solver of complex mathematical problems.

Computers . . .

The high-speed general-purpose digital computer is a device that can solve almost any math problem a mathematician can program. That is, it can solve any problem that can be set up in a series of simple steps. It can't solve a problem a mathematician couldn't solve—if he lived long enough to complete all the calculations. But it can do the calculations much faster.

Although a mathematician must outline the problem sequence to be followed in every small detail, the computer is useful where the sequence is repeated a great many times. There is, for instance, a wide range of partial differential equations where the only method of solution is to guess at an answer. You must go through a large number of operations and come up with an end result, comparing this with the original guess. If the two figures aren't close enough together, you must repeat the procedure with an improved guess. There are also problems that are repeated day after day: ballistics and trajectory problems, design of electric machinery and controls, tabulations of mathematical functions.

The two outstanding characteristics of

a digital computer are *memory* and *choice*. Memory is the computer's ability to store vast quantities of data in predetermined order, and to refer back to these at will. Choice, on the other hand, is its ability to make a decision as to which of two paths to follow. For by proper sequencing of choice operations, it can select one path of behavior from a number of possibilities.

With the exception that no man-made memory yet has a capacity equivalent to man's, the computer's memory is similar to that of the human brain. (There are about a quadrillion cells in the human brain.) It can make decisions like the human being—but can't, as a human being does, base these decisions on intuitive, emotional, or subconscious factors.

These characteristics—memory and choice—are indeed remarkable; much more so than the computer's speed or accuracy. They open large fields of application to digital techniques where computation alone is of little value.

. . . And How Computers Work

Let's look now at how a computer operates. A mathematician prepares a program that is a sequence of simple operations to be performed by the computer: addition, multiplication, reading into and out of its memory, choice, and so on. He prepares this information in a special numerical code. (This is shown in simplified form on the next page. Although the problem is programmed for OARAC—a large-scale digital computer built by General Electric—the principle is similar in most modern computers.) When the mathematician completes his program, he feeds it to the machine.

At this point, the language of the outside world is translated into the language of the computer. For relays and certain magnetic and dielectric components within the computer have only two electrically stable states: ON and OFF. Similarly, its vacuum tubes have two highly stable states: full conduction and cutoff. Because of this, digital computers are most efficient when asked only to pass or not to pass current. They are used most efficiently with binary numbering systems of only two digits, in contrast to our own decimal system of ten.

A number is expressed as a series of 1's and 0's. For example, the binary number 11010 is equivalent to our decimal number 26. Numbers written by the mathematician must accordingly be converted to binary notation. (An introduction to binary arithmetic and its use in digital computers is given on page 14.)

There are numerous ways to represent 1's and 0's in the computer. Again, for example, a pulse of current represents a 1, while 0 is represented by the absence of a pulse; or a positive pulse represents a 1 and a negative pulse represents a 0.

One way to convert decimal numbers to their binary equivalent is by means of an electric typewriter. It is so wired that as a key is depressed an equivalent series of electric pulses are stored on a magnetic tape. Then, when the entire program is converted, the reels of magnetic tape are placed on the computer—which meanwhile could have been solving other problems—and at least a portion of the information is automatically transferred to a more rapid internal memory. The memory could be a rotating magnetic drum, the screen of a specially constructed television tube, or devices of a similar nature.

After transfer, the computer reads the first line of programming from the storage device. Sensing what it must do, it performs the requested operation and goes to the next line, and so on, until the program is finished. Answers are then automatically recorded on magnetic tape; the tape is removed and placed on a special device which decodes and prints the answers on paper in familiar decimal form.

(OARAC is capable of going through similar operations at the rate of 100 per second. It has an extra-large 10,000 "word" magnetic-drum memory, with each word equivalent to a 10-digit number plus an algebraic sign. It uses some 1400 vacuum tubes and 7000 germanium diodes).

Actual computing elements—the devices which add, subtract, and divide—are only a small portion of the digital computer's equipment. The greater portion concerns itself with transferring information from the operator to the computing elements, and transferring back the results. For a digital computer is primarily an information-handling device.

Solving scientific problems, then, represents only a small portion of what is done with digital techniques. There is a wide variety of nonmathematical applications in the military and commercial fields as well, where nothing but different versions of the same problem are solved every day. And consequently,

MR. WAYNE—a Laboratory Group Leader at Electronics Park, Syracuse—is at the control panel of OARAC, a large-scale digital computer. His group is responsible for the design, development, and construction of digital processing equipment and computers.

the machine doesn't have to be programmed.

There are two types of systems that make use of digital techniques: information storage and information processing systems.

Storing Information

With information storage and handling, procedures are repetitive, with relatively little computation. But the number of quantities controlled is large. Examples are . . .

- Control of circulation of a weekly magazine with several million subscribers
- Control of inventory records maintained in a large company
- Keeping insurance records
- Military logistics
- Factory control

Take for example a magazine mailed weekly to five million readers. Applications for new subscriptions must be entered, readers must be notified when their subscriptions are about to expire, and lapsed subscriptions must be removed. In addition, changes of address must be entered promptly, payments recorded, receipts sent back, and sales promotion letters sent to groups of potential customers.

This, as you can see, is a gigantic bookkeeping problem. And though there's little computation involved, a large-scale digital computer could easily handle such a system.

A computer to do all this would have —on tremendously long tapes—all the required data on five million readers. This data would include name, address, age, occupation, salary-class, type of subscription, date of expiration, and so on.

HOW THE DIGITAL COMPUTER SOLVES A PROBLEM

OARAC is a large-scale digital computer with an extra-large memory. (It can solve 1011 simultaneous equations.) The simple illustration that follows will give you an idea of how the computer operates. Actually, the equation used might only be one thousandth part of a highly complicated problem.

In the equation—

$$y=3x^2+5x+2=[3x+5]x+2$$

find y for all values of x between 1 and 1000 in steps of one.

The following information is stored at addresses in the computer's memory—a rotating magnetic drum:

Address	Number
0000	$x=1$
0001	999
0002	1
0003	3
0004	5
0005	2
0006	y

Operation	Address	Instruction	Address
1	1201	21	0000
2	1202	24	0003
3	1203	22	0004
4	1204	24	0000
5	1205	22	0005
6	1206	12	0006
7	1207	31	0006
8	1208	21	0001
9	1209	23	0000
10	1210	30	1215
11	1211	21	0000
12	1212	22	0002
13	1213	12	0000
14	1214	32	1201
15	1215	34	0000

Key to Instructions

21 = put into accumulator
22 = add
23 = subtract
24 = multiply
30 = choice (see further)
31 = read to tape
32 = go back to
12 = write into memory
34 = stop and ring bell

By turning a knob and pushing buttons on OARAC's front panel, the operator tells it to go to address 1201 and perform operation 1. It automatically proceeds from there to operation 2, 3, 4, and so on, performing the operations as follows—

Operation Number	Operation
1	"Bring what is at address 0000 into the accumulator." At this address the number 1 is stored. $(x=1)$
2	"Multiply the number in the accumulator by 3." Result: $3x=3$
3	"Add to what is in the accumulator, the number at 0004." Result: $3x+5=8$
4	"Multiply result of operation three by value at 0000." Result: $(3x+5)x=8$
5	"Add what is in 0005." Result: $(3x+5)x+2=10=y$
6	"Put answer at address 0006 on the magnetic drum."
7	"Record answer on magnetic tape for future printing."
8	"Put into accumulator the number at address 0001."
9	"Subtract x from that number." Result: $(999-x)$
10	"Make a choice . . . if $(999-x)$ is positive or zero, continue with operations 11, 12, and so on; otherwise perform operation 15, ringing bell to indicate problem is finished."
11	"Put x into accumulator."
12	"Add 1, giving $(x+1)$, the new value of x."
13	"Record this at address 0000, making the new value of x available for calculating y."
14	"Go back to operation 1 at address 1201."

From here on, the computer repeats steps 1 through 14 until x reaches 1000. Then operation 10 stops the calculation and rings bell to signal operator his instructions have been carried out.

Daily or weekly information on changes of address, cancellations, and payments is fed into the machine. It then scans the tapes, looking for affected subscribers and making corrections. While scanning, it also notes subscriptions about to expire, sending electric pulses to other parts of its system where names and addresses are printed on special cards. The cards may say something to the effect that a discount will be allowed for an early payment, or that a reader's subscription has expired, or that money is owed on his last payment. Such a machine therefore continuously and automatically has all necessary information on all subscribers and does all the bookkeeping.

Another example of a digital computer for commercial use is a payroll machine. This one receives time cards and other information affecting the pay of an employee. Stored in it also is all additional information necessary to compute the employee's pay. Besides computing each pay, it prints checks and permanently records pertinent data.

You'll note that in these applications there is little computing—no higher mathematics. But digital techniques are still used, numbers are still handled, and most computer operations are performed. There are applications where even less computing is done. The superhighway toll classifier, for example, classifies a passing vehicle by summing up weights at each of its axles and determines its rate per mile.

Among military applications you'll find a variety of logistic computers. These are special types of business machines for sorting and filing information on supplies, predicting future needs, and doing a number of other things too. Here, as in preceding applications, the computer is used only because it's a faster, less expensive way to control simple repetitive procedures.

Processing Information

Where the complexity of data and need for fast information processing presents a problem, the digital computer is more than a successful competitor of man. In fact, it is the only way out.

Processing radar data presents such a problem. For data include detection of friendly and enemy targets, computation of velocities, and prediction of their future positions. Situations must be analyzed. If counter measures are required, they must be determined, initiated, and controlled. When friendly aircraft need help in landing or carrying out their missions, computation is necessary to make decisions.

Radar systems are improved continuously; more and better data become available but we are unable to use them. This situation results mainly from the human operator's relative slowness, even when he is assisted by desk calculators—but more so, from the problem of communication between operators of the system.

Digital techniques are the only solution. Because of their large memories, computers can remember information about a large number of targets. With their tremendous speed of operation, communication becomes a minor problem.

Let's imagine a hypothetical problem where it's desired to automatically control up to 100 aircraft in the initial approach zone of a busy airport—a zone perhaps 100 miles in radius and 40,000 to 60,000 feet high. Each aircraft will need periodic instructions to guide it along a route, insuring safe separation from all other aircraft.

A computer could calculate the prescribed paths and schedules. To do this, it would need data on wind conditions, traffic rules, choice of runway, flight characteristics of the aircraft, and a knowledge of exact position of all the 100 planes. Programming this computation can be thought of as translation into the computer's language of a complete manual of the system's operation. Because the computer has no imagination, no originality, and can only follow explicit instructions given it, the program must be complete in every detail.

Air traffic control is typical of human organizations. That is, as the size of the group grows, efficiency is lost because of intercommunication difficulties. The problem is one of information processing. Here, the computer has an advantage of speed over human beings, but even more important is its impressive superiority in intercommunication. By scanning each bit of information rapidly, it is able to approximate a continuous grasp of the situation.

An Automatic Factory

In the same category of applications as the superhighway toll classifier—where little computing is done—is the automatic factory. Such automation, with the aid of digital data processing, is a field of great promise. In some ways it has already been overglamorized as the forerunner of a new industrial revolution. Various reactions are accordingly produced in the public, often obscuring basic facts.

Some people attribute to the automatic factory miraculous powers to change the whole structure of society and create a Huxley-like brave new world. Still others minimize its value and are perfectly content with the way things are now. Another segment of the public envisions a large manufacturing organization where raw material comes in one door and finished products go out another: where manpower consists of a number of corporation officers and stockholders, plus two maintenance men who replace vacuum tubes when summoned by some giant brain. Then there are those who feel the automatic factory has for many years been a reality. This group claims that automation is, after all, just a series of large or small machines with a number of workers carrying material to—and products from—the machines, and keeping track of what goes on.

Here again, no one group is completely right, no one group is completely wrong. The automatic factory is much *less* than a monster robot operating free of human interference. It is much *more* than a number of small automatic machines working independently.

Simply the Next Step

The automatic factory is simply the next step forward in improvement of our way of life: of providing better products in greater quantities at a lower price. We find in our factories today many automatic machines doing the work people once had to do, and doing it faster and cheaper. The automatic factory will relieve man of still more routine functions, allowing him to use his intellectual capacity to the limit.

What are the functions that could be performed automatically? There are many—some are already performed automatically and others soon will be. For still others, we may have to wait many years. These functions include . . .

- Actual machine operation and tending of machines; inspection of operation and of products in various states of completion.
- Setup of machines and equipment; change of tools; maintenance.
- Starting, accelerating, decelerating, and stopping production according to certain rules; emergency shutdown.
- Materials and product handling; ordering new materials and components; checking need for product.
- Programming work sequences; keeping production records; gathering cost information, and related functions.

To illustrate this, consider the manufacture and assembly of an electronic chassis—the metal frame with its assemblage of parts. In the memory of a central digital computer, all the data and rules needed to perform the functions would be stored.

Components of the same class would be automatically sorted. By measuring their mechanical or electrical characteristics—and by converting them to numbers for comparison with sets of numbers stored in its memory—the computer would sort components and feed them into special containers. These would then be marked electrically or mechanically to indicate their contents.

Stored also in the computer's memory would be dimensions of the chassis, with position and size of holes required. From this information, it would initiate operation of either a milling machine or punch press. And from return pulses, the computer would know at all times displacement of the machine's table or size of its punch, thereby controlling its operation.

Standard machines would be used with the addition of sufficient pulse generating equipment. Thus all information could be deduced by counting pulses or detecting the presence or absence of voltage levels. In the same way, co-ordinates could be determined for the placement of electronic components or for assembly of circuits. The computor would look into its memory for each detailed rule: "Punch a ¼-inch hole 2⅛ inches to the left of, and 1¼ inches up from, the last hole."

When the chassis is assembled, the computer would find in its memory certain inspection criteria. These would be mechanical or electrical—or both; with proper sensing equipment, the computer would determine acceptance or rejection of a chassis. The computer would also keep necessary records: number of good and bad chassis, reasons for rejections, shortage of components, and so on.

Other operations computers might do are: Stop production when the number of chassis reach a predetermined quantity, calculating this quantity from relative speeds of production and other pertinent data; automatically initiate assembly of the next chassis, possibly for a radically different system; cause all operations to cease by sensing emergencies like breakdowns, bottlenecks, or lack of parts. In effect, then, the computer could do anything expressible as simple rules as long as it could sense these rules.

But what other types of operation could make use of digital equipment? Clearly there exists a class of manufacturing that can be performed by single automatic machines—processes where unlimited runs of the same product are required. A good example of this type of automatic factory is the modern bottling plant. Yet, for most manufacturing processes, this isn't an economical solution. For little change in product is possible, and then only at great cost. Extremely long production runs are essential to make such a system practical. Here there is little need for the digital computer.

For most manufacturing processes, however, the over-all function can be broken down into a number of simple ones performed by standard units. The units can be used in various ways to perform different operations: they are the building blocks of the automatic factory. We use them for fabricating as well as materials' handling, inspection, and record keeping. Then by adding a central programming unit and digital data processing unit we obtain an automatically controlled and producing entity. When a new product is to be produced—or a major variation made—the units can be freely arranged, without any physical motion, but with additions and deletions as necessary.

Obstacles and Optimism

The greatest obstacles to automatic production may well be lack of information about what can be done—and lack of interest in how much can be done. What could be done at the present time is far ahead of what is being done. For though there are still many problems—mainly in mechanizing individual machines—many inventions, techniques, and methods are already available for use.

Digital techniques do not imply the introduction into the factory system of a large-scale general-purpose computer: one that's capable of solving partial differential equations, using for its operation thousands of vacuum tubes and germanium diodes. On the contrary, the digital techniques referred to require low-speed components, and few vacuum tubes or germanium diodes. Usually they do little more than keep records and make simple decisions based on choice.

Digital data processing leads to many new applications in the fields of automatic equipment and electronics—applications that are just now undergoing investigation. There's little that computers cannot do. However, numerous problems must be solved before the computer—be it giant brain or automatic control—will become part of our daily lives.

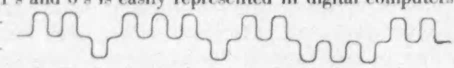
To be specific, present-day computers must be reduced in size by decreasing the number of components and the size of each component as well. The reliability of all repetitive components must be improved so that it compares favorably with that of germanium diodes. Many mechanical problems must be solved. And in addition, people must be educated to realize the importance, limitations, and availability of digital techniques.

Science-fiction is often ahead of the times, but in the field of digital data processing, real science is catching up. Ω

INTRODUCTION TO BINARY ARITHMETIC

It's often said that our decimal system of arithmetic—where the number fundamental to the system is 10—originated because we have 10 fingers. At any rate, it has served us well.

But using the decimal system in the digital computer would require a vast number of electronic and electromechanical components. For each digit from zero to nine would have to be represented by a different electric signal, or combination of signals. On the other hand, a numbering system with only two different digits greatly simplifies things. This is true because electronic and electromechanical components generally have two stable states: full conduction or cutoff in the case of vacuum tubes; closed or open circuit in the case of relays, magnetic devices, and similar components. Thus a number containing a series of 1's and 0's is easily represented in digital computers by a series of electric pulses— +



−

which translated is the binary number— 1 1 0 1 1 1 0 1 1 0 0 0 1 1

And so, the binary system of arithmetic is a numbering process based on the digits, 0 and 1, with the number fundamental to the system being 2. Here is a comparison of the two systems—

Decimal System: $3457 = 7\times10^0 + 5\times10^1 + 4\times10^2 + 3\times10^3$

Binary System: $3457 = 1\times2^0 + 0\times2^1 + 0\times2^2 + 0\times2^3 + 0\times2^4 + 0\times2^5 + 0\times2^6 + 1\times2^7 + 1\times2^8 + 0\times2^9 + 1\times2^{10} + 1\times2^{11} = 11011000001$

Number in Decimal System	Equivalent in Binary System	Binary Radix
1	1	2^0
2	10	2^1
4	100	2^2
8	1000	2^3
16	10000	2^4
32	100000	2^5
64	1000000	2^6
128	10000000	2^7
256	100000000	2^8
..	..	..
..	..	..
..	..	..

Remarks
In the binary system, you move over one place when the exponent of 2 is increased by one.

The decimal number 3457 is converted to its binary equivalent in the following manner—

Highest power of 2 <	3457	is $2^{11} = 2048$ =	100000000000
Highest power of 2 <	[3457—2048]	is $2^{10} = 1024$ =	10000000000
Highest power of 2 <	[3457—(2048+1024)]	is $2^8 = 256$ =	100000000
Highest power of 2 <	[3457—(2048+1024+256)]	is $2^7 = 128$ =	10000000
Highest power of 2 =	[3457—(2048+1024+256+128)]	is $2^0 = 1$ =	1
	Sum:	3457 =	110110000001

Addition and multiplication in the binary system are elementary compared to their decimal equivalents—

Addition

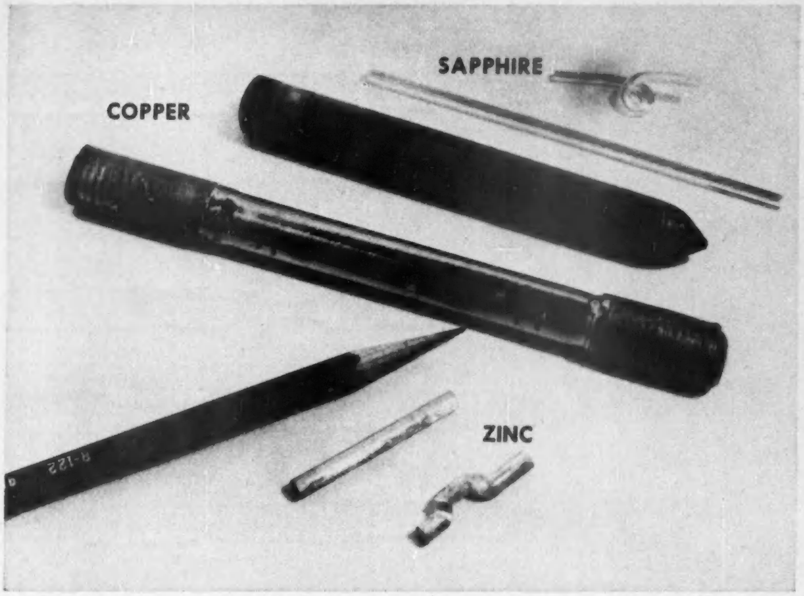
Decimal	Binary
0 +0 = 0	0 +0 = 0
0 +1 = 1	0 +1 = 1
1 +1 = 2	1 +1 = 10
2 +2 = 4	10 +10 = 100
1 +4 = 5	1 +100 = 101
5 +2 = 7	101 +10 = 111
7 +7 = 14	111 +111 = 1110

Binary Multiplication Table

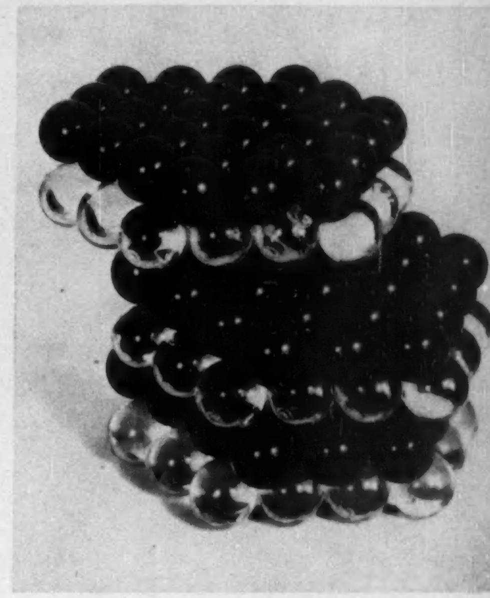
0×0=0	0×1=0
1×1=1	1×0=0

Typical Binary Multiplication	Decimal Equivalent
10111	23
×1100	×12
1011100	46
10111	23
100010100	276

Remarks
With a little practice, you can soon change over from the decimal to binary system. And of course, it has simplifications and shortcuts, just like the decimal system.



SINGLE CRYSTALS before and after testing. Reason why most materials are weaker than they should be is now traced to defects within the individual crystal.



CRYSTAL MODEL shows offset along its slip plane, caused by plastic flow.

Why Metals Are Weak

By DR. J. C. FISHER

That metals are weaker than they ought to be and that their weakness arises through the presence of defects have been recognized in the last 20 years. The significance of this knowledge is only now in the process of being revealed.

The Single Crystal

Metals are composed of crystals in which atoms are arranged according to a definite pattern that repeats itself over and over again. In most commercial materials, many tiny irregularly shaped crystals are packed together in intimate contact. We must know how they behave when acted upon by forces if we are to understand the strength, ductility, and other mechanical properties of materials.

Much of the important and illuminating work concerning deformation of materials has been carried out with single-crystal specimens. Here the entire specimen is composed of one crystal rather than many thousands or millions. Specimens typical of those we have studied are shown (above, left) before and after testing in tension, compression, and bending, respectively. (The copper specimen's central portion was electropolished to a smaller diameter before testing.)

Perfect Crystals Are Strong

The simplest way for an ideally perfect crystal to undergo permanent deformation is for one layer of atoms to slide over an adjacent layer, as illustrated in the model of a single crystal (above, right) with a portion of its slip plane exposed. Shear stresses required for this type of slipping, or plastic flow, have been calculated rather accurately from known interatomic forces. They are about a million pounds per square inch for iron and a quarter of a million pounds per square inch for cadmium—10 to 100 times greater than the stresses at which ordinary iron and cadmium readily deform.

Unfortunately, only a few special crystals have been obtained that appear to be perfect or nearly perfect. Some grow under certain conditions from the surface of cadmium or zinc in the form of thin hairs or whiskers. Others are formed from thin sheets of mica, carefully cleaved from a single mica crystal. These fibers and sheets have strengths equal to those predicted for perfect crystals, verifying the methods of strength computation employed. Such crystals are extremely small and scarce however; they are the exception rather than the rule.

Actual Crystals Are Weak

Except for the metallic whiskers just described, all pure metal single crystals that have been tested proved weak in comparison with the strengths calculated for perfect crystals. For example, a crystal of copper an inch in diameter and a foot long can be bent double by hand. And some typical stress-strain curves for aluminum and zinc crystals

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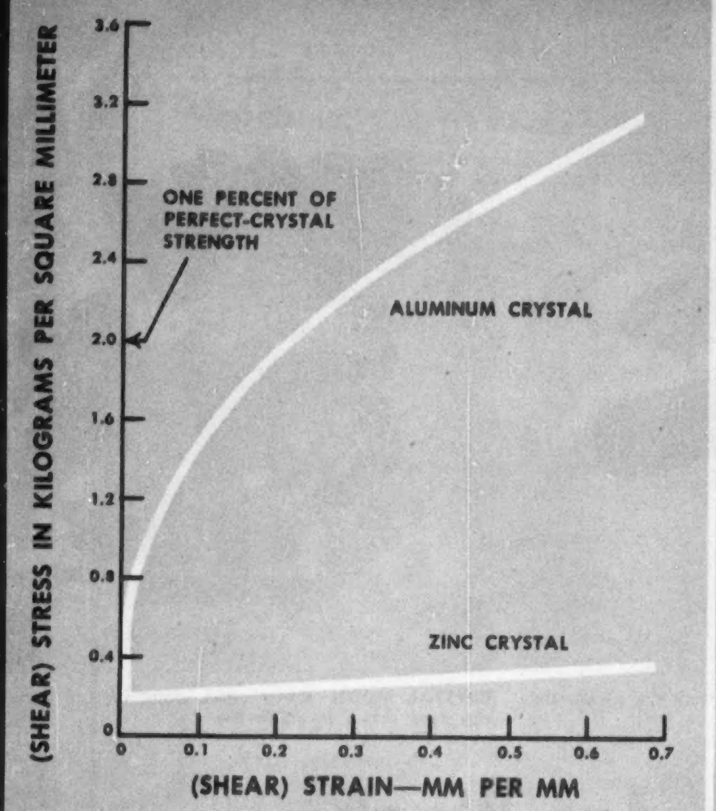
Author of a number of papers on mechanical metallurgy and kinetics of phase transformations, Dr. Fisher is Manager, Physical Metallurgy Section, Metallurgy Research Department, G-E Research Laboratory at the Knolls, near Schenectady. He is working at present on the theory of dislocations and its application to alloy strength.



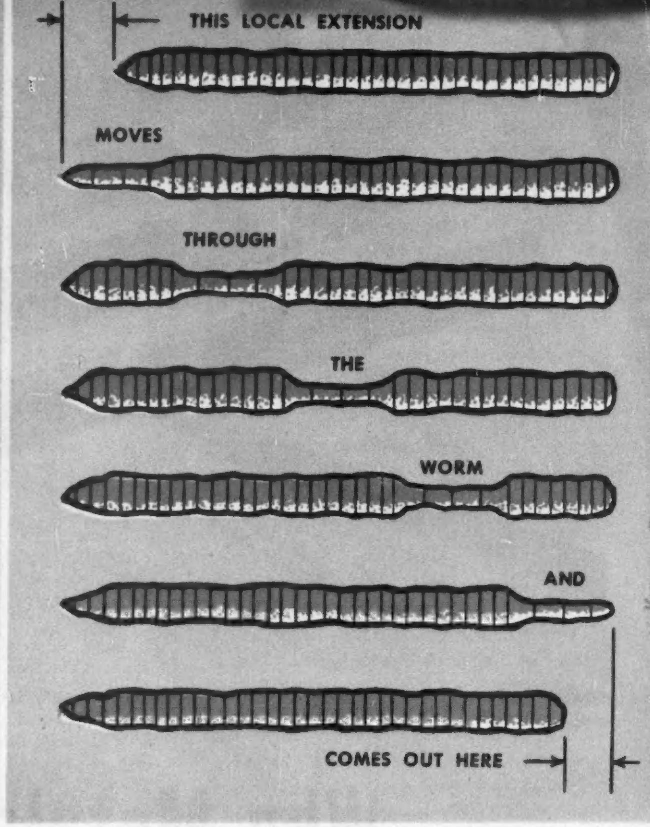


FIG. 1. CRYSTALS of pure metals have much lower yield stress than theoretically perfect crystals.

FIG. 2. EARTHWORM advances beneath ground by rearward motion of a stretched and constricted length.

(Fig. 1) show the considerable deformation produced in them with stresses less than one percent of the values needed to deform perfect crystals.

This plastic weakness of actual crystals is produced by imperfections called *dislocations.* Since it is easier to describe a dislocation in an earthworm than in a crystal, let us look at the earthworm first. (This analogy was originally proposed by Prof. Egon Orowan of Massachusetts Institute of Technology.)

An earthworm in the ground would find it next to impossible to move if it tried to advance all at once—both ends and its middle simultaneously. By stretching its leading end (Fig. 2) forward however and extruding its body along with a wave-like motion, it can advance a step. Note that the worm's *forward* motion is accomplished by *rearward* motion of its constricted stretched length, from its leading to its trailing end. At any given instant it is only this constriction, or dislocation, that moves. By the motion of a dislocation in an otherwise perfect worm, the worm advances.

The dislocation in a crystal is similar to that in an earthworm (Fig. 3). Here, the top half of the crystal glides over the bottom half by the rearward motion of a stretched region. The region passes through the crystal just as a constriction moves along an earthworm, while the crystal's top half moves oppositely to the motion of dislocation.

This crystal defect is called an *edge* dislocation, for it can be viewed as being the place where an extra plane of atoms terminates at an edge inside the crystal.

Another type of dislocation, called a *screw* dislocation, also can exist in a crystal as shown in the photos on the opposite page. Because of its presence, a crystal that would have many atom layers if perfect is converted into a spiral ramp—where a single layer of atoms passes over itself many times. Glide of one portion of the crystal with respect to another occurs in a direction perpendicular to direction of screw dislocation motion. (Screw dislocations are important for a crystal's growth. A crystal containing one can grow indefinitely without the necessity of starting any new layers of atoms.)

What Controls Strength?

Dislocations move with extreme ease in crystals, and their motion under the influence of a stress produces *plastic deformation.* The plastic weakness of most materials is now known to result from the presence of many dislocations in the annealed material, although it is not known how dislocations get into a crystal in the first place. Our best guess is that they are formed during solidification.

Because practical crystals contain so many dislocations, we have the problem of accounting for their strength rather than their weakness. In other words, the problem shifts from explaining why they are so weak in comparison with theoretically perfect crystals, to why they are so strong despite their dislocations.

Where does the modest strength of these practical materials come from? Since their dislocations should glide under nearly zero stresses, it must result from the inhibition, or restraint, of dislocation motion inside these materials.

Several types of restraints can be imagined that might increase the difficulty of dislocation motion.

First, the grain boundaries in polycrystalline metals—where one crystal meets another—should tend to stop the motion of a dislocation; for crystallographic directions change abruptly at grain boundaries. On this basis, you might expect polycrystalline metals to be stronger than single crystals. And so they are.

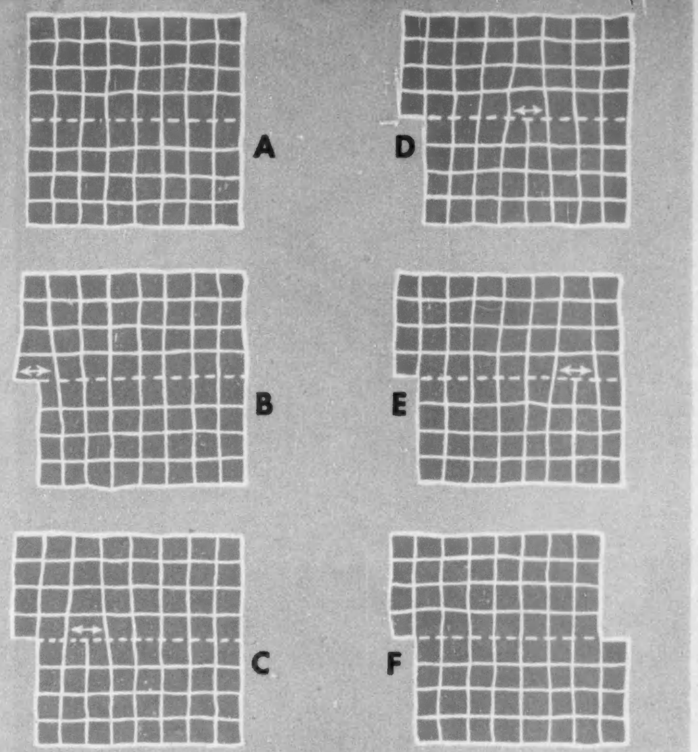


FIG. 3. EDGE DISLOCATION in a crystal moves similarly to earthworm's constriction. Top half of the crystal glides over its bottom half.

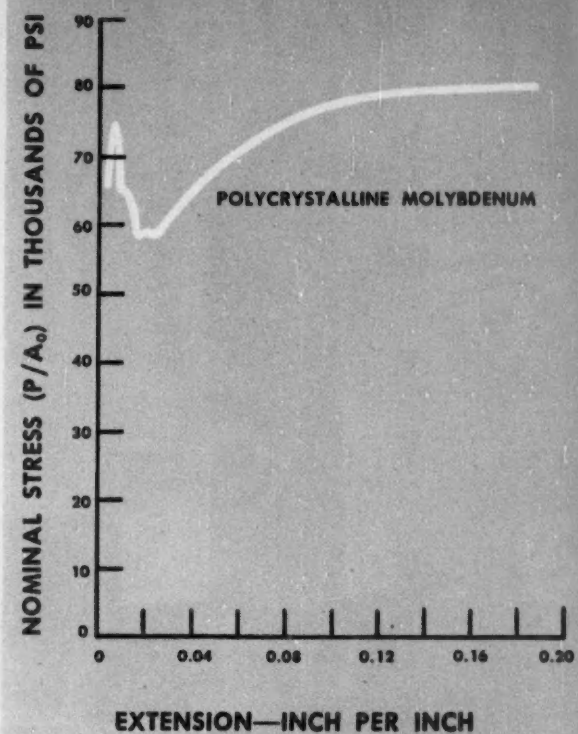


FIG. 4. SHARP YIELD of molybdenum occurs when restrained dislocation breaks free.

Second, you would expect that hard particles imbedded in a metal—such as the iron carbide particles formed during heat treatment of steel—would tend to prevent the motion of dislocations, and to increase strength in much the same way as grain boundaries do. This expectation is also realized.

Third, you might expect that solid-solution alloying would make the motion of dislocations more difficult. (Crystals of a solid-solution alloy contain two or more kinds of atoms that are mixed together.)

It could happen that particular types of atoms would cluster near each dislocation—for example, large atoms in the extended portion and small ones in the compressed portion—so that dislocation energy is reduced. If the dislocation then were to move away, leaving the special atom configuration behind, its energy would have to increase abruptly. Hence, a large stress might be needed in order to break this dislocation loose. Once it becomes free however, the dislocation could move easily and at a lower stress.

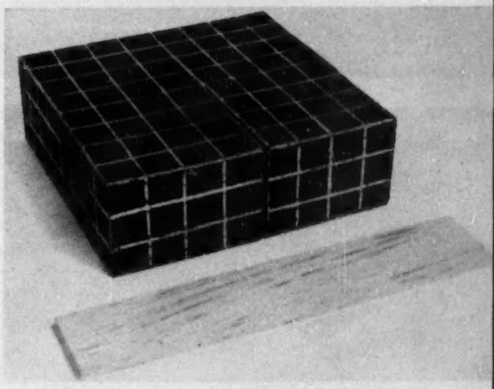
The sharp yield of some metal alloys under stress (Fig. 4) is believed to arise this way, although the actual mechanism undoubtedly is more complicated. Other influences of alloying on the motion of dislocations in metals are just now in the process of being studied.

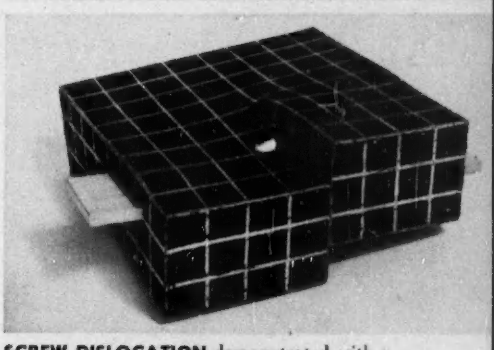
What About the Future?

That the dislocation concept has greatly advanced our understanding of plastic flow is certainly true. Current work in dislocation theory gives promise of enabling us to predict quite accurately the plastic strength of metals and alloys and of nonmetallic materials at *all* temperatures.

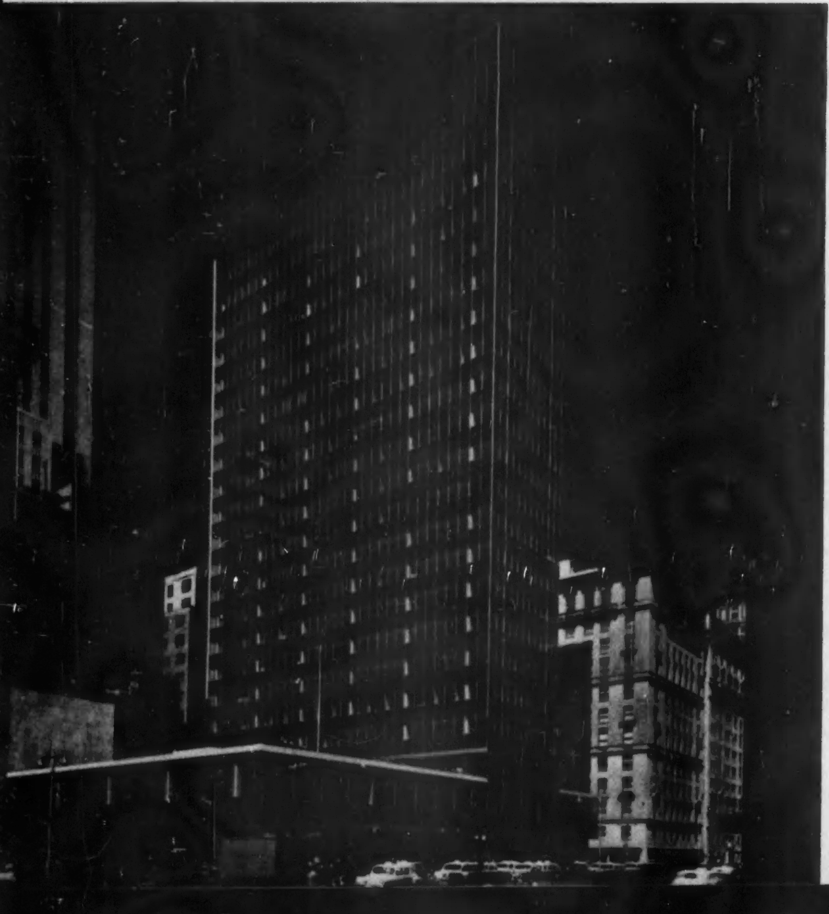
Then too, the dislocation theory may prove to be of some value in understanding brittle fracture—fracture similar to that occurring in cast iron. Brittle fracture is perhaps the greatest unsolved problem in the mechanical behavior of materials, for there is no good model for it, as there is for plastic flow in terms of dislocations.

The mechanical behavior of sapphire is of interest here. Hardest natural substance next to diamond, sapphire at high temperature is as ductile as copper (page 15), although at low temperatures it is as brittle as glass. The reason for this change is not known. What we need is a mechanistic approach to the problem of fracture comparable to the dislocation approach to plastic deformation. Ω





SCREW DISLOCATION demonstrated with a rubber model of a crystal (*top*). When dislocation is present (*bottom*), it offsets the crystal one atomic spacing, thereby converting the crystal's separate atomic planes into a spiral ramp or screw.



Forms and Forces . . .

. . . . in American architecture are typified by a blending of utility and exciting visual effects that negate the old concept, "art is not art unless it is useless." Pictured above is the General Motors Technical Center near Detroit, designed by Eero Saarinen Associates. Blazing colors were baked on ceramic glazed brick in a high-temperature kiln built specifically for the job. The same brick, in a cooler color, is used as an indoor finish. Lever House, New York City, is shown at left. Designed by Skidmore Owings and Merrill, it's another example of the new architecture—a striking expression of a creative industrial society.

FUNCTIONALISM—KEYNOTE OF TODAY'S INDUSTRIAL ARCHITECTURE

By ROBERT L. GEDDES

The Industrial Revolution has caused many changes in our everyday life, and it is not surprising that it also has brought forth something new in architecture—modern schools, houses, office buildings, factories. This architecture is not new in the sense that fashions are new: it is rather the natural and logical consequence of new factors that exist in an industrial society.

The arguments about styles—Gothic, Neoclassic, or Ranch—have no place in the development of industrial architecture or, for that matter, any other. There is no reason why a tall office building, for example, should be related to the "orders" of a Greek temple, with its street floor resembling the podium or base, its main structure the column, and its upper floors a capital. Yet this sort of design has often been done consciously and still is done, sometimes unconsciously. To create a work of art, it's not enough for an architect to adorn the front of a building with 12 columns.

Such new buildings as Lever House in New York, General Motors Technical Center in Detroit (photos, left), and modern houses and schools throughout the country are already aesthetic expressions as beautiful and bold as the greatest architecture of the past. They are expressions of a technological age, having little to do with the architecture of the styles.

It is poetic justice that the building of factories introduced this new architecture, for it is largely by force of circumstances that the design of industrial plants demands that the architect consider function, construction, and economy as essential requirements of building. The result has a clarity of form and structure that does not obscure or apologize for the fact that it is a working place. Indeed, it is a proud fact that the factory building of the 19th century has become the industrial architecture of today.

The factory as such is not very old. It hardly existed at all before 1780, although the Roman armament plants and the medieval Naval Arsenal at Venice contained elements of the factory system. Down to the 19th century, factories were called mills because of the use of water power, and the mill building was an integral part of the landscape in England and our Northeast states. The typical mill building had a structural system which had descended with little change from the Roman tenement houses and from the many-storied warehouses of Amsterdam. They were simple rectangular masonry boxes with timber posts and beams supporting the floors. Fire hazards of such construction resulted in high insurance premiums: demands developed for structural techniques that would resist fire and a building system with such standards as performance and efficiency. These were new requirements for architecture; they were the standards of the machine itself. The factory building had to become part of the tooling of the industry.

From the first, industry demanded greater spans and greater strength in its buildings, and the economical use of power required that all stages of production be brought under one roof. The specialized machinery was enormously heavy and caused vibration of the entire structure. And because of the inherent limitations of wood beams and columns, traditional structural systems were unable to meet these new requirements. The truss—also made of wood—replaced the simple beam. With this built-up member the span could be greatly increased. But the column could not be so easily refined—its size must increase in direct proportion to the increased loads. The use of incombustible iron had been considered for years, and was first applied to replace the wooden post. Using cast iron (and later, wrought iron and steel) to replace the wooden post was a milestone in the history of architecture. And the last quarter of the 18th century saw the first application of iron to major structural elements of buildings.

Architects do not always fully grasp the implications of new techniques and new requirements. In the 19th century it was the engineer and the builder who carried forward the use of iron—the new material—in railroad bridges, train sheds, and suspension bridges. However, it was the Crystal Palace of the London Exhibition in 1851 that fired the imagination of the world with the possibilities of the new material. Here was a skeleton structure 1200 feet long, built almost entirely of glass and metal. Moreover, it was prefabricated in thousands of small parts and assembled on the site—only to be taken apart later and moved to another site. Joseph Paxton, the designer, was known as a builder of greenhouses; to the architects of the time, the Crystal Palace was not a work of architecture. Yet it was to prove more important than the stone monuments of the age.

We trace in the 19th century the first stages of a transformation to an industrial society. These changes were not only technical but also social and philosophical. And we are still in a period of transition, experiment, and adjustment, trying to achieve harmony between man, nature, and the machine. The concern of the architect for man's comfort and well-being has become the basis of planning a building; this approach has been called *functionalism*, but its real basis is the concern for man and his way of life. Recognizing human needs is one function of modern architecture. Great pioneering work has been done by engineers, builders, and architects that gives promise of new buildings and communities in an industrial age. As the pioneer architect Le Corbusier has said: "A great epoch has begun. There exists a new spirit."

We already have wonderful examples of a new architecture in modern houses, schools, and office buildings. It is frequently said that in modern architecture

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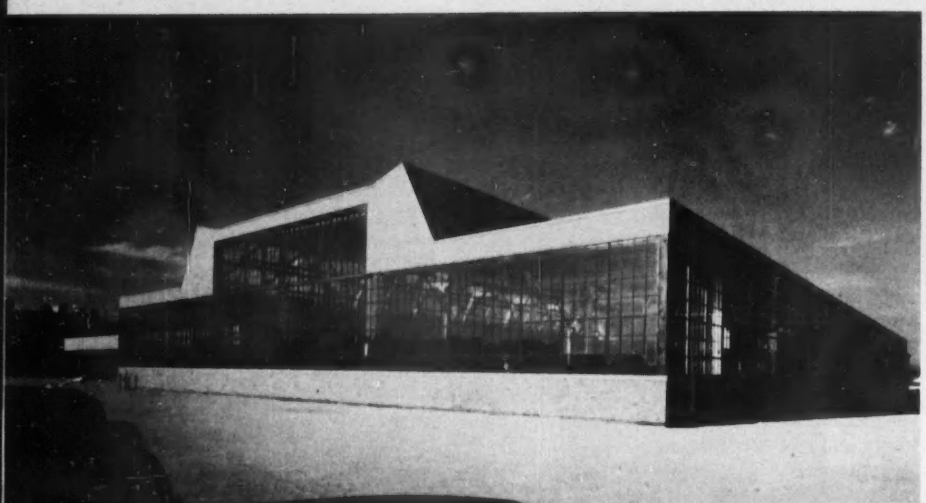
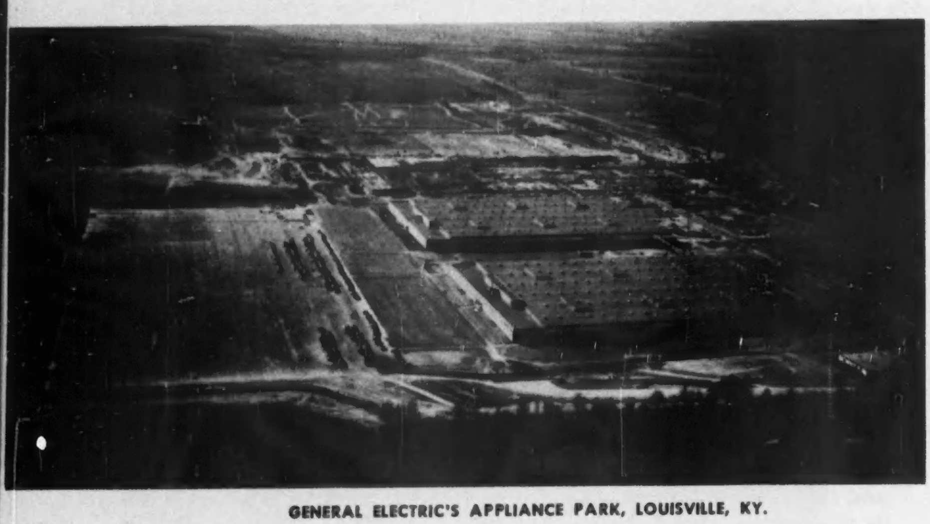
Mr. Geddes lives in Philadelphia where he specializes in architectural design and planning. He is an assistant professor of architecture at the University of Pennsylvania. Recipient of a Traveling Fellowship from Harvard University, he spent 1950-51 traveling abroad, studying old and new architecture.

TRINITY INDUSTRIAL DISTRICT, DALLAS, TEXAS.



DODGE TRUCK PLANT, NEAR DETROIT.



GENERAL ELECTRIC'S APPLIANCE PARK, LOUISVILLE, KY.

all buildings look alike. Superficially this may be true, but surely it is characteristic of all great creative periods. What difference there has been in the individual character of buildings has been due mainly to differences in the essential requirements of function and construction. What are the characteristics, then, of the modern factory?

The starting point in any such description must be the requirements that the manufacturer presents to the architect. These are usually exact and precise and have been derived from the experience of production men and engineers. What does a manufacturer demand of his new plant? According to the late Albert Kahn, noted industrial architect, there are at least eight essentials . . .

- Straight line production where the handling of materials is uninterrupted through the various departments. Raw material is received at one end, moves through production processes and out at the other end in a continuous line so that no part of production crosses another, and all parts and assemblies are brought together at a proper time without congestion.
- Flexibility of interior so the department layouts can be changed or expanded without major structural changes.
- Generous column spacing to allow the most efficient location of machines and supplies, and an open floor area that will cause little interference with work and handling of materials. In general, a 40 by 40 feet or 40 by 60 feet structural bay is preferred for economy and flexibility.
- Properly located utilities that efficiently serve their purpose, but not interfere with production or with possible changes in plant layout. Often the only plant elements that are fixed in position are elevators, stairs, locker and wash rooms, and other mechanical equipment.
- Suitable floors and ceilings made strong enough to carry the loads of machinery and materials and to sustain the vibrations of the production line. Cutting down on the noise level can be accomplished by careful mounting of machinery and by sound-deadening materials.
- Good natural and artificial lighting that is distributed evenly throughout the working area without excessive contrasts and glare. Studies of the effect of lighting on productivity have resulted in more lighting being given the individual job than the general area. Even

with roof monitors, artificial lighting is required, but the total elimination of natural light does not seem advisable for psychological reasons. The color of the walls, floors, and machinery is an important factor in relieving fatigue and increasing safety on the production line.

• Adequate heating, cooling, and ventilating for workers' comfort specialized ventilation for removal of industrial wastes, gas, and dust.

• Low first cost and maintenance that result from skillful planning and economical choice of surface materials, insulation, and structural system.

The modern industrial plant is most of all characterized by a simple frame skeleton, usually of steel or reinforced concrete. The walls generally do not support the roof; they carry only their own weight. Freed from these other burdens they have become, like the roof, a mackintosh against the weather. The development of "skin materials"—corrugated metal, cement-asbestos board, and glass, together with rapid improvements in insulation—has resulted in walls and roofs which are a "sandwich" of many specialized materials. As a result of the manufacturer's requirements and the influence of the structural system, one can recognize a modern industrial plant throughout the world.

But a real definition of a modern factory does not stop with the walls and roof. An industrial architect must make the factory part of the town and countryside—not a blight on both. For many years cities have been preoccupied with the problems of slum dwellings, but too little has been said of substandard factory buildings ill-adapted to the health and well-being of the workers they house in industrial slums. Through lack of planning, they have often created a drab factory town, covered with soot and hazardous to life and productivity in a broad sense.

According to the International Congress of Modern Architecture (CIAM), "Industrial districts should be independent of residential districts (indeed of other districts as well) and should be isolated by means of green bands." The factory should be placed in an industrial zone protecting the residential districts and other zones of the city from the nuisances and hazards of smoke, gases, and factory noise. As a rule heavy industry should be more isolated than light industry, and perhaps only small industries intimately related to urban

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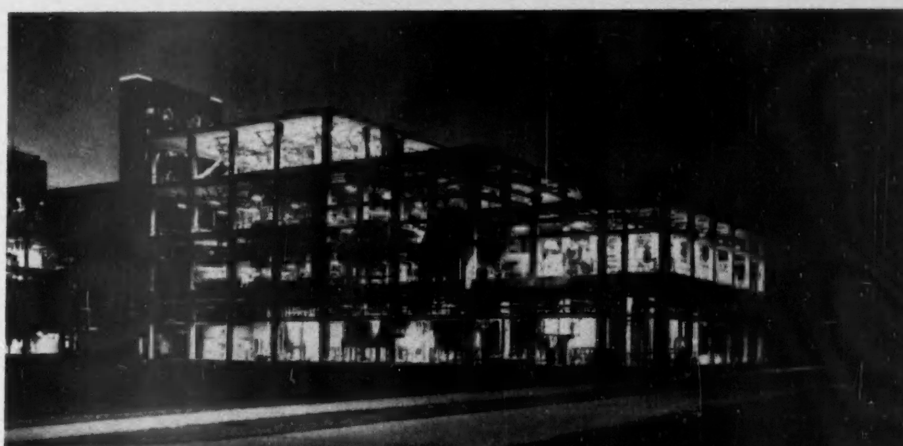
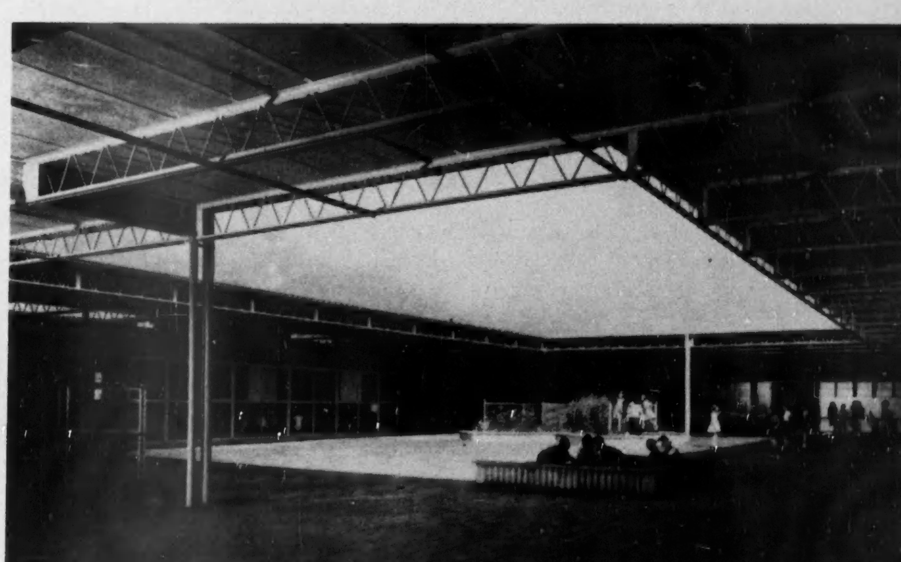
SEAMLESS WELDED OIL TANKS AGAINST A TEXAS LANDSCAPE.



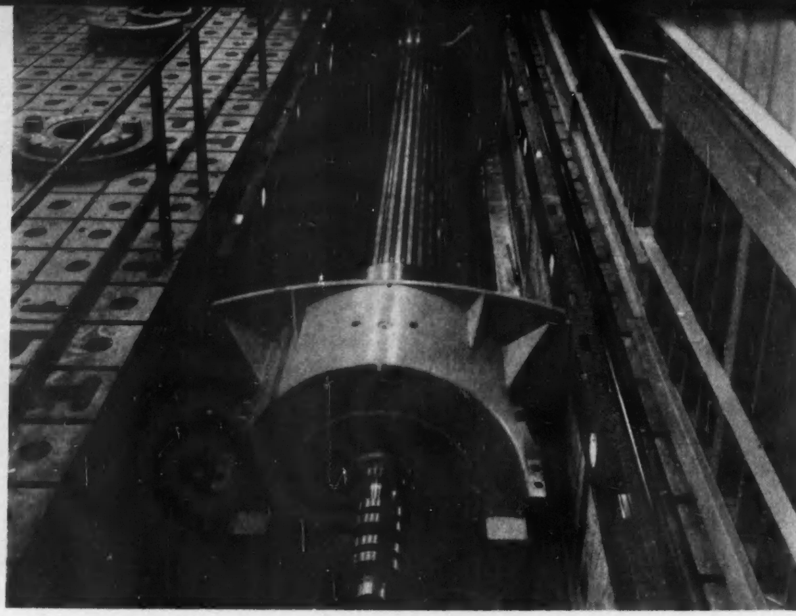
A FACTORY WITHOUT WALLS, CORPUS CHRISTI, TEXAS.



COURTYARD OF MODERN SCHOOL BUILDING LOCATED IN TEXAS.

BALANCING TURBINE-GENERATOR ROTORS

By L. P. GROBEL



PRECISION BALANCING THE COMPLETELY ASSEMBLED ROTOR OF A 100,000 KW GENERATOR.

Large steam turbine-generators—some large enough to supply a fair-sized city with electricity—run weeks or months without letup. And among the factors contributing to this remarkable performance is *vibration-free* operation.

An unbalanced rotor is the common cause of vibration. Its coupled length—turbine rotor plus generator rotor—in today's high-speed machines may be 80 feet or more with its weight exceeding 200,000 pounds. And so you can readily appreciate why low amplitudes of vibration are essential to the large turbine-generator.

To get these low amplitudes, we use a method known as *precision balancing*. Here, the ideal is perfectly balanced rotors before the assembly and shipment of turbine-generators. Although it's not a small chore, we've nearly realized this ideal by careful manufacture and balancing of turbine and generator rotors.

Cause and Effect

The simplest type of unbalance occurs in a thin wheel (Fig. 1) on a shaft. Assume the shaft to be weightless and the wheel's center of gravity a distance e from the shaft center. Then the unbalance is equal to the product of the weight W of the wheel and its eccentricity e. If the wheel and shaft were placed on level ways, the gravity effect of the unbalance would cause it to turn and come to rest with the unbalance at the bottom—a simple example of *static* unbalance.

When the wheel rotates, centrifugal force of the unbalance deflects the shaft in the single-loop form shown as a dashed line. Because the deflection rotates with the shaft, it appears as a vibration. To balance the wheel, a balancing weight w is placed a radial distance R from the shaft center and 180 degrees from the unbalance. The weight is such that $We = wR$.

To go one step further, let's consider a rotor having two wheels (Fig. 2) that are out of balance. If both their eccentricities are equal and in the same angular position, the rotor is statically unbalanced and will run in single-loop form shown by the dashed line. This situation is best corrected by using two equal weights, one in each wheel, to form a static pair defined as two equal weights at the same radius and angular position.

If the individual wheel eccentricities are 180 degrees apart, the rotor is balanced statically but not dynamically. When running, the rotor will be deflected in the two-loop form shown by the broken line. Such unbalance is normally corrected by putting equal weights in each wheel, at the same radius and 180 degrees apart.

Pure dynamic unbalance of a turbine or generator rotor (Fig. 3) will cause the two-loop form of vibration. These unbalances are 180 degrees apart, and the product of the weight and eccentricity of one-half the length is equal to that of the other half.

Higher forms of vibration can be incited in long high-speed rotors by unbalances of the three-loop type (Fig. 4) and the four-loop type (Fig. 5).

In general, static and dynamic unbalances are corrected by placing balance weights in two balancing planes near the ends of the rotor span. Unbalance of the three-loop type, however, requires three-plane balancing (Fig. 6) to correct for the unbalance of each section. Correspondingly, the four-loop type of unbalance requires four-plane balancing (Fig. 7).

Why Precision Balancing?

Rotors are balanced on sensitive balancing machines at low speed. In one type the rotor is supported on spring-mounted bearings and run to a critical speed for maximum vibration. Data on the amount of unbalance and where to place the weights are then read from the machine. Because the rotor is relatively stiff at low speeds, unbalances will be only vectorially counterbalanced. Long rotors will not be in balance when run at higher speeds—unless the balance weights are in approximately the same plane as the unbalances.

To illustrate this, let's assume that a rotor has an unbalance midway between its two end planes. The low-speed balancing machine will indicate a balance-weight correction at each end plane equal to one-half the unbalance and 180 degrees from it. But when the rotor is run at a high speed, the centrifugal force of the midspan unbalance will cause a greater shaft deflection than the

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Mr. Grobel—Supervisor, Generator Mechanical Engineering, Large Steam Turbine and Generator Department, Turbine Division, at Schenectady—is responsible for the mechanical design and operation of generators and the critical speed design and balancing of turbine-generator sets. He joined GE in 1924 on the Test Course.

centrifugal force of the two end corrections, since they are near the end of the rotor span. This difference in deflection will appear as vibration.

Neither can satisfactory correction be made for distributed unbalances in a high-speed rotor when it is assembled in the turbine-generator. For the only balancing planes then accessible are those near the ends of the span.

Prior to our current practice of precision balancing, it was occasionally necessary—and more frequently desirable—to disassemble a machine to correct a midspan unbalance. Roughly, the procedure was: 1) initially balance the rotor in a low-speed balancing machine; 2) assemble the rotor in its own bearings and balance it for distributed unbalance; 3) calculate midspan unbalance and remove rotor to compensate for it, and 4) reassemble the rotor.

As high-speed rotors (3600 rpm) were built larger and longer, we wanted to make accurate and nearly complete correction for distributed unbalances in less time. As a result turbine rotors are now produced virtually free of distributed unbalances by manufacturing them with a high degree of precision.

For generator rotors, however, with their assembly of heavy coils and other parts, accurate manufacturing is not enough. After assembly, precision balancing is completed by balancing them throughout their lengths.

Turbine-generator rotors are designed to have low sensitivity to unbalance. These designs are determined from card-index calculating machines that take into account the effect of flexibility of supporting members in depressing critical speeds below rigid support values. (Critical speeds occur when rotational speeds equal some resonant frequency—deflection of the rotor will be a maximum at that point. A large 3600-rpm machine, for example, has several critical speeds within the running range.)

As a point of interest, critical speeds aren't dangerous. Most modern machines are so well balanced that careful observation is necessary to detect the presence of one. However, since sensitivity to unbalance is a maximum at critical speeds, turbine-generators are designed to have an appreciable spread between their rated speed and any critical speed.

Balancing Turbine Rotors

A thermally stable turbine rotor (Fig. 8) will operate over the wide range of steam temperatures that it is subjected to with insignificant distortion or bending. This is essential so that the rotor remains in balance at all temperatures within the load range. Testing and heating rotors for high-temperature service to assure thermal stability are therefore important items in precision balancing.

Thermal instability arises because of mutilation of steel crystals on the rotor's surface during machine work. This causes some variation in the rate of heat transfer—and expansion—at the rotor's surface. To overcome this the rotor is tested and cured in a heat lathe after all machine work within, and adjacent to, the shaft span is completed. In the heat lathe the shaft undergoing test is heated to a high temperature—and slowly cooled—to eliminate the surface strains.

Turbine rotors for low-speed machines (1800 rpm) are usually of the built-up type with bucket wheels shrunk onto the shafts. But large high-speed rotors have their bucket wheels machined integral with the shaft forgings. Treatment of either type for unbalance differs: Bucket wheels are balanced before being shrunk onto the built-up rotor shaft. Solid-type rotors, on the other hand, are nearly symmetrical; because they are accurately machined, the unbalance of shafts and wheels will be small in most instances.

Great care is taken to minimize unbalances that might be introduced in the assembly of buckets on a rotor. Here again, unbalances are eliminated in one of several ways, depending on the type of rotor and size of buckets. The longer and heavier low-pressure buckets are weighed in a moment balance. This takes into account the weight distribution along their lengths. Moment weights are then charted, and from this data the buckets are assembled on the rotor for minimum unbalance.

With high- and intermediate-pressure turbine rotors having short buckets, accurate corrections are made for any known unbalance in bucket wheels. However, experience has shown us that short buckets are so nearly the same in weight that there's no advantage in weighing and charting them.

Completed rotors are balanced at low speed (Fig. 9) in a balancing machine having high sensitivity. Then they are assembled and turbines run at rated speed. Most turbines will have such low amplitudes of vibration it will be immediately evident that the rotors are in nearly perfect balance.

FIG. 1. UNBALANCE IN ONE PLANE

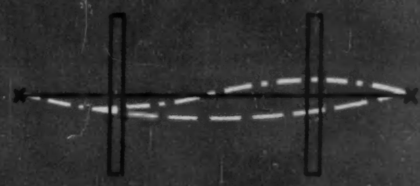


FIG. 2. UNBALANCE IN TWO PLANES

FIG. 3. PURE DYNAMIC UNBALANCE

FIG. 4. DOUBLE STATIC UNBALANCE

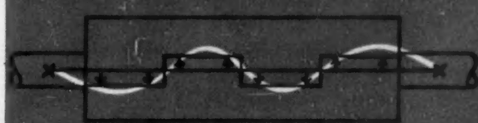


FIG. 5. DOUBLE COUPLE UNBALANCE

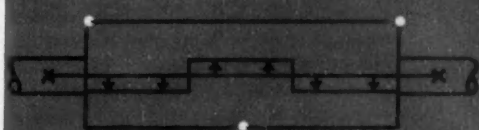


FIG. 6. THREE-PLANE BALANCING

• = BALANCE WEIGHT

FIG. 7. FOUR-PLANE BALANCING

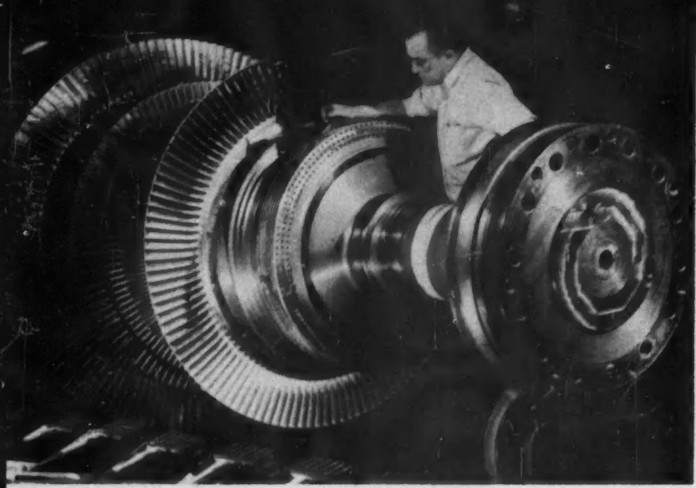


FIG. 8. PRECISION balanced high-pressure turbine rotor—after more machining the rotor will be test run in the turbine casing.

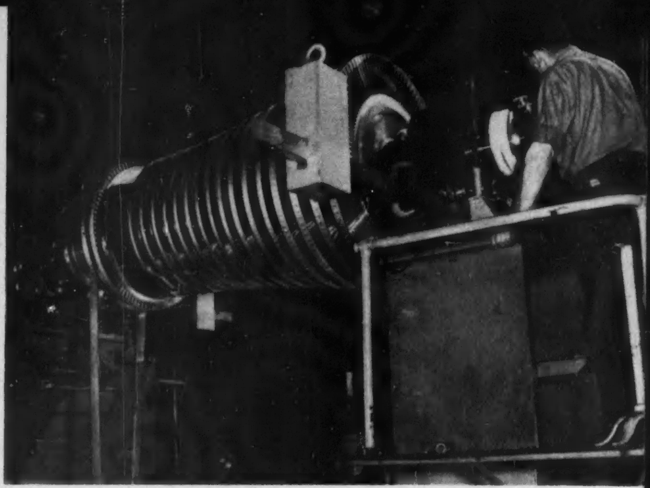


FIG. 9. LOW-SPEED balancing machine tells operator where to locate weights needed to balance this high-pressure turbine rotor.

FIG. 10. PRECISION balanced generator rotor—after assembly in turbine-generator it is test-run to check for further unbalance.

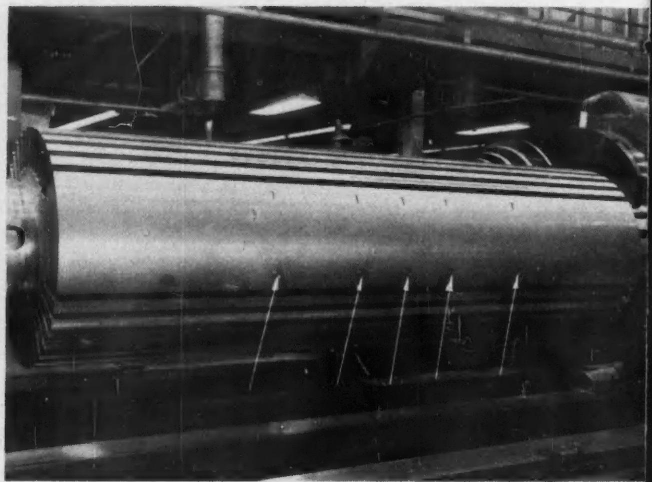


FIG. 11. BALANCE PLUGS of variable weight are screwed into pole faces after machining. Rotor is for 30,000-kw two-pole machine.

Balancing Generator Rotors

The procedure in precision balancing of generator fields (Fig. 10) is necessarily different from turbine rotors. Fields are usually much longer and heavier—as are some individual parts in the field assembly. (A large 3600-rpm field may be over 30 feet long and weigh more than 100,000 pounds.) Machining and assembly operations are carried out to manufacture them in as good a balance as possible. They cannot, however, be assembled with perfect balance.

Alternate-slot milling of the field-coil slots is one practice we use to improve balance. The slot milling machine simultaneously cuts two slots 180 degrees apart. After each pair of slots is cut, the field is turned 180 degrees less one slot pitch to mill the next pair of slots. Small differences in slot dimensions are thus counterbalanced.

After slotting, and after the major part of machine work between bearing spans are completed, the largest 3600-rpm fields are tested in a heat lathe. The test procedure differs from that employed with the turbine rotors, but the objective is the same—to assure thermal stability of the field. A field is first checked in the heat lathe over a temperature range several times greater than its operating range. If it is shown to be thermally stable—as indicated by its nearly unchanging deflection—the rotor is removed from the lathe. If not stable, it is heated to a higher temperature to remove the surface strains. And after cooling, it is checked again for thermal stability.

Before windings are assembled, the field is balanced and correction made in its body portion. Appreciable unbalance is corrected by machining metal from the field or from its ventilating-slot wedges. Next, wedges for each coil slot are weighed. Calculations are made to determine unbalances that may result from their weight and angular differences around the field, and suitable corrections are made. Field coils are also weighed and assembled to give a balanced arrangement. This practice aids in attaining thermal stability because heating of the field coils is then effectively symmetrical. (The I^2R loss of a coil varies inversely as its cross section. If the cross section is not uniform, heating will not be uniform.)

Precision balancing is completed in a balancing pit shown on page 22. This setup permits making accurate corrections for unbalances that may be distributed irregularly along a rotor length. To accommodate fields of different lengths the pit is furnished with bearing pedestals that can be moved on ways. After a field is assembled in the bearings, a cover is placed over the pit. Heat generated by the field's windage is removed with cool air circulated by a closed ventilating system. The 3600-rpm fields are driven by a 3600-rpm steam turbine. When 1800-rpm fields are balanced, a two-to-one reduction gear is interposed.

How Balancing is Done

Balance weight corrections in the body portion of a generator field are made by changing sizes of balance plugs located in the field poles. Full-length plugs are installed initially and weight changes then made by unscrewing them and installing plugs of shorter lengths.

The arrangement of balancing plugs in a relatively small field (Fig. 11) is such that a row of plugs is near each end of the pole face; the opposite pole has a duplicate set. Thus, four rows of plugs permit balance weight corrections at any desired angle.

Long fields will have at least twice as many plugs in each row with a somewhat different distribution than that shown. On the other hand, four pole fields have a single row of plugs along the center line of each pole face. This way, plug changes in either one or two rows will give balance weight corrections at any desired angle.

Balance weight planes are provided in the field's fan ring and ring-centering rings (Fig. 12) so that there are two balancing planes between each bearing and the rotor body. Additional balancing planes are also provided in the coupling and collector-end shaft extensions.

Cut and Try

In balancing, a rotor is brought to speed, and vibration amplitudes of shaft, bearings, and balancing machine data are taken. It is then brought to rest and the desired balance weights installed for the first trial. Run again to balancing speed, data are taken as in the original run. From these two runs, the data are used to determine the disposition of weights for the next trial. This procedure is continued for several runs until maximum improvement is obtained with a given type of balance correction. Next, another type of correction is made and the process repeated.

At first glance you might think this a long roundabout procedure. Actually, the method simplifies and minimizes the work. For one thing, a given correction can usually be made in two or three balance trials. For another, if you try to correct several types of unbalance at once, your chance of doing so is remote; correction for each type must be accurate in both magnitude and angular location. Then, too, this method takes advantage of the fact that vibrational response at certain speeds is much greater for one type of unbalance than another. For example, the response to static unbalance will be greatest at some low speed because other types of unbalance will have little effect. At a higher speed, however, the vibration caused by dynamic unbalance will be greatest so that dynamic balancing can effectively be carried out.

A fairly well standardized procedure is followed in making successive types of corrections. A field is first balanced statically with a static pair. This may be considered two-plane balancing to virtually eliminate single-loop vibration.

Two-loop vibration caused by dynamic unbalance is then corrected with a couple. A sufficient number of static and dynamic balance trials are made until maximum improvement in vibration is obtained. This must be evidenced by data at lower and normal speeds.

In the next step, fields are balanced to correct for three-loop form of vibration. Balancing in three planes is required. Trials are conducted in the same manner as two-plane balancing, except that it is done at the rotor's rated speed. In three-plane balancing—as with all multiplane corrections—it's desirable to use weights of proper relative size, placing them symmetrically in the rotor to maintain the static and dynamic balances you already have.

The next and final step is running the balanced field in its own armature. Vibration of the field and stator are observed during these electrical and mechanical tests. Refinements, if needed, are made then.

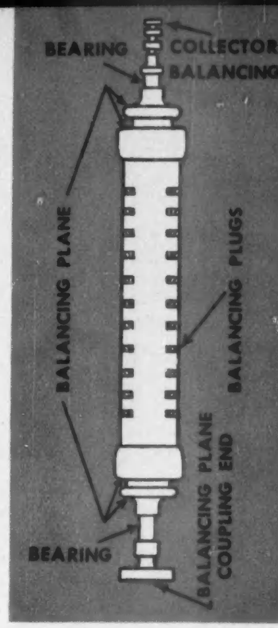


FIG. 12. VARIOUS positions accessible on generator rotor for balance weight corrections.

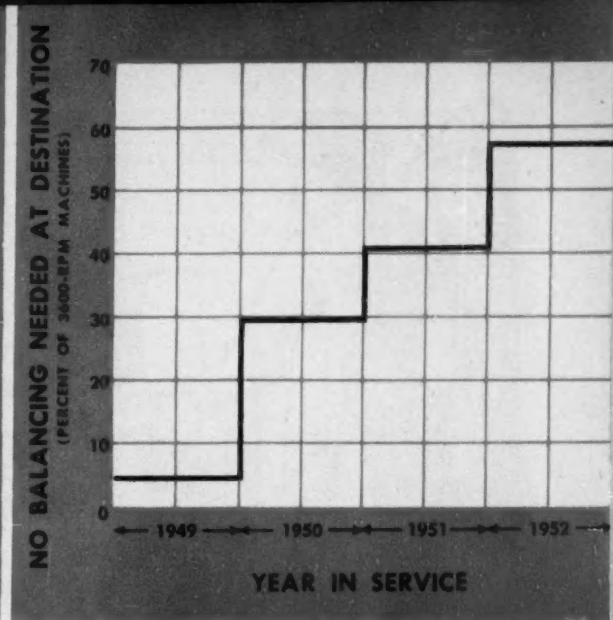


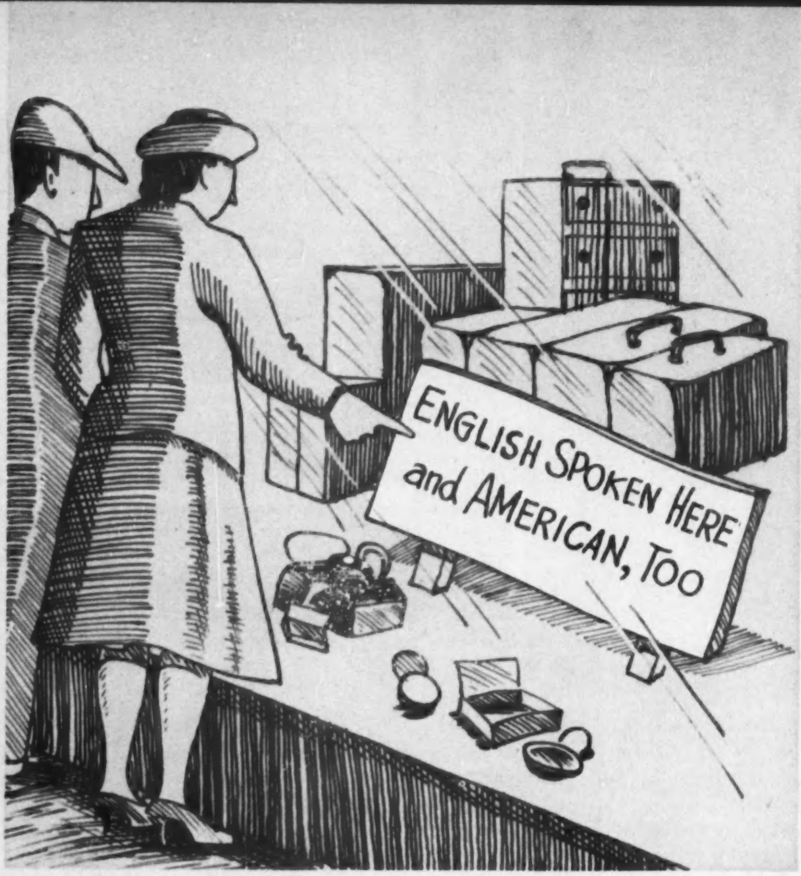
FIG. 13. PRACTICAL EFFECT of precision balancing at factory. During 1952, 58 percent of all turbine-generators shipped needed no further balancing at destination.

What Are the Results?

Precision balanced rotors have given smoother running turbine-generators with a great reduction in the amount of balancing needed at installation. High-speed 3600-rpm units placed in operation in 1949 had an average bearing vibration of 0.42 mils. By contrast, in 1950, when many of the present precision-balancing practices were adopted, this figure dropped to 0.30 mils. And during the years 1950 and 1952, it has remained nearly constant at 0.26 and 0.27 mils, respectively.

The 1949 turbine-generators were good machines. Current reduction of 35 percent in vibration simply means that today's precision-balanced machines have still less vibration. Over the same four year period—1949 to 1952—there has been a decided reduction in the amount of balancing at destination. An average of 7.4 balancing trials were taken on the 1949 machines; this figure decreased to 5.2 a year later, became 2.4 in 1951 and 2.0 in 1952.

The most striking illustration of this is Fig. 13. It shows the percentage of 3600-rpm machines placed in operation with such low levels of vibration they needed no further balancing—convincing proof of the effectiveness of precision balancing. Ω



LANGUAGE BARRIERS OFTEN HINDER COMMUNICATION AMONG LIGHTING RESEARCHERS!

LIGHTING RESEARCH— HERE AND ABROAD

By DR. SYLVESTER K. GUTH

In few branches of engineering are researches more intimately concerned with people than in illuminating engineering. Our eyes are "doorways of light"—our main connection with the world outside. And in every way we use these doorways, light is essential. Little wonder, then, why there's such great interest in lighting research—the study of how we, as active human beings, utilize light and lighting to see.

Twenty years ago there was little that we could truly call lighting research. Yet a recent survey of 90 American colleges and universities—conducted by the Illuminating Engineering Society—showed that 42 were engaged in research on light, vision, and visual environment. Several hundred individual investigations had just been completed or were under way. And to stimulate further work the IES, through a research fund, is sponsoring a number of others. Several industrial and commercial institutions are also contributing to our knowledge in this field. If similar surveys were made abroad, I'm sure they would indicate the same trend.

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Dr. Guth's work is already familiar to our readers—his article, "Visibility," was published in the May 1952 REVIEW. *In charge of lighting research activities at Nela Park, Cleveland, he attended the CIE meeting at Stockholm two summers ago. There he presented a paper describing his latest findings on discomfort caused by glare.*

Get-together in Sweden

The International Commission on Illumination (CIE) met in Stockholm during the summer of 1951. There I visited and spoke with many European investigators doing research in the fields of light, vision, and seeing. We discussed the various programs under way in our countries—our aims and objectives, our views of the problems.

But before briefly giving you my impressions, I think it's important to stress the barriers among peoples: language, for example. There's even a difference between "British" English and "American" English, as one enterprising Swedish shopkeeper is quick to point out in the adjacent sketch. Technical and scientific education, training and experience, heritage, and economic background—all play an important part in a person's thinking and basic philosophies.

These differences often result in varied interpretations of technical articles and lighting practices. Many times, too, translation into another language shades their meaning. The original intent of the writer is changed by the translator's too casual—and, conversely, too literal—evaluation of his writings.

And so, if we're to have maximum international harmony on lighting research in the future, there must be an understanding of people, objectives, and the vagaries of language.

Diverging Viewpoints

We here in America feel that basic research should look ahead and not merely justify present lighting practice. In other words, the fundamental purpose from our point of view is the determination of ideal seeing conditions. For we consider present lighting practice nothing more than a temporary compromise—one imposed by limitations of materials, methods, and economics.

Europeans, on the other hand, are generally more conservative than we and are mainly concerned with the present. Seldom in the past have they devised researches or generalized findings to establish the ideal seeing conditions; in general, we haven't always aimed at the same target. Fortunately, this situation is changing—and with this change is coming a better understanding of each other's approach and viewpoint.

I was interested to find that more than one third of the papers at the Stockholm meeting were reports on fundamental and applied investigations in light, vision, and seeing. The papers were typical of newer research that's currently under way in Europe. Most aspects of light and vision were covered, some of which were academic and provided the investigators with much-needed fundamental information. Others dealt with applied research. Many of the papers paralleled work done here, thus giving us independent checks of our own lighting practices.

Yardstick Needed

The utilitarian goal of lighting practice in America is to provide whatever illumination is needed for the best performance of a given task. I must emphasize however that this is only a starting point. Any final recommendation for quantity of illumination must consider other important factors such as the avoidance of fatigue—the mental and physical stresses not reflected in a man's performance.

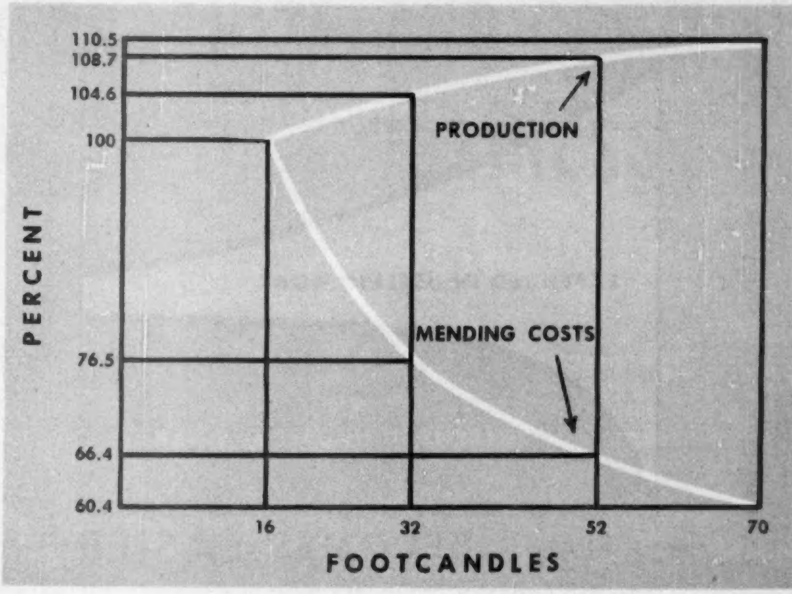
We use various methods to measure how well a man sees in performing a task. Visual acuity, or his ability to distinguish fine detail, is one; brightness discrimination, speed, and accuracy are others. And for many years these were almost the only methods we used. Mostly, they involved the determination of a "threshold" of visibility such as the smallest size test object, usually black on white, that a man could see under given lighting conditions.

But threshold data are difficult, if not impossible, to relate to actual visual tasks. For the tasks themselves vary greatly in size, contrast, configuration, time of viewing, and so on. It has therefore been necessary to devise methods that allow study under "suprathreshold" conditions—illumination of an object above the point of being barely seen. Still, what we really want is a single yardstick that will give us an integrated answer.

In searching for this yardstick many investigators have developed a fondness for one or another of the laboratory techniques. Some, for example, prefer speed of reading with or without regard to the reader's understanding; others go almost exclusively by his accuracy. Considerable use is also made of suprathreshold visibility. This method, which employs a specially designed viewer (May 1952 REVIEW, pages 26–28), appraises the relative visibility of almost any task.

Laboratory vs Field

A British investigator has made some excellent contributions to our knowledge



CASE HISTORY of how lighting research contributes to industry. As illumination in a textile mill was increased, its production rose steadily, while mending costs fell.

of the effects of illumination upon a person's speed and accuracy. While his data are limited to a specific task—cancelling out broken rings having a given gap orientation—they are useful for determining lighting levels in terms of human performance. They give, for example, the illumination requirements corresponding to 85, 90, 95, or 98 percent of a person's maximum performance. (Other types of visual tasks must of course be evaluated for a more complete assessment of performance.) Recently, he published data on people from 20 to 50 years old. His results provided substantiating information regarding the decrease of a person's performance with age and also showed that an older person needs much higher illumination for his best performance.

Several of our own investigators have explored the possibilities of setting up "work miniature" situations in the laboratory. For detailed studies, they've simulated certain characteristics of workaday tasks such as movement, configuration and size, time of viewing, and so on. Important possibilities are indicated by their work.

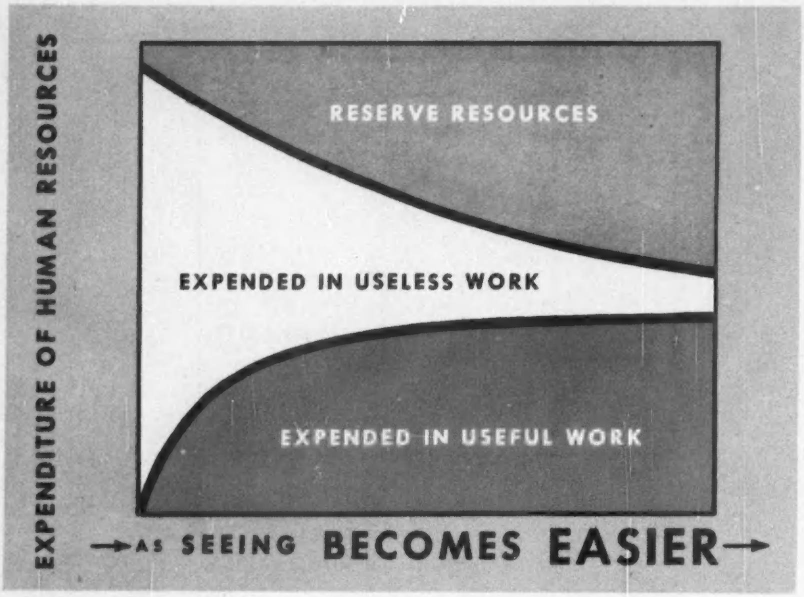
But while laboratory data are satisfactory to a point, in the end we must confirm results with actual field tests. In America we've tried a number of such tests and those properly executed gave us factual data for office and industrial tasks. The results of one seven-year field study of operations in a textile mill are shown above. You'll note that as illumination was increased from 16 to 70 footcandles, textile production also increased, while mending costs went down. One day it may be possible to predict such data from laboratory studies. At any rate, a lot more work needs to be done in this area of lighting research, especially in putting laboratory investigations on a practical basis.

Easy Seeing

A phase of lighting research that hasn't received too much attention abroad is ease of seeing—the energy we expend in performing visual tasks. This probably is the most involved aspect of lighting research. For basically the study of ease of seeing is research in performance and lighting quality that includes benefits received—or penalties paid—by human beings.

Unfortunately, many investigators still cling to the view that when a worker's output is maximum, the ease with which he sees is also maximum. Studies we made years ago show this just isn't true. With various yardsticks—nervous muscular tension, blink rate, and others—we found that less human energy is expended as illumination is increased. Even for such a relatively easy task as reading a well-printed book, there's less stress on the reader with higher levels of illumination—though actually the book could be read in less light at the same speed and accuracy.

Other investigators in America have reached the same conclusion, and this



BROAD CONCEPT of lighting as Americans see it. Europeans are now beginning to accept this point of view; once they evaluated lighting in terms of useful work only.

broader concept is finding acceptance in Europe, too. (I certainly hope we'll see many researches of this kind soon launched all over the world.)

The broader concept of lighting is shown diagrammatically in the illustration above. A person's production of useful work increases as seeing becomes easier; and, conversely, his expenditure of energy in useless work decreases. But his over-all efficiency continues to increase with higher levels of lighting, even though his useful output may not do so appreciably. And as you can see, his reserve resources, or energies, are consumed at a slower rate. Therefore, the real efficiency of a worker is the ratio of energy he expends in doing useful work to the sum of his useful and useless work.

Comfortable Seeing

One of the most important current phases of lighting research is the study of quality of lighting—the elimination of unobvious glare and undesirable brightness that cause a person distraction, annoyance, and discomfort.

Today's higher levels of illumination make people more conscious of discomfort. But discomfort is a sensation. Accordingly, only the people who experience it can truly appraise it. This presents a problem because under identical lighting conditions individuals may vary in their appraisals.

Many investigators here and abroad have tackled the problem. The British in particular are making extensive studies of visual discomfort. Their work generally parallels ours, although their methods differ in several respects. They generally use a small-scale setup with adaptation brightness—the wall brightness of a room, for example—as their primary variable; we ordinarily use a larger-scale arrangement and vary the brightness of the light source rather than that of the wall. It's significant, however, that results of the two methods are in agreement. The same can be said of results obtained by the Dutch, although the scope of their investigations is less broad.

More recent studies of brightness and glare in the various countries, including our own, have included full-scale experimental arrangements. These are necessary to appraise practical lighting situations. And along with other studies, they are leading us to logical conclusions that can be used as a sound basis for illuminating engineering. But what's more significant, we all seem to be independently arriving at the very same answer, even though we use different methods.

Light and Color

Another currently important aspect of lighting research is light and color—the effects so-called white light sources have upon such things as the appearance of colored objects and a person's ability and effort to see. The interest has largely been stimulated by the use of fluorescent lamps. For they provide us with radiant energy of various wave lengths, or colors, which when viewed as a whole, furnish white light. (Light from incandescent lamps is also considered white, but actually it's yellowish.)

In research on light and color, physical, physiological and psychological problems are intertwined in a most complex way. Sometimes it's difficult to separate them to see how the color of light influences a person's vision. Color adaptation, subjective appearance of colors with various light sources, color preference, and color vision are the object of much basic research here and abroad. Many of these studies have arisen because of the appearance of colors and, to a certain extent, upon unsupported opinions that seeing is less efficient with fluorescent lighting.

Extensive studies carried on in Canada and America indicate that the quantity of light—not its color—is by far the most important factor in terms of ability to see. No measurable difference has yet been found between the so-called white light sources ranging from the yellowish-white of tungsten filament lamps to the bluish-white of daylight fluorescent lamps. These studies were, however, concerned only with black, white, and gray objects. Obviously, when colored surfaces are viewed, the color of the light source can and often does considerably affect seeing. This is especially true where a person must detect small color differences.

The field of light and color is a relatively new one, and our knowledge of it is inadequate. Still, in the not too distant future, some worthwhile results should be available, for color research is being actively pursued in various countries.

Meeting of Minds

In this article I've indicated only the general types of researches currently under way here and abroad. Yet they are specific enough to show the headway we are making toward a common goal. Thanks to meetings like the one held two years ago at Stockholm, those of us who are active in lighting research can get together informally to promote this trend.

I believe that differences in the basic philosophies of lighting are more imaginary than real. True, narrow viewpoints still exist in every country. But these are broadening as we gain more knowledge of the interrelations of light, vision, and seeing. Ω

HOW TO PLAN, ORGANIZE, AND CONTROL MARKETING IN YOUR BUSINESS

Review STAFF REPORT

- **Here you'll find a definitive answer to the problem that management is facing today: how can we make sure our ability to sell will keep pace with our ability to produce?**

- **Organization of marketing functions frees managers from the weight of detail work, so that they may plan ahead continually to assure a more prosperous future.**

- **You'll make the marketing functions in your business easier and more effective by using the philosophy, tools, or processes of this progressive program.**

Like most companies, General Electric has been steadily expanding its production facilities since the end of World War II. This means, of course, that more goods must be sold in the years ahead to keep those production facilities at work. At the same time, management is faced with the problem of keeping marketing and distribution costs within the margins imposed by the road blocks of higher labor costs, increased tax burdens, and so on.

This article, based on interviews and discussions by REVIEW editors with J. L. Busey, Vice President—Marketing, and the Department Managers of the Marketing Services Division, New York, tells how General Electric is dealing with that problem.

Late in 1951 the recently established Marketing Services Division—the over-all marketing staff of General Electric—was given the task of developing a marketing concept equal to anticipated needs. The basic question facing them was "How can we make sure that our ability to *sell* will keep pace with our ability to *produce?*"

With this problem as the starting point, members of the staff went out into the Company's many operating departments to get the best ideas, experiences, and opinions from the men who are specifically charged with selling the many G-E products. Despite consistent use of a carefully prepared interview outline, they came back with *questions*, not *answers*.

These questions considered existing habits, vague policies, faulty organization, men working at cross purposes rather than pulling together, inadequate plans, the relation of marketing to general management, and other major problems of that kind. Many of them called for clarification by top management before the staff could get anything approaching a satisfactory answer for the men on the firing line in operating management. After considerable study, however, they found that most of these puzzlers could be telescoped into three broad questions.

Three Major Questions

The first query was: "What is the work to be done in marketing in the General Electric Company? That is, what really belongs in marketing? Not in theory, but in sound down-to-earth operating practice, what are the functions that belong in marketing? And how does marketing fit into the over-all management pattern? Where are its boundaries? How does it relate to manufacturing, engineering, and finance; and to general management—where these boundaries seem a bit hazy?"

The second of these was: "How should we set up the Marketing Services Division so it can give effective, practical help to the operating departments and divisions in getting this work done? What is the scope of our job, and how should we organize for it?"

Question three was just as big and equally difficult: "How can we get this modern planned concept of marketing whipped into a package the operations will buy? And then how do we convince the men in operations that this is not a theoretical or complicated idea, but really a simple, practical, sound way to manage the marketing aspects of any business?"

In working toward answers for these three questions Mr. Busey and his staff had two great advantages. The first was a basic concept of professional management developed and sponsored by the president of General Electric—Ralph J. Cordiner. The second advantage was that they were able to obtain and factor into their plans the combined knowledge and experience of the management men in the Company's 21 operating divisions and 54 operating departments.

Management as a Profession

Mr. Cordiner has defined *management* as "... the science of establishing proper objectives and efficiently utilizing human, material, and time resources to achieve the objectives."

He has also provided a key to a clearer understanding of the *professional* nature of management as a function, in these words...

"There is a growing recognition that management is a distinct profession. It is developing all the time-honored characteristics of a profession: a body of special knowledge; high standards of ethics and performance; a responsibility to the public; and a concern with the development of qualified members of the profession."

MARKETING FUNCTIONS

FUNCTIONS	CONTENTS
MARKETING MANAGEMENT	• LEADERSHIP • PLANNING • ORGANIZING • INTEGRATING • CONTROLLING } **ALL MARKETING FUNCTIONS**
CUSTOMER RELATIONS	• Creating, building, and maintaining good relations with customers, potential customers, and trade associations • Sales co-ordination • Inspiring good customer relations practices • Personal contact and availability • Policy assistance • Interchange of information • District Marketing Councils
1 MARKETING RESEARCH	• Marketing studies and research for use in all marketing functions • Study of current conditions, trends, and forecasts of —General business activity —Basic economic conditions —Industry activity and position
2 PRODUCT PLANNING	• Control of products—lines and programs • Integrating, planning, and timing: additions, eliminations, and modifications • Formulation of pricing, discounts, conditions, terms, and permitted costs • Products' functions and quality level • Appearance, identification, cataloging, and packaging • Simplification, standardization, and adaptation • Appraisals: competitive offerings, markets, buying motives, and plans vs results
3 ADVERTISING AND SALES PROMOTION	• Media relations • Radio and television • Copy research • Sales promotion • Exhibits and displays • Product publicity • Advertising business procedures • Production and distribution
4 SALES	SALES MANAGEMENT • Sales analysis and control • Sales training • Management of headquarters and field sales organization • Operation and control of sales and distribution channels • Carrying out pricing, discounts, conditions, and terms SALES PLANNING • Formulating sales objectives and policies • Product sales analysis • Planning and recommending sales and distribution channels • Formulating and recommending distribution policy • Analyzing needs and recommending on pricing, discounts, conditions, and terms • Planning sales and merchandising programs and methods SELLING • Customer contacts and relations
5 PRODUCT SERVICE	• Establishing service objectives, policies, standards, plans, and programs • Service training programs • Management of headquarters and field product service organization • Warranties and protection plans • Service of products after sale • Repair parts (supply, inventory control) • Service manuals and bulletins
6 MARKETING ADMINISTRATIVE SERVICES	• Sales forecasting • Sales budgets • Sales records and statistics • Production scheduling to meet sales requirements • Control of finished goods inventory • Warehousing • Order Service • Marketing office management (headquarters and field) • Marketing expense budgets, analysis, and standards
7 MARKETING PERSONNEL DEVELOPMENT	• Recruiting • Selection • Training • Placement • Development • Inventorying personnel • Marketing compensation

With this kind of progressive thinking provided by top management as a base, it was the Marketing Services Division's task to define marketing and to identify its functions for the General Electric Company. It was also their task to convince the men in the many operations of the need to become more professional marketing managers and to aid them in developing and applying the tools required for this new profession.

Research Background

The starting point for research was a Marketing Manager concept that had been introduced in General Electric in 1948. This definition of marketing objectives required much broader responsibility for marketing managers than had been given to the sales managers under the previous form of organization. Acceptance and application of this marketing manager plan varied greatly throughout the Company. Some operating departments took the plan and put it to work; others did not.

Research in operations showed that the tremendous growth of the Company since 1948 literally demanded a restudy of this concept of marketing—in terms of the size of the business, the number of customers on the books, the enormity of competition, and the planned growth and decentralization of the Company.

It was necessary to retrace the whole path of marketing organization and add every fact, every idea, and every experience that research in actual operations could find to develop the kind of concept that would meet present needs and the needs of the immediate future.

Functions of Marketing

The Marketing Functions Chart (opposite) is the key to this whole concept of marketing. This concept incorporates the best ideas from the 1948 plan. To them were added all the principles and experience research could find, inside and outside the Company. The Marketing Services Division staff then went through the tortuous process of threshing out this new concept with many of the men in operations. They brought in a task force of five marketing managers from operating departments to give it the third degree, and then gave it a continuous going-over in staff sessions.

What they ended up with, you see on this chart. They fitted these seven basic functions of marketing into a logical, complete, integrated package which they are sure meets the needs of General Electric marketing today. As Mr. Busey points out, they knew that some of the operating people would quarrel with this concept. They knew some would think part of their job had been taken away, and that others would fear something had been added that they shouldn't have or didn't want.

It was necessary to make very, very clear to operating people at this point that they were talking in terms of *functions*—not *organization*. Functions and organization are related, but they aren't the same thing. *Functions* is the work to be done. *Organization* is who does the work.

The Marketing Services Division had been organized based on this approach. The organization was built to take care of functions—not people. It was built on the basis of work to be done. That is why this functional inventory and functional analysis were the essential first step.

You'll see that marketing management is the top function on this chart. In considering this function, it is important to bear in mind that the general manager of each G-E business—each department—has the profit and loss responsibility, and the authority to deal with all aspects of the business.

The general manager delegates to the marketing manager responsibility and authority for leadership, planning, organizing, integrating, and controlling all functions of marketing.

Next you see "customer relations," an over-all function of marketing in every business.

Now you come to the seven basic functions of marketing. These embrace all of the work to be done in marketing. Set up on the basis of a careful and detailed functional inventory and a functional analysis in all operations, they are . . .

• Marketing Research. A continuous gathering, analyzing, and interpreting of facts and opinions concerning marketing, that cut across all other functions because they are useful to each function.

• Product Planning. Making certain that new products are added, old ones dropped, or dragging ones changed at the right time. It involves setting up clean-cut objectives for the complete line of products, and adopting policies in tune with these objectives.

• Advertising And Sales Promotion. Planning, creating, and scheduling all advertising and sales promotion, including media. Copy and media research, and co-ordination of advertising with other marketing areas.

• Sales (Planning and Management and Selling). Planning, creating, and activating both long- and short-range sales plans (developed from data supplied by the other six functions); planning sales and merchandising programs and methods as related to over-all sales forecasts, budgets and plans, volume, profit and expense considerations, quotas and allocations, and training of salesmen.

• Product Service. Formulating and executing service policies and programs, including warranties, exchange policies, and protection plans, as well as the development and execution of service training programs.

• Marketing Administrative Services. Obtaining facts and figures from all available sources (including marketing research) and properly analyzing, organizing, and interpreting them for management approval and use. It includes development of methods, procedures, forms, and records essential for sales forecasting; also production scheduling and inventory control.

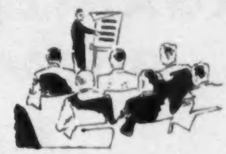
• Marketing Personnel Development. Recruiting, selection, training, placement, development, compensation, and evaluation of marketing personnel.

There you have in outline form an inventory of marketing work essential to General Electric. You have the seven basic functions of marketing and the over-all management function which directs and ties them together.

Marketing Organization

Only after this functional inventory was complete were Mr. Busey and his staff ready to start developing their organization structure. As you see how they are set up in the Marketing Services Division and why they did it this way, you will observe some principles that apply in developing any organization plan.

What the Marketing Services Division set out to do was to group like work. Since they were starting practically from scratch, they had few of the usual organization problems which arise where history or an established situation hin-



ders such an objective approach. They dealt first with the job to be done, not the people who were to manage or perform the work. It was their aim also to find that structure which would assure the best co-ordination and control of the work to be done to accomplish the basic objective of the Marketing Services Division; namely, to provide to operations useful and efficient assistance and service on the functions of marketing.

The functional organization structure of the Marketing Services Division grows directly out of the specific and logical definition of functions. The organization stems from the arrangement of the basic marketing functions. Since the Marketing Services Division must deal with the over-all marketing functions (to advise, assist, and serve operations), it is natural for its organization components to parallel the basic functions.

In presenting this program to operating management Mr. Busey urged that they make sure all the functions of marketing outlined are provided for in their individual marketing organization structures. He did not recommend that any operation set up an organization component for each of these basic functions, nor that it directly parallel the organization structure of the Marketing Services Division.

It was fully recognized that the specific marketing organizations for the many businesses of the Company must be established in accordance with the specific requirements of each. At the same time it was obvious that each business must provide for the carrying out of each of the seven basic functions of marketing, since each represented actual work to be done.

The Organization Chart on the next page shows in functional outline form what management engineers call a functional organization structure: that

ORGANIZATION AND MANAGEMENT

G-E MARKETING SERVICES DIVISION

MARKETING RESEARCH

Services Department

MANAGER

Provide Marketing Research services, advice, and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions

Conduct audits of effectiveness, economy, and efficiency of marketing research performance

Specializing in:
- Marketing studies and research for use in all marketing functions
- Study of current conditions, trends, and forecasts of
  - — General business activity
  - — Basic economic conditions
  - — Industry activity and position

Promote interchange and usefulness of information on marketing research and forecasting techniques, procedures, and activities

PRODUCT PLANNING

Services Department

MANAGER

Provide Product Planning services, advice, and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions

Conduct audits of effectiveness, economy, and efficiency of product planning performance

Specializing in:
- Control of products—lines and programs
- Integrating, planning, and timing: additions, eliminations, and modifications
- Formulation of pricing, discounts, conditions, terms, and permitted costs
- Products' functions and quality level
- Appearance, identification, cataloging, and packaging
- Simplification, standardization, and adaptation
- Appraisals: competitive offerings, markets, buying motives, and plans vs. results

Promote interchange and usefulness of information on product planning experiences, techniques, procedures, appraisals, ideas, studies, standards, organization, presentations, and outside services

ADV E
SALI ES

S er

Provide Adv ert
services, c dv
President— -M
Group Ex ec
Divisions, c nd
Divisions

Conduct aud its
and effici anc
promotion pe

Specializing i n:
Media r ela
Radio a nd
Copy re sea
Sales pr om
Exhibits an
Product pu
Advertis ing
Product on

Promote inte rch
formation on
motion p lici
media, an d e

PRESIDENT

VICE PRESIDENT—MARKETING

Assist the President, Group Executives, and Operating Management to obtain optimum sales volume and profits at least cost by:
- Aiding in the formulation of over-all marketing objectives, policies, and plans
- Providing marketing services, advice, and counsel
- Conducting audits of effectiveness, economy, and efficiency of marketing performance
- Creating, building, and maintaining good customer relations
- Promoting the usefulness and interchange of marketing information

Voice of Management
Marketing functional leadership
Assist in over-all Company management as member of President's staff

MARKETING SERVICES DEPARTMENTS

V ERTISING AND L ES PROMOTION

S ervices Department

MANAGER

v ertising and Sales Promotion
c dvice, and counsel to Vice
— -Marketing, as directed to
x ecutives and other Services
c nd as requested to Operating

d its of effectiveness, economy,
i ency of advertising and sales
performance
i n:
r elations
a nd television
e search
r omotion
s and displays
publicity
s ing business procedures
on and distribution
e rchange and usefulness of in-
on advertising and sales pro-
licies, organization, activities,
d experiences

SALES

Services Department

MANAGER

Provide Sales services, advice, and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions
Conduct audits of effectiveness, economy, and efficiency of sales performance
Specializing in:
- SALES MANAGEMENT
  - Sales analysis and control
  - Sales training
  - Management of headquarters and field sales organization
  - Operation and control of sales and distribution channels
  - Carrying out pricing, discounts, conditions, and terms
- SALES PLANNING
  - Formulating sales objectives and policies
  - Product sales analysis
  - Planning and recommending sales and distribution channels
  - Formulating and recommending distribution policy
  - Analyzing needs and recommending on pricing, discounts, conditions, and terms
  - Planning sales and merchandising programs and methods
- SELLING
  - Customer contacts and relations

Promote interchange and usefulness of information on sales policies, organization, activities, and experiences

PRODUCT SERVICE

Services Department

MANAGER

Provide Product Service services, advice and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions
Conduct audits of effectiveness, economy, and efficiency of product service performance
Specializing in:
- Establishing service objectives, policies, standards, plans, and programs
- Service training programs
- Management of headquarters and field product service organization
- Warranties and protection plans
- Service of products after sale
- Repair parts (supply, inventory control)
- Service manuals and bulletins

Promote interchange and usefulness of information on product service policies, organization, activities, techniques, procedures, and studies.

PRESIDENT

VICE PRESIDENT—MARKETING

Assist the President, Group Executives, and Operating Management to obtain optimum sales volume and profits at least cost by:

- Aiding in the formulation of over-all marketing objectives, policies, and plans
- Providing marketing services, advice, and counsel
- Conducting audits of effectiveness, economy, and efficiency of marketing performance
- Creating, building, and maintaining good customer relations
- Promoting the usefulness and interchange of marketing information

Voice of Management

Marketing functional leadership

Assist in over-all Company management as member of President's staff

MARKETING SERVICES DEPARTMENTS

ADVERTISING AND SALES PROMOTION

Services Department

MANAGER

Provide Advertising and Sales Promotion services, advice, and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions

Conduct audits of effectiveness, economy, and efficiency of advertising and sales promotion performance

Specializing in:

- Media relations
- Radio and television
- Copy research
- Sales promotion
- Exhibits and displays
- Product publicity
- Advertising business procedures
- Production and distribution

Promote interchange and usefulness of information on advertising and sales promotion policies, organization, activities, media, and experiences

SALES

Services Department

MANAGER

Provide Sales services, advice, and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions

Conduct audits of effectiveness, economy, and efficiency of sales performance

Specializing in:

- SALES MANAGEMENT
  - Sales analysis and control
  - Sales training
  - Management of headquarters and field sales organization
  - Operation and control of sales and distribution channels
  - Carrying out pricing, discounts, conditions, and terms
- SALES PLANNING
  - Formulating sales objectives and policies
  - Product sales analysis
  - Planning and recommending sales and distribution channels
  - Formulating and recommending distribution policy
  - Analyzing needs and recommending on pricing, discounts, conditions, and terms
  - Planning sales and merchandising programs and methods
- SELLING
  - Customer contacts and relations

Promote interchange and usefulness of information on sales policies, organization, activities, and experiences

PRODUCT SE

Services Depart

MANAGER

Provide Product Service serv counsel to Vice President directed to Group Execu Services Divisions, and Operating Divisions

Conduct audits of effectivene efficiency of product serv

Specializing in:

- Establishing service obj standards, plans, and
- Service training program
- Management of headqu product service organiz
- Warranties and protecti
- Service of products after
- Repair parts (supply, inve
- Service manuals and bull

Promote interchange and formation on product ser ganization, activities, te dures, and studies.

CUSTOMER RELATIONS

Commercial Vice President — Marketing Services Division
Commercial Vice President — New York
Commercial Vice President — Philadelphia
Commercial Vice President — Atlanta
Commercial Vice President — Chicago
Commercial Vice President — Cleveland
Commercial Vice President — Dallas
Commercial Vice President — San Francisco

Provide Customer Relations service, advice, and counsel to Vice President—Marketing, as directed to Group Executives, and as requested to Operating Divisions
Conduct audits of effectiveness, economy, and efficiency of customer relations performance
Specializing in:
- Creating, building, and maintaining good relations with customers, potential customers, and trade associations
- Sales co-ordination
- Inspiring good customer relations practices
- Personal contact and availability
- Policy assistance
- Interchange of information
- District Marketing Councils

Voice of Management—as deputies of Vice President—Marketing

S

T SERVICE

Department

NAGER

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Executives and other
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MARKETING ADMINISTRATIVE SERVICES

Services Department

MANAGER

Provide Marketing Administrative services, advice, and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions
Conduct audits of effectiveness, economy, and efficiency of marketing administrative services performance
Specializing in:
- Sales forecasting
- Sales budgets
- Sales records and statistics
- Production scheduling to meet sales requirements
- Control of finished goods inventory
- Warehousing
- Order Service
- Marketing office management (headquarters and field)
- Marketing expense budgets, analysis, and standards

Promote interchange and usefulness of information on marketing administrative service policies, activities, techniques, procedures, and studies.

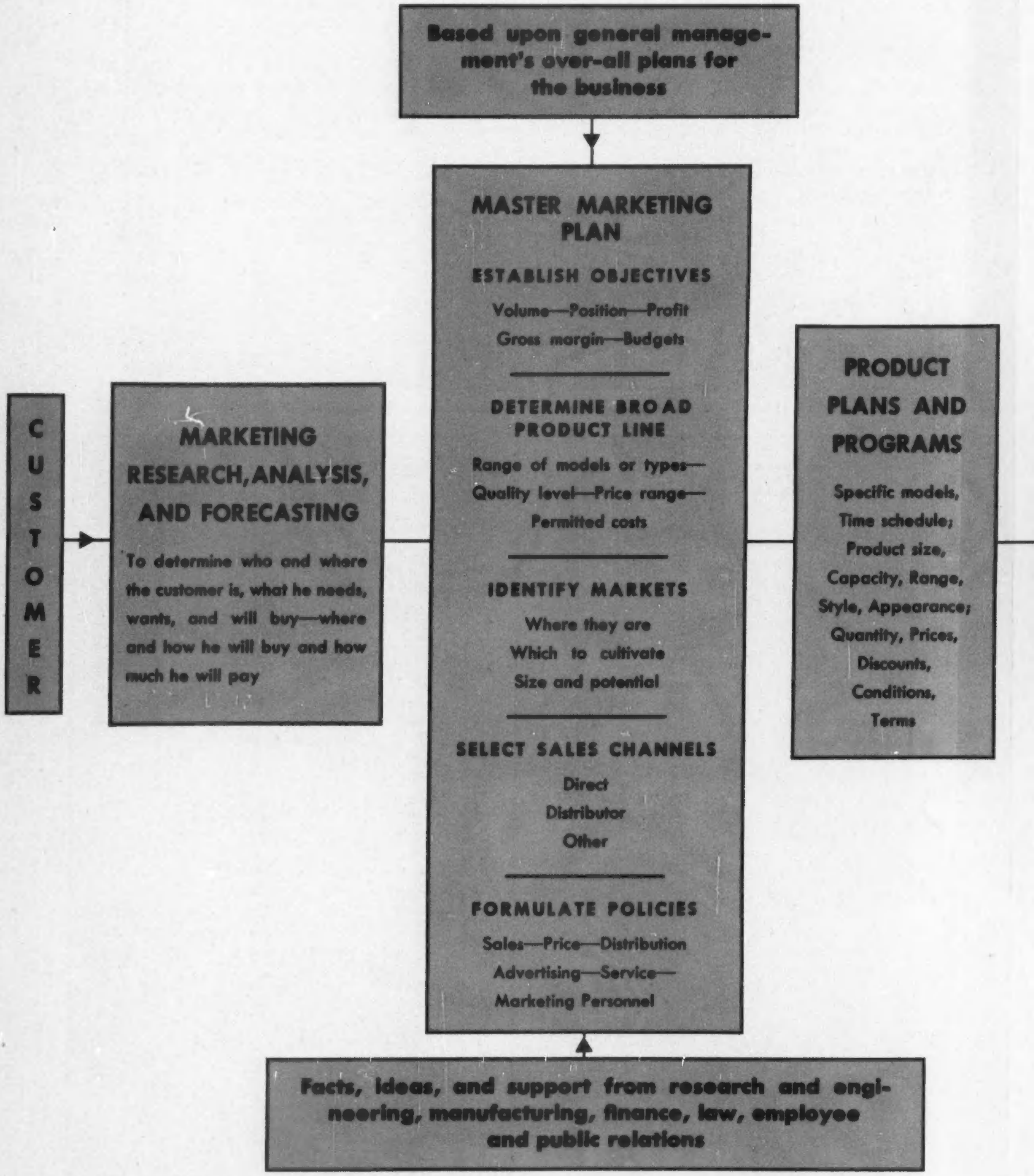
MARKETING PERSONNEL DEVELOPMENT

Services Department

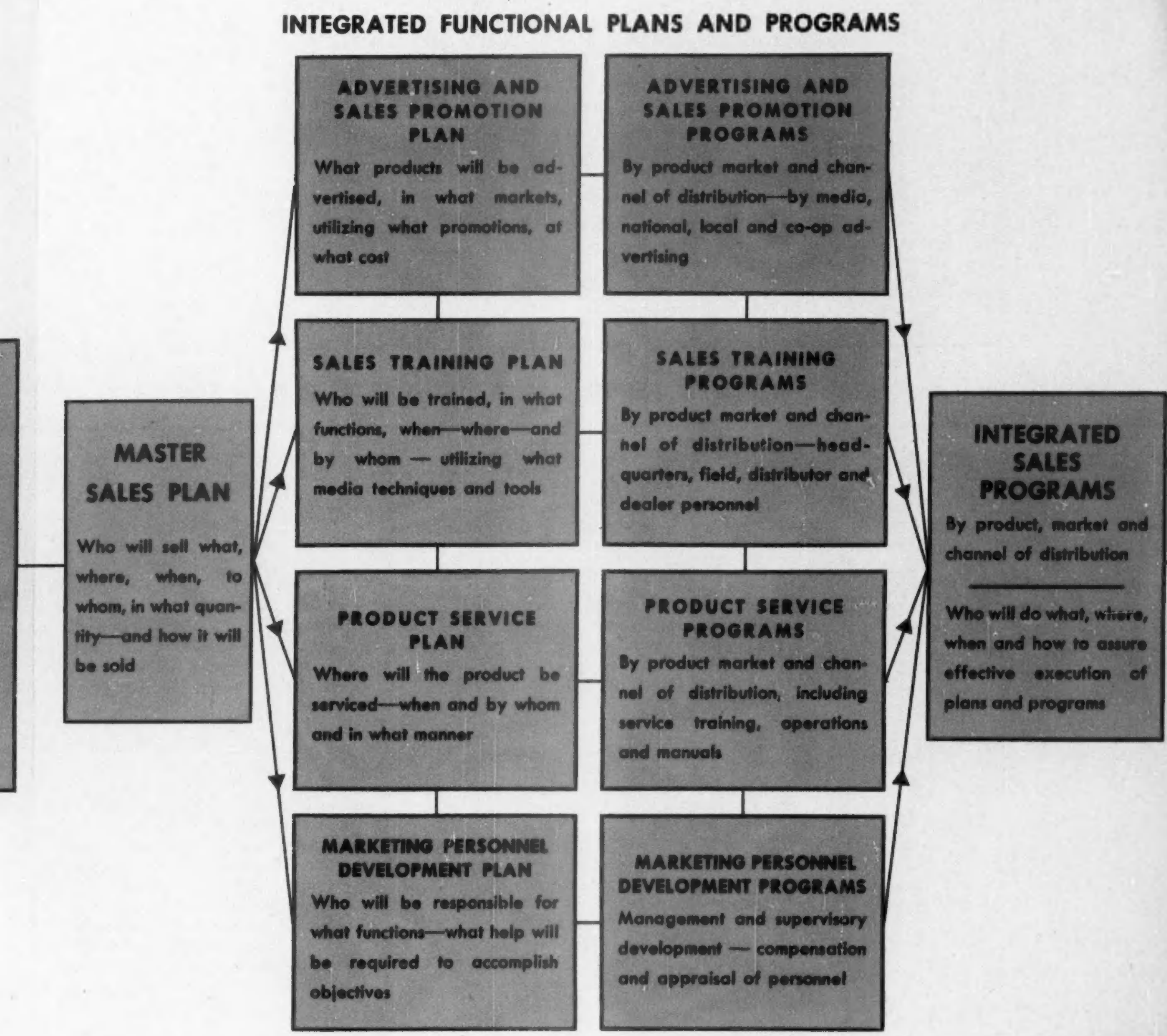
MANAGER

Provide Marketing Personnel Development services, advice, and counsel to Vice President—Marketing, as directed to Group Executives and other Services Divisions, and as requested to Operating Divisions
Conduct audits of effectiveness, economy, and efficiency of marketing personnel development performance
Specializing in:
- Recruiting
- Selection
- Training
- Placement
- Development
- Inventorying Personnel
- Marketing compensation

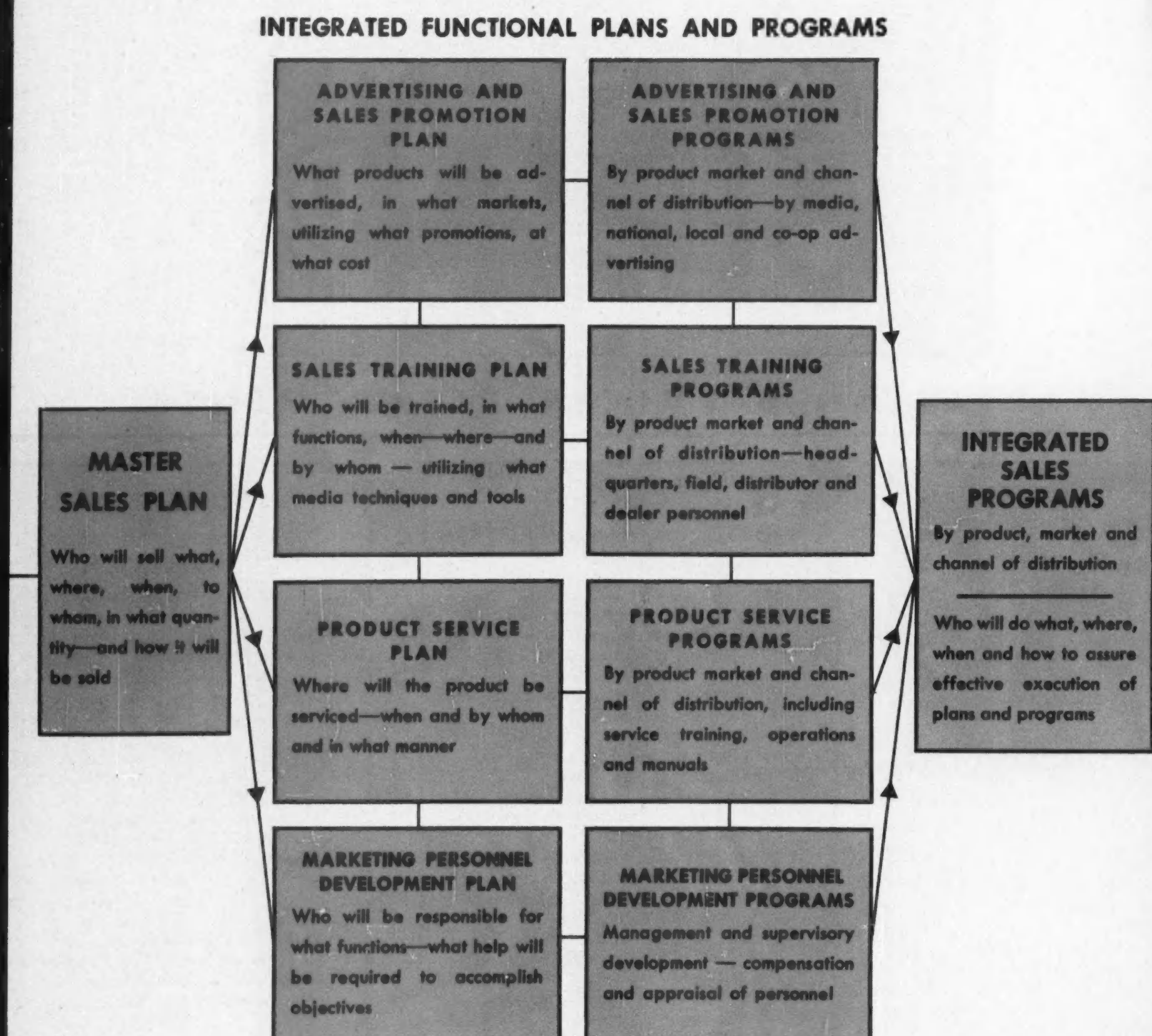
Promote interchange and usefulness of information on marketing personnel development policies, programs, procedures, and experience

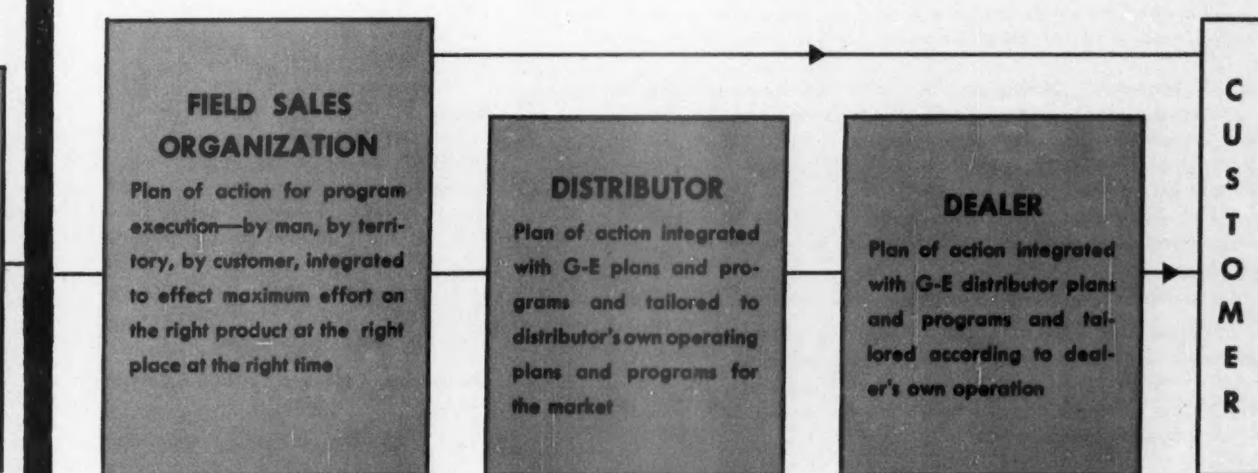

Based upon general management's over-all plans for the business
MASTER MARKETING PLAN
ESTABLISH OBJECTIVES
Volume—Position—Profit
Gross margin—Budgets
DETERMINE BROAD PRODUCT LINE
Range of models or types—
Quality level—Price range—
Permitted costs
IDENTIFY MARKETS
Where they are
Which to cultivate
Size and potential
SELECT SALES CHANNELS
Direct
Distributor
Other
FORMULATE POLICIES
Sales—Price—Distribution
Advertising—Service—
Marketing Personnel
CUSTOMER
MARKETING RESEARCH, ANALYSIS, AND FORECASTING
To determine who and where the customer is, what he needs, wants, and will buy—where and how he will buy and how much he will pay
PRODUCT PLANS AND PROGRAMS
Specific models,
Time schedule;
Product size,
Capacity, Range,
Style, Appearance;
Quantity, Prices,
Discounts,
Conditions,
Terms
Facts, ideas, and support from research and engineering, manufacturing, finance, law, employee and public relations

THE G-E MARKETING PLANNING PROCESS



THE G-E MARKETING PLANNING PROCESS




FIELD SALES ORGANIZATION
Plan of action for program execution—by man, by territory, by customer, integrated to effect maximum effort on the right product at the right place at the right time
DISTRIBUTOR
Plan of action integrated with G-E plans and programs and tailored to distributor's own operating plans and programs for the market
DEALER
Plan of action integrated with G-E distributor plans and programs and tailored according to dealer's own operation
CUSTOMER

HEART OF THE MARKETING CONCEPT

In General Electric, the marketing management of each operating department is expected to provide these three fundamental requirements:

1. A Factual Marketing Plan. It calls for each business to have a written yet flexible marketing plan developed in terms of specific short- and long-range objectives for profit and leadership; which assures that we will have available a product that people want, at a price they are willing to pay, where it is wanted, and when it is wanted.

(The Marketing Plan makes clear *what* is to be done, *when*, and *why*.)

2. A Functional Organization Structure. It calls for an integrated company and distribution organization, designed to carry out this marketing plan and all of the required marketing functions effectively, economically and on time.

(The Organization Structure makes clear *who* is to do the various parts of the marketing job and *where*.)

3. A Managed Operation. It calls for a controlled, well-managed operation in which all of the marketing functions are co-ordinated and integrated by a dynamic organization which carries out the plans to meet the established objectives of the business.

(The Managed Operation assures that the organization carries out the plan *when* and *how* it is needed.)

is, the structure and work to be done and how such work is assigned in the Marketing Services Division. Similar charts are made for the Marketing Section of each operating department.

Experience with this program demonstrates that a good organization chart can be a valuable management tool. Correctly planned and developed, it tells more than the lines of authority and the delegation of responsibility. A good organization chart . . .

- Demonstrates the flow and processing of the work load.
- Shows provisions for growth in the business. (It does not restrict growth, as a poor chart would.)
- Suggests the economy and efficiency of the operation. (It indicates how a big job can be done better with fewer people by close integration.)
- Reflects a structure which provides for development of management personnel.

Management Position Guides

Another tool of professional marketing management which is directly related to the functional organization chart is what General Electric calls a "management position guide." (See the July 1952 REVIEW for an article on this subject by Harold F. Smiddy and Byron A. Case.)

Mr. Busey and his associates conceive a management position guide to be a great deal more than what is customarily found in a job description. They believe it to be a workable document that serves not only the man in the job himself, and his superior, but those in association with him—those who report to him, those who work with him, and those from whom he must get honest co-operation.

As a member of the Marketing Services Division points out "We have seen job descriptions that were written only to show the boss that the writer was so busy he needed a helper. That is not a management position guide."

Each of the position guides developed in this program contains a clear and comprehensive statement of 1) function, 2) responsibilities and authority, 3) relationships, and 4) accountability of the position.

The position guide for the Vice President—Marketing is the base upon which all of the jobs of the Marketing Services Division stand. Similarly, the position guide for the marketing manager of an operating department provides a sound base for all of the jobs in his organization.

The box for each position on the functional organization chart is a summary of the complete description of the job contained in its corresponding management position guide.

Man Requirements

Another related tool is the "man requirements outline." This is a specification for each job which is almost as detailed as the management position guide. It states clearly what the man should *be*, what he should *know*, and what he should *do*. Along with the management position guide, it provides a basis for sound manning of each job in terms of its specific requirements and a tool for periodic rating.

As indicated earlier, it was the Marketing Services Division's assignment to develop a program and tools for establishing a high degree of professional marketing management throughout the many operating areas of General Electric. They did develop such a program and the tools required. These tools are now being used, with assistance in their application by staff members, in most operating departments.

Professional Marketing Management

The nature of this program is reflected by the following definition: "Professional marketing management is the planning, organizing, and carrying out, in an expert, scientific manner, of all the functions involved in moving our products to the consumer with optimum sales volume and profits at minimum expense."

Stated another way, this program defines marketing as the function of each business that . . .

- Makes sure we know what and where our markets are.
- Sees that we have the right product, at the right place, at the right time, at the right price.
- Supports our products adequately with advertising and sales promotion.
- Sells to the greatest possible number of customers, through the most efficient and economical sales and distribution channels.
- Provides effective customer and product service.

"...we get so busy...there is no time for planning new products..."

As presented to operating people, this concept of marketing embraces three fundamental requirements: a factual marketing plan, a functional organization, and a managed operation. These three requirements are defined in Heart of the Marketing Concept on the opposite page.

Marketing Planning Process

A tool provided for building the kind of plans called for in this concept is the Marketing Planning Process shown in the flow chart on pages 33-35. Mr. Busey and his staff believe it to be the first ever developed. As you can see in this chart the process starts and ends with the customer. Its base is careful research and sound forecasting. It keys all plans, programs, and activities to a master marketing plan and a master sales plan, thus providing a well-mapped road to planned profits.

The tools provided for organization development are the inventory of functions, the functional organization chart, the management position guide, and the man requirements outline previously mentioned.

A tool provided for over-all management and control of the marketing operation is what is called a "master calendar of major marketing events." This is a schedule which keeps everyone in the marketing operation informed on the target dates for product introductions and changes, field tests, major sales activities, advertising and sales promotion programs, and so on, thus assuring close co-ordination and integration of all important activities in every functional area of marketing.

How Does It Work in Practice?

Practical businessmen who have become acquainted with this program have asked this pertinent question: "This all seems to be sound theory *but* how does it work in practice? What are your various businesses doing with it?"

Limited space permits us to give only a few examples.

The marketing manager of one department took the inventory of functions list, cut it up in strips, sorted out the kinds of work, pasted them on the chart of his existing organization. . . and found that he had a surprising number of functions that were not assigned or provided for in his business. With this as a starting point, he developed a new organization which provided for all the kinds of work to be done, eliminated overlaps and confusion, and provided a far more effective and efficient structure.

The marketing manager of another department came to the New York staff with his organization problem. The staff went through this whole organization process with him. They found that he was so swamped with emergencies and routines that he couldn't get his important planning and managing work done. The structure he inherited loaded him, in effect, with three full-time jobs: marketing manager, product planning manager, and sales manager. With staff assistance he developed a new setup that frees him for his important basic jobs and delegates important responsibility and authority to functional managers under him.

In both these cases, a good organization approach resulted in less, not more, management personnel, and fewer layers in these operating organizations.

Following is an example of how the marketing planning process works in actual practice . . .

The general manager and marketing manager of one of the G-E consumer products departments applied this approach to their business. Although in this field for many years, the Company had never received more than six or eight percent of the available business. They studied the market and selling practices in the field. They planned and developed a new product with new, promotable, merchandisable features. They eliminated all other models in the line. By doing this they were able to establish a new, low retail price, with an excellent gross margin. They found they couldn't afford to establish a house-to-house organization, nor depend on distributors and dealers to demonstrate the product . . . so they bought a television show to demonstrate the new model. In short, they developed a master marketing plan, with a sound product plan at its heart, and an integrated sales plan. With it they have doubled their industry position.

A Simple Formula

If you were to reduce this concept of marketing to its simple essence, you would find that it amounts to a rather simple formula for the application of professional management to the business of marketing.

You start with a thorough study of the existing evidence: from the study you establish the objectives. Then you analyze the work to be performed in order to reach the objectives. Then you develop the plans required. Next you put together the most efficient kind of organization structure which best aligns the component parts of the major functions with respect to grouping like work together, irrespective of historical practices, special situations, or the vested interests of the people.

Then you properly staff your organization to get the work done with the minimum of people required to accomplish your objectives, and you install the right procedures so you can control the business and perform your accountability function.

In presenting this program to the Company's general managers and marketing managers Mr. Busey said:

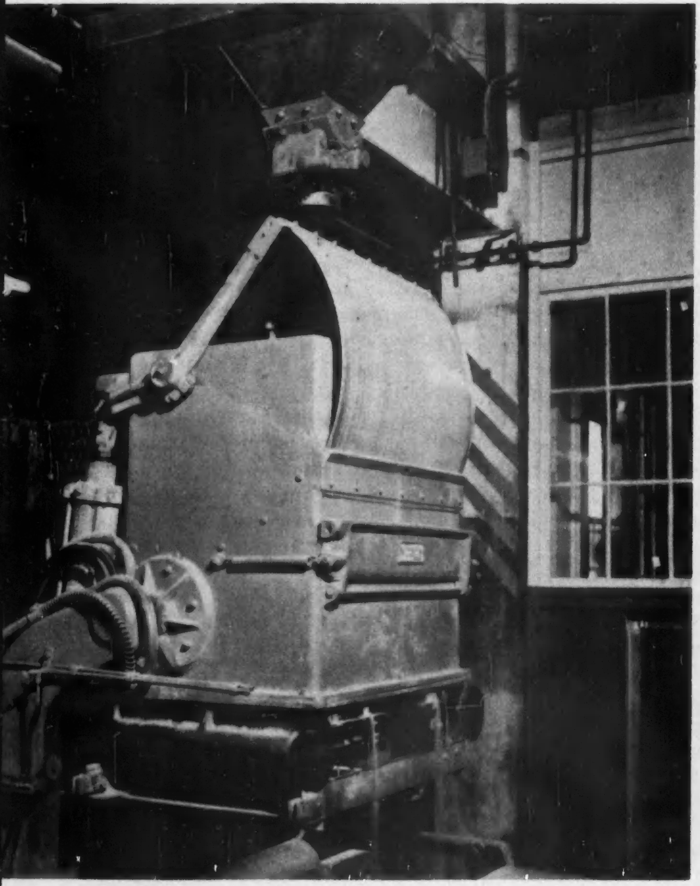
"To my mind, the greatest contribution any of us can make to our Company is to so organize our functions and people that we, as managers, get the time required to plan, plan, plan ahead. As it is, we get so bogged down with the weight of undelegated responsibility and detail work load that we have to meet emergency situations with emergency measures. The assignments of the day seem to be far out in front of the organization to handle them. Consequently, we get so busy putting out fires that there is no time for planning new products, planning new markets, planning new promotions, planning new profits . . . when it is this very ability to plan which can prevent emergencies."

Results reported from the first full year of experience indicate that this program and its tools form a firm basis for sound planning, good organization, and effective control of the marketing functions. Operating management men are finding that this is a simple, practical, sound way to manage the marketing aspects of any business.

In making the material for this article available for publication in the REVIEW, Mr. Busey said: "Our customers and other friends in industry are welcome to use the philosophy, the process, or the tools which this program contains. We believe that they can help to make the marketing job in any business easier and more effective." Ω

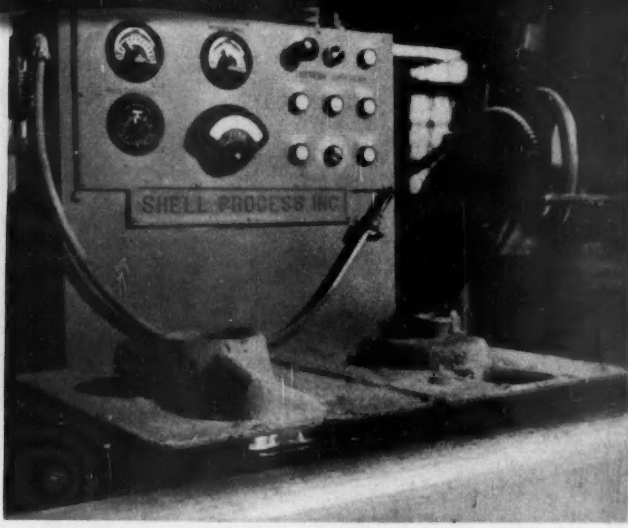
1 Casting an alloy-steel propeller by the shell-molding process. A first step is mixing sand with powdered phenolic resin—an organic material that hardens with heat. Here, foundryman pours in fine sand that will make up 94 percent of mix. A small amount of kerosene is added as a dust-suppressing agent, and six-percent dry powdered resin mixed in for 15 minutes. Meanwhile. . .

2 Operator sprays the propeller pattern with a special silicone-emulsion parting agent at the ejection station, after heating it to an operating temperature of 500 F. Transfer of pattern between oven—partially obscured at left—and ejection station is automatic. The purpose of this step is to facilitate later removal of the finished shell mold from the pattern. Next. . .

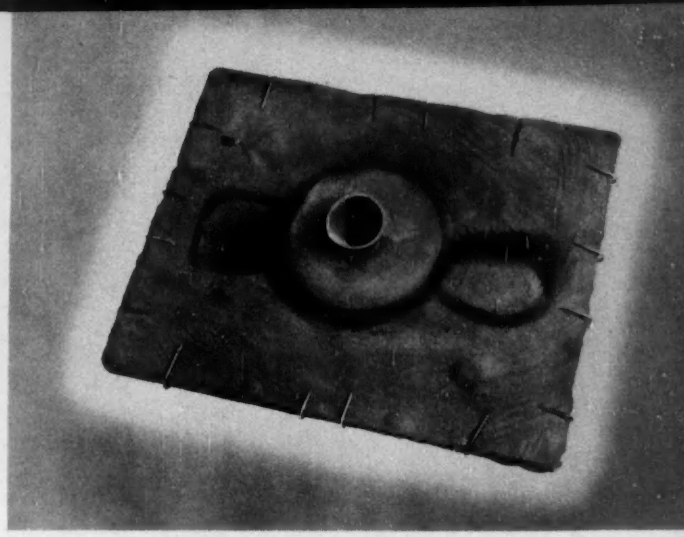


3 The hot pattern wheels along on its carriage to the investment box and clamps in place onto the bottom. Formation of the shell mold begins when the curved louver that supports the sand-resin mix—supplied from the chute above—swings upward, dumping and spreading mix onto the hot pattern. Now begins a heat transfer process that determines how thick the shell will be, for. . .

4 Build-up of shell thickness is function of "investment time" preset by the operator. Absorbing heat, the mix changes to a soft dough-like mass that adheres to the hot pattern. For a one-quarter inch thickness, 10 to 20 seconds may be needed. The box then inverts itself (*above*), excess mix falls away, and the louver closes, trapping excess for later use. Automatically. . .



5 The pattern moves from investment box to the oven; there the dough-like mass is baked to a hard shell. When done, its color will vary from bright yellow to dark brown. A final shift back to the ejection station and the hardened shell (*above*) is "stripped" from its pattern. This is done by an ejector plate that applies upward pressure against knockout pins. After this operation . . .



6 The ejected shell's upper and lower halves are next assembled to form the mold. Halves can be bolted together with speed nuts, held by spring clamps, set in mechanical jigs, or stapled. Adhesives in the cold state—or the resin itself in the hot state—can be used to join them. Here the propeller mold is fastened together with ordinary wire staples. On the next page you'll see how . . .

Shell Molding Comes of Age

By A. J. BZDULA and H. A. TAYLOR

About 90 percent of all durable goods have component parts that originate in the foundry as metal castings. These products—whether an iron sink or the brass fixture for it—are usually cast by pouring molten metal into green-sand molds, so called because the sand is mixed with clay and water to get a workable material.

There are several drawbacks to this method. Molds are heavy, cumbersome, and weak. Castings can't be molded to close tolerances or with smooth surfaces, and a number of machining operations are needed to finish the piece.

Lately, however, many foundries have swung over to the use of shell molds. Light, cooky-like, and sturdy, they are only one-quarter-inch thick. The molds are made of fine sand and a thermosetting phenolic resin by a process that's almost entirely automatic. (Phenolic resins are thermosetting; that is, they harden with heat, and once hard, won't melt or soften. Telephone handsets and the distributor cap in your automobile are typical applications.)

Briefly, the process consists of mixing sand—94 percent—with about six percent of the finely powdered phenolic resin. (See picture sequence.) This mixture is dropped on a hot metal pattern. The pattern is then inverted to drop off excess sand-resin mix, leaving a thin dough-like shell about one-quarter-inch thick adhering to the pattern. After the shell is hardened by additional heat, it is stripped from the metal pattern with excellent reproduction of all details. Two mating shell halves are then assembled to form a complete mold.

Castings made by the shell-mold process are smooth and can be held to extremely close tolerances. Thus, expensive machining operations normally needed for green-sand castings are cut down and sometimes eliminated altogether. As a result, the new method produces better castings at a faster rate while at the same time reducing labor costs.

•

After graduating as a metallurgical engineer Mr. Bzdula spent a year on GE's Chemical and Metallurgical Training Program. In 1949 he joined the Chemical Division, Pittsfield, Mass., where he is now a foundry specialist, Phenolic Product Sales. With GE for six years, Mr. Taylor is a Phenolic Products Engineer, Chemical Materials Department, Pittsfield. He has been active in development and application of phenolic resins for foundry use.

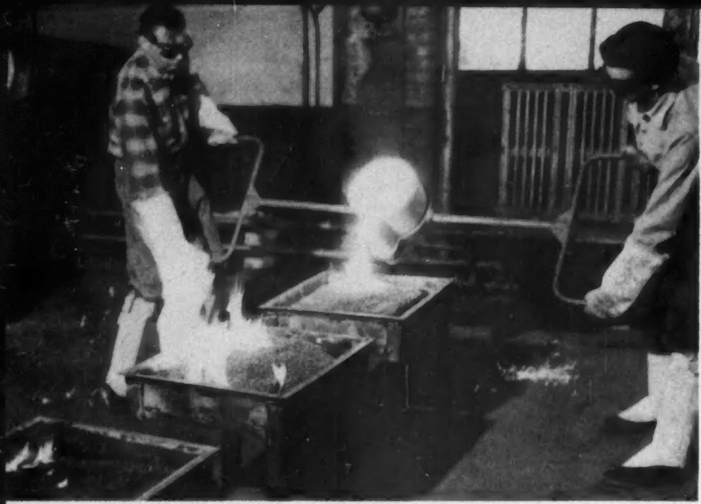
Gradual Acceptance

When shell molding was first introduced to American industry in 1947, the skeptics doubted that it would ever be of economic use. But this skepticism has largely been overcome by new advances in materials, techniques, and mechanization.

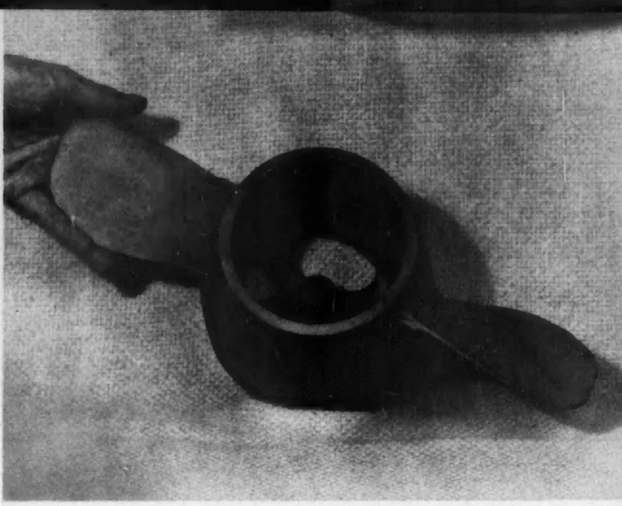
The newcomer is now earning a respected position in the foundry industry. For example, more than 200 of the nation's 5800 foundries are engaged in full- or small-scale production of shell molding or in some phase of development work. Numbered among those in full-scale production are companies making automotive parts, railroad castings, aviation parts, kitchen equipment, and plumbing fixtures.

One reason shell molding has scored so successfully is that less labor and floor space are required for a given casting because only five percent by volume of the sand needed for conventional green-sand castings is used. Other advantages of the shell process are. . .

- Mechanized equipment enables one operator to turn out shell molds at a rate of 35 to 500 per hour.
- Molds with complex patterns are made as easily as those with simple shapes.



7 Molds for propellers are placed in rectangular boxes, or pouring flasks, and steel shot is packed around them. Packing material is necessary for these particular shell molds, otherwise, pressure of molten metal might distort or break them. As metal is poured, resin in the mold burns away, leaving only fine sand to form a smooth accurate surface on the casting. Finally. . .



8 The finished product is removed from the pouring flask and cleaned. Practical effect of the propeller's smooth finish is to reduce the number of subsequent machining operations. For mass production, the last two operations—pouring metal, removing and cleaning cast product—are performed automatically. By the shell-molding process, almost any metal can be cast to close tolerances.

• Unskilled labor can readily handle the production of shell molds once the engineering problems in mechanization are ironed out.

• Cleanliness of the process not only makes for better morale and working conditions, but for cleaner castings.

• High casting yields are obtained because of the mold's smoother surface and its insulating effect.

• Costs of cleaning the castings are reduced; in some cases, sandblasting has been completely eliminated.

Almost all metals are successfully poured into shell molds. In the ferrous field, excellent results are obtained with gray, malleable, and ductile irons. Good castings are also made with high-alloy steels—such as the alloy-steel propeller above, right—and with ferritic and austenitic stainless steels.

In the nonferrous group, some metals successfully poured are aluminum, tin-bronze, magnesium, and brass.

So new is the shell-molding process that it isn't yet feasible to make cost estimates with any accuracy. Still, even at this early stage of development, it is competitive with other casting techniques in many applications. Further refinements will make it more so.

What Goes In

Specific materials needed for making shell molds are: a proper sand, a phenolic resin, a silicone parting agent, and sometimes, a dust-suppressing agent.

SANDS—The higher the fineness of a sand the better the finish of a casting. Sands used for making shell molds are finer than those used for green-sand molds. However, fine sand reduces a mold's permeability and requires a larger percentage of resin. For the higher-melting alloys, coarser sands are usually employed to allow escape of hot gases as the alloy is poured.

In addition to having a high silica content, proper grain shape, and wide particle distribution, sands for shell molding are dry and free of clay and organic materials. Clay is kept to a minimum because it not only reduces flowability of the sand-resin mix but absorbs resin to greatly reduce the mold's strength. A high silica content, on the other hand, is necessary to insure high sintering and fusion points. Addition of zirconite sand or iron oxide helps keep these points high, and also reduces penetration of the mold by higher-temperature alloys.

RESIN—Finely powdered thermosetting phenolic resins of the two-stage type—the resin must melt before it hardens—have proved best for binding the sand. Along with other desirable properties, they are highly uniform and capable of reproducing intricate patterns. To determine their properties, sample shells are made and tested for tensile strength, flexure, hot rigidity, and permeability.

PARTING AGENTS—To release the hardened shell from its metal pattern at high temperature, a release agent of some sort is necessary. Silicone emulsions have proved best suited for this operation. Early emulsions built up an objectionable layer on the pattern, but a new 35 percent silicone solids emulsion has eliminated this difficulty.

DUST-SUPPRESSING AGENT—More and more, wetting agents are being frowned upon because they inhibit flowability and packing characteristics of the dry-sand mixture. And they also somewhat reduce the baked strength of the mold. However, where there's a dust problem because of fine particles of sand and resin, an addition of 0.2 percent kerosene or light oil to the mixture solves it nicely. This is also true where the denser sands tend to segregate from the resin after prolonged investment or dumping cycles.

Mixing and Pattern Making

Equipment to make shell molds can be simple for investigation purposes or complex for mass production. Complexity is introduced only to speed and control the process, the basic operations remaining the same. Requirements include a sand-resin mixture, a metal pattern, an investment box, an oven, a pouring flask, and a back-up material.

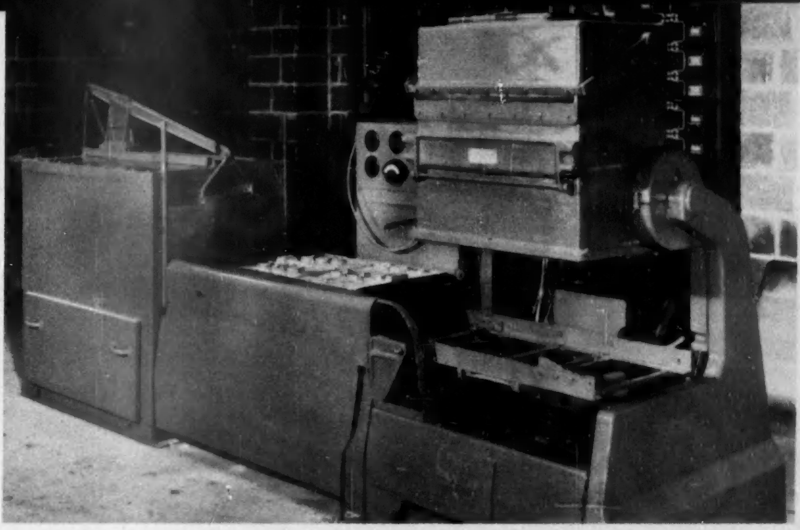
Various type mixers have successfully been used to blend the sand and resin: mullers, cement mixers, blenders, tumbling barrels, and paddle mixers. The "mortar and pestle" action of a muller insures a homogeneous mixture and is most widely used. However, the mixture must not be mulled too rapidly or the heat generated will change its properties.

The pattern on which shell molds are made is the most critical piece of equipment in the whole process. For a casting can be no better than the pattern on which its mold is made. Any mark or roughness on the pattern is reproduced on the shell and, in turn, on the casting. Metals best suited have good abrasion resistance, large heat capacity, and small dimensional change when alternately heated and cooled. These metals are gray iron, mild steel, and hard copper-base (Ni) alloys.

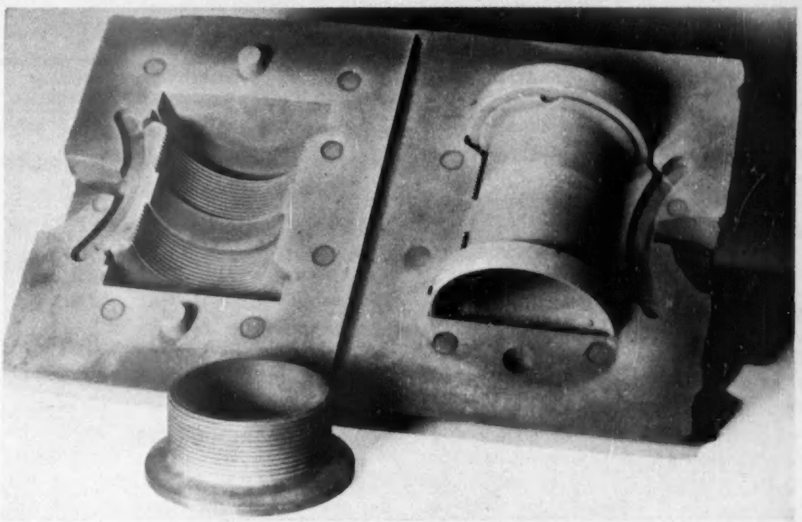
Aluminum is used for development work because of its ease of machining. It isn't recommended for long-run production patterns because: 1) it mars easily, 2) it cools rapidly, 3) its thermal expansion is high, 4) sharp corners of the pattern tend to round off, 5) if temperatures exceed 650 F, its tendency for warpage is great, 6) ammonia that is given off when the resin is baked etches its surface. Besides, an aluminum pattern doesn't release the shell mold as well as copper or iron-base patterns.

Ejection pins are strategically located in the pattern to better facilitate removal of the shell. Where pins come in contact with the shell, they have rounded caps, one-half to three-fourths of an inch wide. This way they apply uniform pressure over a wide area and their tendency to punch through the shell is minimized. The wide cap also serves to cover the hole between the pin body and the pattern, thus preventing sand from entering and freezing the pin.

Pins are mounted individually with a spring on each or attached to a common base plate with larger springs only on the corner pins. Either way the springs are made of stainless steel to withstand the high operating temperatures. It's important that they apply pressure evenly in removing the shell.



SINGLE-PATTERN MACHINE of the type used to turn out shells for preceding pictures. Left to right are oven, ejection station, and investment box. Equipment takes little space.



SHELL-CORE PROCESS eliminated four machining operations from this threaded nickel-silver plumbing fixture. Here, molten metal is poured with the mold in upright position.

Investing the Mix

The investment box—constructed of wood or metal—is a means of applying the sand-resin mix to the hot metal pattern. It also serves as a container for excess mix.

Many designs have been devised to provide perpendicular fall of the mix onto the pattern's surface. The investment box shown in the picture sequence has a louver that slides open, enabling the mix it holds to drop onto the metal pattern clamped to the bottom. After sufficient build-up time, the box rotates through 180 degrees, its closing louver entrapping excess mix for subsequent shells.

The open end of the box is designed to insure against any build-up of sand-resin mix—hardened by heat conducted from the pattern—along its upper edges. This is done with silicone rubber, heat-resistant plastics, a water-cooled lip, or through use of a raised metal strip on the pattern.

For good distribution of mix over the pattern, height of the investment box should be at least 10 inches. Height alone isn't the critical factor, however. Good distribution is better obtained by controlling the angle at which the mix falls—a fall perpendicular to the surface of the pattern is ideal.

Baking and Pouring

Needed to heat the pattern and cure the dough-like shell is a controlled heat source. Temperature distribution along the pattern, not the oven's temperature, is most critical here. For variation from the hottest to the coldest part of the pattern should not be more than 30 to 40 F. Oven temperature, on the other hand, should be high enough to rapidly cure the shell. At the same time, it should put enough heat back into the pattern to make up for heat lost when the cold sand-resin mix is invested.

In practice, oven temperatures range from 600 to 1400 F; pattern temperatures range from 350 to 600 F. The higher oven temperatures give a faster cure, while higher pattern temperatures give faster build-up. Used for heat sources are gas-fired ovens, oil-fired ovens, radiant gas heaters and infrared radiant heaters with parabolic reflectors.

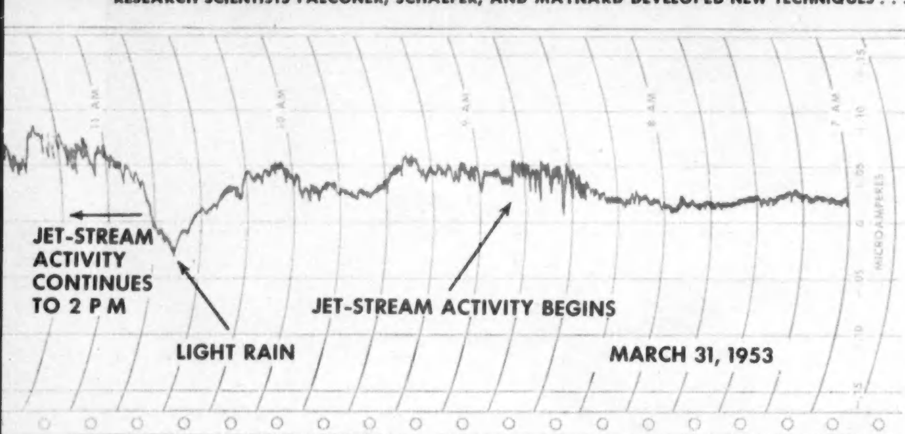
A pouring flask supports the shell mold—and back-up material—while the molten metal is poured. It's the same width as the shell and has several vertical positioning slots. Hinged at the bottom, it can be opened to allow back-up materials to flow away from the solidified casting. (In a mechanized process, the casting would drop to a moving belt beneath the flask.)

For most applications, a material to back up the thin shell mold is needed to

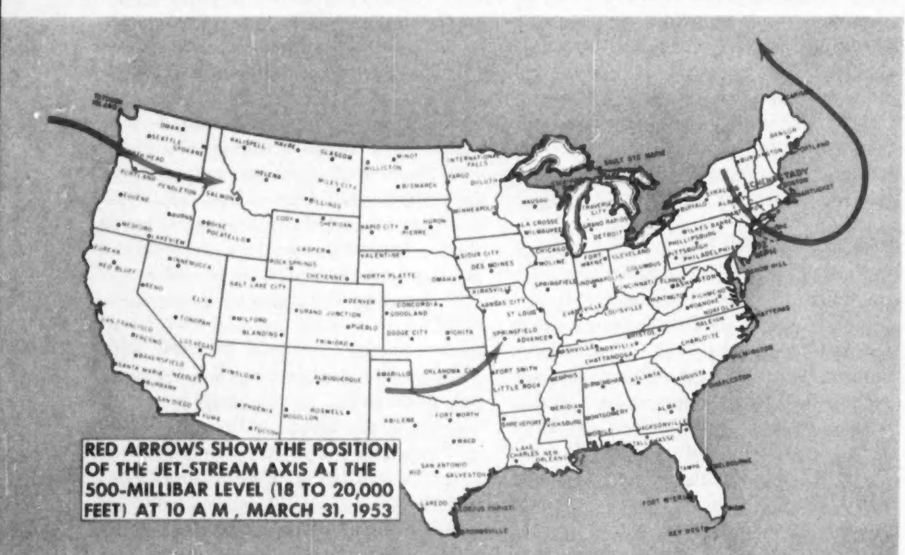
CONCLUDED ON PAGE 59

"The Jet Was Chasing Its Tail"

RESEARCH SCIENTISTS FALCONER, SCHAEFER, AND MAYNARD DEVELOPED NEW TECHNIQUES . . .



. . . LIKE USE OF THE POINT COLLECTOR THAT RECORDS ATMOSPHERIC ELECTRICITY, TO HELP . . .



. . . LOCATE THE POSITION OF THE FAST HIGH-ALTITUDE WINDS OF THE JET STREAM.

Review STAFF REPORT

Roaring through the upper atmosphere at altitudes of 20,000 to 40,000 feet are narrow rivers of wind moving at speeds of 100 to 300 mph.

This is the jet stream—a recently discovered meteorological phenomenon first encountered during World War II. Every once in a while, and quite unaccountably, B-29's had trouble making their way to targets in Japan, and just as unaccountably they were sometimes whisked homeward by high-speed tail winds.

Over Germany, British pilots occasionally became entangled with similar atmospheric disorders. An example of impressive confusion involved one bomber that wound up 100 miles south of Berlin and made a lonely and anticlimactic run north to the German capital where it dropped its bombs one-half hour late. Another on the same mission never did get to Berlin. Finally, turning homeward, this pilot found himself over Paris when he should have been over the southern part of England.

After the war, meteorologists began a thorough investigation of the jet stream. Much of the work was centered at the University of Chicago under the direction of Dr. Carl G. Rossby, noted Swedish meteorologist now at the University of Stockholm.

Researchers soon determined that these wind rivers were sometimes 100 to 600 miles wide and circled the globe. They also found that the jets had a tendency to meander across the sky in no set pattern. In the North American continent, for instance, they seemed to favor the area north of a line drawn roughly between the West Indies and Mexico City, and south of a line through the northern part of Alaska, Victoria Island, and the middle of Greenland.

In this area two or three jets are usually present. (Meteorologists seem to prefer to bunch them together and merely refer to "the" jet stream, possibly because they're usually most interested in the one nearest to them.) Although the jet stream heads in a general easterly direction, its wayward path is such that it occasionally assumes serpentine forms so that in some locations it may actually be flowing toward the west.

The jet stream also assumes erratic behavior in an up-and-down direction, as well as side-to-side. At times, the whole thing assumes the rather frightening aspect of a gigantic roller coaster, stretched end-to-end, snaking through the sky at high velocity.

In cross section, a jet can be pictured as more or less circular in shape. The wind at the core moves at the highest speed; as you approach the edges of the stream, the wind velocities begin to fade. Sometimes, researchers discovered, the cross section is not circular, but is in the form of a teardrop, with the long axis not always in an up-and-down position.

At times, branches may shoot out from the core of the stream. These are "jet streaks;" even to this day they're a complex and puzzling business to meteorologists. They won't be discussed here.

When two or more jet streams converge, air piles up and an action called *blocking* may occur—weather systems slow down, forecasts become ridiculous, and weathermen become churlish. "It's a hard thing to detect," a meteorologist said recently. "The weather goes according to the book several days in a row and then all of a sudden it stops and we have the same weather for several days. Late in March a weather system got stalled over the Northeast. The jet was chasing its tail, and it rained for days. We had one of the wettest Marches in history."

(The jet stream, incidentally, has nothing to do with jet aircraft, except that possibly they both move at high speeds and high altitudes. Researchers at the University of Chicago labeled it in 1947 because its characteristics paralleled those of ocean currents, such as the Gulf Stream.)

Pinpointing the location of the jet stream is of importance to aircraft operations, and to meteorologists.

Commercial and military air services aren't interested in bucking the jet stream, but they are interested in getting a boost if it happens to be going in the same direction as their aircraft. Such free rides can do remarkable things in reducing flight time and fuel consumption.

Meteorologists, although they haven't found out everything about how the jet affects weather, have some evidence that high-velocity jet streams tend to steer precipitation in storm areas.

As one meteorologist remarked, "It would be a great aid in forecasting if we knew at all times where the jet is located."

But determining the exact whereabouts of the jet stream isn't easy. It took laborious, detailed, and time-consuming work over the past seven years to collect all the data that's now available.

The usual manner of detecting high-velocity high-altitude winds is to send up sounding balloons and follow them by radar. This method of charting is limited: not so much by the technique itself, but because there are only about 60 weather stations in North America equipped to carry out such work. Jet-stream maps released daily by the combined Weather Bureau Army-Navy (WBAN) are based on such meager information. For instance, the location of the jet stream in the Northeastern part of the United States is determined by reports from only one or two stations. Draw a line from Washington to Chicago, and run another to northern Maine—frequently there's one weather station in that triangle that's been able to measure winds at high levels. The location of a mere filament of high-speed winds is determined from this lone observation.

"The jet stream also assumes erratic behavior in an up-and-down direction, as well as side-to-side. At times, the whole thing assumes the rather frightening aspect of a gigantic roller coaster, stretched end-to-end, snaking through the sky at high velocity."

Up to a few months ago, that was the situation in regard to techniques available to accurately determine the location of the jet stream. Since then, two promising methods have been developed. Both are fast and inexpensive.

Recently I drove out to General Electric's Research Laboratory about five miles from downtown Schenectady. In the huge modern buildings, located high on a bluff overlooking the Mohawk River, all phases of the Company's fundamental research is conducted. Only a small section of the vast operations are devoted to studies of the atmosphere, and it was there I met three scientists who have been active in weather research: Dr. Vincent J. Schaefer, Raymond E. Falconer, and Kiah Maynard, pictured on the opposite page. All were with Project Cirrus that carried out the famous cloud-seeding operations ("Project Cirrus—The Story of Cloud Seeding," November 1952 REVIEW).

I talked first with Schaefer in his fifth-floor laboratory, surrounded by large photographs of cloud formations and weather phenomena, and the clutter of a well-used workshop. In a corner was the famous home freezer where man-made snow was created for the first time in 1946. Schaefer is a big man in his middle forties, with straight unruly hair, who talks clearly, logically, and without any hesitation.

He became interested in weather research 10 years ago, I learned, when he and Dr. Irving Langmuir, who also worked on Project Cirrus, made a study of precipitation static that was requested by the Secretary of War. Much of that year's work was carried out in a laboratory atop Mt. Washington in New Hampshire. As the research progressed, both scientists became more and more interested in the atmosphere and in meteorological problems.

"One day while in Schenectady," Schaefer told me, "I happened to notice a rather spectacular group of clouds coming in from the northeast at high altitude. This was quite foreign to what I had been led to believe, because most high-velocity winds at high altitude are supposed to come from the west. I spent considerable time in observing these clouds. I took a number of photographs, using infrared film, and I also took some stereo pictures, but I didn't do anything more about it, except mention the clouds to Dr. Langmuir. I'm afraid he didn't believe me at the time, because as far as I know, he wasn't aware of these unusual cloud movements either."

Schaefer observed these varying cloud forms not only around Schenectady but in other parts of the world. There was always a consistent pattern to the clouds; they seemed to show a definite river-like structure, and they would come from certain regions for days at a time. They puzzled him.

In 1947 he attended a lecture by Rossby in New York on disturbances in the Westerlies. Sometime later he heard Jerome Namias, Chief of the Extended Forecast Section of the U.S. Weather Bureau, give a paper on the jet stream.

"It was then," Schaefer said, "that I decided to investigate a little more as to whether I might expect to find clouds

CIRRUS streamers are of great complexity and move at high velocity at high altitude. They often have long tufted streamers and sometimes very large whorls. At times there is the suggestion of air movement in a helical forward motion, something like a huge corkscrew. This produces complex shear lines in the thin clouds of ice crystals that make up this cloud form.

CIRROCUMULUS clouds also move at high altitudes (25,000 to 40,000 feet) and high speeds. They appear as small, white rounded cloud patches in a blanket-like structure. Sometimes they are scattered in a random fashion; sometimes there may be six or seven of them in a line. The latter perhaps indicates that they are forming at the crest of waves.

associated with the jet stream that I had just heard about."

Shortly afterwards he talked with Rossby and Dr. Horace Byers of the University of Chicago. He asked them where the jet stream might be expected in the wintertime and in the summertime, and was told that it would be rather unlikely that the jet stream would be as far north as Schenectady at the times when he thought he had observed it. However, they did point out that maybe cloud forms could be found that were related to the jet stream, but they didn't know of any observations along those lines.

A year ago this spring Schaefer began to devote some of his spare time to the problem. His investigations took on a new meaning because the weather station at the G-E Research Laboratory began to receive daily high-altitude wind charts by radio facsimile. To Schaefer, these charts appeared to be an ideal way to find out if the cloud forms he had been observing were related to the jet stream.

About the same time another event took place that aided his studies. The Research Laboratory entered into a letter contract with the Munitalp Foundation. (Munitalp is "platinum" spelled backwards. It was formed in 1948 by Albert W. Johnston, a mining engineer of Greenwich, Conn., whose casual concern with the weather's effect upon his yachting activities developed into a major interest in meteorology.) This contract permitted Schaefer to spend a small amount of time with the Foundation to assist in solving basic problems in meteorology.

"It seemed to me that this was an ideal way to carry out a study of the jet stream. Most of my observations during the past years had been done on my own time at home or on vacation trips, so this looked like a good chance to develop a rather interesting project."

For one phase of the Munitalp program, 10 lapse-time motion-picture units were built for field photography. To test several of the units, Schaefer used some of the strange cloud forms he had observed for subject matter. During May, June, and July of last year the jet stream was in the Schenectady area and Schaefer photographed "some very spectacular exhibitions of these spectacular clouds," as he described them.

(Schaefer later determined that the jet stream seems to favor the Northeast, particularly the region around Schenectady. One possible explanation is that weather systems coming across the country are bounced northward by the Appalachians, and billow out of the windgap formed by the Catskills and the Adirondacks.)

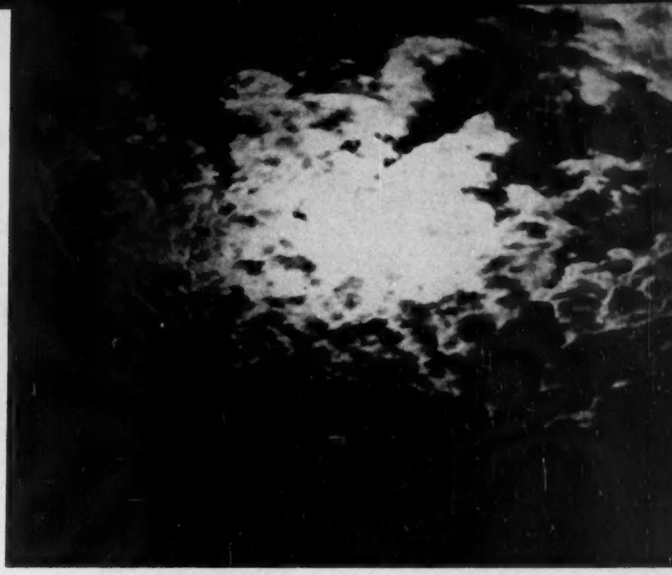
Correlation between certain cloud formations and the general passage of the jet stream over Schenectady was encouraging, but much work still remained.

In planning an auto trip west during July of last year, Schaefer decided to make daily observations of cloud forms. At the same time, Falconer and Maynard at the Research Laboratory's weather station were to send him daily radio-facsimile maps showing the location of the jet stream. This would afford a good opportunity to see if any definite correlation could be obtained. Schaefer was interested in variations in the basic cloud forms, and also in finding out whether a typical cloud form that he saw in the Schenectady area could also be observed over, say, the Great Plains or the mountains of the West.

"The first night of our trip we stopped in the vicinity of Canandaigua Lake in the western part of New York State, and we witnessed one of the most spectacular displays of these clouds that I have ever seen. But every day as we headed west we saw the same kind of clouds and I began to get discouraged. I began to feel that maybe after all I had been observing a very common type of cloud, and that they were so universal that they couldn't possibly be related to the jet stream. Well, we kept on seeing the same clouds. Once or twice the thought did cross my mind that maybe I was just fortunate and that the jet stream actually was in our vicinity for a rather persistent period.

"The day before we arrived in North Dakota I began to think that maybe after all I *was* observing the jet stream, because we had traveled for nearly 500 miles with a most spectacular line of these clouds overhead. The line was coming toward us and continued all day long. I estimated that the clouds were

ALTOCUMULUS-LENTICULAR clouds of the jet stream appear lens-shaped. From the ground they look to be thin at the edges and thick in the middle and often quite symmetrical. At times they are piled one on top of the other, appearing like a great stack of pancakes. Their altitude is about 20,000 feet, but in general they don't show evidence of rapid movement.



ALTOCUMULUS-BILLOW clouds form as a billow, or a series of billows or waves. These clouds frequently extend from horizon to horizon with the waves formed in parallel bands at right angles to the air flow. At times the cloud sheet may appear to the casual observer as a relatively thin layer with the pattern of the units arranged in a more cellular form.

traveling about 100 mph, and that at least 1500 miles of cloud had passed overhead during the day."

Around noon, Schaefer said, he saw a storm develop right *under* these clouds. It didn't develop from cumulus clouds, but came about by a thickening of the cirrus clouds, with the cirrus crystals falling down and apparently starting off a downward flow of air that was compensated for by an upward movement. In less than an hour, a full-fledged storm was under way. This was a region where "frontogenesis" occurs, that is, where cyclones often seem to start. "It looked to me as though I was actually witnessing the birth of a cyclone, not the type of thing that one thinks of as a tornado, but more as a line squall."

Before nightfall, Schaefer was convinced that instead of just having these clouds everywhere, he had actually been fortunate in having the jet stream in the vicinity of his travels during the past three or four days. He immediately sent a special-delivery letter to Falconer asking him for the high-altitude wind maps and requesting that they be sent on to him at Missoula, Mont., where he would be in a couple of days.

When Schaefer reached Missoula, he described his experiences to friends in the Forest Service who expressed a great deal of interest. The maps had already arrived from Falconer, and he was pleased to find that on the days in which he had observed the most unusual clouds the jet stream was almost overhead. "On the basis of this I felt pretty good about the general situation, and decided to continue the observations in even greater detail," he said.

While in southern Idaho with the Forest Service people, he helped them install the lapse-time motion-picture cameras on mountain tops. Each day his group kept an eye on the sky to find out if they could detect the so-called jet-stream clouds. For two days the sky was cloudless from horizon to horizon, except for a line of clouds that was far off to the south, several hundred miles away. "I told Jack Barrows, the Chief of Fire Research of Region 1, that to me it looked similar to the line of clouds that I had been observing as related to the jet stream, and it would be a wise idea to keep an eye on it. The next day we were on another mountain about 50 miles away and this same line of cirrus clouds was visible, this time much nearer. The following day the line of clouds was overhead and I told Barrows that I was so sure now that these clouds were related to the jet stream that if we found the map did not show it, the map would be wrong. I was as confident as that.

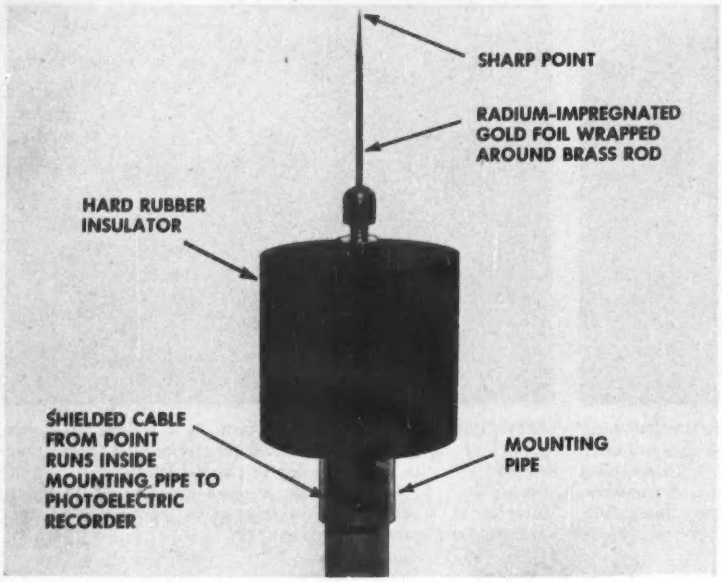
"The next day we went to Spokane and checked with the local weather bureau to find out where the jet stream was the day before. They in turn referred us to the local Air Force base. Well, we had no difficulty in locating the weather officer at the base, and as we went into his room I looked around, and scattered all over the place were jet-stream maps. I asked the young lieutenant in charge of the operations where the jet stream was, and without a moment's hesitation, he said, 'It's overhead, and yesterday it was over Grangeville.' That's just where we had seen it the day before. This, of course, made me feel very good because it corroborated our ideas in an almost amazing degree."

A few days later Schaefer flew to Seattle. Enroute, he photographed clouds that seemed to be related to the jet stream. He discussed this with Phil Church, Head of the Department of Meteorology at the University of Washington, and he too became interested. Although Church hadn't been paying much attention to the general subject, he immediately sensed the importance of this and pointed out to some of his associates that it was something well worth spending more time on.

Passing through Wyoming on his way home, Schaefer had several opportunities, particularly in the vicinity of the Grand Tetons, to photograph more jet-stream clouds by lapse-time photography. On the trip he kept daily records of cloud forms observed for later checking against the jet-stream maps.

By the time he arrived in Schenectady, he was, as he told me, "extremely confident" that the special cloud types he had identified were closely related to the jet stream and could be used to locate the jet stream.

I asked him what some of these clouds looked like. He swung around in his



THE POINT COLLECTOR . . .

. . . consists of a fine brass point about 2½ inches long and $\frac{1}{16}$ inch in diameter mounted on the top of a 10- or 15-foot pipe, and insulated from it. Strips of radium-impregnated gold foil are wrapped around the point. The lead from the point goes to a sensitive General Electric photoelectric recorder to ground. Falconer has found a sensitivity of about 0.50 microamperes (full scale) to be best. When a sufficiently high potential develops in the vicinity of the point, a corona-discharge current results and is indicated on the recorder.

Cost of a setup like this is between $800 and $1000; the major item of expense is the photoelectric recorder.

Falconer has run field tests on a less elaborate outfit, using the same point, but utilizing a nonrecording, ultrasensitive microammeter capable of reading down to 0.01 microamperes. He figures the total cost at about $150. It doesn't have the advantage of continuous recordings, but sample readings every hour or so would give an idea of what's going on in the atmosphere. A network of these points could help locate the jet stream.

chair and pulled a large loose-leaf volume of photographs from a bookcase. Spreading some of the pictures on the desk in front of us, he described the four basic cloud types (pages 44-45).

On the basis of his observations, Schaefer told me after we had looked over the photos, he decided to present his findings to meteorologists in a technical paper. What kind of a reception had his paper received, I asked.

"Well, of course, as often happens when something new is presented, there's a certain amount of conservatism, but I find in general a great deal of interest. This is particularly true of the meteorologists associated with the big airlines of the world. I've had many requests for more information not only from this country but also from abroad.

"For instance, the Pan American Airways division that flies in Brazil has no ground network to locate the jet stream by the use of sounding balloons. But if they could use clouds to indicate the location of the jet, even in a very rough way, it would be of great importance to them, especially when crossing the Andes. The latest I heard is that they're planning to set up a program of study related to such observations.

"In this country, American Airlines and Pan American have asked me to talk to their operations people. I've had discussions with the Comet group in England—they're the people who fly the jet airliners from London to Johannesburg—and got from them many interesting comments as to clear-air turbulence and other conditions encountered in their north-south flights. Captains of British Overseas Airways have also told me of strange turbulence as related to special cloud types.

"I'm glad to say that this kind of observation is becoming more and more common; that is, co-operation with our group and with other people interested in making actual observations. We're also getting postcards and letters from amateur meteorologists who are making observations. They describe the cloud types observed, and mention the times and locations. Thus far they've shown excellent agreement with observed jet-stream locations as found on our maps."

Schaefer told me some interesting things about the "discontinuity" of the jet stream: it has a tendency not only to go up and down and around but also to fade away. This feature is of interest to pilots—not so much from the fact that they may run *out* of the jet stream but that they may run *into* it. Then, too, the pilot may be riding the jet and suddenly get into some turbulence. "Cobblestones" is the terminology.

"If you observe the characteristics of these clouds, you can sort of visualize the kind of things that pilots can get into," Schaefer explained. "Some of the clouds show no turbulence whatever, while other clouds, especially at the outer edges, show extreme turbulence. This is shown by a rotational motion that becomes apparent by viewing the lapse-time movies. One of the characteristics the jet stream appears to have is a helical vortex in which the air is moved in a screw-like forward motion. At the boundary layer between the high-velocity winds and the air that isn't moving so fast, you'd expect to find the extreme turbulence that would result in uncomfortable flying conditions."

After we had talked more about cloud forms, Schaefer took me up two stories to the Laboratory's weather station in the penthouse. Maynard and Falconer were busy with the late afternoon "progs" (prognostications), as they call them, for the next day.

The weather station has windows on three sides and commands an imposing view of the countryside. On a long bench on the north side of the room were many recording instruments. To the left, weather charts were racked on large bulletin boards. The radio-facsimile receiver was finishing its daily run by transmitting the Dick Tracy comic strip and bulletins from the *New York Times*. It emits an irritating, undulating whine. Schaefer checked some maps, then left.

"Schaefer . . . also noted some mysterious readings . . ."

Both Falconer and Maynard are amiable, earnest, and in their thirties. Maynard was busy at a desk near the windows, finishing his daily reports, so Falconer told me about his experiences in locating the jet stream.

"As I guess Vince has already mentioned, we were sending him a lot of maps last summer that showed the location of the jet stream as indicated on our radio-facsimile maps. Well, during the course of my work, I decided to try a method of more easily identifying a lot of my past records. I have a folder for each day that I've been out here—that's about five years—and each folder has the charts from our various recording instruments for the 24-hour period involved. To make it a little easier to find the information, I decided to put colored tabs across the top of each folder—certain colors in certain positions on the folder would indicate at a glance the general type of day—whether the wind was strong or light, whether it was cloudy or clear, and other interesting things.

"In the process of making up the color coding, I decided to indicate whether the jet stream was in the vicinity of Schenectady, since I thought that would tie in with any records we might have of jet-stream clouds. But in thinking of that, it occurred to me one day that we have often wondered why on some days we get more positive current readings on our radioactive point collector [described on the opposite page] than we do on other days. This was brought out more noticeably after I increased the sensitivity of the instrument.

"I decided to see what made the needle go a little further off zero on some days than it did on others, and when I increased the amplification, I found there was considerably more 'structure' to fair-weather conditions than I had noted before. So I thought that I had better check this over and see whether it had any relation to the presence of the jet stream. I went back through the records and found that on days when the jet was over this area we had recorded higher positive current readings than we did on some other days. In checking back particularly outstanding cases, it really showed up every time."

Falconer pointed out that during stormy conditions there was always plenty of activity on the recorder—both positive and negative—so those couldn't be counted. But he was interested in positive readings on fair days, or days in which only a few clouds were in the sky.

He kept at his research and the picture began to fill in rapidly. He found that high positive readings usually indicated the presence of the jet within 150 to 200 miles (illustration, page 42). He also found that the presence of the jet stream in the area, particularly if it came from the South or Southeast, was usually a signal that rain was right behind. (A jet from Canada usually brings clear, cool weather.)

As far back as 1949, Falconer made a formal report about unexplained, positive "pips" on a point-collector recorder. "I didn't know what caused it," he said, "but I did know that rain usually followed within 6 to 12 hours. I used it for forecasting on many occasions and it usually worked out." He guessed that now, based on their present knowledge, rain will follow the jet stream 75 to 80 percent of the time.

(Schaefer, I learned later, also noted some mysterious readings during January and February of 1944 when he was using a point collector in the study of the "properties of particles of snow and the electrical effects they produce in storms." His report states: "The electrical effects in this period were considerably greater than were encountered in any of the positive-current snow storms observed during the winter. In this . . . . period the skies were clear of any apparent clouds . . . . A study of the surface and upper-air map does not reveal any obvious reason for this abnormal amount of atmospheric electricity." Today, Schaefer is quite sure that his point collector was registering the passing of the jet stream.)

The point collector, I learned, can detect the jet stream on both clear and cloudy days. With the jet nearby on clear days, the positive readings increase to 0.05 microamperes or higher and stay there for some time. On cloudy days the positive readings may or may not reach the 0.05 microampere reading if the jet stream is near. When clouds of tiny water droplets—but without precipitation—move over the collector site, the positive current indication is usually reduced. However, if a definite increase in positive current is noted that reaches 0.04 microamperes or higher, it usually means that the jet stream is nearby.

I asked Falconer why the jet stream gave positive readings.

He took me over to one of the weather maps and pointed out the location of the jet, and also some fair-weather areas in the United States. He told me that the negative charge in the earth is being neutralized continually by a downward current flow of positive electricity in all parts of the world where the weather is fair. The negative charge in the earth, he went on to say, is generally believed to be generated on a world-wide scale where thunderstorms are in progress. Each thunderstorm cell transfers a high negative charge to the earth via lightning, while an equal positive charge is transferred to the conducting regions of the high atmosphere. Up there it's dispersed and provides the positive charge for the descending fair-weather current.

"The jet stream," Falconer continued, "in its meandering around the world passes over stormy areas as well as areas of fair weather. In fact, thunderstorms and heavy rain usually will be found under or close to the major axis of the jet. It's my feeling that some of the high positive charge generated in the stormy areas gets into the jet and is carried along with it. Soon the jet moves out over a fair weather region and you get a high positive reading on your collector."

Falconer is optimistic about the point-collector technique to accurately locate the jet stream. A network of points throughout the U.S. could probably pin-point the jet to a high degree. Although the one at the Laboratory can detect the presence of the jet within 150 miles or so, there is some indication that the positive readings are at a maximum when the major axis of the jet is directly overhead, and that the readings decrease on both sides of the major axis.

A combination of the cloud types and point-collector methods of locating the jet stream would be ideal and relatively inexpensive, according to Falconer. When there are no clouds in the sky, the point collector would do the job alone. "And if your collector were indicating jet activity, and you could see the right cloud forms, you could really pin the thing down." —PRH

American Institute of Mining & Metallurgical Engineers

By EDWARD H. ROBIE

Geological and mining engineers were named as two of the five professional groups to be included in the American Society of Civil Engineers when it was formed in 1852. But 19 years later these two groups decided to form a society of their own—The American Institute of Mining Engineers—the second of the great national professional engineering societies.

Early History

Three mining engineers in the anthracite district of Pennsylvania issued the call for the first meeting, to be held in Wilkes-Barre in May 1871. They proposed an organization with ". . . two great objectives: First, the more economical production of the useful minerals and metals . . . Second, the greater safety and welfare of those employed in these industries." These aims persist to this day, although safety is now almost exclusively the concern of the Bureau of Mines, the National Safety Council, and individual State agencies.

Twelve of the 19 AIME officers elected for the first year were residents of the anthracite district. In those days hard coal was mined in almost as great a quantity as soft coal. The first oil well had been discovered only 12 years earlier.

Most of the iron made in the country came from the eastern magnetites. Steel was still a novelty—only 84,000 tons were produced in 1871. Fourteen thousand tons of copper were smelted, mostly from the native copper ores of upper Michigan. Lead production was 20,000 tons, zinc, 7000. Aluminum and magnesium were unknown, as was sulphur, except for a small amount from pyrite. The first Portland cement plant was built in 1871. Thus although both mining and metallurgy have been practiced for at least 5000 years, it is readily understandable that an urgent need for a professional society in the United States to serve practitioners did not precede the AIME.

During the first 40 years of its existence the Institute was largely a one-man show. Dr. Rossiter W. Raymond—one of the 22 men present at the first meeting—served as president for three years, secretary for 27 years. "He was the mainspring of the activities of the Institute, its presiding genius, its chief spokesman." A golden life-size bas-relief of Dr. Raymond is displayed in the Engineering Societies Building in New York, just north of the main entrance. Under his direction the AIME achieved international recognition for the high quality of its published papers. Its membership increased about 100 each year from 1871 to 1910 and comprised the top men of the profession. Some 30 percent lived outside of the United States. Through rates of exchange and the restrictions of war this percentage has now decreased to 15 percent of a membership that currently totals 19,000.

The AIME moved into its new home on 39th Street in New York in April 1907, along with the Mechanical and Electrical engineering societies. Andrew Carnegie, an AIME member, provided $1,050,000 for the building, and each society put about $200,000 into the land. The building is now inadequate for its purpose and plans are under way for a new home.

Physical metallurgy began to be important early in the 20th century. In 1907 a separate professional society—the American Brass Founders Society—was formed. Five years later its name was changed to the American Institute of Metals. And in 1918 this group joined forces with the Mining Institute, whose name was enlarged to American Institute of Mining and Metallurgical Engineers, Incorporated—truly a formidable title. But the official abbreviation remained AIME, however. The physical metallurgists formed the Institute of Metals Division of the Institute, the first of its professional Divisions.

Organization

With the growth of the petroleum industry in the last half century, many mining engineers entered that field. Their increasing numbers resulted in the formation of a Petroleum and Gas Committee of the Institute. So vital was this group in the AIME that the Petroleum Division was formed in 1922. Other professional Divisions were formed in this sequence: Iron and Steel, Coal, Mineral Industry Education, Industrial Minerals (Nonmetallics), Minerals Beneficiation, Extractive Metallurgy, Mineral Economics, and Mining, Geology, and Geophysics. Practically every type of professional interest in the mineral industry now has a Divisional home in the Institute.

The 10 professional Divisions are grouped into the three principal Branches of the mining industry . . .

- Mining—a Branch embracing half of the Institute membership and comprising Mining, Geology, and Geophysics; Minerals Beneficiation; Industrial Minerals; and Coal;
- Metals—a Branch accounting for one fourth of the AIME membership and comprising Extractive Metallurgy; Iron and Steel; and Institute of Metals (physical metallurgy);
- Petroleum—a Branch embracing the remaining quarter of the Institute membership and consisting solely of the Petroleum Division.

Two Divisions—Education and Economics—remain outside of the Branch organization. The former embraces the educators who have their own teaching problems but whose professional interests extend into the fields of the other Divisions. Those whose interests lie

Mr. Robie became AIME Secretary in 1949. Prior to this he served as Editor of Mining and Metallurgy *and as Assistant Secretary of the Institute for 16 years.*

MOUNTAIN OF COPPER ORE, BINGHAM CANYON, UTAH—REMOVAL OF 135,000 TONS OF ROCK PRODUCES 92,000 TONS OF ORE DAILY.

primarily in mineral economics also cannot be confined to any one or two of the three Branches.

The Branch setup—peculiar to the AIME among all the national engineering societies—was developed to meet a special need. Petroleum engineers have little or no interest in mining or metallurgy. A physical metallurgist or a steel man has but little interest in petroleum, geology, or mining.

Publications

Until a few years ago the AIME had one monthly magazine for all three of these Branch groups, but its appeal was largely confined to the older member whose professional interests and friendships were broad, extending throughout the industry. For the younger operating men something more specialized was needed. And so in 1949 AIME began to publish three new monthly magazines—*Mining Engineering*, *Journal of Metals*, and *Journal of Petroleum Technology*—one for each Branch.

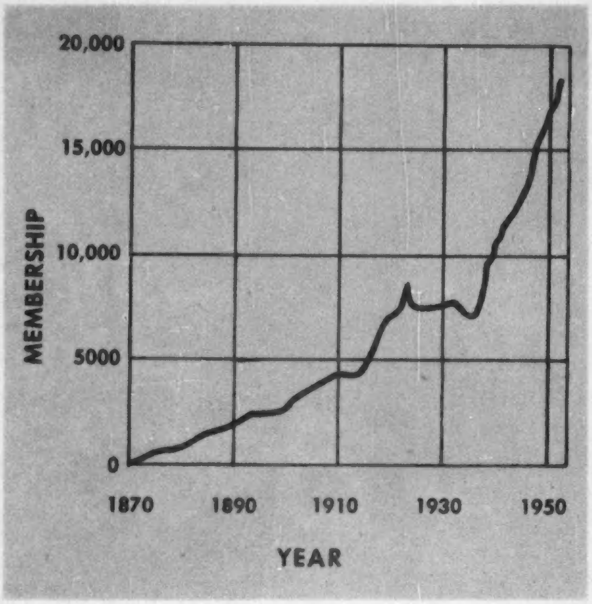
Common to all three journals are reports of actions taken by the AIME Board of Directors and news items of interest to all members. Each of the journals consists essentially of the three types of material: 1) *Transactions* papers—scholarly papers of permanent interest presented at Annual and Divisional meetings worthy of separate binding; 2) Advertising—directed to the Branch group that the specific journal reaches; 3) Feature articles of current interest, highlights of industry news, editorial comment, personal items concerning members, and the usual short material commonly found in technical magazines.

This new journalistic venture for the Institute has been highly acclaimed by members—and has naturally been attractive to advertisers, also.

At the year's end the *Transactions* sections of each journal are bound, making three annual volumes, one for each Branch. These are sold at cost to members who wish to keep the technical papers in permanent form. Other special volumes on specific subjects are published from time to time, their cost being underwritten by various funds established for the purpose. They are reasonably priced to the public and students, and Institute members enjoy a substantial discount. Some prove profitable for the funds that underwrite them: others are issued for the good of the profession without expectation of financial gain. And many are given free to Junior Members.

Publications of the Institute also include three annual volumes issued by the Iron and Steel Division, comprising the proceedings of the Blast Furnace, Coke Oven and Raw Materials Conference, the Open Hearth Conference, and the Electric Furnace Steel Conference. They are an authoritative and comprehensive record of American practice in these important fields. The volumes are given free to Conference registrants, sold to others.

Although perhaps the most tangible benefits of AIME membership, the publications are not regarded by many members as the most important. Many other publishers supply technical magazines, the subscription prices of which are considerably less than the cost of Institute membership. No other organization, however, offers opportunities comparable to the AIME for professional men in the wide mineral technology field to assemble, read and hear technical papers, discuss them, and become



CURVE SHOWING TREND OF GROWTH IN THE AIME MEMBERSHIP.


EXCAVATING A RARE METAL ORE FROM A SMALL MINE IN COLORADO

acquainted with other members. No other organization covering this great field has the committee organization, permitting a large percentage of the membership to join in a great co-operative effort to promote the welfare of the industry and themselves through the personal interchange of experience and the forming of invaluable professional friendships.

Meetings

By far the largest meeting of the year is the Annual Meeting, held in February. Every other year it is held in New York with an attendance numbering about 3500. In odd-numbered years the Annual Meeting is held in another city—Chicago, San Francisco, St. Louis, or Los Angeles—when some 2500 attend. Numerous other all-Institute, Branch, or Divisional meetings are held throughout the United States and many have been held in other countries—mostly in Mexico and Canada. Field trips to plants and other areas of interest to members are often a feature of these meetings, usually held in the late summer or fall. Attendance at such meetings frequently runs between 1000 and 2000.

Still more numerous are the Local Section meetings. Forty-nine Local Sections practically blanket the United States: others function in Mexico, Brazil, Peru, and the Philippines. Some have weekly luncheon meetings, many have monthly dinner meetings, and others meet at stated intervals during the year. Most of the meetings are primarily technical: others are essentially social, perhaps a dance or a picnic with members of the Auxiliary.

The work of the Auxiliary includes granting substantial scholarships to some 225 students, establishing libraries in remote mining camps, aids of various kinds to men in the armed forces, and helping to meet a variety of civic problems.

Most of the Local Sections have one or more Student Chapters of the Institute within their territory. They assist the Chapters in various ways and endeavor to instill a professional consciousness in the young men—and some young women—before they graduate.

Awards

Administration of funds to finance awards and medals for conspicuous professional achievement is one of the responsibilities assumed by most professional societies. The AIME possesses some $76,000 in endowed funds for this purpose. Gold medals or awards of other kinds are given for distinguished achievement in mining administration, coal mining, mineral beneficiation, nonferrous metallurgy, mining technology, and in petroleum production. Other medals and awards are specifically limited to men not over 33, 35, or 40 years of age for conspicuous technical achievement, for writing the best paper published by the Institute, or the best paper on a specified general subject. Most of these honors become a feature of the Institute's Annual Banquet.

Students are not neglected in these awards. Many of the Local Sections give prizes for the best student papers offered, or presented before the Section. The best of these ultimately win recognition in the annual national student prize-paper contest, with five prizes of $100 each.

Membership

Membership in one of three classes is offered in the AIME. Junior Member is normally the grade attained immediately after graduation. At the age of 33 the Junior Member must change his status to Associate Member or, if he has at least six years of experience and at least three years in positions of responsibility, he can attain the full professional grade of Member.

Many prominent people have been on the AIME roster. Herbert Hoover—former President of the United States, and President of the AIME in 1920—is, of course, our outstanding member. Of the present members of President Eisenhower's Cabinet, the Secretary of the Treasury, George M. Humphrey, joined the Institute 31 years ago; Secretary of Defense, Charles E. Wilson, 11 years ago.

What does one get out of a professional society like the AIME? Everything that our forebears have put into it, if we are but sagacious enough to claim our heritage. Ω

1910 Walker Brothers' mechanical dishwasher, predecessor of the General Electric machine on right, sold for $20.

1953 Electric dishwasher washes and dries the dishes for a family of six in 47¼ minutes. It doubles as a dishwarmer.

Engineering the Electric Dishwasher

By G. H. WOTRING

Few tasks are more repetitious and distasteful to the average housewife—or her family—than washing a stack of dishes three times a day, seven days a week. You can see the picture: The hot soapy water reddens her hands and ruins her manicured nails. Meanwhile, the moist steam leaves her complexion oily, her hair hanging limp, and her disposition dampened.

Same in Old Days

The idea of a machine to rid the housewife of this dishwashing chore isn't so new as you might think. For the first patented dishwashing machine—using a paddle wheel to splash water over dishes—is on record as early as 1850. More surprising, a patent was taken out 15 years later for a dishwasher that operated on the principle still used in many automatic machines today. That is, an impeller located in the conical bottom of its cylindrical tank pelted soapy water at dishes set in racks above. (The impeller was rotated by a hand crank.)

Over 30 patents were issued for various types of dishwashing machines by 1900. Within the next few years Willard R. Walker and his brother, Forrest A. Walker, took up development of a dishwashing machine that was to be the predecessor of General Electric's dishwasher. This machine (above) was finally marketed in 1910. Holding few dishes, the hand-powered model was only 16 inches in diameter, but enough were sold to encourage the brothers to continue. Its price of $20, incidentally, included a free trial.

Off to a good start, the Walker Brothers equipped subsequent models with pulleys for gasoline-engine drive and, in 1914, with electric-motor drive. Their popular 1918 electric dishwasher, pictured on the next page, sold for $125. Even at this high price more than 300 machines were purchased. Finally, the postwar building boom of the early 1920's created a demand for their "electric sink"—a sink and electric dishwasher designed in a single unit

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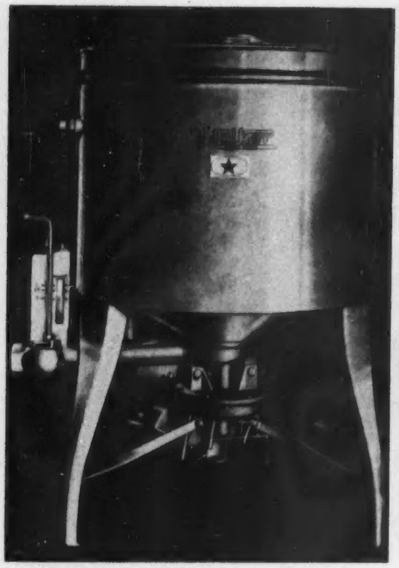
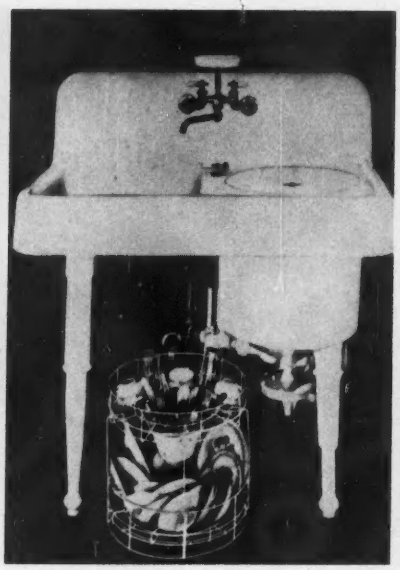
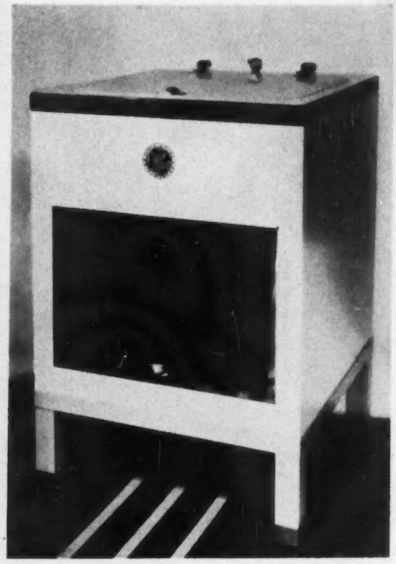
With General Electric for 24 years, Mr. Wotring has worked on design of clothes washers, electric blankets, and electrically heated aircraft equipment—and holds nine patents in these various fields. He is Engineering Manager—Dishwasher Development Engineering at Appliance Park, Louisville, Ky.



ELECTRIC DRIVE Walker Brothers' dishwasher of 1918 was a popular model. Priced at $125, more than 300 machines were sold.



ELECTRIC SINK was marketed by the Walker Brothers in early 1920's to satisfy demand created by the postwar building boom.



FIRST MACHINE bearing G-E trademark sold in 1932—two years after GE purchased control of Walker Dishwasher Corporation.

(photo above, center), and the brothers were well on their way.

In 1930, GE bought controlling stock in the Walker Dishwasher Corporation. Two years later the first machines bearing the General Electric name were produced and sold. Marketed in a 24-inch-wide unit (photo above, right), and in a variety of electric sink models, the machine was top-loading and manually controlled. It required 14 manual operations to wash one load of dishes.

Modernized Version

In contrast to manual operation of the first G-E machine of 1932, today's dishwashers are completely automatic. Designed as a single unit or as an electric sink, they are of the undercounter "drawer" type shown on the preceding page. The tub and assembly roll out from under the working surface on an extension slide for loading or unloading dishes. And the dishwasher automatically . . .

- Measures the proper amount of water into the tub.
- Introduces the detergent at the proper time.
- Circulates the washing solution and rinse water over the dishes.
- Drains the tub at proper intervals and prevents overflow at any time.
- Maintains water temperatures by supplying heat.
- Supplies both heat and air ventilation for drying dishes.

Washing dishes in water too hot for hands, the dishwasher's operating cycle (illustration, next page) lasts 47¼ minutes. It includes two 45-second prerinses, a five-minute wash period, and three 45-second rinses followed by a 28½-minute drying period. (The remaining time is used for draining and refilling the machine.)

Washing Process

A solenoid-operated water-inlet valve allows approximately one gallon of hot water to enter the tub during each 45-second fill period. The same amount of water is circulated during the wash and rinse periods, its temperature being maintained or increased by a heating unit at the bottom of the tub. About seven gallons of water are used to wash a load of dishes serving a family of six—less than the average housewife uses to wash an equivalent quantity. (Smaller families can store dishes in the machine from meal to meal for a full load.)

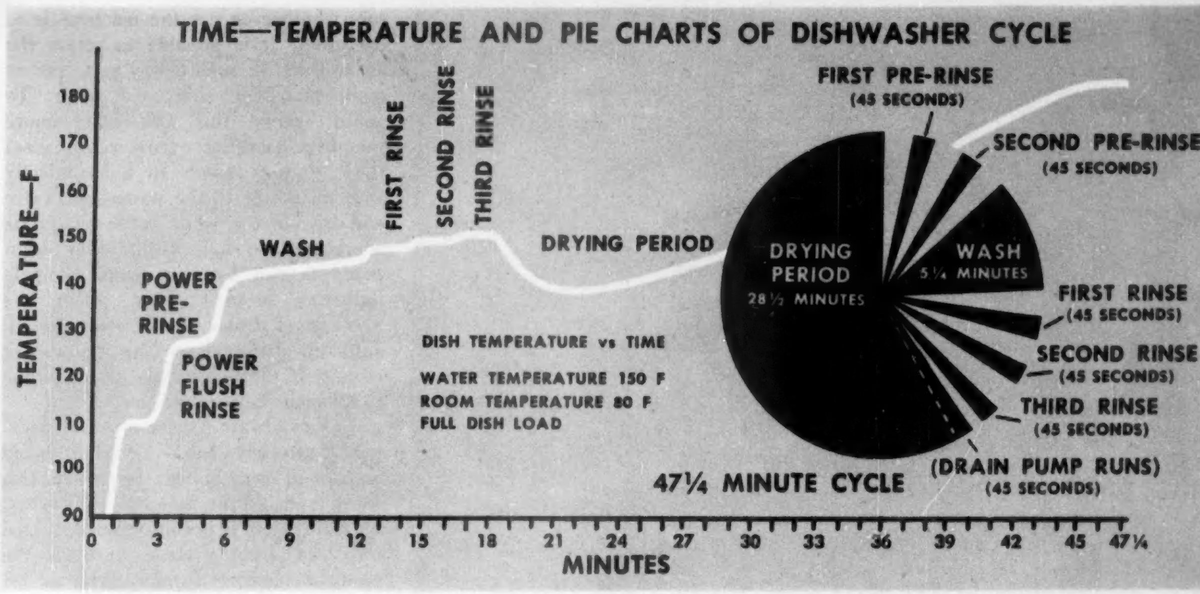
Dishes are held in two racks: one at the bottom of the tub and one at its top. Cups, glasses, silverware, and small dishes are placed in the top rack; larger pieces, in the bottom rack. (Racks are designed to facilitate equal spacing and proper positioning of pieces.) Beneath the bottom rack in a well of the tub is an impeller direct-connected to the machine's main motor.

Mechanical force of the swirling water and physical-chemical action of the detergent combine to remove food soils. The dishwasher's whirling impeller imparts a high velocity to the wash solution. Striking the lower part of each dish at an oblique angle, the solution spreads fanwise over its entire surface. Since the source of this stream is a two-bladed impeller, the force exerted on food particles lodged on the dish is pulsating in nature—and more effective than if it were continuous. Particles are buffeted until their adhesion to a dish is overcome. Borne along as the hot solution circulates, they are never allowed to rest, and are eventually flushed out the drain.

More Than Meets the Eye

But many factors influence electric dishwashing. The mineral content of water in the United States, for example, varies greatly. New England water generally is soft; that is, free from calcium and magnesium salts that react with soap to form hard lime films. On the other hand, Midwest water is medium-hard. It frequently contains dissolved solids that may cause white spots to form on dishes where drops of water evaporate. And, iron in water will oxidize and cause a reddish-brown stain.

With extremely hard water, a water-softener is almost a necessity. Even so, softened water will retain spot-forming solids. For water softeners used in the home do not remove the dissolved solids but merely replace the film-forming calcium carbonate with nonfilming sodium carbonate.



HEAT LOSS OF 150 F WATER SUPPLY TO DISHES AND TUB IS GRADUALLY COMPENSATED FOR BY A BUILT-IN HEATING UNIT.

The temperature of water introduced into an electric dishwasher materially affects its efficiency. For efficient electric dishwashing, the water temperature should be approximately 150 F. However, even where automatic water heaters are used, temperatures are sometimes too low because of occasional high demand, such as when washing laundry. An auxiliary heater within the dishwasher cabinet is one answer, but it adds to initial and operating costs of the machine.

A refrigerator will work no matter how items are placed in it. Not so with the dishwasher. Dishes must be loaded to conform to a definite water-dispersion pattern, and racks must be designed accordingly. Types of dishes must be considered too. Where dishes are dark in color, water spots otherwise unseen may stand out clearly. Silverware is still another consideration. If silverplate is thin or worn, some detergents bring copper to the surface and give it a brassy appearance.

A family's eating habits also affect dishwashing because some food soils wash off easier than others. For example, water-soluble sugars and syrups are easily washed away. So are fats when acted upon by a detergent. But certain other foods—such as egg yolk, mashed potatoes, rice, and oatmeal—cling tenaciously to dish surfaces and are difficult to remove.

Finally, dish drying is a combined function of temperature, dish cleanliness, and humidity. The machine must be designed to dry satisfactorily under all conditions normally encountered.

Detergent Another Factor

The fatty substances in soap react with calcium in hard water and calcium-containing foods to form an insoluble lime deposit on dishes. To remove this film requires a mild acid, such as vinegar. In fact, periodically washing dishes with vinegar was once a regular procedure in hard-water areas.

During the mid-1930's a new phosphate compound was discovered that did away with the problem. This softener combined with calcium in hot water in a way that prevented the latter from reacting with soap or alkalis. By compounding this phosphate with an alkaline cleanser and certain other chemicals, a dishwashing detergent was produced that almost eliminated lime film altogether.

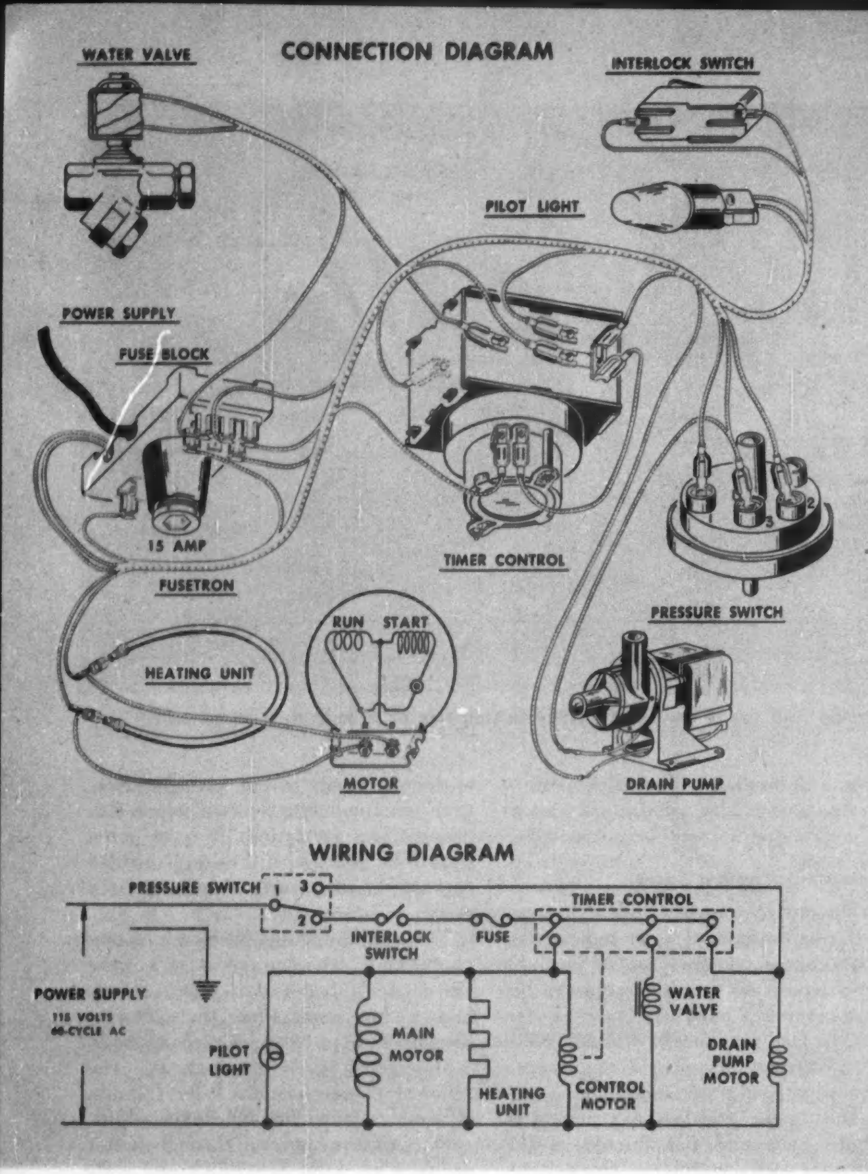
Technically speaking, detergents include all cleaning agents: water, soap, synthetic cleaning agents, laundry bleach, and so on. Their main purpose is to improve the soil-removal characteristics of just plain water, without leaving the lime film or water spots mentioned before. A detergent must not foam excessively. A blanket of heavy foam greatly reduces the water's mechanical scrubbing action and is difficult to remove without leaving streaks. (So far we know of no way to get good wetting without some suds.) Designed to dissolve easily in hot water, a detergent contains enough water softener to prevent film formation. It must penetrate food soils on dishes and dissolve or suspend them until they are rinsed away.

Through the years, dishwashing-machine and detergent producers have searched for better detergents. It was known for some time that laundry bleach—sodium hypochlorite—added to a detergent would improve its soil-removal characteristics. What's more, it would remove tea and coffee stains, even improving drying through better drainage of water from dish and glass surfaces. As a result of this finding, bleach or its equivalent is now added to some detergents in the manufacturing process.

Some Design Features

The dishwasher's two-bladed impeller, molded from a wear-resistant rubber-phenolic plastic, is surrounded by a metering band. This band meters water flow to the impeller, providing better water distribution and reducing surge. Also surrounding the impeller is a sheathed heating element. It not only maintains water temperatures of the wash and rinse cycles, but supplies heat for forced warm air during the drying cycle.

A tub of drawn steel—white porcelain-enameled inside—is fitted at the top with a gasket to insure watertight operation. Mounted below the tub and



FLOODING of dishwasher at any time is prevented by water-actuated pressure switch. Note in wiring diagram that switch is connected ahead of control circuit's fuse.

behind the dishwasher's front panel is the cycle-timing control—an electric timing motor equipped with cam-operated switches. It controls the entire operation. Its cams specify the time for operation of the various subassemblies.

From the timer, a shaft leads up to the housewife's control dial on the front panel. She starts the washing operation cycle by: 1) turning the locking handle down to lock the tub in place and start the main drive-motor, and 2) rotating the control dial a short distance to the left to start the cycle. A red light tells her the machine is in operation.

It's possible to interrupt a cycle at any time by turning the locking handle back to the horizontal position. This shuts off power to the cycle-timing control and drive-motor, permitting the housewife to add overlooked items. Then when she restarts the machine it will continue its cycle from the point of interruption. If she chooses to start a second load more quickly, she can skip the Dry cycle by rotating the control dial to the Off position and drying the dishes by hand.

The housewife can also use the dishwasher to warm dishes for serving hot food. When the control dial is at Dry, the impeller circulates air heated by the heating unit through the machine.

Added Insurance

A safety water-level switch—operating on a water-pressure principle—prevents too much water from entering the tub, whether or not the machine is in operation. It is possible to rotate the control dial in such a way as to put in more than one charge of water. To guard against this and other more remote possibilities, excess water causes the pressure switch to automatically shut off power to the water-inlet valve and drive-motor, while at the same time energizing the drain pump. (The drain pump is run by a separate two-pole induction motor.) Then when the water level drops, the pressure switch automatically recloses the dishwasher circuit. If the pump fails, the machine will remain inoperative.

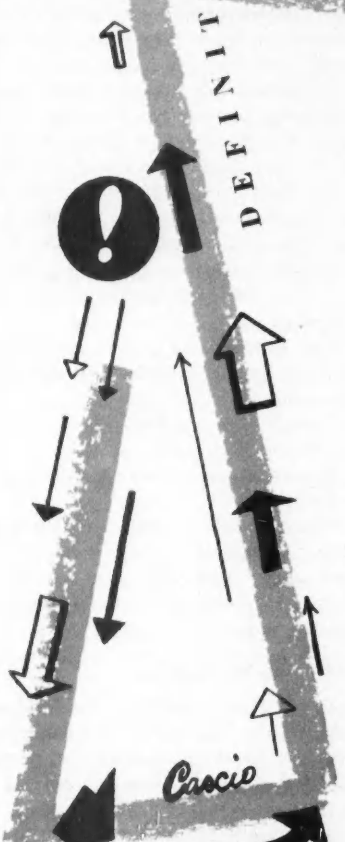
There's always danger of water backing up through a house drainage system because of some failure. To prevent this water from getting into the dishwasher, its drain pump is not directly connected into the drain system. Instead, the pump discharges through a nozzle set above a drain in the sink's working surface. Thus, an air space separates nozzle from drain and makes it impossible for a plugged-up drain line to contaminate the dishwasher.

The timer-control circuit—which includes the main drive-motor, heating unit, and water-inlet valve—is protected by a fuse. But connected ahead of the fuse is the pressure switch with a connection to the drain-pump motor. This way the pump will drain excess water as signalled even though the fuse in the main motor circuit has blown (diagrams, opposite).

Dishwasher's Future

Today, dishwashers are used in three percent of America's wired homes, and as you would expect, the business has real growth possibilities. The younger generation is becoming dishwasher-conscious, and builders are equipping more new homes with electric dishwashers than ever before. This increasing public acceptance, coupled with better performance, points the way to their mass production at correspondingly lower costs for the mass market.

Looking to the future, chemists are searching for detergents that will remove food soils in less time and also eliminate spotting in hard-water areas. Washing characteristics of the dishwasher are being improved. Racks to permit greater capacity and versatility are under study. Tests are under way that have as their goal the better and faster drying of dishes—preserving both the good temper and good looks of the American housewife. Ω



SOLVE DESIGN PROBLEMS WITH A CREATIVE APPROACH

By L. W. GUTH

Is creative ability born in a man, or can he consciously and deliberately develop this ability? Perhaps the answer is that a combination of both shapes creative ability.

Substantiating the theory that man can acquire and develop creative ability, it is believed that creative engineering is in part a combination of: 1) an active and inquisitive mind, 2) an inner drive that is satisfied only by a job well done, 3) a broad background of fundamental knowledge, 4) a creative approach to any problem.

The first two requisites are characteristics inherent in the individual; the last two can be stimulated and developed. The primary concern is with the fourth quality—a creative approach to design problems. But before taking this up, let's consider how problems are obtained.

Attention is generally concentrated on problems presented by a manager. To be most effective, a creative engineer must learn to sense a need rather than to have someone else do this for him. A true invention is made when an individual not only creates the form of the device but is also the one who recognized the need for such a device.

To develop to positions of engineering leadership an engineer must learn to discover and develop new devices and concepts beyond the expressed needs of industry. A feeling of constructive discontent must also be nurtured. Develop the habit of asking yourself: What other ways can we do this? How can we improve this? Why don't we have a device to do this? New methods, new devices, new improvements will not be found—unless you look for them.

When Sir Alexander Fleming observed the absence of bacteria around a spot of penicillin, he was *examining*. He saw the same thing many other scientists had seen. But fortunately, he did not stop simply with recording this phenomenon. Instead, he asked himself: What is the nature of this phe-

EVALUATION AND SELECTION OF METHOD

1—Cost
- **Development program**
- **Finished product**

2—Time allowed
- **For development**
- **For reaching production stage**

3—Accuracy
- **Sufficient for specifications**
- **Better than specifications**

4—Power requirements

5—Space requirements

6—Tools and machines available
- **Adequate for production**
- **New machines required**

7—Materials required
- **Common and easily obtained**
- **New materials or scarce materials**

8—Production difficulties
- **Standard tolerances and procedures**
- **High tolerances and involved processes**

9—Patent difficulties
- **All patents involved held by Company**
- **Patents held by competitors**

10—Appearance

11—Complexity
- **Operation (type of people who will operate it)**
- **Maintenance (type of people who will maintain it)**

12—Consequence of faulty operation

13—Versatility of application
- **Coverage of field desired**
- **Supersedes predecessor and competitors' device**

14—Operating environment effects
- **Corrosive atmosphere**
- **Dust**
- **Vibration and shock**

15—Safety features

nomenon? Can it possibly be of some use to mankind? Fleming was not only curious about the laws of nature but also willing to make an effort to carry on research and development of the ideas he had.

A willingness to contribute, accompanied by a mind prepared to explore new avenues, is essential to creative thinking. For the creative engineer, being content to devote full time to solving other people's problems is a form of mental laziness. Because an engineer's efficiency in thinking of *new* practical solutions is quite low, it is necessary that he be most prolific of ideas in order to produce a number of good inventions. The same applies to recognizing *new* problems. For example, hundreds of new ideas for new product lines were probably considered before the suggestion was made to produce the Disposall (Registered trade-mark of General Electric Company) kitchen waste unit. Still it was a result of continual searching for new conveniences for the consumers before the one idea that "took" was found.

Deliberate and organized thinking is a vital part of creative thinking. It is especially important in the early years of an engineer's experience that he learn how to improve his creative ability. He must increase his effectiveness to solve problems assigned to him and thus prove his ability before he is allowed to carry out his own projects.

The approach to almost any design problem may be broken down into four basic phases . . .

Definition of problem
Search for method
Evaluation and selection of method
Solution

These constitute only the idea stage of the solution. For if one is to produce consistently usable and worth-while solutions to problems, he must employ a creative approach.

Definition of Problem

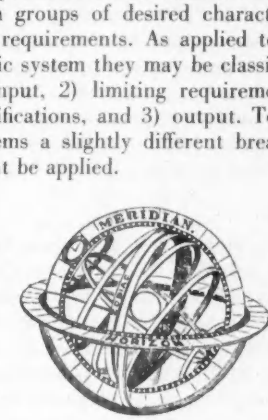
When the design engineer tackles a new project, he gives particular attention to specifications—the first and highly important phase of solving a design problem, often overlooked by engineers. By specifications we mean the actual definition of the problem wherein many more factors than rating, weight, size, and other quantities are considered: the engineer must endeavor to investigate the fundamental problem involved.

Not so long ago a division in GE desired to increase the rate at which the paper capacitors were wound. A machine wound the alternate layers of paper and tinfoil on a bobbin to make the basic part of a paper capacitor. When considering how these capacitors could be produced at a higher rate, the immediate solution seemed to be to increase the speed of rotation. But this resulted in tearing the paper. The people experienced in capacitor manufacturing then concluded the difficulty was caused by moisture and other conditions that weakened the paper in such a way it could not stand the high speed. Closer study disclosed however that speed had very little to do with the problem—it had all been a matter of acceleration. Use of electronic motor control to limit the acceleration of the machine easily solved this part of the problem. But still no increase in capacitor production resulted. So a time-and-motion study of the operation was made. This showed that most of the time consumed was spent in threading the machine and in feeding in the two little tabs that make the electrical connection between the plates and terminals on the completed capacitor. Thus, months after the program to develop a faster capacitor winder was started, the real problem was discovered. Perhaps the final approach seems obvious *now*, but all too often the obvious way becomes apparent only after costly false starts.

Consideration of liquid-filled capacitor leak testing reveals how more basic problems are often present. For example, if the container can be made leakproof, there is no need for leak testing. Even more basic would be a capacitor with the desired characteristics that does not use a fluid and hence has nothing to leak.

The more basic problem is not always easier to solve. The inventor of the revolutionary LP (long-playing) records took a more basic approach to the problem of producing continuous music than have those who developed the record changers. Likewise, in removing snow from city streets, man-made snow storms could be investigated as a means of keeping snow from even falling on city streets. From these few examples we can see the wisdom in the saying, "The more fundamental the approach, the simpler the solution." This is generally true because it means that the problem was thoroughly defined and the basic factors were considered in the forming of the solution.

After you make a complete definition, the problem can be broken into three main groups of desired characteristics and requirements. As applied to a dynamic system they may be classified as: 1) input, 2) limiting requirements or specifications, and 3) output. To static systems a slightly different breakdown might be applied.



The three groups can best be explained by considering a typical design problem. Take the design of a new type noiseless wall switch for home use: The specifications can be subdivided as. . . .

1) Input
   - Mechanical motion of activation knob
   - Only a small force desired to activate switch
2) Limiting requirements
   - Must fit into standard outlet box
   - Noiseless operation
   - Must work satisfactorily and safely with 110 or 220 volts ac or dc
   - Cost must be in range of standard switches
   - Long trouble-free life
   - Allowable drop across contacts
   - Current rating
   - Appearance
3) Output
   - Mechanical movements of contacts
   - Required time-and-motion characteristics to break arc

Although not complete and detailed, this serves to show how the groups can be arranged. In a relatively simple design complete quantitative data may not be necessary. Generally though, all dimensions, forces, voltages, and so on should be known quantitatively. If experience has been gained in the field, design sense or "feel" may give adequate measures. But to depend heavily upon mental extrapolation of past designs frequently results in costly failures.

Search for Method

Once the problem is completely analyzed and broken down, means of bridging the gap between input and output are sought. Here experience and background knowledge play the leading role. For in this area a keen mind with a true sense of design curiosity can reveal its vast store of facts on materials, processes, phenomena, devices, mechanisms—and more important—the sources of such information.

Some inventors believe there are at least eight ways of doing everything, and they strive to investigate most of them before making a final selection. In essence this belief is held by all highly creative people. A person is no longer creative when he becomes satisfied that a certain procedure is the *only* way: the creative mind is an active, nonhabitual mind that always seeks new and better ways of doing things. Not merely content to criticize the present system, such a mind weighs the "other seven" that might be employed.

Because of the number of ways that things can be done, depending on memory alone is often an inefficient way of uncovering the best possible means of solution. Jotting down in a notebook your ideas or any devices seen or conceived in the past will serve as an excellent refresher. Publications on inventions or mechanism also serve to suggest ideas and stimulate thought toward a new system.

Another way to stimulate creative thinking is to "search for power"—the attempt to perform the required motivation or sensitivity by electric, mechanical, hydraulic, electronic, or chemical means. For example, in measuring temperature it is possible to use energy converters such as thermopiles to produce electricity, bimetal to produce mechanical energy, expansion of fluids and gasses to produce hydraulic or pneumatic pressure changes.

The method of attack for the more complex problems—seldom solved by a single step—becomes one of successive development or synthesis leading from the input to the final output by successive stages. You should seek all the basic or fundamental theories and phenomena that might be applied to the solution. The creative engineer must objectively approach this synthesis unhampered by a leaning toward a particular field of engineering.

As an example of synthesis, let's consider the design of a thermal cutout for a motor. The input would be heat. And the first part of the synthesis would be a search for all phenomena that respond to application of heat. In the next stage you would consider the "output" from these individual phenomena

"Organization . . . will aid rather than hinder creative thinking."

as the "input" to the next successive stage. This method recently led to the invention of an improved thermal cut-out based on a radically new application of the basic concept that mercury will boil when enough heat is applied.

By using the method of synthesis you can produce a more creative and successful combination. The young engineer attempting to visualize the solution in one step may want to adopt a standard system rather than seek a new combination that might be better. Only after considerable experience can an engineer expect to think of a complete system with much consistency unless he has made a thorough synthesis.

In the search for method it is important that it be unhindered by judicial thinking. All ideas, regardless of how fantastic, should be noted—the imagination works best when unrestrained. Think of the skepticism "conventional thinking" could have introduced in the early contemplation of releasing the almost unbelievable amount of energy available in the atom. And not too long ago capable engineers "proved" that the ramjet engine wouldn't work. Fortunately, the engine didn't know that. Besides, at this point, methods are being sought, not selected.

Evaluation and Selection of Method

In the next step—the evaluation of the various methods—each system must be thoroughly considered as it affects all the design requirements. You should place particular emphasis on time and economic factors. Each problem will largely determine the weight a given factor carries in the final selection. You'll find some of these factors listed on page 56. Not all of the items, however, apply to all development and design problems. In the early stages of a development program the requirement of new tools and machines may often be set aside until samples have been built and tested. Test results can then help determine whether retooling is feasible. The decision for timing all the factors of evaluation into the development program rests with the engineer. He may even recommend a change in the specifications if his evaluation shows that a better product would result.

Sometimes the evaluation of the methods will show the necessity of redefining the problem and of making a new search for method. Preliminary tests and mathematical calculations should be made to verify expected results. Inadequate application of engineering fundamentals in the early stages will usually result in loss of time, money, and prestige.

Solution

When working out the details of the method selected, the various steps are repeated on the components required. Thus the phases are used simultaneously in other than simple problems, and each portion of the design is evaluated as the details are solved. Component designs should be checked with the specifications of the over-all design and the listed requirements of the component.

Beware of the fascinating tangents that lead the unwary astray. Stop digging at details occasionally and look at them in the light of the over-all job. Keep your nose to the grindstone, but do not become blinded to the total picture of the subject.

When the problem involves primarily test work or calculation, you should remember that the numbers you obtain are seldom a saleable item but rather pose the question: "So what?" In other words, you are not finished until you can show how the results affect the finished product. Having lived with the details of the analysis or test, you should be able to make recommendations to improve quality and price of the device.

Strive to meet all specifications and time schedules by proper planning. Have parts completed in sequence that will best permit partial testing. Do not delay design and construction of one part that will needlessly prevent proper testing of many other parts. Keep in mind that instructions for manufacturing and operation can be as important as the design itself. The customer may not know exactly how to operate your brainchild unless you tell him.

Little details are important too—nuts, bolts, washers, and bearings are part of the design. Perhaps the draftsmen can select these for you, but it is your responsibility to check and approve all of these "minor" details. Little things like insufficient wrench clearance to requiring special adjustment tools can destroy the market for a particular model. In the final analysis the proof of the solution is in customer acceptance and profit to the company.

Practicability

The processes as outlined here are recommended as a guide in establishing your own approach. After you gain practical experience in a given field, your early methods of attack will be modified accordingly. Time and effort spent on analysis and search for method and evaluation may be reduced by previous consideration of similar problems.

The first four stages of a creative approach given earlier in the article are somewhat flexible in application and must be employed as dictated by the problem. Such organization of mental effort will aid rather than hinder creative thinking.

The definition must be a complete breakdown and study of the design data and requirements. And the fundamental or basic problem should be sought. Grouping of facts and characteristics into input, limiting requirements, and output must be well considered if the final design is to meet specifications.

The second stage—search for method—is the place where creative thinking can be stimulated. Here the use of synthesis in the search for a method is apt to be most creative. Fundamental theories and phenomena are the keynotes of this synthesis. The basic plan might be the search for power or the seeking of the eight ways. Keep your judicial mind suppressed in this phase.

In the evaluation stage the engineer picks the most practical system from the standpoint of engineering and economics. His choice is not overinfluenced by the novelty and ingenuity of a method or by the established acceptance of a method. In short, he picks the best solution for the problem at hand, thus striving to be a practical creative engineer and not a Rube Goldberg.

The solution of the problem in a form suitable for practical use is the prime function of an engineer. All the factors determining the quality, adherence to specifications, and saleability of a product at a profit stand as a composite rating of the engineer that made it. Ω

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Mr. Guth is on an engineering exchange program in product design for the Electric Sink and Cabinet Department, Appliance Park, Louisville. He started his career with GE on the Test Course seven years ago; was advanced to the Creative Engineering Program which he later supervised for three years.

Industrial Architecture—

(*Concluded from page 21*)

life—such as repair and service shops—should remain within the city. In that way each function can be placed in its best possible environment.

Pictured in this article are photographs of but a few of the many possible examples of new factories that more or less meet this broad definition. The Trinity Industrial District, for example, is an area of more than 1100 acres located a few blocks from the downtown business district of Dallas. It is in a planned and restricted zone served by three major railroads and directly accessible to main highways entering Dallas, without passing through the congested downtown area.

General Electric's Appliance Park Project under construction at Louisville is a vast specialized undertaking consisting of five large manufacturing buildings, each having more than 10 acres under a continuous roof. This was designed by F. A. Fairbrother, Architect; George H. Miehls, Engineer; and Albert Kahn Associated Architects & Engineers Inc. At one end of each building is a sizeable office unit. Large parking and service areas are provided. To the west of the five buildings are the boiler house and other service facilities such as the mill water reservoir, the main power substation, and the industrial waste-treatment plant. Ultimately, a large warehouse for storage and shipping of finished products will be constructed. The manufacturing buildings have a steel frame with trusses spanning 100 feet. The over-all size of these units is 600 by 800 feet, indicating that they have been designed for straight line production and great flexibility.

General Motors Technical Center near Detroit is a campus-like development for research and development units, surrounding a mile-long lake. It is perhaps the most important group of industrial buildings yet created by modern architecture.

The Dodge Corporation half-ton truck plant near Detroit, designed by Albert Kahn Associates and built before World War II, is notable for its clean design. The roof monitors flood the interior with light. The trusses provide "hanging" space for the wash rooms, suspended in such a way that they do not hinder production. The exterior of the building can be looked upon as a handsome and elegant object, conceived with precision and machined like an industrial product. It has the same beauty that you can find in a piece of sculpture. Look at industrial architecture today and you may well question the old concept that "art is not art unless it is useless."

We have a new architecture. It is being carried forward by a host of progressive architectural firms from Boston to San Francisco and Dallas to Detroit who express the functional or occupancy requirements in their planning and design work. We will build great cities, wonderful homes and schools, and even more productive factories from the functional designs of these firms. If it is safe to predict the shape of things to come, let's say that the factories of the future may be influenced by two trends which are only now becoming apparent. The "automatic factory" may become a reality. In the chemical industries the control room has now become a pillbox on the side of a huge structure, and factories that are only skeleton frames, without walls, have already been built. This is only a startling preview of other types of "automatic factories."

But in the machine tool trades, man's skills are too closely allied to production. In these workshops the size and scale of the factory may more closely resemble the courtyard school in Texas—designed by Donald Bartheleme, Architect—with a greater emphasis being placed on the psychological factors involved in production. Such factors as the "feeling of responsibility," "togetherness," and "team spirit" on the part of the workers may play as influential a role in shaping the factory of the future as the use of cast iron has played in the past century. Of one thing we can be certain: the factory of the future will not look like a Greek temple! Ω

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44–45	Dr. Vincent J. Schaefer
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50	United States Vanadium Co.
55	Salvatore Cascio

Shell Molding—

(*Concluded from page 41*)

withstand the molten metal's metallostatic pressure. However, some small shells can be backed by spring-loaded mechanical fingers, while still others may require no backing at all.

Back-up material can be steel or copper shot, or quarter-inch gravel. Shot packs well, is dense and well-suited to a mechanized process, but when spilled on the floor it constitutes a safety hazard. Although gravel isn't slippery underfoot, its use in a mechanized process presents more of a problem because it's difficult to handle, lacks the permeability and density of shot, and is an insulator. (To date, shot is most commonly used.)

Newcomer Gaining Ground

Over a dozen companies are coming on the market with production machines for the shell-molding process. They offer two basic types: single-pattern and multiple-pattern machines. The single-pattern machine (photo, page 41) will produce about one shell a minute. Multiple-pattern machines—usually of the merry-go-round type containing from two to a dozen stations with a single pattern at each—are capable of turning out up to eight shells a minute. The speed of multiple-pattern machines is determined by the time needed to form the dough-like shell on the pattern.

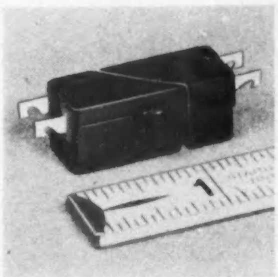
Jobbing shops and smaller production foundries use single-pattern machines, while foundries with long production runs prefer the multiple-station type.

Not mentioned thus far are shell cores, used with shell molds to cast hollow shapes. (A shell mold with its core inside is shown in the lower photo, page 41.) Shell cores can also be used with conventional sand molds. In many cases their material cost to the foundry is less than their solid-sand counterparts. And unlike sand cores, they don't absorb moisture. Shell cores also provide excellent means for venting gas because they are hollow.

The advantages of shell molding for the foundry industry are many. Smooth surfaces and intricately detailed products can be rapidly cast to tolerances of a few thousandths of an inch. Thus, expensive machining operations are reduced or done away with entirely. The result is a more saleable product that will eventually account for a sizeable portion of the industry's business. Ω

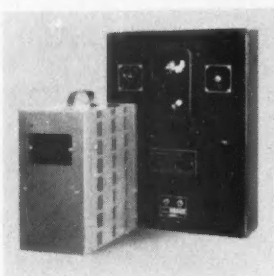
DIGEST

TIMELY HIGHLIGHTS ON G-E COMPONENTS



Switchettes are versatile, have high current rating

A wide range of design problems can be solved by G-E general-purpose switchettes. They are corrosion-proof, vibration-resistant, small, lightweight. Efficient at sea level or at 50,000 feet, in ambient temperatures from 200F to −70F. Ratings up to 230 volts, 25 amp. a-c; 250 volts, 25 amp. d-c. See Bulletin GEC-796.

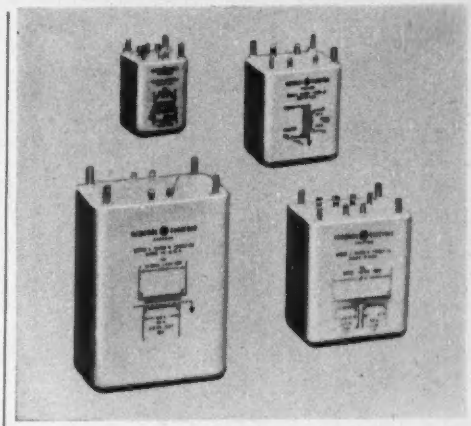


Inductrols—for automatic or manual voltage regulation

Compact design of G-E inductrols lets you fit them into any location. They offer micrometer-fine control, autotransformer efficiency. Hand-operated and automatically operated models are available for indoor service 600 v and below on circuits 3 to 520 kva. Bulletin GEC-795 covers single-phase inductrols; GEA-5824, 3-phase models.

New iron weighs only 8½ oz.

The new 120-v, 60-w G-E lightweight iron is designed for high-speed, production-line soldering on electronic, instrument, and communications equipment. Thin, 5/16-inch diameter shank gets the ¼-inch tip into places a regular iron can't reach. Balanced design allows the soldering of more joints per minute. Long-lasting Iron-clad tip needs no filing or dressing. See Bulletin GED-1583.



COMPLETE LINE includes 11 sizes

G-E cast-permafil* transformers designed to meet MIL-T-27 specs

The small, light design of General Electric's new line of cast-permafil transformers makes possible greater flexibility in many electronic designs. Sealing these solventless-resin-type transformers for life has eliminated the need for metal enclosures and fungus-proof coatings. Construction is simple—terminals are anchored directly in the tough, solid, shatter-resistant permafil mixture to cut size and weight by 20 per cent. Machined and punched parts have been kept at a minimum for lower cost.

Cast-permafil transformers have an expected life of 1000 hours or more at 130 C ultimate. The complete line of 11 sizes is available in various terminal arrangements, and is designed to meet MIL-T-27 (Grade 1) performance requirements. For more information, write General Electric Co., Sect. 667-25, Schenectady 5, N. Y.

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