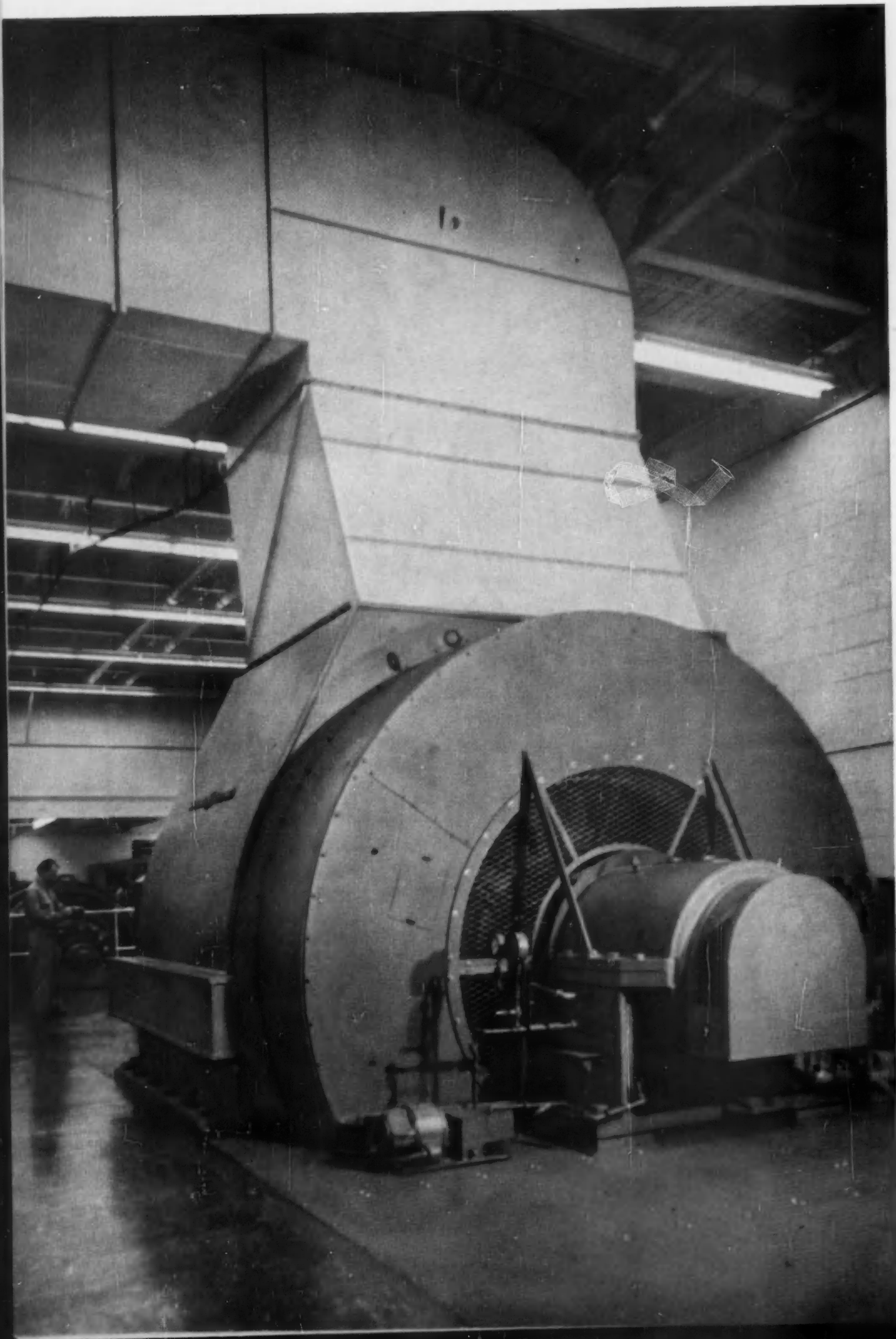
GENERAL ELECTRIC Review



MARCH 1956

Dr. H. G. Pfeiffer, A.B., Drew (1941), M.A., Syracuse (1944), Ph.D. in physical chemistry, California Institute of Technology (1949), came to the General Electric Research Laboratory in 1948. In addition to his studies of dielectrics, Dr. Pfeiffer's scientific interests include work in x-ray spectrography, spectrometry, statistics, and electrochemistry. He has been head of the Laboratory's dielectrics unit since 1954.

Dielectric research that can lead to improved insulators

Dr. H. G. Pfeiffer leads General Electric study group

Science has found perfect electrical *conductors* (several elements are "superconductors" at temperatures near absolute zero), but the perfect *insulator* has not been achieved — and may not exist. Although theoretical perfection may be unattainable, scientists are convinced that better understanding of "breakdown" and similar phenomena will lead to improved insulating materials for many practical applications. At the General Electric Research Laboratory a group led by Dr. H. G. Pfeiffer is finding significant new fundamental knowledge about the sources of electric strength. For example, their study of liquid insulators has shown why the *area* of electrodes has a substantial effect on transformer-oil breakdowns. Their work also has shown that the sparking potential of simple hydrocarbon gases can be predicted from molecular structure. Now Dr. Pfeiffer and his associates are applying insight gained from studying liquid and gaseous dielectrics to help solve the even more difficult problem of understanding what keeps electrons from moving through solids.

Progress Is Our Most Important Product

GENERAL ELECTRIC

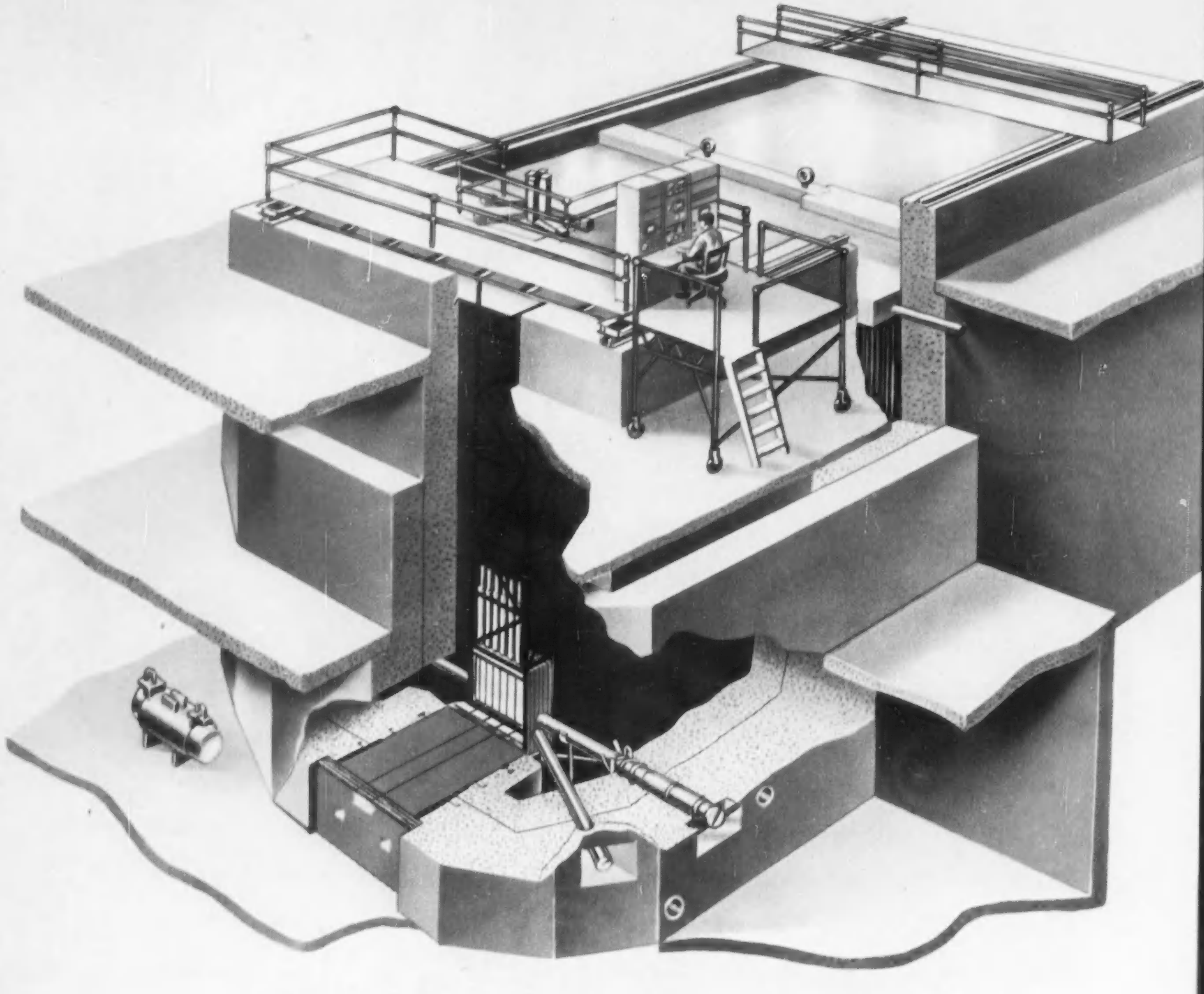
MARCH 1956 • VOLUME 59 • NUMBER 2

GENERAL ELECTRIC Review

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

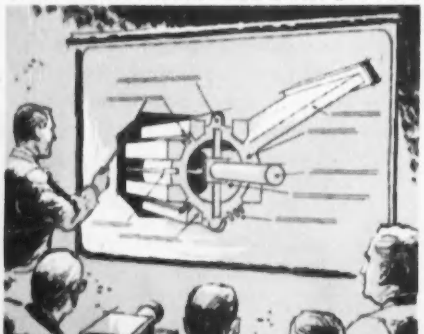
COVER—General Electric's Test Center in Schenectady contains a 60,000-kva synchronous generator driven by a variable-speed d-c motor. Its 4188 square feet provide room for switchgear and motor-generator sets for excitation and drive power. This source of variable frequency and power factor permits accurate testing of large rotating electric machinery. Ektachrome by George Burns.

THE GENERAL ELECTRIC REVIEW IS ISSUED IN JANUARY, MARCH, MAY, JULY, SEPTEMBER, AND NOVEMBER BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NY, AND IS PRINTED IN THE U.S.A. BY THE MAQUA COMPANY. IT IS DISTRIBUTED TO SCIENTISTS AND ENGINEERS THROUGHOUT INDUSTRIAL, CONSULTING, EDUCATIONAL, PROFESSIONAL SOCIETY, AND GOVERNMENT GROUPS, BOTH DOMESTIC AND FOREIGN. . . . THE CONTENTS OF THE GENERAL ELECTRIC REVIEW ARE ANALYZED AND INDEXED BY THE INDUSTRIAL ARTS INDEX, THE ENGINEERING INDEX, AND SCIENCE ABSTRACTS. . . . SIX WEEKS' ADVANCE NOTICE, AND OLD ADDRESS AS WELL AS NEW, ARE NECESSARY FOR CHANGE OF ADDRESS. . . . ADDRESS ALL COMMUNICATIONS TO EDITOR, GENERAL ELECTRIC REVIEW, SCHENECTADY 5, NY.



SWIMMING POOL REACTOR, one of three G-E research reactors available under the 7-point program, is designed to produce large quantities of neutrons. Its flexibility, safety features, and high flux potential appeal to universities and research organizations.

NEW GENERAL ELECTRIC 7-POINT PROGRAM:



1 REACTOR SPECIFICATIONS are prepared to meet your research requirements. These include a report on core, control, and reactor components.

2 BUILDING STUDY also includes complete co-ordination of all plans for the many facilities required in the reactor and laboratory buildings.

3 HAZARDS SUMMARY REPORT: We help you prepare study for submission to AEC Division of Civilian Application.

How General Electric can help you enter advanced nuclear research fields

New G-E 7-point program simplifies procedure for obtaining a nuclear research reactor

There is more work involved in obtaining a nuclear reactor for advanced research than simply ordering one. Specific research requirements must be determined beforehand, an appropriate design selected, and necessary AEC construction permits and licenses obtained. Other essential steps are covered in the program outlined below.

NEW GENERAL ELECTRIC 7-POINT PROGRAM is a plan designed to materially aid you in putting a research reactor to work. Through this program you can obtain any one of three General Electric research reactors: The Swimming Pool Reactor, Heavy Water Research Reactor, or the Nuclear Test Reactor.

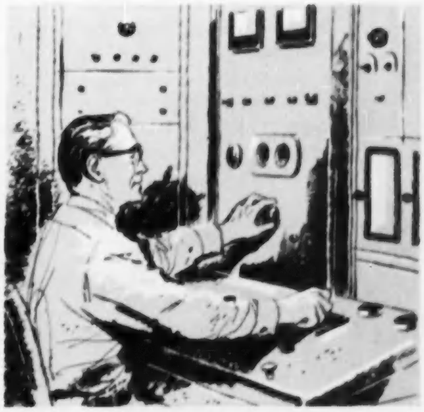
FOR MORE INFORMATION on these three research reactors and the new General Electric 7-point program, write for bulletin GEA-6326, General Electric Company, Section 191-1, Schenectady 5, N. Y.; or contact your nearest G-E Apparatus Sales Office. Outside the U. S. and Canada, write to: International General Electric Co., Inc., 570 Lexington Ave., New York, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC

4 MANUFACTURE OF REACTOR is accurately co-ordinated with other construction plans, thereby assuring centralized project scheduling.

5 REACTOR INSTALLATION is completed at the site by the men who have followed the design and manufacture of the complete system.



6-7 START-UP AND SERVICE by experienced personnel is added assurance that proper operation of your nuclear system will be maintained.

THE ENGINEER AND HIS DREAMS

On Tuesday, January 31, this year, Leonid A. Umansky, esteemed General Electric engineer and a friend of all who have been privileged to know him, was presented the highest medal awarded by the American Institute of Electrical Engineers—the Edison Medal. This award was made in recognition of accomplishment throughout his engineering life: his continual envisioning of opportunities for the enormous output of products from industry for the American people. His dream was the electrification of industry. Today it is a living reality.

Umansky, born in Russia, July 23, 1890, came to our United States of America in December 1915, entered the General Electric Test in February 1919, and became a citizen of the United States, February 4, 1927. Of this he has said:

> "I came to this country over 40 years ago with a college education and very little else. Here I got the opportunity to be a free man, to work in my chosen field, and to develop to the limit of my own ability. This country and its people have adopted me as one of their own. And for this I am deeply grateful."

Just as Edison dreamed a dream of an electric incandescent lamp, so did Umansky 40 years later dream his dream of the electrification of our great manufacturing industries. Step by step he worked, day and night, to bring his dream into being. The record of his work is most impressive. Because it shows the continuous threads of activity so typical of the engineer, we have summarized it on the opposite page.

In your study of this record, you see the engineer applying his mathematical calculations to the physics of the phenomena to make them useful, telling others of his work, adding blocks of new knowledge to the structure of previous building, ever visualizing new opportunities ahead, ever advancing to new and greater accomplishments, ever climbing to greater heights. That is Umansky. That is the engineer.

One of the great strengths of our industrial vigor is the teamwork of the engineers of the electrical manufacturing companies with the engineers of the great industries of our land. Of this Umansky has said:

> "It was always stimulating to work hand in hand with my many friends outside General Electric, in customers' organizations and elsewhere. I know that we could not have carried on our work without their confidence, encouragement, friendship, and, very often, their initiative. Many of the things I have learned I learned from them. There is nothing finer than the cooperative engineering spirit which is alive in many of our industries."

And it was one of Umansky's industry engineer friends who said of him:

> "It was L.A.U.'s enthusiasm in all aspects of the particular job that he was working on that won the respect of our management, mill, engineering, and electrical personnel."

That's what engineering teamwork is made of.

Of young engineers in industry, Umansky has said:

> "In my work in General Electric, I have found that each new generation is better equipped for work than the preceding one. The younger men, themselves, are not necessarily better—after all they are made of the same clay. School training might possibly be more advanced. But what is most important is their desire to keep on learning and to broaden their knowledge. They seem to realize that a college diploma is nothing but a hunting license to hunt for more education. And they go and hunt."

All honor to our dear friend and engineer, Leonid A. Umansky, Edison Medalist 1955. He has worked with his associates to make dreams come true. He confesses that at times he does envy a little the younger generation of engineers who in the next 40 years will create, develop, and work with things, some of which exist only in our dreams at present, and many others of which are as yet beyond.

EDITOR

HIS DREAMS BECOME REALITIES

1920 Developed formula to calculate performance of flywheel motor-generator sets for mine hoists.

1922 Published in G-E REVIEW method of calculating steel-mill auxiliary drives.

Made tests to determine electric power required to roll hot steel strip, important for the development of continuous strip mills.

Made oscillographic tests of reversing blooming mills.

1923 Published method of calculating steel-mill drives with flywheel.

Published in *AIEE Journal* method of mechanical computation of root-mean-square values.

1924 Presented before AISE a paper titled "Selection of Reversing Drives for Rolling Mills."

Presented before AISE a paper titled "Adjustable Speed Drives for Rolling Mills"—still the only review available on a-c adjustable-speed drives.

1925 Developed new type of a-c adjustable-speed mill drives with interchange of slip energy between several drives.

Made tests on existing rolling mills to determine the feasibility of driving them with synchronous motors. This stimulated the use of synchronous machinery for this service.

1926 Recommended and applied the first electrically driven flying shear following a continuous rolling mill. Successfully installed in 1927.

Published a mathematical analysis of performance of liquid slip regulator.

From this time on, worked extensively on development of electric drive for wide continuous strip mills.

1927 Personally investigated steel-mill practices in Germany, France, Belgium, Luxembourg, and England.

1929 Engineered first electrically driven start-stop bloom shear.

1933
1934 Worked on development of cold-strip mills. Developed an indicating and regulating tensiometer.

1935 Investigated and published with T. M. Linville analysis of transient speed regulation of d-c motor drives. This was a novel approach to the subject, as theretofore engineers did not recognize clearly the difference between steady-speed and transient characteristics.

1936 Developed automatic power factor control for large strip mills—the method now universally used in the industry.

1936
1937 Developed new method of driving runout tables and coilers for hot-strip mill using d-c motors. A Charles A. Coffin Award was granted for this accomplishment.

1937 Initiated development and encouraged wide application of amplidynes in steel mills. Directed first application of automatic pinhole detectors for cold strip.

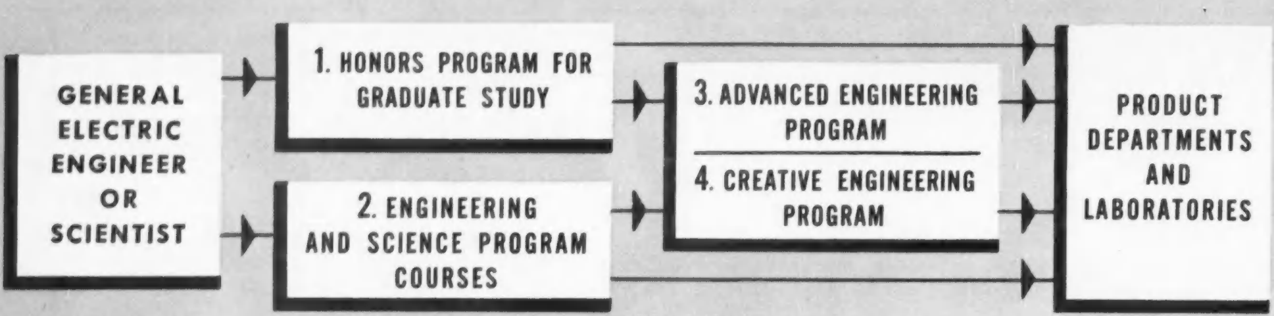
1939 Made first application in United States of America of power rectifiers for rolling mill drives.

1940
to
1945 Stimulated and encouraged development of modern industrial power-system practices; electronic control applications; power rectifiers for electrochemical, mining, and other industries; amplidyne applications in all industries. Organized an electronics school for industrial application engineers.

1945
and
on Stimulated application of rectifiers for printing-press drives and steel mills. Encouraged development programs and industrial applications of magnetic amplifiers and process instrumentation. Encouraged applications of gas turbines to pipe lines and locomotives. Organized training courses for application engineers, including a course on regulating systems.

Brought into closer participation the engineers in the AIEE Industrial Groups and initiated and advanced the AIEE Industry Conferences.

G.E. announces new Honors Program: latest addition to advanced-study opportunities



Further formal education as you learn and earn at General Electric

(1) Honors Program

G.E. selects qualified employees and reimburses them for tuition, fees, and books in connection with graduate study at universities located near G-E operations. You may participate in the tuition refund plan in one of two ways in selected G-E plant locations; by taking individual graduate courses while working a normal 40 hour week, or by carrying approximately one-half an academic load while working a reduced 20-hour week. You work full time and receive full pay during the summer months, unless time for thesis work is required.

(2) Engineering and Science Program Courses

Covering a variety of subjects—from engineering and production problems to product design and advanced physics—these G-E courses are the stepping stones to either the Advanced, or Creative Engineering Programs.

ADVANCED TECHNICAL COURSE consists of actual engineering problems in areas such as dynamics, electromagnetic fields, fluid flow, heat transfer, servomechanisms.

ENGINEERING DESIGN COURSE provides a background in materials, methods, and manufacturing processes, with instruction tailored to improve the engineer's design ability.

You may also take any of the numerous Specialized Technical and Departmental Courses that are continually offered.

(3) Advanced Engineering Program

To select and train technical leaders, this program combines extensive class and home assignments, with a 36-hour work week in association with Company technical leaders. The program is rigorous but the hard work pays off, for since its founding in 1923, 75% of its graduates have become engineering specialists and managers. Selection for the program requires either a Masters Degree or graduation from the Advanced Technical Course.

(4) Creative Engineering Program

This course is designed to help you make maximum use of your imagination and resourcefulness in solving problems and contributing new ideas. The number of patents registered by graduates of this program is almost double that of other engineers in General Electric. The one-year graduate-level Company course presents the latest techniques in creative engineering. Problems are worked on an individual basis or team basis. Complete facilities are available for construction of models and prototypes needed to demonstrate and develop any ideas.

For complete information write Mr. W. S. Hill, Engineering Services, Bldg. 36, General Electric Company, Schenectady 5, New York.

956-6

Progress Is Our Most Important Product

GENERAL ELECTRIC

ENGINEERS IN INDUSTRY

G.E.'s CLARENCE H. LINDER, *Vice President—Engineering, defines the challenge of technology.*

Industrial progress hinges on the engineers' ability to apply amazingly complex technology to the problem of creating new goods and services. It is vital that the engineer at G.E. be given every opportunity for self-development in his chosen field, and so the far-reaching educational programs described on this page are designed to satisfy three specific needs.

The Team Approach

The team approach to complex technical projects is extremely important in industry today. It brings together competent men with a wide variety of training and experience to blend their abilities in the solution of problems. To be prepared to work as a member of a team, the engineer must develop appreciation and understanding of the work and contribution of the other members. Recognition of this need is the basis of teaching philosophy all through the programs.

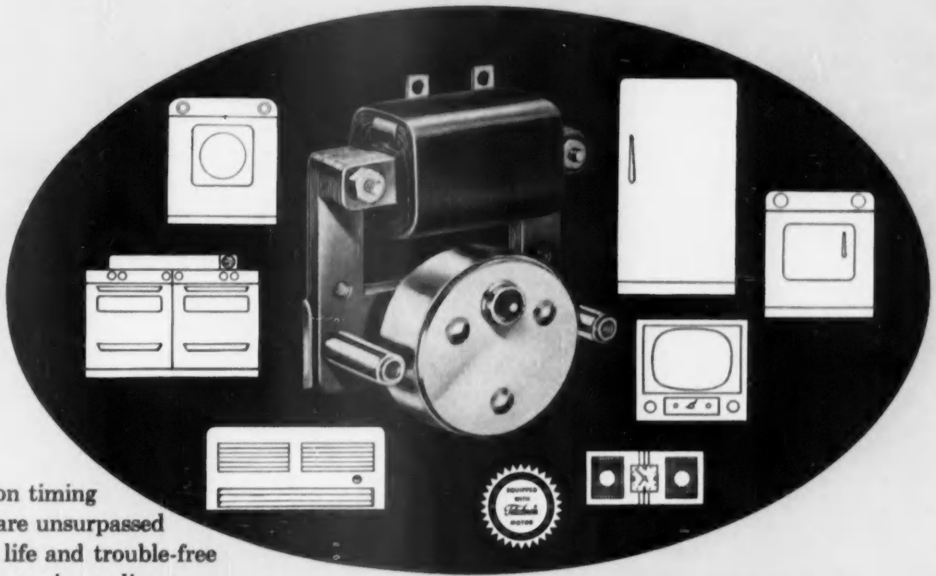
Importance of Supporting Sciences

Many of the problems facing engineers in modern industry are not found in the principal engineering sciences, but have shifted into areas which have been thought of as supporting sciences. An engineer working principally in aerodynamics, for example, may find the main roadblocks in his work are the limitations of the materials which are available. By working closely with experts in the field, the engineer must in fact influence the development of new and better materials.

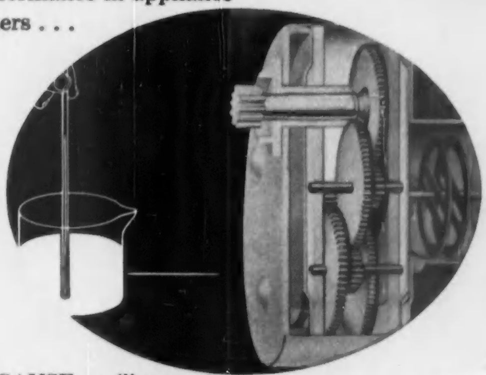
Broad Technical Backgrounds

The solid core of industry's engineering effort is a body of men thoroughly grounded in the fundamentals of basic science. With the explosive increase in technology, the engineer and scientist need to keep abreast of all allied areas. G-E advanced-study programs give this opportunity.

Why America's leading appliance timers are powered by the leader in timing motors!



Telechron timing motors are unsurpassed for long life and trouble-free performance in appliance timers . . .



BECAUSE capillary action feeds oil to moving parts. The oil, drawn up between the plates, furnishes a continuous source of lubrication for all bearings.

Telechron timing motors come in a wide range of speeds and torque ratings . . . rating for rating, a Telechron timing motor will outlast and outperform any other synchronous timing motor made.

BECAUSE rotor is so light it floats on water . . . lightness gives faster starts and stops without bearing wear. In operation, rotors virtually float in the magnetic field, with the rotor shaft supported on the film of oil in which it rotates.

For full information, simply write to or phone Telechron Timers and Motors, Clock and Timer Dept., General Electric Co., 223 Homer Ave., Ashland, Mass.

Telechron timers make sales easy—automatically

With SAC in North Africa

Review STAFF REPORT

Moving a large industry from one location to another takes a lot of planning, time, and money. A plant must be built or bought; production at the old site phased out; and employees selected, alerted, briefed, and moved. The old plant must be sold, and the company shutting down must do everything possible to ease the impact on the community. And during it all, products must roll off *some* assembly line in sufficient quantities to keep customers happy.

Many of these same problems beset the management of a Strategic Air Command Bomb Wing when it recently moved from a base in the southern part of the United States to one in North Africa, some 3000 miles away.

The Strategic Air Command (SAC) has a substantial investment in its medium Bomb Wings—some quarter of a billion dollars each, to be exact. The permanent facilities didn't move, of course; and because they still had to be there when the Wing returned after its 45-day mission, there was no searching around for a buyer and no worry in the community about men being out of jobs. But the items that did go on the mission make an imposing list: Boeing B47 *Stratojet* bombers (three squadrons, normally 15 planes each), a number of KC97 tankers, plus maintenance and support personnel and a substantial amount of equipment—everything from a can opener to a portable 36-bed hospital. This is enough to sustain a Wing at operating vigor for 30 days at an advance base where only a minimum of facilities exists. Thirty days would allow time for more conventional forms of supply to get organized. But it may all

be unnecessary; some observers believe that 30 days is far longer than any future conflict will last.

In regard to new plant facilities, the strain on the Wing was eased somewhat because it didn't have to purchase or build its overseas base. But it was the first Wing to go into one of the bases that had just been completed in North Africa, and the operation wasn't without its disruptive overtones. "Sure, there's some sweat," a Wing officer remarked, "but you never know if a new base is ready until you drop a Wing in and start operating. Then you find out a lot of things in a hurry."

An industry may take two years to transfer an operation, but SAC in less than a week moved this Wing as a routine gesture. And during the entire movement no one relaxed the constant alertness that is SAC's trademark. "If the whistle should blow . . . ," as the current phrase goes, the B47s of any SAC Wing can mount a full-fledged strike in a matter of hours, and an entire Wing can be pulled out of its home base in not much more time. SAC is a hard, tight outfit.

Also, no "production" as such had to be phased out at the Wing's home base for the simple reason that production never stopped before, during, or after the move. SAC's sole product is training hours, because more training hours mean more proficiency, and more proficiency means that a higher concentration of retaliation can be focused on the enemy.

The Wing Commander, a Colonel—tall, young, and fitting the popular conception of a scholarly college professor—heads this operational complex. A graduate engineer of Purdue, he has a long Air Force career, much of it with General Curtis E. LeMay, SAC's top man.

He has a corner office in the Wing Headquarters Building, a clapboard structure on the flight line at the base. He shares it with another colonel, his Deputy Wing Commander. The wood-paneled office has a carpet on the floor, venetian blinds on the windows, fluorescent fixtures overhead, and two somewhat worn oak desks. On the walls are pictures of President Eisenhower, General LeMay and other Air Force officials, and the ever-present cutaway of a B47. An incessant pipe smoker, the Wing Commander constantly swivels around to a large container of tobacco on the table behind him.

A FEW HOURS TO ANYWHERE: BOMBERS OF THE STRATEGIC AIR COMMAND—AT HOME OR OVERSEAS—ARE ALWAYS IN POISED READINESS.

He speaks clearly, slowly, and unsmilingly, with a touch of a Midwest twang. To him, SAC is part of the new era in the Air Force; the days of the "wild blue yonder" are gone. In its place, he says, is a dedicated group of young management men acutely aware of their mission as a deterrent force against war plus their responsibility toward the taxpayer by efficiently managing their investment.

"This is big business, and the sooner we can live down some of the glamor the better off we'll be," the Commander said recently, just before his Wing moved. "We have an investment in equipment and men, and we've got to keep them producing in the most efficient way that we know. We're not in this business to dedicate airports. Our job is to get the maximum number of bombs on the targets for the least amount of money."

His aircrews reflect the disciplines and attitudes of their leader. The average age of aircraft commanders is 33 (airmen are a younger group with an average age of 26); they've been married four years and have two children. Their job description and position guide is devoted exclusively to how they can become increasingly proficient in every aspect of managing two associates (pilot and navigator-bombardier), and an airplane worth $2.3 millions. The government has close to $450,000 invested in every aircraft commander, and the amount of time and training to get him to this degree of competence is about the same as that required to turn out a top-calibre surgeon.

An aircraft commander has about 4000 hours in the air; many of them have 1000 hours on B47s. General LeMay is constantly looking over everyone's shoulder.

You won't find any pin-up girls or other macules on the B47s of SAC. "After all," a lieutenant colonel remarked recently when asked about this, "we're 15 years older now."

The Wing received notice of its mission a few weeks before departure date. Soon after, a survey team flew to North Africa to study the local situation—housing, maintenance, facilities, traffic control, sanitation, local customs, recreation, and currency.

On their return, the information was printed and distributed to all personnel during a series of illustrated briefing lectures. Concurrently, arrangements were worked out with the Military Air Transport Service (MATS) so that support aircraft—primarily C124 *Globemasters*—could aid in the haul.

A move like this involves no frantic packing of items because they've been crated in flyaway kits and warehoused for months. Phase 1, 2, or 3, plus the weight, volume, and contents, is stenciled on each kit. Logistics officers know the exact location of every item in the warehouse.

The phase numbers are actually priority numbers—Phase 1 items sent first, followed by the others. Technicians are also assigned a priority, for equipment at an advance base is useless if it can't be serviced. But the coordination and planning call for even more than that. Because the Wing must always be ready to go into action—even during a training deployment—not all technicians of one type are shipped out at one time. During a move there will be, for instance, some radar experts at the advance base, some in transit, and some at the home base.

The Master Mobility Plan—a large loose-leaf volume about the size of the Manhattan telephone directory—beautifully delineates the entire logistics and planning procedure. It lists every necessary item, including human beings, plus weight, number required, and priority.

Initial steps of the movement consisted of sending contact teams ahead to various stations along the Wing's route. Part of their job consisted of integrating the mass deployment into normal traffic routines. When the actual movement began, the bombers, tankers, and cargo aircraft carried out their part of the operation with a high degree of polished skill. The entire action bore the imprint of many hours of meticulous planning.

Around the North African base the flat, semiarid land reminds one of El Paso, Las Cruces, and White Sands Proving Ground in New Mexico. The snow-capped Atlas Mountains, much like the American Rockies, form a dramatic backdrop; east of them stretches the Sahara Desert. Beside the long black-topped highway that passes near the entrance to the base, Arabs till the soil with single-point plows pulled by donkeys or camels. Overhead, some of the most complicated mechanisms ever devised by man leave their long vapor trails etched in the cobalt sky.

Wing Headquarters is a large two-story building of concrete block. On the first floor are maintenance shops; on the second, offices where Wing operations are conducted. When the Wing moved in, the building was empty; in some sections, Arab and French workmen were finishing construction.

Shortly after the bombers and tankers arrived, operations were almost at a peak. Equipment was requisitioned from the base warehouse. Diesel-driven generating units were set up outside the Headquarters to provide emergency power. Telephone and radio crews had highest priority. Central Maintenance Control was soon in full-blown operation, dispatching orders to armament, electronic, and engine technicians via radio. In the Armament and Electronics Building nearby, portable test equipment checked out radar and other equipment. (On training missions like this, the flyaway kits are not used. They are warehoused, and supplies are requisitioned from the base's supplies.)

"A deal like this is good for all of us," observed the Wing's Engineering Officer. "We have to use our ingenuity to get the job done. It's a lot of hard work, but I think we're all feeling better for it. There's real satisfaction in setting up an operation and seeing it get under way and into full swing."

An hour-long crew briefing was held in Wing Headquarters. It involved a rundown of local flying conditions, radio-range frequencies, corridor flying, filing of flight plans (in triplicate), ground control approach, what constitutes a formation (three or more planes), and overflying Spanish Morocco or Spain (prohibited unless diplomatic clearance is obtained, usually requiring three days).

Flight operations gained momentum, too. Multiplane bomb strikes were mounted a short time after the last B47 touched down. From then on, the tempo increased. In-flight refueling operations were standard procedure; B47s were constantly shooting landings and take-offs. Missions that involved grid navigation, radar bombing runs, celestial navigation, gunnery, and pressure-pattern navigation were daily routines. These training missions fulfill two objectives: increase the crews' proficiency and provide a deterrent force on a global basis.

On the following pages you'll follow a REVIEW editor and photographer in a pictorial tour showing various phases of this typical SAC overseas deployment . . .

"Moving a SAC Wing is like moving an outfit half again as large as Eastern Airlines," says the Deputy Wing Commander (left). To a B47 crew member (right), it means 40 to 50 hours of preparation—a discipline shared to an equal or greater extent by members of all crews.

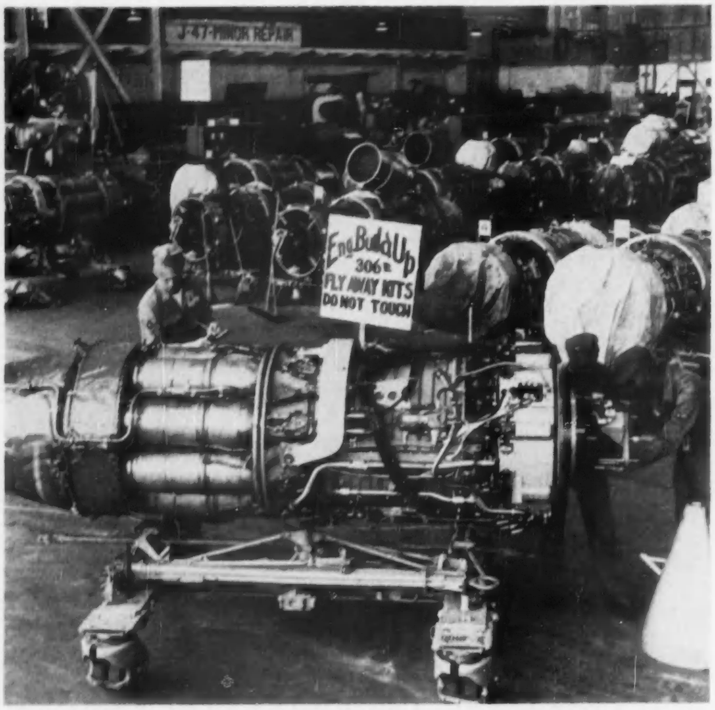
PLANNING: Every Item, Every Routine Is Documented; Nothing Is Left to Chance

Even though the Master Mobility Plan (above) completely coordinates and integrates every facet of a Wing movement to an advance base, there are still certain things that only individual crew members can do. Routes must be plotted, check points determined, engine power settings worked out, and procedures organized for every type of emergency. Crew members tote well-stuffed briefcases.

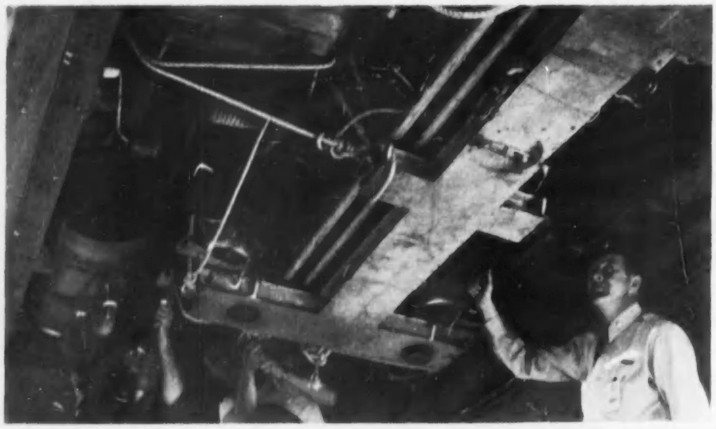
Although crew members put in long hours of individual study, teamwork is stressed to a higher degree in SAC than perhaps any other branch of the armed services. And teamwork pays off in another factor besides combat capability and skill—morale. It is not only high among the flying teams but also evident throughout the entire command—an impressive, overriding aura of pride-in-outfit.

FLYAWAY KITS are shipped on a priority basis, always warehoused and ready. Technicians move on a similar priority schedule.

BRIEFING of the Wing's 2000 men—important from a morale standpoint—includes a Survey Team report, "The Big Picture."



JET-ENGINE FLYAWAY KITS ARE ALWAYS READY. FOR A MOVE, SOME OF . . .



. . . THE *STRATOJETS* USE THEIR BOMB BAYS TO CARRY SPARE ENGINES.

STRATEGIC AIR COMMAND (Continued)

MOBILITY: "When t

Thoreau once* said, "The swiftest traveler is he that goes afoot." But it was never possible for Thoreau to lift his eyes above Walden Pond and see the thin white traceries of vapor trails and know that once more the aircraft and men of the Strategic Air Command were on the move. And today, if Thoreau traveled to Europe, Africa, Alaska, or the far reaches of the Pa-

SCOOTERS HAVE BEEN HUMOROUSLY LABELED, "SAC's SECRET WEAPON." BUT THEY'RE NECESSARY TO KEEP CREWS MOBILE ON LARGE BASES.

n the Whistle Blows," a Wing Can Move in a Very Few Hours

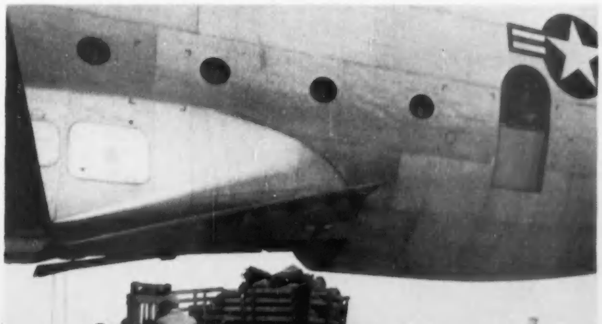
cific, he would see in the skies similar testimonies of SAC's global mobility.

SAC is responsible only to the Joint Chiefs of Staff. When JCS established the Command in 1946, they envisioned that SAC should be prepared at all times to conduct offensive strategic air operations on a global basis. Today, SAC can do just that.

A Wing can move with the studied competence of a training mission (photos), or it can blast out of its home base in the matter of a few hours—a feat that brings into play every aspect of skilled management and planning.

SAC men are gone many days of the year. Their families are adept at packing B4 bags on short notice, and their children have strong muscles from waving goodbye and welcome home.

And when they get back from a long training mission, there'll be more of the same. The Wing Commander said, "I wish I could give the crews and the troops a few days off when we return, so they could get acquainted with their families. But it can't be done. As soon as we're back, some of the boys will be off on other missions. But that's SAC . . . we have to be ready all the time. . . ."

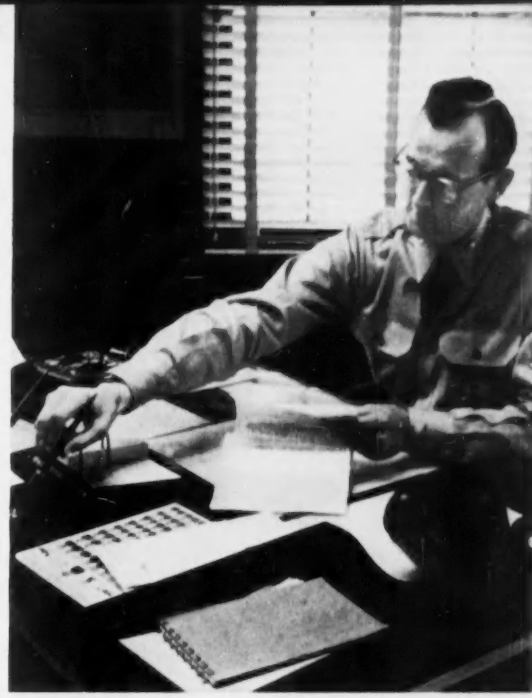


GLOBEMASTERS OF THE MILITARY AIR TRANSPORT SERVICE (MATS) HELP THE WING MOVE CARGO AND TROOPS FOR THE LONG-DISTANCE HAUL.

PROBLEMS THAT MAY HAMPER THE WING'S COMBAT CAPABILITY ARE CHECKED CONSTANTLY BY THE WING COMMANDER (RIGHT).

FACES OF SAC: CREW MEMBERS AND AIRMEN ARE SPECIALISTS WHOSE SOLE AIM IS KEEPING THEIR WING AT THE HIGHEST PROFICIENCY.

"Four-headed monsters" is a worthy name for SAC Aircraft Commanders. They not only are proficient in handling one of the most complicated and unforgiving pieces of apparatus ever devised by engineers but also are experts in navigation, bombing, and radar practice. And in the case of Wing Staff Officers, you can add a fifth head—that of talented management men who have all the abrasive responsibilities of operating a multimillion dollar business (left), as well as the persistent paper work (right).



MEN: They're a Mature, Dedicated Group of Family Men Whose Average Age Is 33

CREW BRIEFING SESSION: THERE IS A COMPLETE, SILENT INTENTNESS—AT ALL TIMES A SOBER REALIZATION OF THE JOB TO BE DONE.

ARMAMENT, designed and built by General Electric, is radar controlled and gives the B47 a heavyweight punch to the rear.

SECURITY is tight everywhere. The Wing took along its own Air Police who went on immediate 24-hour duty at the advance base.

The days of the omniscient Crew Chief are over in SAC. There's still one assigned to each aircraft, but he no longer knows everything about anything as he did during World War II. It's impossible. Today, problems of a complex nature are taken care of by squads of experts in the maintenance of engines, armament, and electronics. They're radio-dispatched from Central Maintenance Control, which services the entire Wing. Repair records are kept on punch cards. All this pays off; many of the B47s have more than 1000 hours on their G-E jet engines (below) without overhaul, a tribute to the engines, maintenance system, and the technicians of SAC.

EQUIPMENT: It

MULTIPURPOSE BOEING KC97 TANKERS GIVE A WING UNLIMITED RANGE AND CAN ALSO BE USED FOR MOVING CARGO, TROOPS, OR PATIENTS.

It Receives the Best of Care by Skilled Technicians

IFR

By the time you read to the bottom of this page, there's a good possibility that somewhere in the world a KC97 tanker of the Strategic Air Command will have refueled another aircraft in midair. Such a procedure takes place on the average of once every three and one-half minutes, 24 hours a day, seven days a week. In-flight refueling (IFR) is its name, and it means that only crew endurance limits the range of SAC bombers.

During the training mission in North Africa, the Wing flew IFR missions day and night, under all conditions. They were only a small part of the total of 150,000 hookups that the men of SAC make during the course of the million or so hours they fly in a year's time.

Watching the operation from the tanker gives you an eerie, suspended, slow-motion feeling. You look down through a big picture window, over the shoulder of the boom operator (often referred to as "Casey" in more lurid accounts), who lies in a prone position on the "ironing board" in front of you. You see the silver snout of the B47 come into sight, moving slowly back and forth and gradually easing toward a hook. The operator keeps the boom fixed until the bomber is in position—then he extends the nozzle and makes the connection (photo).

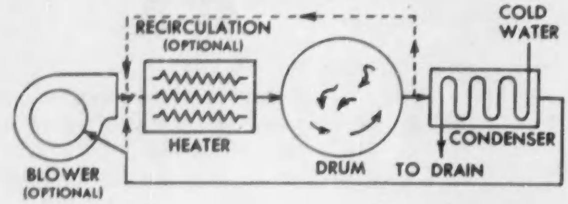
In all, it's a nervous operation, and requires a good deal of highly polished skill from the boom operator, tanker pilot, and the B47's key man.

The tanker must maintain a steady course at full power. The pilot knows when the B47 is approaching because he can feel the bomber's bow wave lift his tail. There's also a slight jar when they connect. If the B47 pilot is heavy-handed on the throttles, he can literally shove the tanker along by as much as 25 mph.

An aircraft commander of a B47 remarked: "There's not too much to a hookup in smooth air and with good men in the tanker. No sweat, even though there is some annoying back-wash."

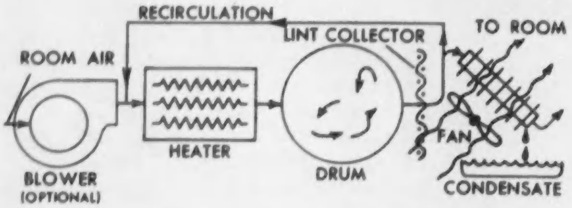
In rough weather, it's different. "In the dark, with turbulence and rain, it can be a real hairy operation. I really earn my flight pay." —PRH

CLOTHES-DRYER SYSTEMS . . .



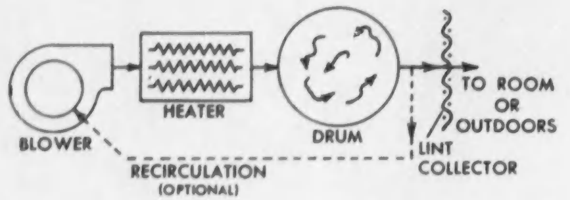
CLOSED CYCLE

Lint, moisture, and 60 to 90 percent of the heat go down the drain. This cycle requires no outside duct, but it does necessitate cold water and drain plumbing. Because plumbing is necessary for washing, all combination washer-dryers use this system. The dryer condenser uses 0.3 to 0.5 gpm.



OPEN CYCLE WITH AIR-COOLED CONDENSER

Use of low net air flow allows air to pick up five times as much moisture as a noncondensing design. Large volume flow cools the condenser that removes about half the moisture (two quarts a load). Because air condenses in the air duct, venting to the outside is difficult. If water is used to cool condenser, the closed-cycle system offers more advantages.



OPEN CYCLE

This system can be designed for either high or low air flow, with recirculation if desired. High air flow decreases air temperatures but not thermal efficiency. A blower can be placed at any point in the system; heat and moisture can be ducted outdoors.

Taking the Guesswork Out of Drying Clothes

By J. M. PINDER and R. L. DUNKELMAN

Today, three-million housewives pit their wits against their clothes dryers. When your wife sets the control timer on her dryer, she's staking her judgment against a machine loaded with soggy clothes. If she overestimates the time, diapers dry harshly and synthetic fabrics come out with deep-set wrinkles. Underestimating the time means starting the machine again or gambling on mildew. Your wife solves this problem as best she can by devising her own method for timing various clothes loads: although the technique may vary, it probably involves looking at the load, perhaps hand-weighing it, and factoring in experience and intuition.

But getting the clothes to dry properly makes only part of the story. Your wife also wants her dryer to condition fabrics by damp-drying them; sprinkling them for ironing; fluffing pillows; dusting drapes; giving a fresh, clean odor to fabrics; handling nylon as well as cotton; and occasionally operating as a space heater.

For a truly automatic clothes dryer, the control should not only satisfy all the above needs but also remove the human element insofar as possible from the drying operation, even if errors are made in setting the control. Such a control would end guesswork, overdrying, underdrying, and all the accompanying ills.

•

Both Mr. Pinder and Mr. Dunkelman began their G-E careers on the Test Course in 1951 and 1948 respectively. Later, while on the Creative Engineering Program, Mr. Pinder's assignments primarily concerned home appliances. He is now a development engineer, Home Laundry Department, Louisville, Ky. Until recently Mr. Dunkelman was a design engineer in the same department. He has since gone into business for himself.

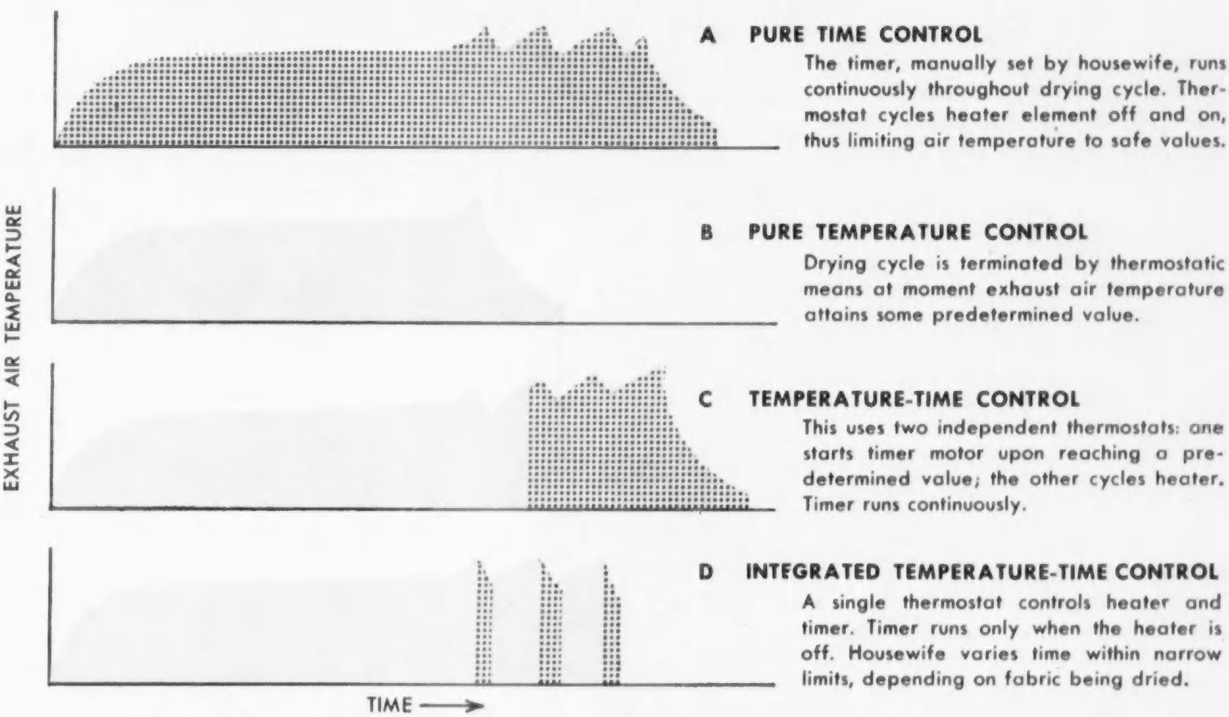
Development of such a control makes an interesting story.

Prior Control Systems

For an automatic clothes dryer today, the most widely used control—a motor-driven timer—runs continuously throughout the drying cycle (illustration *A*, opposite). Your wife estimates and selects the run time. The dryer is also equipped with a cycling thermostat that controls the rate of power input, thus limiting temperatures to safe values. Based on previous experience, your wife manually sets the timer to a position that she thinks will handle the load. But for accuracy, she must consider such factors as room temperature, voltage, humidity, type of fabric, amount of water in the fabric, and air flow.

To better illustrate the vicissitudes of time setting, let's look at a combination of only two of these factors and their effects on drying: ambient conditions

CLOTHES-DRYER CONTROLS . . .



DOTTED AREAS INDICATE THAT TIMER MOTOR IS ENERGIZED.

and voltage. To say that she may overlook both does not reflect on your wife's ability. For her prime motivation in setting a timer to a particular dial position is likely to be dictated by what she believes to be the size of the clothes load and the amount of water in it. She doesn't know if ambient conditions are ideal or if voltage is high or low.

For a moment, assume that you have purchased a dryer with a heater designed to dissipate 4600 watts at 240 volts. Suppose that the appliance is installed in the basement, where temperatures vary 30 F from winter to summer. Line voltage may fall as low as 220 volts. The total heat input will then differ from that at rated voltage.

The difference in the heat input from summer to winter under these conditions equals the power difference due to voltage variation, plus any differences in the available heat content of the incoming air. The difference due to voltage is

$$4600\left[1-\left(\frac{220}{240}\right)^2\right]=730 \text{ watts}$$

The difference due to inlet air conditions can easily vary from 0 to 1000 watts, depending on inlet air temperature and humidity. These two variables alone suffice to complicate accurate time estimation. A really bad estimate could result in overdrying or underdrying fabrics.

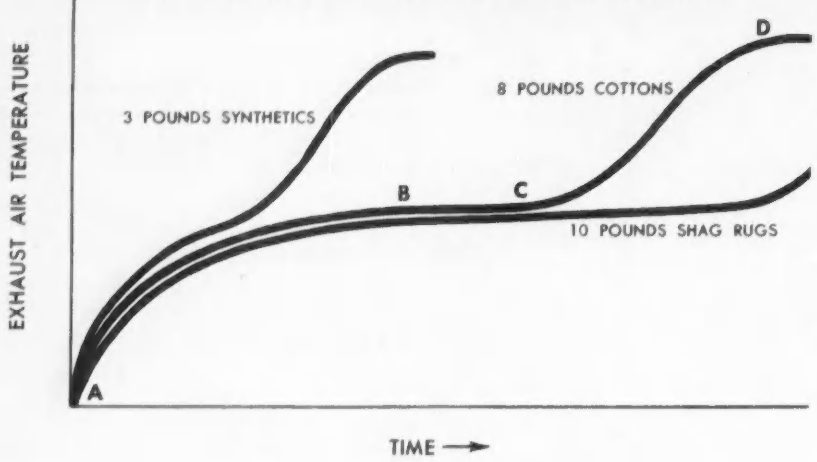
Underestimating the time results in damp clothes that are susceptible to mildew. This forces your wife to reset the control for additional time, and in so doing the machine loses a portion of its automaticity. Your wife soon finds that the appliance purchased as an automatic device is not so automatic after all but requires her periodic attention.

On the other hand, overdrying can give clothes a harsh feel or sometimes even damage fabrics. If the overestimation is slight, unironable wrinkles in both synthetics and natural-fiber materials could result. Worse, high-temperature tumbling after natural fibers are completely dry can produce serious damage: fracture brittle fibers, permanently impair water absorption, and decrease tensile strength. Because damage to synthetics is primarily a temperature phenomenon, extreme temperatures at the end of the drying cycle must be avoided.

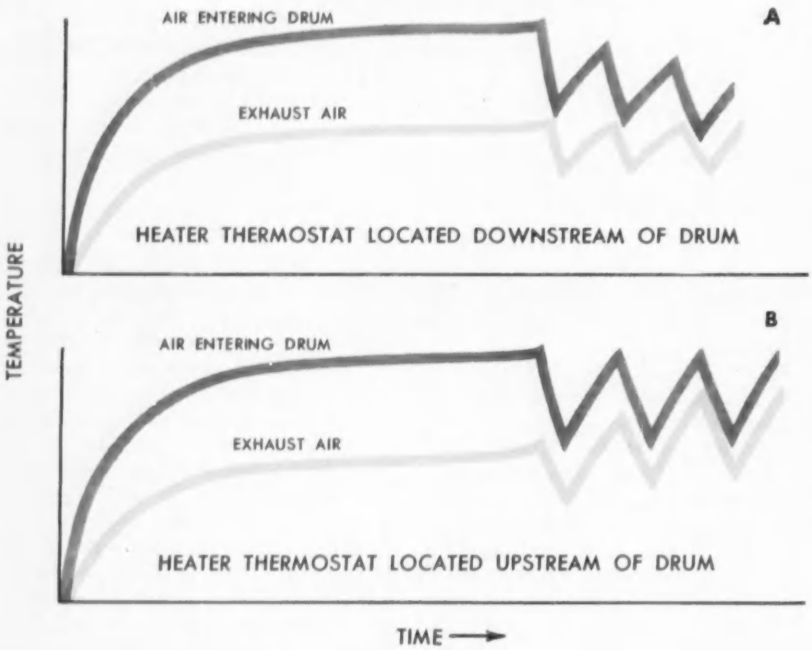
A relationship exists between temperature variation of exhaust air and time for several clothes loads in a dryer that has no temperature control and, therefore, constant heat input (illustration, top, next page). At the start of the cycle, most of the input power is used to warm up the system: metal parts, clothes, and water. At first, temperatures gradually increase until the first plateau region is reached, when the evaporation rate stabilizes because free water is available at the clothes surfaces. The duration of the plateau depends on the quantity of water in the clothes load. For small loads of synthetics, plateau *BC* is extremely short; on the other hand, if the load were towels containing 10 pounds of water, the plateau might well be 60 minutes. The plateau temperature changes little with various load sizes, other conditions remaining constant.

At the end of the first plateau region *C*, the capillaries of the cloth can no longer supply the surface with excess water at the previous evaporation rate. And so, the temperature of the exit air rises toward the second plateau *D*, because the incoming air now has more than enough energy to evaporate the available moisture. This abrupt upsweep in the exit-air temperature in region *CD*

DRYING CLOTHES WITHOUT TEMPERATURE CONTROL



EFFECT OF THERMOSTAT LOCATION ON TEMPERATURE PATTERNS



PERFORMANCE DATA ON AUTOMATIC CLOTHES DRYER

Load Weight (Pounds)	Fabrics	Total Drying Time (Minutes)	Final Water Retention (Percent of Dry Weight)
2	Diapers	20	5
3	Synthetics	22	5
3	Synthetics	12	1
8	Cottons	55	2
8	Cottons	47	6
8	Cottons	82	6
2	Towels; Bath Mats	42	4
8	Shag Rugs	83	2

can be effectively used to control the cycle if the intelligence is properly interpreted. Because no control was used in this example, the temperature levels off at a second plateau, where the radiation and convection losses from the machine equal the power input.

At the end of the first plateau, the decrease in available water for evaporation manifests itself in two ways: the absolute humidity of the exhaust air decreases and the temperature rises, suggesting two classifications of controls other than straight time devices . . .

- Humidity devices—quantitative or rate-of-change.
- Temperature-sensitive devices—quantitative or rate-of-change.

An absolute- or relative-humidity sensing device could be used to detect the lack of free surface moisture, but thermostatic devices are preferred because of their simplicity, availability, and low cost. The next question is whether to end the drying cycle by thermostatic means when a predetermined temperature is reached or to prolong the cycle beyond the predetermined temperature point for a period of time.

Some nominally automatic dryers on the market terminate the drying cycle at the moment exit air reaches a particular temperature (illustration *B*, preceding page). Although this type of system compensates satisfactorily for many of the variables encountered in the drying process, it falls short in its performance on some fabrics. Tests indicated that certain fabrics—particularly heavy ones such as cotton throw rugs, mattress pads, and terry cloth—cannot deliver moisture by capillary action from the interior of the material to the surface as rapidly as moisture is being evaporated from that surface. Thus the interior might be damp while the surface is relatively dry. This insulates the moist interior of the cloth, causing the trip point of the thermostatic device located in the air stream to be reached prematurely with respect to actual dryness.

The New Automatic Control

In the development of a control, the latter type was ruled out because 1) heavy fabrics were still damp, and hence required manually resetting the control to arrive at acceptable dryness and 2) if the actuation point of the thermostat were set excessively high to accommodate the heavy materials, the low-temperature synthetics would be damaged—a disadvantage not fully overcome with an adjustable thermostat. Permitting the housewife to select cycling temperature implies, even admits, that the highest obtainable setting is not safe for some fabrics.

To keep clothes and air temperatures as low as possible, the control thermostat of the new General Electric dryer is placed in the exhaust air stream. The exit-air temperature is thus maintained constant at the end of the drum, forcing the temperature of the air entering the drum to decrease (illustration *A*). If the heater cycling means were situated to sense entering air temperature, as they are in some dryers, the temperatures would follow different patterns (illustration *B*). This represents an undesirable situation because the heated entering air being maintained at a constant level causes the exhaust-air temperature to climb at the end of the cycle to reach the incoming level. Thus clothes temperature, following the air temperature, ironically rises at the time when the cloth fibers are most susceptible to heat damage.

The heat system of the new dryer is an open-cycle design utilizing high airflow low-intensity heating, as did the 1955 unit. The automatic control (illustration *D*, page 23)—a highly simplified, though effective, time-temperature integrator—receives two inputs: 1) time, determined by the housewife's fabric indication and 2) exhaust-air temperature, controlled by a bulb-and-bellows thermostat. Both inputs are utilized during the final stages of drying, the thermostat controlling the length of the full-power portion of the cycle. All fabrics dry at full heat until the clothes approach dryness, thus achieving a reduction in over-all cycle time while the individual fibers are well encased in a protective water film. As the last free water evaporates, the temperature rise triggers the timer and removes power from the heaters.

The timer totals heater OFF time while the clothes load cools at a rate dependent on its mass and the constantly diminishing water migration rate. At a second preset temperature, power returns to the heaters and the time summation ceases. This is repeated until the time built into the control for the particular fabric type setting has been consumed. Although the total OFF time is constant for any one setting, varying amounts of power are consumed after the first thermostat actuation, depending on load size. The particular load being dried controls this variation, thus eliminating insofar as possible the human error of timer setting. For example, both a three-pound load and an eight-pound load of medium-weight cottons are set on the same dial position. Tests showed that under average conditions the small load cycled seven times and the heater consumed 0.82 kw-hr after the start of integration; the large load cycled six times and consumed 1.30 kw-hr.

This new system embodies a single control knob (photo). The timer proceeds continuously in the SPRINKLE and DAMP-DRY zones. The SPRINKLE zone is used to dampen clothes for ironing, to fluff pillows and blankets, and to dust drapes and slip covers. A removable perforated canister with a three-pint capacity dispenses water droplets during tumbling, not only rapidly distributing uniform moisture but also substantially reducing ironing preparation time and effort. The DAMP-DRY zone can be utilized to damp-dry pieces for immediate ironing or as a timer when the dryer is used as a space heater. Each of the AUTO-DRY zone's three fabric areas—Delicate *D*, Normal *N*, and Heavy *H*—is sufficiently wide to permit some degree of adjustment. This enables the housewife to influence the dryness at her own discretion, yet does not give her enough latitude to make gross errors.

Typical test results show the ability of the control to cope with extreme load conditions, at the same time maintaining relatively constant ultimate moisture retention (Table). The final water retention is in accordance with the natural regain that occurs in fabrics stored on shelves in the home.

Thus the development of the new control system achieves a step toward more complete automation of the laundry process. And dry, fluffy clothes are produced every time. Ω

SINGLE DIAL CONTROL has separate settings for each type of fabric. The dryer automatically adjusts drying time and temperature to the fabric, load size, and water content.

The Manpower Situation—1956

By DR. MAYNARD M. BORING

Never before in history has the engineering profession faced so many vital problems as it is encountering today. The new materials and devices rapidly developing for the armed forces, almost without exception, will find their usefulness in normal peacetime production. The demand of the public for improved standards of living, together with the recognition of the need to aid less fortunate people, is throwing a burden on the engineering profession not felt by previous generations.

Industry is aware of the serious shortage of well-trained engineers and that it needs not only more but also—and even more important—better trained manpower. This shortage will likely continue for at least several years. Thus adjustments in education and better utilization of our present manpower must be developed; and under the new educational patterns now emerging, industry must find ways and means to use in the engineering team many individuals who do not have a full engineering education.

Manpower studies during the past few years reveal that immediate remedial steps must be taken to insure the future of national security and to maintain our improving standard of living.

A major movement is under way to appraise our public school system. Teacher shortages and inadequate plant facilities, as well as rather severe criticism of the high school program, have aroused public interest, indicating clearly that the public recognizes preparation for the professions as a vital part of the public school responsibility. Too often, because of the large number of young people attending public schools, education has geared its program to the average child with little or no attention to the gifted.

The recent White House Conference and activities of the National Commission for the Public Schools, in addition to the development of 38 state committees for the public schools, indicate the seriousness of purpose that confronts our school system. Alarm has been expressed over the fact that the number of high school students taking mathematics and science courses has been decreasing for a number of years—in many schools even the course in science has been abandoned. These trends indicate the necessity for corrective measures.

Sweeping Educational Changes

The American Society for Engineering Education (ASEE) recognizes the need for improvement in engineering education, and during the past three years a group of outstanding educators and industrialists thoroughly studied the present-day engineering curriculum. They made sweeping recommendations for improvements to meet today's conditions.

Scientific developments and the increased complexity of engineering since the end of World War II have been enormous. Many new materials have been developed; the increases in speeds and temperatures have been phenomenal. The new vistas opened by advances in atomic energy and other scientific investigations have infinitely accelerated engineering problems. The development of computing mechanisms and the increased development toward the automatic factory all demand engineers with a much greater scientific and mathematical understanding.

Recommendations of the Committee on Evaluation of the American Society for Engineering Education seem to be almost universally accepted. Many engineering colleges are busy with changes and improvements in their curricula, and some of the present freshman classes already feel the impact of the proposals of this study group.

Since the war, the number of engineering graduates has steadily decreased, although the class of 1955 shows an upturn in numbers, which is expected to continue during 1956. But even so, the supply doesn't begin to meet the demand. Substantial increases both in enrollment and in the demand for graduate students again throw an added burden on colleges at the same time that they are being required to greatly step up their reserve programs. One of the major problems industry now faces is that substantial numbers of potential engineering graduates coming from the high schools are inadequately prepared. In fact, studies indicate that the length of the typical four-year engineering undergraduate program has increased to 4.7 years. The extra period is largely used in attempts to make up high school deficiencies.

It takes time to effect the sweeping changes that are being started, and progress will not wait. Engineers graduating this year and next will be faced with many complex problems, and they will probably find that in some areas their preparation is inadequate. Because many developments now being used are not included in textbooks, it is vital that each young engineer realize that he will be forced to step up his study habits rather than try to ride on only his present information.

Recent legislation in military manpower laws recognizes the importance of engineers and scientists to the national defense and to the economy. Under the new arrangements, at least some of our engineers and scientists will be able to serve their military requirements in a short time so that the periods away from their professional activities are not going to be so serious. Studies in the military units themselves have resulted in greatly improved utilization of men's talents, thus removing the reasons for past criticisms of military utilization. The men who go into military service should find the experience useful as a foundation stone in their careers.

•

In more than 30 years of recruiting for General Electric, Dr. Boring—Consultant, Engineering Manpower, Engineering Personnel Department, Schenectady — has interviewed more than 100,000 candidates for the General Electric engineering programs. Recognized today as one of the nation's leading authorities on manpower, he came with the Company in 1916 on the Test Course. Among his many activities, Dr. Boring serves as Chairman of the Engineering Manpower Commission of the Engineers Joint Council and is President of The American Society for Engineering Education.

Areas That Can Be Fortified

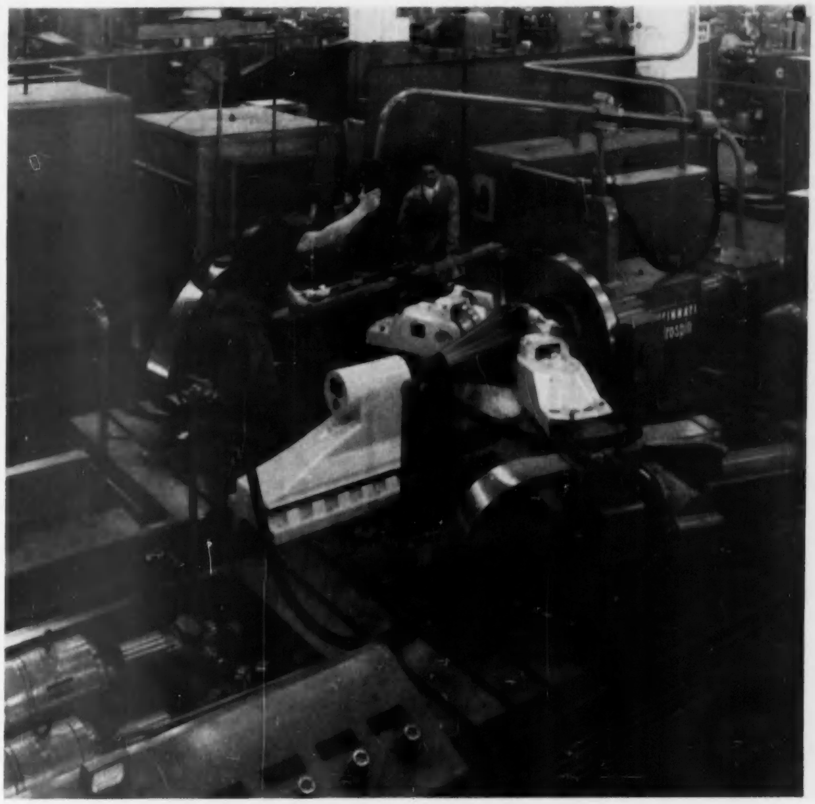
For several years a small number of young men from technical institutes have entered industry. Though not properly recognized by industry in the past, the technician's value has been enhanced by the shortage of engineering graduates which is now stimulating both the production and use of the technician. Many of the problems or parts of problems encountered by the engineering profession can be handled by people with two years' training. Thus industry should seek to employ such personnel.

College education in the United States is relatively inefficient. Only one half of the available or qualified people go on to higher education, and only one half of those who start finish at the bachelor degree. Many reasons, often of a financial nature, contribute to this high loss. However, a high percentage do not go ahead with their education because of lack of motivation or guidance. Granted that we as a nation cannot afford to have all of our brain power in the professions, certainly we should be able to improve and to realize a higher percentage of our potential.

One of the most critical problems that we as a nation face is the teacher shortage. Inadequate salaries and the loss of the social position of the teacher are problems that must be solved, for the development of our young people cannot be delayed. Fortunately, these problems are being seriously studied, with the hope that improvements can be made to insure a continuing supply of qualified teachers. We must remember that fundamentally the teachers are processing our most valuable raw material—young people.

Demands of Industrial Development

The industrial development of the United States has gone further than that of any nation in history. This industrial development has been largely the responsibility of the engineer, and the demand for goods here and abroad clearly indicates that it must go even further. As automatic factories develop, the completely unskilled worker will be less and less in demand. To reach full productive power, industry must recognize that the educational system forms the foundation of it all. Despite the stress placed on improvements in mathematics and science, our social and cultural development must be equally developed if we expect to remain strong and to maintain our place as the leader of nations.



NEW TECHNIQUES, such as are used in this machine that cold-rolls hollow conical and tubular parts for General Electric turbojet engines, have heightened the demand for engineers who have a greater scientific and mathematical understanding.

Let's consider our educational system as a screening process. Then the young men who have the ability and the opportunity for going on to higher education must not only accept the responsibilities of leadership in their immediate profession but also recognize the definite obligations to their communities and the nation. Logically, the graduates of higher institutions should supply the majority of the leaders of the future.

We must remember, however, that not all the brains are possessed by college graduates; many outstanding people will develop without the advantage of education. Every effort must be made to see that such people are recognized and utilized.

Government studies indicate that we are approaching saturation in the schools under present conditions and under our present system. The development of technology in other nations—particularly those under the control of the communists—has been stepped up, and apparently today a number of them exceed our own. Clearly, international tensions will continue for a long time, requiring all our diplomacy to be able to live in a peaceful atmosphere. And bear in mind that the mistakes of one generation are always passed on to the next.

Industry must recognize its responsibility to education because its entire source of manpower comes from the public schools and institutions of higher learning. Both financial aid and guidance are needed. Postschool education is needed to develop each individual to the limit of his capabilities, and industry cannot depend on our educational system to provide such activities.

We are facing a bright but complicated future—a challenging and stimulating one to members of the engineering profession. The younger men recently graduated, together with the groups coming along, will have to take over all too soon. Industry must work diligently to see that adequate preparation is provided and that every aid is extended to these groups. For the chores of these men will be even more complicated than the problems of today. High quality manpower is in America, and with adequate tools we will continue to advance and maintain the lead that we have enjoyed in this great country. Ω

Diffusion Short Circuits in Metals

By DR. ROBERT E. HOFFMAN

• Migration of atoms across grain boundaries is analogous to electron flow in a conductor. Difference in a material's chemical composition corresponds to voltage variations.

• Metallurgists, beseiged with demands for new materials, find that grain-boundary diffusion accounts for changes in grain size and affects the final properties of an alloy.

No doubt at some time or other an electric short circuit has inconvenienced you and, perhaps, even damaged your property. But don't think that short circuits are always undesirable. An analogous phenomenon, called diffusion short circuits, can occur in solids. Unlike the electrical kind, they often greatly benefit the metallurgical industry.

To acquaint you with the subject of diffusion, let's pursue this analogy.

Protracted Migration

In high school physics, you learned that if a difference in electric potential, or voltage, exists between two points in a material, electrons flow in such a direction as to relieve the potential difference. The electron flow, or current, is proportional to the potential gradient. And the proportionality constant is defined as electrical conductivity—the reciprocal of resistance.

Similarly, a difference in chemical composition in a material generally leads to a flow of atoms through the material that diminishes the composition gradient. Under steady-state conditions, the current of atoms is proportional to the gradient of concentration; the symbol D designates the proportionality constant, or the diffusivity. This flow of atoms—usually, but not always, the result of a composition difference—is called diffusion. And the magnitude of the diffusivity D characterizes rates of diffusion.

To illustrate this phenomenon, a layer of pure water was floated on a column of blue copper sulfate solution (photo, top). One week later, a faint coloration visible just above the original interface showed that a noticeable amount of the copper sulfate had diffused into the pure water. With time, the coloration extended further into the pure water until, finally, the copper sulfate was distributed uniformly through the tube.

A similar experiment could be carried out with two layers of solid material. But because atoms in a solid are packed together so tightly and rigidly, rates of diffusion in solids are thousands or millions of times slower than in liquids. Thus during a reasonable time, the extent of diffusion in solids is of microscopic dimensions, demanding special techniques to observe it.

Soap-Bubble Analogy

Now let's look at the arrangement of the atoms in a metal.

The surface of a metal seen under a microscope sufficiently powerful to resolve individual atoms might appear similar to a raft of soap bubbles (photo, lower, page 29). Metallurgists think this concept fairly accurately represents the structure of a metal. Notice that though the bubbles (or atoms) in some areas are arranged in straight lines, these lines run in different directions in each area. These well-ordered atom groups are called crystals, or grains. In the grain boundary—the narrow band between any two grains—the atoms are much less densely packed.

Composed of many similar layers of atoms superposed one on the other, a real metal has a continuous network of grain boundaries.

If you deposited a layer of metal B on the surface of a different metal A having a structure similar to the bubble raft, you might reasonably expect the B atoms to find it easier to migrate down through the grain boundaries than through the closely packed grains. In other words, the grain boundaries would act as short circuits for the diffusion of B through A.

The first experimental verification of this phenomenon was found in 1924 by Dr. Saul Dushman and Dr. L. R. Koller, General Electric Research Laboratory. Measuring changes in electron emission, they deduced the rate that thorium diffused to the external surface of thoriated tungsten filaments. At temperatures near 4000 F, this rate increased notably with the decreasing grain size of the filaments, and they interpreted this observation as an indication that thorium migrated primarily by grain-boundary diffusion.

Later, GE's Dr. Irving Langmuir, winner of the 1932 Nobel Prize in Chemistry, demonstrated that at temperatures near 4800 F the rate of arrival of thorium at the surface was governed not by grain boundaries but by the rate of diffusion through the grains themselves, the process of lattice diffusion. From these data and the measurements of Dushman and Koller, he made rough calculations of the grain boundary diffusivity D_b, the lattice diffusivity D_l, and the dependence of each on temperature. These calculations showed, for example, that for the diffusion of thorium through tungsten at 4400 F D_b is about 700 times larger than D_l.

Simple Proof

Although other indications of rapid grain-boundary diffusion appeared, no more quantitative results were obtained until 1948. Instituted at this time was a comprehensive investigation of self-diffusion in silver—the diffusion of radioactive silver into ordinary pure silver. This particular diffusion system was chosen because of its simplicity and because the use of radioactive isotopes permitted more accurate measurements.

That grain boundaries actually serve as diffusion short circuits was demonstrated in this manner: A thin layer of radioactive silver was electroplated onto one flat face of a pure-silver cylinder and then heated to 1400 F for several days. Next, the remaining radiosilver and a two-mil layer of ordinary silver beneath it were ground off this sample. The new face was put in contact with a photographic film. Because photographic emulsion responds to radiation just as it does to light, the film blackened at points corresponding to regions of high radiosilver concentration in the cylinder.

The black lines in the radiograph (photo, right, page 30) exactly match the grain boundaries in the silver.

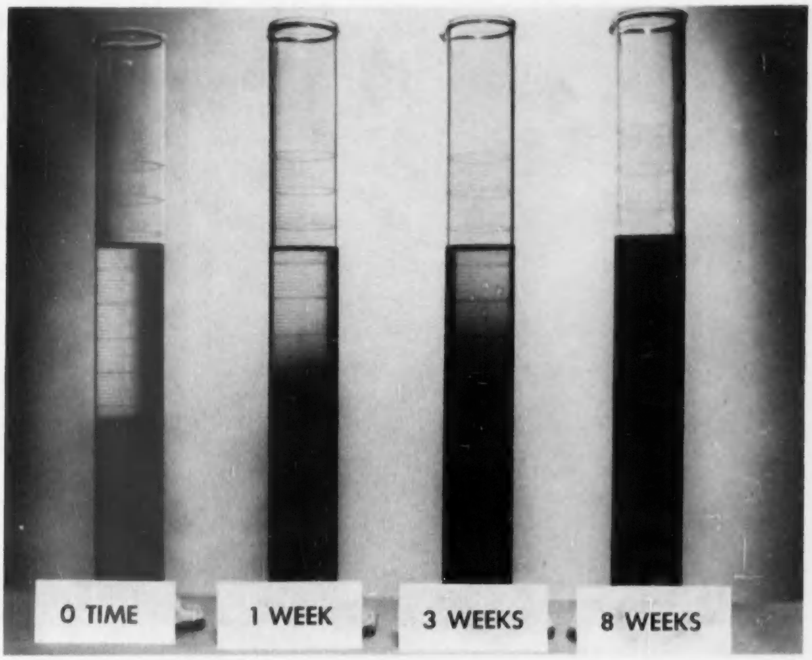
Comparison of the high concentration of radiosilver in these boundaries with that in the grains indicates that the radiosilver diffused more rapidly along the boundaries. Evidently the different boundaries contained varying amounts of radiosilver, because some are scarcely visible in the radiograph.

To understand this phenomenon, look at the bubble raft again. The boundary running from the lower portion toward the upper center obviously differs from the others. In fact, close inspection shows that this particular boundary is made up of almost equally spaced regions of disorder, called dislocations. These are separated by regions where the bubbles are packed together almost as tightly as in the grains.

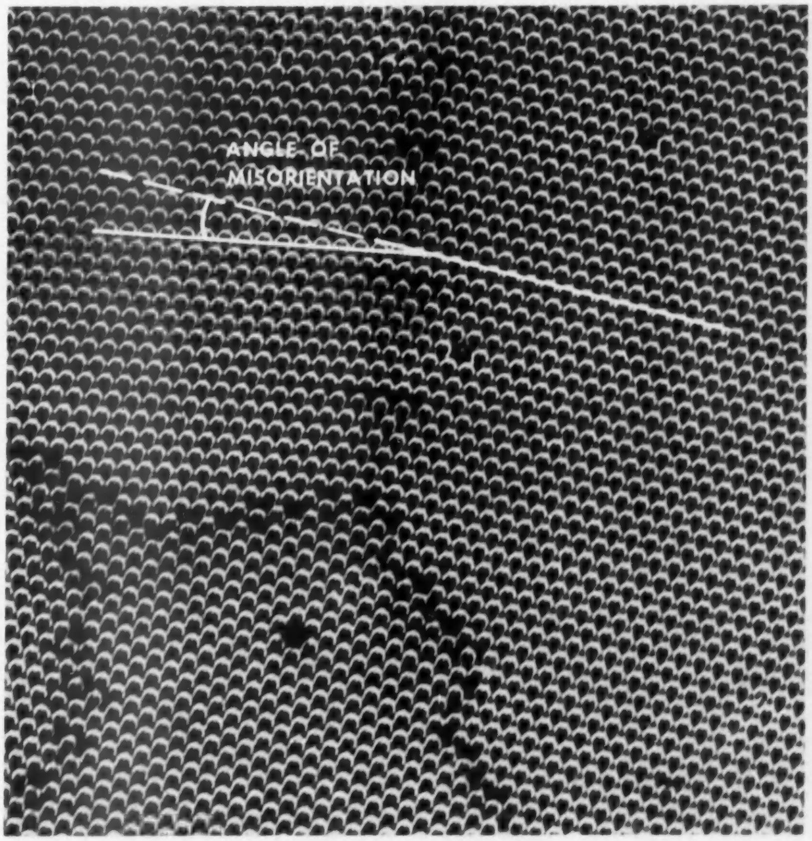
Current theories indicate that you can expect such dislocation when the rows of atoms are nearly parallel in the grains separated by the boundary; in other words, when the misorientation of the two grains is not too large. What's more, the number of dislocations per unit length of the boundary is nearly proportional to the angle of misorientation. When this angle becomes larger than 15 or 20 degrees, however, the dislocations then are so close together that the boundary appears as a more or less continuous slab of disorder, as in the other three boundaries of the bubble raft.

Quantitative measurements of the actual distribution of the isotope in samples with carefully controlled misorientations confirmed this general conception of the nature of grain boundaries. These results also showed the rate of diffusion along dislocations to be essentially independent of misorientation. Thus the total number of radioactive atoms that diffuse through a unit length of a boundary between grains of low misorientation will be relatively small—rapid diffusion occurs only in that fraction of the boundary occupied by dislocations.

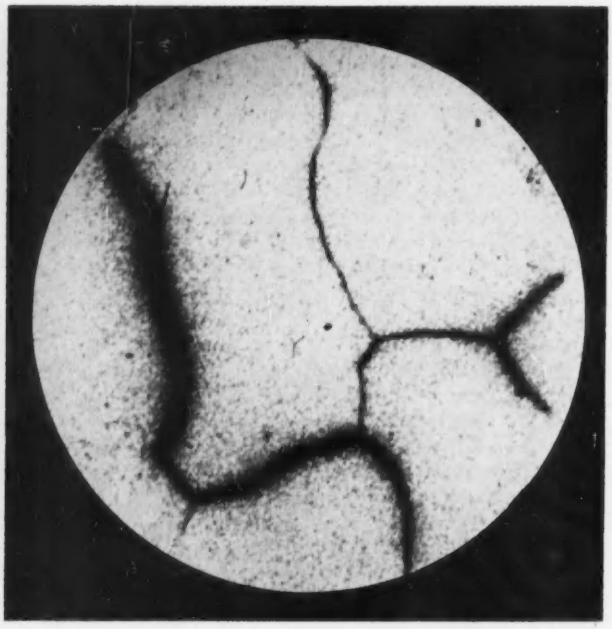
Large single crystals of silver containing no grain boundaries were also prepared for obtaining measurements of the lattice diffusion coefficient D_l. Comparison of these data with the results of the quantitative grain-boundary measurements yields values of the ratio D_b to D_l. The ratio varies from 10^4 near the melting point of silver to 10^{18} in the vicinity of room temperature. The magnitudes of these numbers strikingly demonstrate the ability of grain boundaries to act as diffusion short circuits, especially at low temperatures.



COPPER SULFATE ATOMS diffuse upward into column of pure water, illustrating possible migration, although millions of times slower, through layers of solids such as alloys.



RAFT OF SOAP BUBBLES represents structure of metal. If the angle of misorientation exceeds 15 or 20 degrees, grain boundary becomes a continuous disorder (lower portion).

DIFFUSION SHORT CIRCUIT: Two-mil layer was machined off pure silver bar after radioactive silver had been applied and heated to 1400 F for several days (left). Radiograph shows high concentration of radioactive silver that diffused through grain boundaries.

Practical Effect

Short-circuit diffusion is by no means a mere laboratory curiosity. It is well known, for example, that you can often markedly alter the mechanical and magnetic properties of an alloy by changing its grain size.

The initial grain size of a casting is determined primarily by conditions that existed during the solidification process—the kind of mold, the rate of freezing, the distribution of impurities, and others.

Metallurgists often know enough about these factors to produce a desired grain size within limits. This grain size isn't stable, however. Instead, it can change completely during subsequent forming and heat-treating operations.

Generally speaking, at temperatures high enough for diffusion to occur at a significant rate, the average grain size spontaneously increases. Some grains grow larger; others disappear. The steps in this process are thought to be 1) dissociation of the atoms from the lattice of one grain, 2) migration of the atoms across the boundary, and 3) subsequent attachment of the atoms to the lattice of a neighboring grain. Grain-boundary diffusion—essentially the same as migration across the boundary—thus becomes one of the factors that determines the rate of grain growth and, accordingly, the final properties of metals.

Distribution of the atoms of the alloying elements also strongly affects the final properties of an alloy. Consider, for example, an aluminum alloy containing about four percent copper and used extensively in the aircraft industry. When you heat such an alloy to about 1000 F, all of the copper dissolves and becomes uniformly distributed through the aluminum. But the solubility of copper in aluminum decreases with decreasing temperature, amounting to no more than a few tenths percent below 400 F. If after annealing at 1000 F the alloy is subsequently annealed for several hours, say, at 300 F, a large fraction of the copper leaves the solution and precipitates in the form of finely dispersed particles of the intermetallic compound $CuAl_2$. The alloy is significantly harder and stronger after the copper has precipitated.

This change from the alloying element's uniform distribution to localization at various points obviously involves diffusion. In fact, in some alloys, the observed rate of precipitation just about agrees with what you would expect from known rates of lattice diffusion. In other alloys, though, the rates of precipitation calculated from lattice-diffusion coefficients are millions of times slower than those actually observed.

The Research Laboratory's Dr. David Turnbull has recently investigated this apparent anomaly. He found that the growing edge of each precipitate particle is always attached to a grain boundary. Thus the atoms of the alloying element that lie on or very near the boundary can diffuse through the boundary to the precipitating particle. The particle consequently lengthens, inducing the grain boundary to move to a new position where it picks up more atoms and funnels them into the precipitate. Such a mechanism, permitting precipitation to occur largely by grain-boundary diffusion, seems plausible because measurements show that grain-boundary diffusion coefficients can be millions of times larger than lattice-diffusion coefficients. Here again you see the role of diffusion short circuits in providing more useful materials.

Materials for High Temperature

Metallurgists today are besieged with demands for materials that can retain sufficient strength to be useful at the increasingly higher temperatures encountered in jet engines, steam turbines, and other power-producing devices. These demands have necessitated the development of procedures for fabricating the so-called refractory materials—materials with high melting temperatures. Because the difficulty of melting a substance under controlled conditions increases as the melting temperature rises, the sintering technique frequently replaces melting.

The term sintering denotes the process of compacting fine powders, usually under high pressures but at temperatures below the melting point. (The cube of sugar you use in your coffee, incidentally, is an application of sintering to a nonrefractory substance.) A material with the same density as melted material is the desired end product of such a process. At some intermediate stage of the reaction, however, each particle attaches to its neighbors by relatively narrow bridges, leaving a large number of isolated voids, or pores. The completion of sintering then depends on some mechanism for filling these empty spaces.

In an attempt to understand this mechanism, Dr. J. E. Burke has looked at partially sintered compacts of alumina (Al_2O_3). A band along each grain boundary (photo, top) has completely densified, while the interiors of the grains remained porous. This strongly suggests that the grain boundaries serve to transport the material from the outside surface to fill the holes. And it again demonstrates the usefulness of diffusion short circuits.

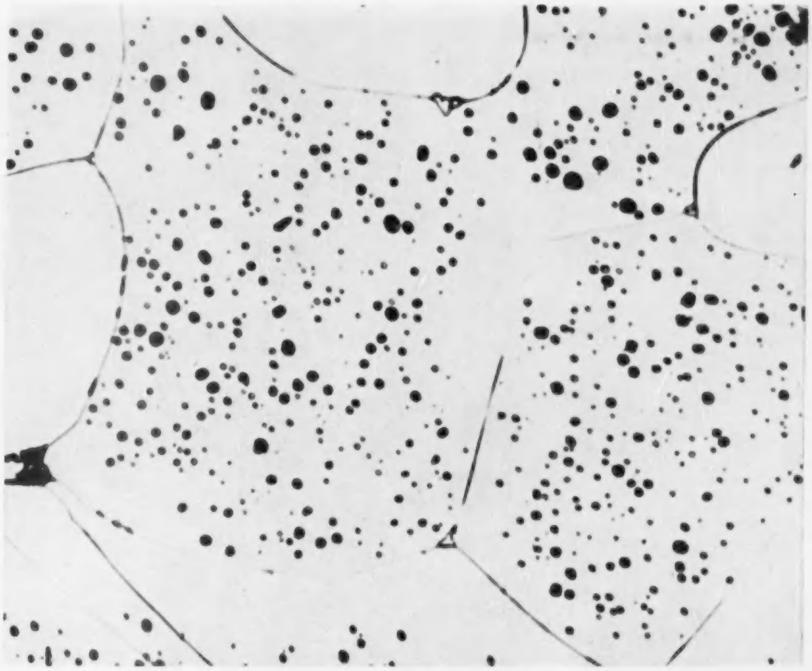
On the other hand, circumstances occur where the action of diffusion short circuits can be troublesome.

For instance, many alloys strong enough to be used at high temperatures suffer from the disadvantage that they oxidize readily. It is common metallurgical practice to coat such alloys with a thin layer of metal more resistant to oxidation. Putting such a material in service at elevated temperatures tends to diffuse the atoms of the surface metal into the base alloy, eventually exposing it to the action of the oxidizing gases. Rapid diffusion along grain boundaries only hastens this action. To maximize the useful life of such materials, metallurgists must learn how to minimize the effects of grain-boundary diffusion.

More Research Needed

Although still in its infancy, the study of diffusion short circuits has already produced two significant results: a better insight into the fundamental nature and structure of grain boundaries and a more thorough understanding of the behavior of commercial materials during fabrication and use.

As metallurgists learn more about grain-boundary diffusion rates and the factors that control them, you can expect still more significant results. Ω



BANDS densify along grain boundaries of partially sintered alumina, while interior of grains contain isolated voids, indicating that boundaries serve to transport material to fill holes.

ANGLE OF MISORIENTATION in grain-boundary diffusion is one of the author's concerns as a research associate in the Metallurgy and Ceramic Research Department, General Electric's Research Laboratory, The Knolls, Schenectady. With the Company since 1948, Dr. Hoffman's special fields are diffusion in metals and kinetics of solid-state reactions.

Ten years ago, decorative surfacing moved into the kitchen. Since then, homes, offices, restaurants, and schools have a new look as . . .

Plastics Surfacing Heralds an Era

By GEORGE C. RASSMAN

In just 10 years, decorative plastics surfacing has mushroomed into a multimillion-dollar business, competed for by more than a dozen manufacturers.

As a durable surface, it beautifies kitchens and bathrooms and enhances living-room furniture (photos, above and page 37). Office desks and other equipment are surfaced with it. In school, chances are that your child studies from a desk topped with this hard-wearing material. Now, the latest innovation is decorating walls in homes and offices.

Wherein lies the secret of its almost magic appeal to the public?

No Mystery

The real value of decorative plastics surfacing lies right on its top: long years of service plus attractive patterns and colors make it the ideal surfacing material. It is impervious to more than 25 stain-producing materials common in your home—coffee, tea, ink, alcohol, acetone, cleaning fluids, dyes, citric acids, crayons, ammonia, and gasoline. All these can be removed with the wipe of a damp cloth or soap and water.

Resistance to heat—even that of a burning cigarette for a limited period—is another important property of decorative laminates. To test a standard sheet of Textolite (registered trademark of General Electric) surfacing, a pan of wax heated to 356 F is taken from a stove and set on its surface. After 20 minutes the pan is removed. No blistering, warping, or other discernible surface marring results.

This temperature provides an ample safety factor for your wife's cooking utensils that contain boiling water or similar liquids. Most electric coffee makers do not exceed 356 F, either. But the temperature isn't sufficient for such things as deep-fat fryers, baking utensils, flatirons, soldering irons, and hot plates.

Other properties that make laminated plastics the ideal surfacing material are its color fastness and its resistance to moisture—it retains dimensional stability over an extreme range of humidity. Another important factor: great progress has been made in the ease of fabricating decorative plastics surfacing. New adhesives and application techniques have extended the use of laminates in the do-it-yourself market.

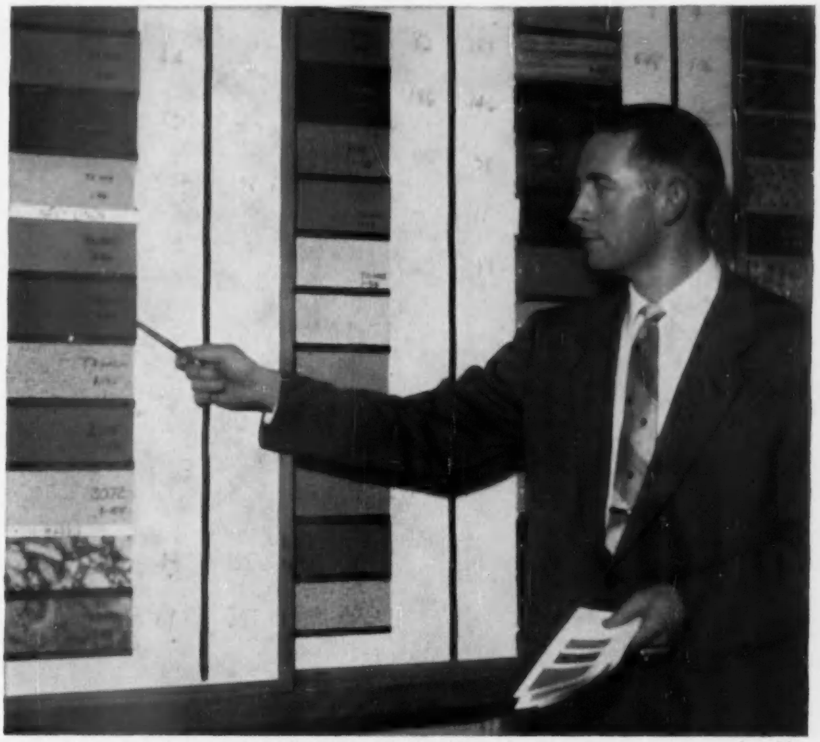
What It Is

Laminated sheets and boards are not new; they've been used some 25 years as insulating materials in the electrical industry.

By adding a sheet with a special design, plus a top overlay of transparent resin-treated paper, and by applying heat and pressure, you get an ideal surfacing material. In most instances the decorative sheet is paper imprinted with color and pattern. But sometimes wood veneers or fabrics are used for the decorative effect.

Eight or nine sheets of kraft paper, individually impregnated with resin, go into a standard one-sixteenth-inch-thick sheet of Textolite surfacing. Print and overlay sheets are treated in the same way. The overlay sheet becomes transparent after treatment with resin. In fact, all the papers are transformed from soft, absorbent materials, like your desk blotter, into hard and brittle ones.

These sheets of treated paper—kraft, decorative, and overlay—are stacked into a build-up. A special steel plate placed on top gives the laminate its desired finish. Many build-ups with a separator sheet between each are then placed in a press. And after curing under heat and pressure, the individual sheets of each build-up fuse into a solid laminated sheet. When their undersides are sanded, they become the familiar sheets of decorative surfacing you purchase from the dealer.



CHOOSING POPULAR SURFACING PATTERNS, the author compares survey results. Mr. Rassman—Supervisor, Industrial Design Section, Laminated and Insulating Products Department, Coshocton, Ohio—came with GE in 1950. Holder of several design patents, he is responsible for developing, styling, and maintaining new patterns and colors for Textolite.

More Than Meets the Eye

In this admittedly competitive field of decorative plastics surfacing, what makes a consumer choose one product over another? No one producer dominates the field with surfacing material high in all known properties; each tailors his product to known standards of quality.

The answer lies in color and pattern, dictated by the consumer's personal tastes and the contemporary way of living.

To anticipate these changing trends, the future must be forecast carefully. The development of up-to-the-minute patterns and colors, suitably selected and manufactured, can't be left to chance. Patterns and colors are chosen only after exhaustive studies. Interior decorators, furniture shows, and store sales are checked continuously to gage tastes in home, office, hotel, and institutional décor. Perhaps next year's market for decorative surface styling will veer toward a contemporary tone. Or, it might show a touch of the traditional.

Color—a potent force in modern business—is a difficult subject to analyze. In styling consumer goods, some colors are profitable because they help to sell the product; some lose money because they don't. With color such a dominant factor in the sale of decorative surfacing, opinions must be supported by facts. Field research must guide the choice.

Such research is an effective way to time the pulsating changes in style. Beginning with interior decorators and ranging from design studios to retail department stores, all areas that influence style are checked continuously. To further grasp the trend, stylists attend home building, furniture, decorating, and allied trade shows across the country.

Home and trade magazines are another guide. In fact, some magazines conduct color clinics at furniture and merchandise shows.

Choosing Colors . . .

Choice of the right colors is essential to big volume and rapid turnover in the decorative-surfacing industry. Colors for Textolite surfacing, for example, are designed with the cooperation of Faber Birren, this country's leading authority on colors. They are checked for acceptance by American Color Trends, the research division of Birren's organization.

The whole merchandising process, from manufacturer to jobber to retailer, must be guided with one big factor in mind—the American public. Where styling is speculative or based on enthusiastic guesses that don't reflect public taste, you risk losses and unsold inventories.

Consumer research is constantly undertaken in behalf of Textolite plastics surfacing to measure the course of color preferences, anticipate rising colors, and protect against declining ones. Color-preference polls are made by recording sales and preferences on groups of merchandise common to your home. For example, American home owners currently buy laminated plastics tables and countertops in this order: gray, 29.2 percent; red and pink, 21.6 percent; yellow, 16.7 percent; and green, 12.7 percent.

(For a further discussion of how the public's color preference is gaged, see Box on page 36.)

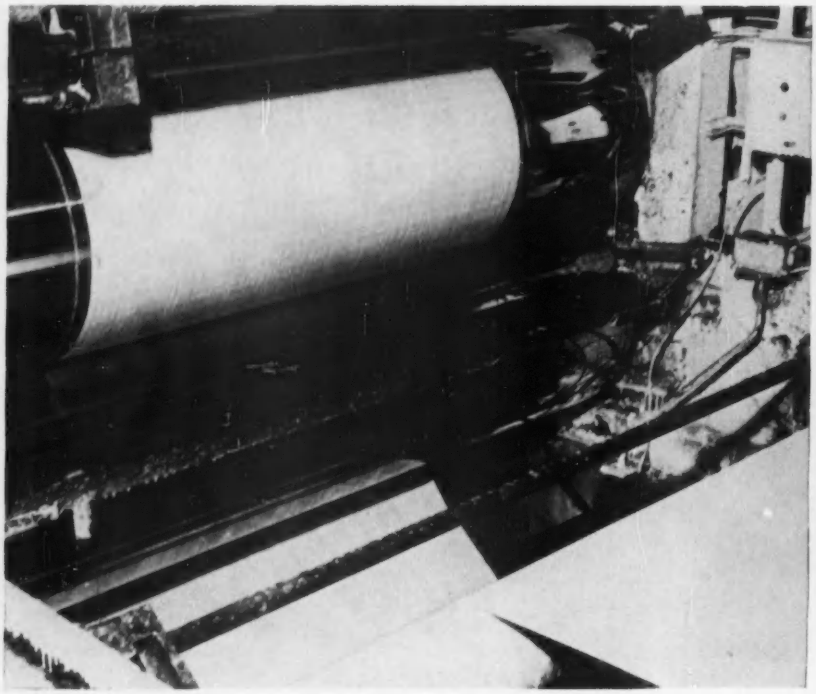
. . . and Patterns

Although the right color is always essential, pattern has become a major factor in consumer preference for the past three years.

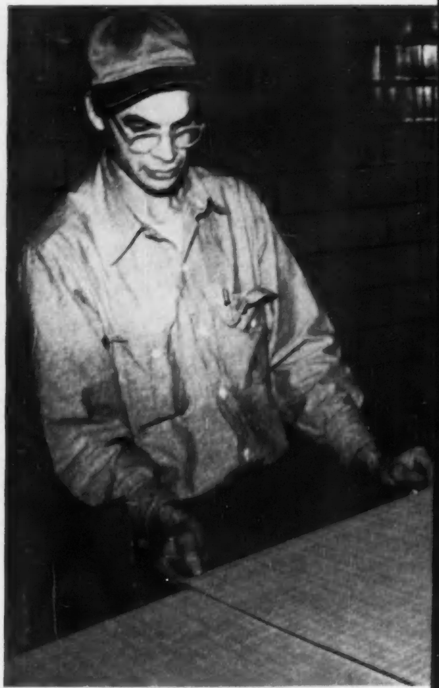
Unlike the automobile industry where each year's new model is the most popular, a new pattern in the laminated plastics field takes three years to hit its stride in sales. This applies particularly to such areas as kitchen work surfaces where the standard patterns—designed to appeal to the majority of people—are long-lived.

TEXT CONCLUDED ON PAGE 36

OVERLEAF: PICTURE STORY OF MANUFACTURING PROCESS



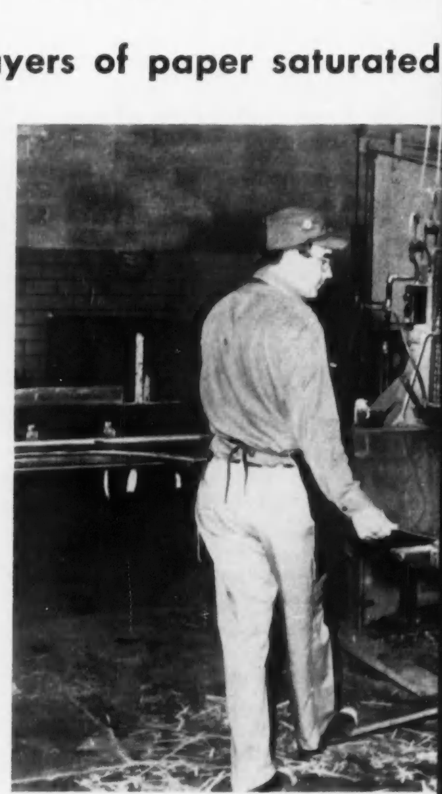
1 Crosscurrent paper print spindles through melamine resin bath into a drier in the manufacture of Textolite decorative laminates; top overlay sheet is similarly treated. Kraft paper that makes up bulk of laminate is impregnated with phenolic resin.



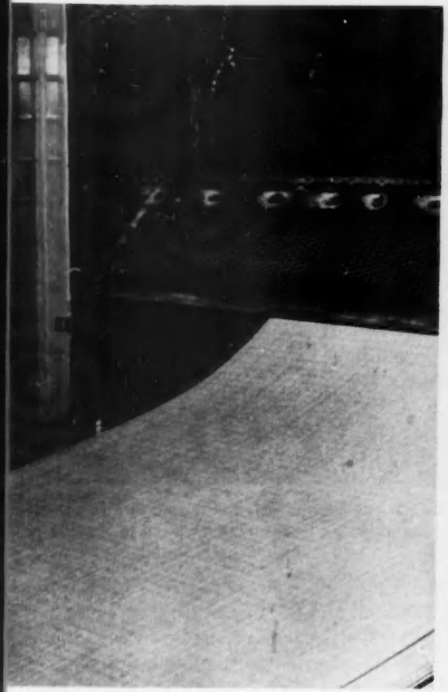
2 Treated paper print, once an absorbent blotter-like material, travels out of curing oven hard and brittle and is then cut into sheets.

DECORATIVE PLASTICS SURFACING—layers of paper saturated

4 Build-ups are stacked one on the other, with a separator sheet between, and heated in a large hydraulic press, one press handling many build-ups. When this curing process is complete, individual sheets of each build-up are fused into a solid laminate.



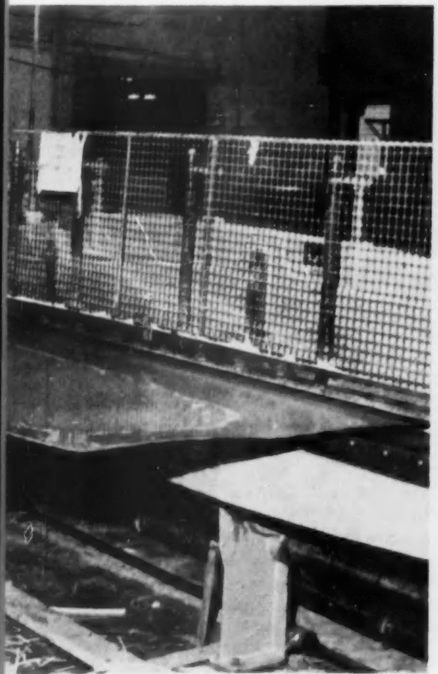
5 A separated four- by eight-foot Textolite laminate is now trimmed of all its rough edges on a giant shear cutter. Next, its smooth



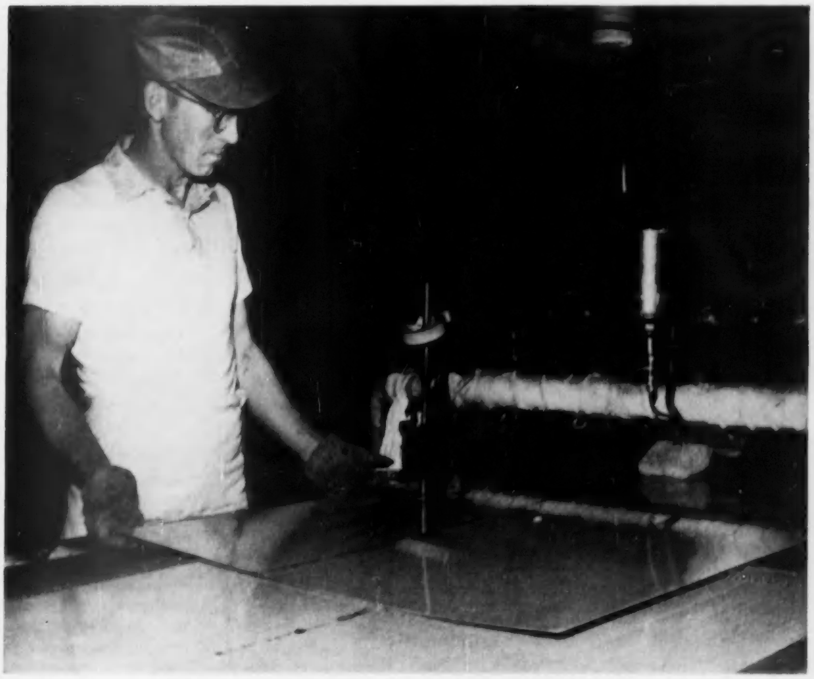
All papers undergo this transformation. The top overlay sheet is transformed into a tough transparent material.

3 After papers are cut to size, they are stacked in a build-up for pressing. Build-ups are composed of eight or nine sheets of kraft paper topped with the decorative print, transparent overlay, and a steel press pan to give the laminate its desired finish.

d with resin and fused together under pressure (Story begins on page 32)



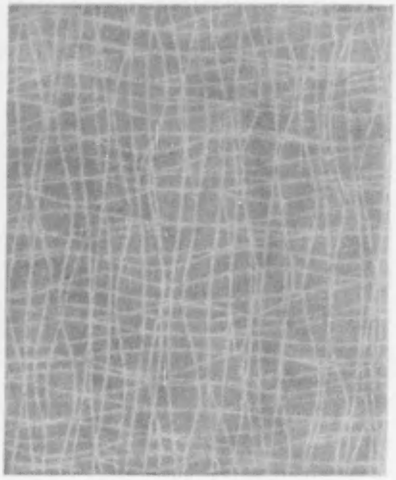
underside will be sanded to a rough surface that readily accepts a special rubber-base adhesive. Close tolerance assures uniform thickness.



6 Finally, after laminate is carefully examined, G-E monogram is rolled on to identify the product as Textolite—a durable and highly attractive surfacing material that you can apply with either hand or power tools and a special pressure-contact adhesive.

CROSSCURRENT: First original exclusive textured design, a subtle plaid, was planned to avoid sharp definition of lines.

MING: Gold spatter distinguishes this precedent-setting pattern. Still fashionable, this texture is available in 12 colors.



MEDLEY: Second original design is a formation of loose threads photographed to provide an interesting shadow background.

Far more elusive than color choice is the factor of personal taste for patterns. Often, people's pattern choice relates to something seen years ago, say, an imported piece of merchandise. Such nostalgic reflection can swing the weight of their preference for a pattern. It could also be a popular choice because newness and originality capture the buying interest.

Selecting a pattern for Textolite plastics surfacing requires knowledge of both existing and discontinued patterns of all decorative-surfacing manufacturers. You might term it artistic insight into what new texture or combination of graphic media would be truly unique. To develop the idea into a practical design suitable for mass production requires much skill.

Each new pattern represents the ultimate in planning. Like looking for the needle in the haystack, it results from painstaking search. Patterns are sifted and selected from many original designs and photographic effects. Here again, you dare not leave the decision to only a few people. A sample pattern is shown to customers, fabricators, distributors, and consumers to formulate the need and direction of new styling.

Case History

Early patterns of decorative laminates, namely, mother-of-pearl and linen—forerunners of today's complex designs—were common to all manufacturers.

Today the mother-of-pearl pattern is on the downward swing. Although many people predicted its end years ago, it still remains high in sales. On the other hand, linen—a universal pattern—appeals to all.

Back in 1946, Textolite plastics surfacing was being produced in mother-of-pearl and linen patterns, some solid colors, and a handful of woodgrains. Because of the desire for a more distinctive product, it was decided to develop exclusive designs. (Many of these original patterns were developed by the late W. B. Petzold, a recognized authority in industrial design.)

Crosscurrent, the first original exclusive design, provided a new approach to patterns (photo, left). The textured design, made of short lines placed in one direction and then cross-printed, gives a subtle plaid effect. Because of the directional problem involved, designers carefully avoided sharp definition of the plaid. Any pattern that presents a directional or block effect is difficult to match when you join two sections.

Medley, second of the original designs, is based on an abstract formation of loose threads photographed to give a shadow background (photo, right). This achieves an unusual and attractive sense of depth.

The design history of Medley bears out the importance of color to a good pattern. Soft pastels were originally used in 1948. But after several years a market

SURVEY OF CONSUMER COLOR PREFERENCE

Basis: Plastics Cutlery-Tray Sales

Preference	Color	Percentage
1	Yellow	27.5
2	Gray	19.8
3	Red	16.8
4	Pink	15.3

Basically, consumer's color-preference surveys—an elaborate undertaking—are made by tabulating direct over-the-counter sales. For example, consumer research groups test housewares sold in specified cities across the country; then they check the sales by the colors selected.

The research organization making this particular survey reports yellow as a heavy seller against three hues of red: red, flame, and pink. From these findings, you can easily conclude that yellow, gray, and red are top-selling colors and should be offered in any housewares line. Incidentally, flame red—highly popular two years ago—is falling in demand, whereas the preference for pink is rising. Pink and coral, although fourth in preference, are making the most rapid gain in sales percentages. Thus these colors should be included in new items.

survey indicated the need for some new colors. And so, in 1952, with the help of color consultant Birren, the Medley line was restyled for color, bringing immediate success.

Ticking It Off

An awareness of the need for a distinctive decorative pattern other than woodgrains and common kitchen types accompanied the new color trend. This called for a pattern applicable to occasional furniture in the den and living room, such as coffee tables, and even in the bedroom.

Shortly, the Ming pattern, which set a precedent, was created (photo, center, opposite page). For the first time in any decorative laminate, a gold-print spatter design was introduced. Coupled with rich colored-base papers—such as red, green, blue, black, and brown—this gold-spatter design quickly became a high-style item. Its popular character lent itself to newer kitchen and dinette colors, such as pink, charcoal, persimmon, and turquoise. Subsequently, it became available in 12 colors, the largest number of any Textolite pattern.

Innovations in Ming patterns were initiated by a new spatter technique. And this texture is still fashionable.

Two of the first surfacing applications were dinette sets and kitchen countertops. And for a long time, because of limited colors and patterns, the range of application remained small. Woodgrains appeared but met with a generally reluctant acceptance, partially because of poor printing techniques. As techniques improved in making authentic reproductions, woodgrains became popular. Their natural appearance helped to increase the sale of occasional tables and furniture.

Soon, consumers requested tough, nonstaining decorative plastics surfaces on furniture. The introduction of new patterns and harmonizing colors opened new markets. Styling of dinette sets improved. And better countertop patterns increased the demand for combined kitchen-and-dining units with plastics surfacing. Plastics tops were utilized for case goods such as bureaus, dressers, desks, and cabinets.

Manufacturers of metal office furniture began using leather and similarly patterned plastics materials that are color styled to give the proper light reflectance for office conditions. This consciousness reached the school-desk market: old wooden-desk tops were refinished with plastics surfacing. And manufacturers of new school desks played up the durable and attractive surfaces of their product.

As public demand for plastics surfacing increased, the number of firms engaged in its production became larger—and the market, more competitive. This unconditional public acceptance has today convinced many manufacturers of the need to put plastics surfacing on their products.

The scope of laminated plastics surfacing is literally beyond comprehension. As each day unfolds, you'll find that more and more conventional surfacing materials are being replaced on work areas. Interest in color schemes for kitchens alone has generated a tremendous potential.

You can choose from dozens of color-pattern combinations, and the number is growing. Last year, 15 new color-pattern combinations of Textolite laminates were introduced.

One of the most recent color-pattern combinations, and certainly one of the most striking, is Fantasia. Keyed to the growing trend toward Italian styling in furniture, the new pattern closely simulates the warmth and beauty of broché fantasia marble. Perfect registry of the marble's delicate pink and gray required a new manufacturing process.

Crystal Gazing

What about the future? A program is under way to conquer the field of wall surfacing. New patterns and specifications for applying them will be developed.

Nationally known architects are counseling the use of Textolite surfacing in integrated and flexible wall dividers for the modern concept of living. These architects feel that your home should be designed around what you do in it, arranged for making your actions as pleasantly comfortable as possible. In the future, for example, the inner walls of your home may be of honeycomb construction, with decorative plastics surfacing on both sides, affording additional beauty and facility. They can be perforated to allow warm or cool air to enter a room.

To most Americans, a house was always thick walls and a roof. Then a leading architect, Frank Lloyd Wright, proceeded to lighten the roof so that walls could be integrated with large glassed areas, decorative panels, and room dividers. This brought the beauty of the outdoors into the home.

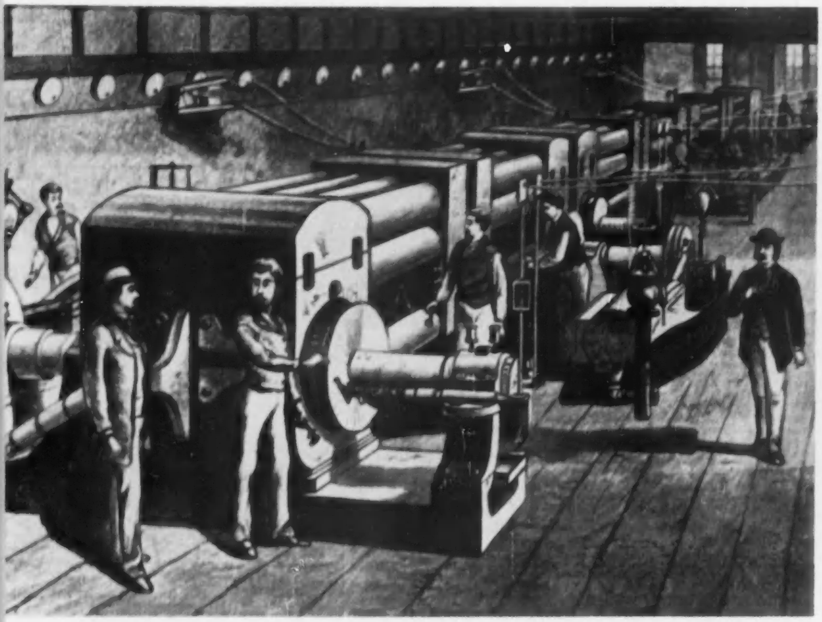
In this American concept of open living, decorative plastics surfacing will play a leading role. Ω

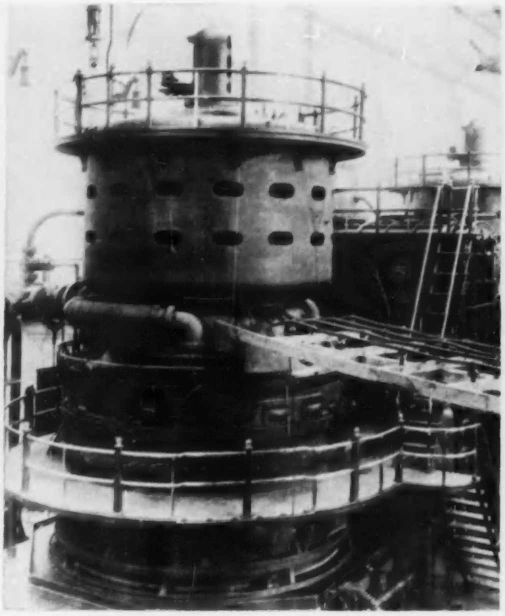
BATHROOM vanette surfacing resists water, soap, and many of milady's toiletries.

DINETTE table, with matching chairs, was a natural application of plastics surfacing.

RESTAURANT tabletops, readily cleaned, are sanitary and wholesome in appearance.

SCHOOL-DESK tops are durable; old desks can be refinished with decorative plastics.





EDISON'S PEARL STREET STATION (LEFT), NEW YORK CITY, BEGAN OPERATING IN 1882. SINCE TURBINE INSTALLATION AT FISK STREET (CENTER), CH

The Engineer's Role in Today's

By H. L. HARRINGTON

The electric power systems of today present a challenge to the engineering student who is about to choose the field of his lifetime work. Let's examine some of the broader aspects implied in the term power system and how it offers the young engineer the widest opportunities—fully as great as some of those of the newer fields of electronics and nucleonics—to exercise all his training, ingenuity, and skill.

The power system encompasses the whole field, from the giant turbogenerators in our power plants right down to the light bulbs and electric clocks in your home. And what a wealth and variety of devices and facilities lie between. Does this mean that the power system is simply an aggregate of machinery, wires, and the like that transforms other forms of energy into electric energy and delivers it to our customers in usable form to perform almost countless tasks? It is not that simple. We must think of the power system as a living, growing ever-changing entity.

Moreover, the system must adapt its output in exact harmony with the constantly varying demands of the people it serves in spite of storms, heatwaves, and cold snaps. An aggregate of daily output curves of a power system gives a clear picture of the living habits of our people and the growth and vigor of our industrial establishment.

The engineer must prepare in advance to cope with the expanding and ever-changing requirements of the entire system which to a large extent has been placed in his care to guide its course over the future toward a continuously bigger, better, and more economical power supply for our country.

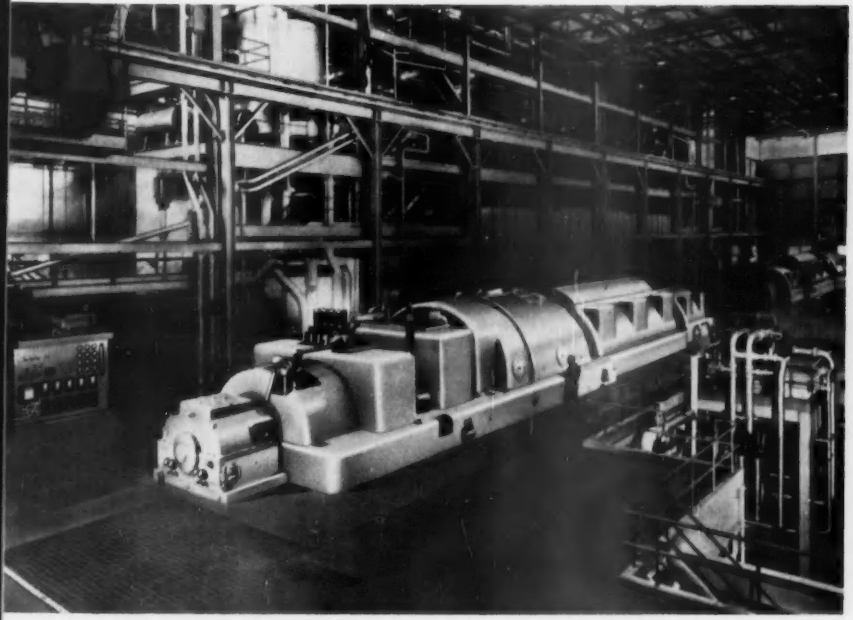
New ideas, improved apparatus, and better ways of doing things are products of individual thinking; but they would be of little use to the world locked up in the individual mind or even used only by the individual's immediate associates. In the give and take of our schools, societies, and associations, these new ideas are broadcast and made available for the widest possible use by all. Many engineers firmly believe that this free interchange of professional know-how has been a primary factor in the tremendous growth in the economy of our nation, contributing greatly to our continuously improving standard of living.

To get a better insight into power systems, let's look into history at the first ones. Why were they created? And why did they continue to grow at such a phenomenal rate so that they are now one of the world's major industries?

In 1954, we celebrated Light's Diamond Jubilee—the 75th anniversary of Edison's invention of the incandescent lamp, the first practical means of producing light from electric energy for general use. But it could not be generally used without a practical source of electric power that could be used in the residences and commercial establishments of the day. Therefore, Edison, with his boundless energy and ingenuity, set about providing such a source of power. He had already conceived and brought into being a practical engine-driven generator, then known

•

Mr. Harrington joined Niagara Mohawk Power Corporation, Buffalo, NY, in 1923 and at present is Chief System Electrical Engineer. He is responsible for coordination of all phases of electrical plant planning, including cooperation with neighboring public utilities.



CHICAGO, IN 1903, ELECTRIC OUTPUT HAS MADE INCREDIBLE GAINS WITH MODERN TURBINES.

Power Systems

as a dynamo, or jumbo. Edison thus was faced with the same problem that confronts us today and that has confronted engineers during the whole intervening period—that is, the development of useful and practical components and fitting them together into a working system supplying electric power to customers at a reasonable price.

Now, what are the fundamental obligations of a power system, from the very first one down to the great systems of today?

First of all is its obligation to those it serves—its customers. It must be prepared to furnish reliable electric power service in any quantity required and at as low a cost as possible, consistent with the second and third requirements.

The second obligation is to its owners, who put up the money that makes the system possible in the first place. The system must be designed, operated, and managed so that the revenue received from the customers will provide for all necessary operating expenses with enough left over to provide the owners with a reasonable return for the use of their funds.

The third obligation is to its employees. No enterprise can long be successful without a loyal and efficient group of employees who actually make it work. Furthermore, from the employees largely come the ideas for improvement and expansion so necessary for our ever-growing ever-changing power system.

This final obligation brings us to our main theme—the role of the engineer in the modern power system.

Just what is the engineer's role? Think of him as having an interest in and a responsibility for all phases related to the physical plant of the power system: its equipment and the procedures used to make it function. Briefly, its principal phases include . . .

- Planning for the extension and improvement of the system
- Design of the component parts to implement the planning objectives
- Construction of the physical plant as planned and designed
- Operation and maintenance of the physical plant.

Now let's examine each phase in more detail to see how they fit together in an unbroken chain in a system's structure, showing the engineer's role.

Planning

Planning simply means outguessing the future—how much will the nation's power system expand in the next 5, 10, 20, or more years? What facilities all the way from the generating stations to the customers' meters must be added to meet such expansion?

We cannot underdo the job because our system would then fail in its primary obligation—the ability to supply reliable electric power service in any amounts as demanded by the customers. Nor can we overdo it because then we would have excess facilities that would not be in full-time use, and the owners would suffer.

The basic foundation for all planning work is the fine art of load forecasting—a fine art because forecasting cannot be called a science at this stage of the game. Here the engineer works closely with the economist and the statistician to interpret past records and project the results into the future.

From this he forms a conception of the future load and its distribution in his area, in turn forming the basis of some concentrated thinking on what new power supply facilities must be provided, where, and when.

Take the problem of new generating capacity, for instance. If economically feasible hydro capacity is available for development, location is no problem. The site is fixed by nature, and it becomes a matter of devising an economical transmission system from the site to the load centers or to the existing bulk power system. However, addition of thermal capacity may open a wide choice of sites. The ultimate choice depends on site and foundation conditions, availability of adequate condensing water, cost of fuel delivered to the site, transmission reinforcements required, and effect of flue gases and fly ash on neighboring communities. Each new installation imposes a whole new set of conditions.

With the site and size determined, a detailed analysis must then be made of the various transmission-system alternatives: Where are the best and most economical points of connection to the system? what transmission voltage should be selected? how many circuits? what conductor size? Finding the right answer is necessary to render reliable electric service at the lowest possible cost.

"His problem involves the whole gamut of human relations . . . ."

The a-c network analyzer is an invaluable tool in helping us to arrive at the right answer. In the early, simple systems an economic balance could usually be determined by pencil and paper calculations. Such simple methods are no longer feasible on our present-day widespread, complex systems that require newer electric and mechanical aids in solving these problems. The planning for generating-capacity expansion and attendant transmission reinforcements usually involves several network-analyzer studies.

The activities of the planning engineer do not stop with the big items of the system, that is, the generating units and bulk transmission. Similarly, careful planning must be exercised in expanding not only the subtransmission and distribution systems but also the secondary services and meters for the individual customers.

Design

As the planning phases of system expansion are completed, the design engineer steps into the picture. He transforms the broad requirements conceived by the planning engineer into final working drawings and specifications for everything from a complete new steam-electric or hydroelectric generating plant to the primaries, secondaries, and services for a new residential community.

He must include both hydro and steam, transmission, distribution, and utilization—and even generation by nuclear energy, the newest energy source. Each of these broad fields of the power system is made up of a multitude of component parts—protective relays, current transformers, voltage transformers, overhead ground wires and ground resistance, insulation coordination, and synchronous machines. The design engineer selects the combination of components that will accomplish the over-all plan in the most efficient and economical manner possible, keeping in mind the responsibilities to customers and owners.

The principle of standardization plays an important part in this process of selection. Mass-produced standard components are generally more economical than specialized designs. However, if carried too far, standardization can deter rather than help, particularly if it tends to shut off new ideas or the adoption of improved methods.

Construction

In this field the construction engineer supplies the vital link between the design engineer and the contractor or company forces actually building the facilities. He must see that the expansion plans as conceived by the planning engineer and developed into actual designs and specifications by the design engineer come into being as planned and designed.

Cost control is an important element among the multitude of details involved. Construction costs must be kept within the budgeted funds, else the whole objective of best service at lowest possible cost may be lost. His problem involves the whole gamut of human relations with contractors, who expect the best profit from each job, and with labor, who expect the best return for each day's effort.

Operation

Now, presumably after planning, design, and construction are temporarily completed (they are never fully completed), a power system is ready to operate. The engineer's responsibilities now involve operation and maintenance.

More and more as time goes on, engineers are selected as power plant superintendents; superintendents of transmission and distribution; and superintendents of system operation, or power control. For their technical know-how familiarizes them with a power system's components, how they are put together, and how they must be treated to produce the best results. A system properly planned, designed, and constructed could fail completely to produce the optimum results were it not cared for in a precise manner in everyday operation.

The power control engineer must work with plant superintendents to plan programs of maintenance so that important apparatus can be taken out of service for repairs with the least detriment to system performance and to insure that all work is scheduled in the order of its importance.

He has one overriding responsibility —to see that all the power supply facilities of the system work as a team to insure that the requirements of all the customers are met in the most economical and reliable manner.

This simply means that the ever-changing requirements for power are supplied with minimum daily operating costs. This involves the full utilization of available hydro resources and the loading of steam sources for minimum fuel consumption. The principle of loading steam sources for equal incremental fuel costs has been well established. In recent years, modification of this principle to recognize the effect of transmission losses has been acknowledged. In other words, we must load our sources to equal incremental cost delivered to the load centers. Helping to solve this important problem are several forms of automatic computing machines, including penalty factor computers, the Early Bird, and others that aid in modifying the principle of equal incremental plant cost to satisfy the requirement of equal incremental cost of power delivered to load centers.

Each system is not only a study in itself with special problems and special applications of automatic equipment but also a challenging problem for the operations, or power control, engineer. Much work remains to be done in the field where the possible saving in everyday operating costs to a power system runs into incredible figures.

Other Activities

In addition to his preoccupation with the purely physical facilties of the power system, the engineer is often called upon to perform many other duties that help the system to function smoothly in its everyday operations. These include assistance to lawyers in preparing working arrangements with neighboring systems for the maximum benefits from interconnection; administration of such operating agreements to insure the equitable division of operating savings among participating systems; and assistance to his financial associates in preparing operating and construction budgets so that necessary funds are available at the appropriate times.

This picture of a power system shows how engineers have a continuing responsibility for its growth to meet the ever-increasing demands of our nation for reliable electric power service. And this must be done at the lowest possible cost consistent with a fair return to those whose funds have made it possible and a reasonable reward to the employees responsible for its continued success. Ω

AMERICAN SOCIETY *of* TOOL ENGINEERS

By HARRY E. CONRAD

Through the science and art of tool engineering, American industry has created the highest standard of living in the world's history. One of the youngest of all technical professions, it's an outgrowth of mass production. Webster's *Collegiate Dictionary* defines tool engineering as that "... branch of engineering in industry whose function it is to plan the processes of manufacture, design and supply the tools, and integrate the facilities required for production of given products with minimum expenditure of time, labor, and materials." This is a new definition, just as tool engineering is new compared with older technical professions.

Understanding the American Society of Tool Engineers (ASTE) and its accomplishments requires a knowledge of the tool engineer and his importance in industry. The definition of tool engineering covers a wide area, going far beyond the customary narrow definitions of tools and tooling. An accurate definition of a tool is anything that multiplies the effectiveness of man's efforts; thus a tool could be a lathe, a conveyor, a gage, or even a plant building.

To the tool engineer belongs the responsibility for the selection and utilization of the right production tools necessary for maximum efficiency in turning out a broad variety of goods for our modern civilization. This profession, more than any other, sets our present civilization apart from other civilizations.

Thus ASTE—the major engineering society furthering the development, interests, and know-how of this profession—faces big and constantly growing demands. The standard of living cannot continue to improve by relying on and using only yesterday's equipment and knowledge.

And so the Society not only works to keep its members abreast of the latest equipment available today but also tries to give them a good look at equipment and processes still in idea or development stages.

Organization and Growth

In 1932 when ASTE was chartered, no college or university had even considered teaching tool engineering. The Society, formed by 15 tool engineers, had grown to 114 members when its Charter closed on March 3, 1932. These and most of the thousands who later joined the Society did not have formal tool-engineering training. Their knowledge was acquired through practical experience—pioneers charting the way in a new branch of engineering.

Because of the Society's limited resources, progress at the outset was slow. In 1933, funds totaling less than $200 were tied up by the bank holiday—a near-fatal blow for a fledgling group publishing a monthly technical journal. But the generosity and personal financial efforts of members with the vision to see the future of the Society enabled ASTE to surmount what might have been a crippling setback.

In 1935 the Society chartered chapters in Racine, Wis., and Cleveland, Ohio—first steps in a national growth that has continued at a steady pace for the last 20 years. With four more chapters added the following year, national membership passed the 500 mark. The Society headquarters, originally located in the office of the first national secretary, moved to a separate office in 1936.

A 60 percent increase in membership a year later brought the realization that a full-time executive secretary was needed and that the Society's services should be offered to those who would eventually become full-fledged tool engineers. To meet this need, three classes of membership—senior, junior, and student—were offered to tool engineers in their various stages of development.

Today, ASTE members total more than 32,000 in 129 chapters in the United States and Canada (illustration, page 43). Most major industrial cities have chapters, with new ones being formed as other areas become more industrialized. During these years, tool engineering has grown from a rather nebulous art into a scientific concept. In this transition, ASTE has played a major part in facilitating the broad dissemination and interchange of information relating to the design and application of production equipment and processes. Furthermore, the Society has been prominent in encouraging the teaching of tool-engineering subjects in the nation's technical colleges and universities. More and more, the student can acquire a broader theoretical basis in tool engineering before beginning his practical education after graduation.

As the Society grows in chapters and total membership, the addition and expansion of services to industry and individual members contribute to its continued growth. The ASTE Purpose states that the Society is organized to advance scientific knowledge in the field of tool engineering and—through its members—to engage in research, writing, publishing, and dissemination of such information.

Technical development of the individual member has been a primary goal of the Society from its inception. Much work and study have gone into the arranging of technical meetings that offer subjects of the greatest interest to the largest possible number, presented by authorities in their fields. The quality of these programs soon attracted favorable attention to ASTE.

Because of ASTE's growing importance, membership, and services, a national headquarters building was necessary to not only house the staff required to perform its duties but also allow room for expansion. Consequently, in 1948 a large, modern headquarters building (photo, next page) was constructed at 10700 Puritan Avenue, Detroit, Mich. This handsome building—financed partially by a bond issue to

•

Mr. Conrad is Executive Secretary of the American Society of Tool Engineers. He has served in this capacity since 1945.

ASTE NATIONAL HEADQUARTERS—10700 Puritan Avenue, Detroit, Mich.—was constructed in 1948 to accommodate the larger staff needed to fulfill the growing duties.

the membership—is one of the finest structures of its type in the country and a source of pride to all the members.

Publications

One month after the Charter closed, the first ASTE journal was published. Adopting the title *The Tool Engineer* in 1934, it is still published today. A large full-time staff works closely with the Society's officers and Public Relations Committee, keeping a steady flow of technical information on the latest industrial techniques, machinery, and tooling.

The Society also publishes and distributes data sheets covering basic design features of all forms of industrial equipment; compiles and edits handbooks; and supplies trade and business publications and tool engineers with copies of complete technical papers presented at its national meetings. Selection of topics and speakers for the national meetings makes up an important segment of this information program.

By keeping a finger on industry's pulse, ASTE committees and the national headquarters staff know the subjects of the greatest current interest and the men best qualified to discuss them. Because the technical meetings enjoy a wide reputation for attracting quality audiences, leading engineers and manufacturing executives willingly present papers at these sessions.

During World War II, tool engineers shouldered a big share of the nation's production burden; and, significantly, membership in the Society more than tripled. At the beginning of the war, ASTE had 5670 members; the number increased to 17,198 by the end of hostilities.

These were busy years for the members, both on their jobs and in the Society. Many taught in the Government's Engineering-Science-Management War Training Program. And the Society helped publish and distribute war-training material—particularly the well-known New York State Education Department monographs.

Still, in 1943, ASTE did not hesitate to launch another much-needed project—the publishing of a handbook for tool engineers. The board of directors allocated an initial appropriation of $5000 for the project.

Following the exploratory and research work necessary to make the handbook authoritative and complete, the project got into high gear with the appointment of an editor in July, 1945. After years of research and editing, the first edition of the *Tool Engineers Handbook* made its bow in July, 1949. Its 2070 pages contain over 1800 illustrations, as well as hundreds of charts and tables written by some 250 technical experts. Myriad man-hours went into its preparation, and an investment of nearly a quarter of a million dollars preceded its publication. These are only statistics; the real value of this work lies in its acceptance by industry as the world authority. Demand remains strong; the *Handbook* is now in its sixth printing.

Work began immediately on a second edition and is still going on today so that the newest materials, ideas, and equipment will be included in the next edition. A full-time staff keeps ASTE technical publications up to date and recommends new publications when the need arises.

Four years ago, work was started on the *Die Design Handbook*—another major ASTE undertaking. Published in 1955, it's an authoritative source for complete details on design of sheet-metal products, process planning, theory and calculations, outstanding designs for all types of dies, die sets and elements, presses and accessories, and materials. Containing 700 illustrations and 125 tables, this volume is available to anyone in industry, as well as ASTE members.

Individualized current topics also receive their share of attention. Since 1934, ASTE has supplied its membership with data sheets describing numerous types of industrial equipment. Recently, this service has been expanded to include more information from leading manufacturers.

Research and Education

The ASTE Research Fund fosters research in the broad field of tool engineering and sponsors projects either entirely from the fund or partially subsidized by industry. Leading industrialists serving on this research committee give their time unselfishly in the interest of developing improved techniques of production. The foremost engineering schools and research centers in the nation handle the various research projects selected. The fund's director coordinates work at the various locations and acts as liaison between the committee and the research centers. To qualify for the fund, the projects must 1) apply to the field of tool engineering; 2) concern the basic, practical objectives; 3) advance the science of tool engineering; 4) result in economy of industry operation; and 5) allow unrestricted use of findings.

The appointment of an Education Committee in 1939 launched the first step in creating an educational program, presenting it to colleges and universities throughout the country. The purpose of such a program was to give basic knowledge to engineering students interested in making tool engineering a career.

Although the committee's initial efforts met with a discouraging reception, its work continued, ultimately producing tangible results. Today, numerous courses equip both undergraduate and graduate students for careers in tool engineering. Wholehearted cooperation from the more progressive universities, colleges, and technical schools made these achievements possible.

For those already in the field, the Society conducts a large number of one-day on-campus conferences at leading engineering schools for discussion of problems pertaining to tool engineering. Planning and carrying out these programs involve the cooperative efforts of ASTE national headquarters, chapters in the area, and the faculty of the school that serves as headquarters for the conference.

The Society awards several scholarships annually for advanced tool-engineering study in the United States and Canada, supplemented by scholarships granted by individual chapters. The ASTE also cooperates with the Engineers' Council for Professional Development (ECPD) and with educators in formulating specific curricula in the field of tool engineering. Local chapters, too, work with universities and technical and secondary schools in their geographic areas, developing educational programs of value to young men interested in tool engineering or engineering in general. They advise young men who have questions about their careers and try to help them decide whether they have an aptitude for tool engineering.

Service to Industry

Another milestone for the Society and industry occurred during 1938 when the first ASTE Machine Tool and Progress Exhibition—a big undertaking for so young an organization—was held in Detroit. The officers and members breathed a heavy sigh of relief when the 162 exhibitors attracted a large, enthusiastic turnout from industry. Today, the biennial ASTE Industrial Expositions attract 30,000 to 40,000 registrants from hundreds of industrial centers in the United States and Canada, plus numerous visitors from foreign countries. Because these expositions contribute much to the advancement of knowledge of industrial processes, techniques, and machines, companies use them to introduce new ideas and products to large top-flight audiences.

Recent Awards

Last year at the ASTE Annual Meeting, four new annual awards recognizing achievements in the tool engineering field were announced. . . .

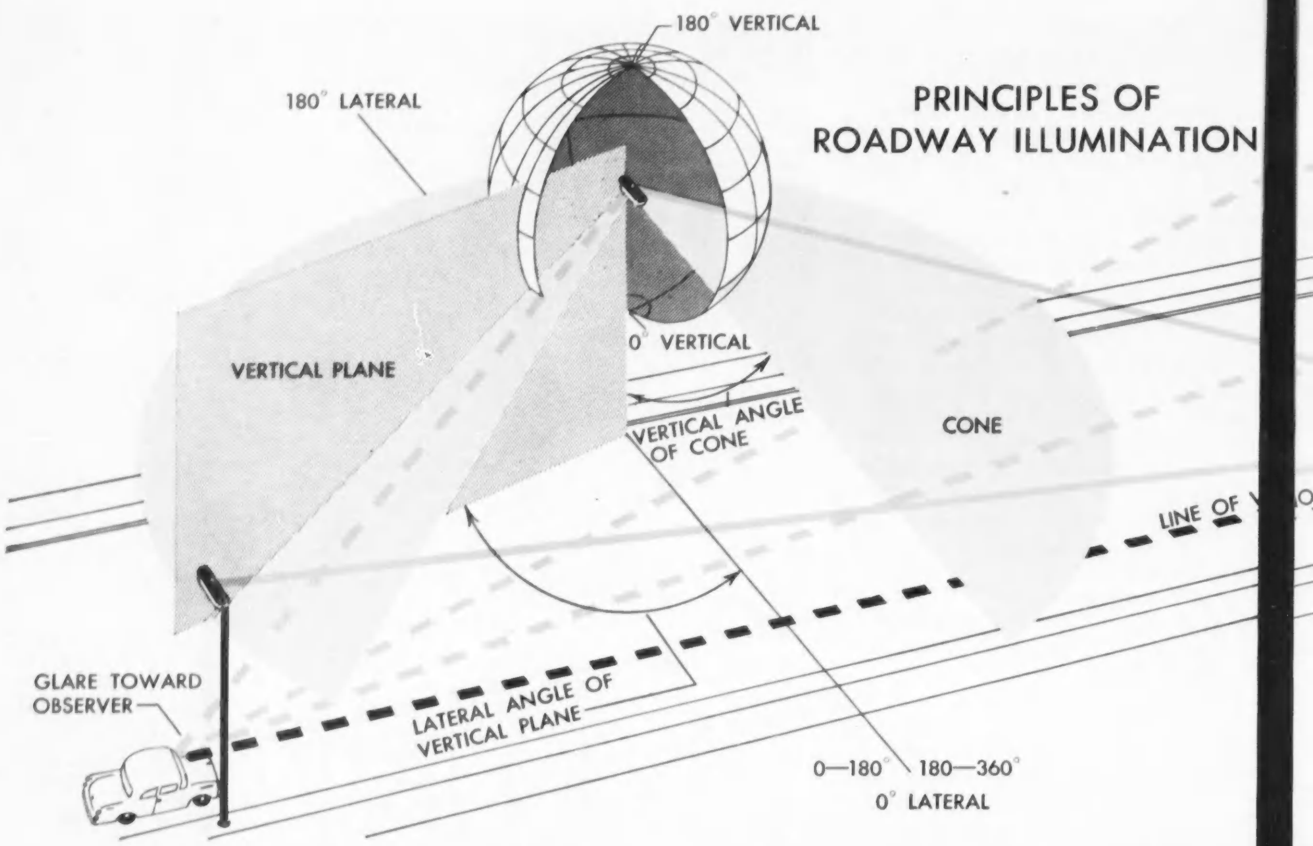
- ASTE Progress Award—awarded to Ernest R. Breech, Chairman of the Board of Ford Motor Company, for improvements in the field of manufacturing techniques and production methods
- ASTE Engineering Citation—awarded to Phillip McKenna, President of Kennametal Inc., for skill in the development of tool-engineering principles
- ASTE Gold Medal—awarded to Fred M. Colvin, Editor Emeritus of the *American Machinist*, for outstanding contributions to industrial progress during his 69-year career as an author and editor
- Joseph A. Siegel Memorial Award (in honor of the Charter President of ASTE)—awarded to O. B. Jones, President of the Detroit College of Applied Science and one of the Society's founders, for outstanding contributions to the Society.

The Society's Future

ASTE's exact course may be difficult to prophesy, but based on its past experience, continued expansion in membership and services can be safely assumed. Several new projects are being discussed currently; and because the Society throughout its history has earned a reputation for results, action will undoubtedly be forthcoming.

Without question, tool engineers will continue to play an increasingly important role in the production picture. Take automation as one example of their ever-growing industrial role. Many technical sessions, both at the national meetings and at the local chapter level, have helped individual members in understanding the advantages of automation and solving its attendant problems. Electronics, atomic energy, and other rapidly expanding fields are also being studied so that tool engineers will be kept up to date on any significant developments affecting their profession.

As long as ASTE maintains its progressive leadership and continues to attract members eager for knowledge, its growth both in numbers and in stature is assured. Ω



Good Streetlighting Equals Visibility

By J. STUART FRANKLIN

When driving or walking at night along the comfortable well-lighted streets and sidewalks of your home town, you feel an inner sense of security. Good streetlighting (photo, top) contributes to this, making nighttime activities safe and pleasurable. Your use and appreciation of comfortable well-lighted streets can be attributed to the pleasant atmosphere of the well-lighted interiors in which you work and play. For safety's sake, your ability to detect objects on or along the roadway can be enhanced in a comfortable environment. Good streetlighting achieves this by providing visibility with comfort. And installations become a matter of civic pride by having a pleasing daytime appearance as well.

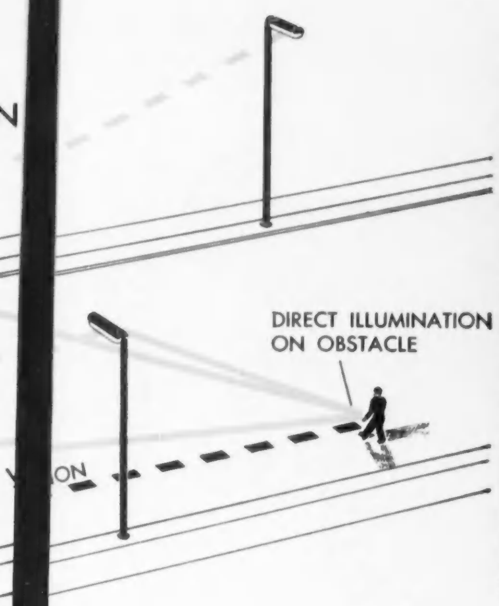
Differing considerably in construction and appearance from those of the past, modern streetlighting luminaires utilize the natural laws of light reflection, refraction, and transmission to give a rectangular pattern of light on the roadway. To achieve this, asymmetric reflectors, usually of aluminum, and refractors, generally glass or plastics, were designed (photo, lower, opposite).

Factors That Affect Seeing

Four factors primarily determine how you see an object as you drive along a road (Table, page 47). In addition, many other important but less understood or controllable factors affect your seeing—glare from oncoming headlights, brightness of roadway surroundings, and weather plus your own immediate condition. Assume a constant driving speed and a given obstacle size; whether you see the obstacle depends primarily on its brightness silhouetted against the pavement and the amount of annoying and unwanted light, or glare, reaching your eyes (illustration). The various luminaires provide light on the obstacle, light on the roadway, and glare in the driver's eyes. In other words, pavement and obstacle brightness are positive factors that aid your seeing; whereas luminaire brightness, or glare, decreases it. A happy balance between these and other factors provides good seeing.

You may ask, can these things be predicted or measured? Because lighting is both an art and a science depending on the human being as the ultimate seeing machine, prediction and measurement in this area are not exact sciences. However, our knowledge of this subject constantly increases as work progresses in laboratories both here and abroad. With present-day knowledge you can measure . . .

- Intensity of light emanating in any direction from a source, measured in candlepower
- Density of the light on an object (illumination, or light per unit area)



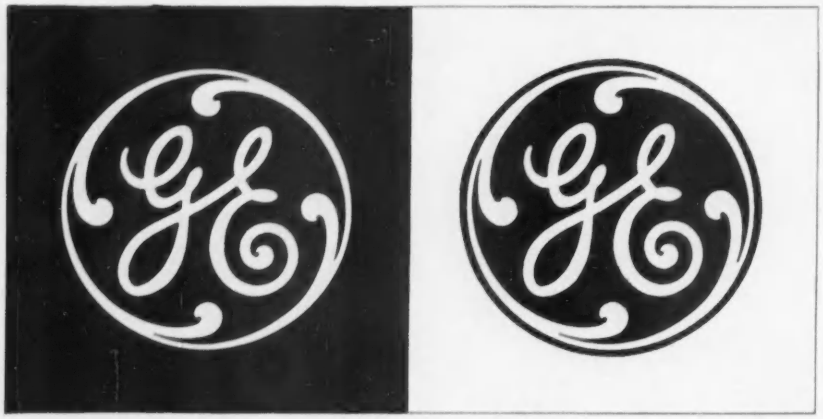
WELL-DESIGNED STREET LIGHTING provides a pleasant environment for pedestrians and drivers who are accustomed to comfortable interior lighting. The brightness of the obstacle against the pavement and the amount of unwanted light reaching the driver's eyes from the luminaire (illustration, left) determine whether he will see the obstacle he is approaching.

Plus Comfort

- Quantity of light on the object, measured in lumens
- Brightness of the object (the particular aspect by which you see the object).

Of all these physical characteristics of light and light sources, only brightness stimulates the eye. The visual effect produced depends on the conditions under which the object is viewed. For example, a lighted street-lighting luminaire, although unnoticed in the daytime, could annoy people with its brightness at night, yet become invisible in a thick fog. A glance at the illustration on the next page should convince you that although the intensity, density, and total quantity of light striking the two areas enclosing the G-E monograms are the same, the light leaving these two areas differs. Here the eye responds to the reflected light, which depends on the reflectance characteristics of the various areas of the

GLASS REFRACTOR for luminaire is discussed by author Franklin (right). Mr. Franklin joined GE's Test Course in 1939, later entering the Outdoor Lighting Department. In 1953, as Supervisor, Photometric Laboratory, Outdoor Lighting Department, Hendersonville, NC, he became responsible for all photometry and development of test equipment and procedures.



THE BLACK AREAS ABSORB MOST OF THE LIGHT, BUT THE WHITE AREAS REFLECT IT.

DISTRIBUTION PHOTOMETERS ANALYZE LIGHT INTENSITY TO PREDICT ROADWAY ILLUMINATION.

two monograms. The black areas absorb most of the light; whereas the white areas reflect it. Thus you see everything by the visual effect produced. However, don't conclude that the other factors are not important for they often help to predict brightness.

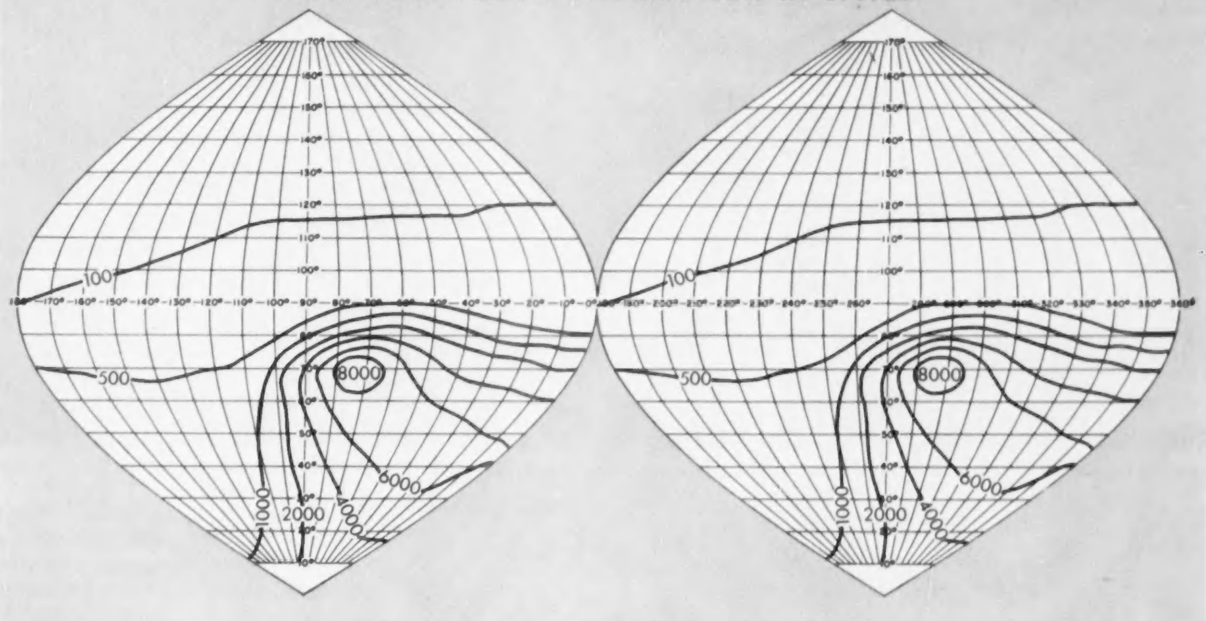
The Principles of Photometry

The science of photometry concerns the measurement of light by visual comparison or by some physical method that gives the same results. Because the human eye is the basis for all photometry, visual photometry requires that the operator make a light balance between a known and unknown brightness. On the other hand, physical photometry uses physical-type light receivers—light-sensitive cells like those in photographic exposure meters—corrected to respond to light as does the standard-observer curve. Over 30 years old, this empirical curve represents the response of the eye of many observers to light of various wave lengths. Photometers may be either visual or physical, designed to measure the various aspects of light.

The photometric laboratory of GE's Outdoor Lighting Department is the outgrowth of a half century of research and progress in the measurement of light from outdoor-lighting equipment. Many of its specialized and unique photometers have been designed and built by laboratory personnel. The testing procedures used are those recommended by the Testing Procedures Committee of the Illuminating Engineering Society (IES). New procedures are pioneered by the laboratory and presented to the IES Testing Procedures Committee for adoption.

To predict roadway lighting performance, an analysis of the light intensity radiating in every direction from the luminaires must be made on distribution photometers (photos). In effect, the luminaire to be tested is placed at the center of an imaginary sphere having a radius equal to the test distance. Light measurements are then taken in the direction of the luminaire, at intervals on a meridian of longitude. The resultant light-intensity curve occurs on a given vertical plane. If these light measurements are taken at intervals on a parallel of latitude, the resultant curve of light intensity occurs on a given cone. The American Standards Association (ASA) and the IES use this cone and vertical-plane designation partly to specify streetlighting-luminaire perform-

LUMINAIRE LIGHT DISTRIBUTION IN SPACE



A LUMINAIRE DISTRIBUTES ITS LIGHT IN PATTERN REVEALED BY MEASUREMENTS AS PLOTTED ON SINUSOIDAL EQUAL-AREA GRAPH.

ance. However, they recommend that a complete analysis of the light distribution be made. Light is then recorded at equal intervals of latitude and longitude and plotted in the form of lines of equal light intensity on a sinusoidal equal-area projection of a sphere (illustration). This projection not only keeps areas in their true relationship with corresponding areas but also permits use of graphic analysis. A complete analysis involves between 500 and 750 readings, depending on the complexity of light distribution. Testing, calculating, and plotting results for a fluorescent streetlighting luminaire takes several days.

Distribution photometers, operated by hand or mechanized, permit plotting curves of light output. Automatic punching of test data on IBM cards is included on some photometers. To eliminate unwanted, or stray, light from reaching the physical-type light receiver, the photometer operates in a room having black walls, ceiling, and floor. Along with the proper baffling of the light, this helps to assure the measurement of only that light coming from the equipment under test. Surprisingly, the main sources of error in the laboratory are the same as those that plague the amateur photographer in his homemade darkroom—dirt, stray light, and lack of attention to detail.

Not all photometers are black; some are white (photos, top, next page). Spherical and hemispherical photometers are based on the principle that the brightness of any part of the inner surface is proportional to the total light flux emitted by a source. Therefore, they will measure the total light output of bare lamps, streetlighting luminaires, floodlights, or searchlights. The only one of its kind in the world, this integrator is more than 35 years old, still in daily use, and contains what was once the world's largest iris.

A two-meter-diameter sphere (photo, center, next page) is used for lamp calibration purposes. Because the laboratory's primary concern is light measurement, the standard lamp becomes the basic reference of measurement. These lamps look like ordinary lamps but are calibrated for either total light output or light intensity in a given direction when operated under specific physical and electrical conditions. They are obtained directly from the United States National Bureau of Standards in Washington, DC, or from nationally recognized standardizing laboratories.

Performance

From these basic data, you can calculate the luminaire efficiency—how much of the generated light reaches the street (illustration, next page). Then the light density on the roadway is calculated and plotted in lines of equal density, or illumination. Next, the lighting installations are designed in accordance with ASA's *Standard Practice of Street and Highway Lighting*.

The future holds some promising results from the calculation and measurement of visibility along the street. Present calculations for specified conditions of roadway, luminaires, obstacle, and observer permit specifying average visibility along a particular driving lane as a single number. Several numbers may exist for the street as a whole—one for each driving lane.

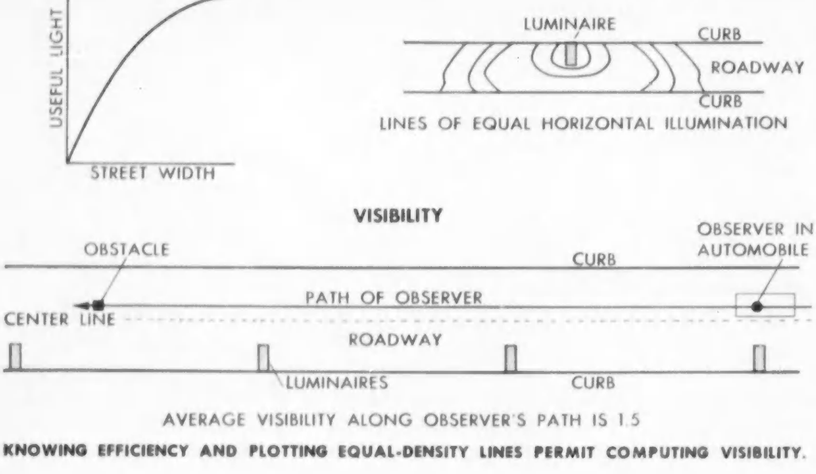
These numbers tell more about a streetlighting installation than all the curves in the past have told. They represent the dynamic performance of a typical night-seeing task by a standardized observer.

FACTORS IN HIGHWAY VISION

Factor	Description
TIME	Available to observer for seeing depends upon his speed of travel.
SIZE	Of obstacle, such as a hole in the road or a person on the road.
BRIGHTNESS	Of the pavement, obstacle, and luminaires.
CONTRAST	In brightness between obstacle and pavement or between luminaires and background.

HEMISPHERICAL PHOTOMETER MEASURES TOTAL FLUX EMITTED BY SOURCE, WHETHER STANDARD LAMP, LUMINAIRE, FLOOD, OR SEARCHLIGHT.

STANDARD LAMP FROM BUREAU OF STANDARDS CALIBRATES LUMINAIRE TEST LAMP.



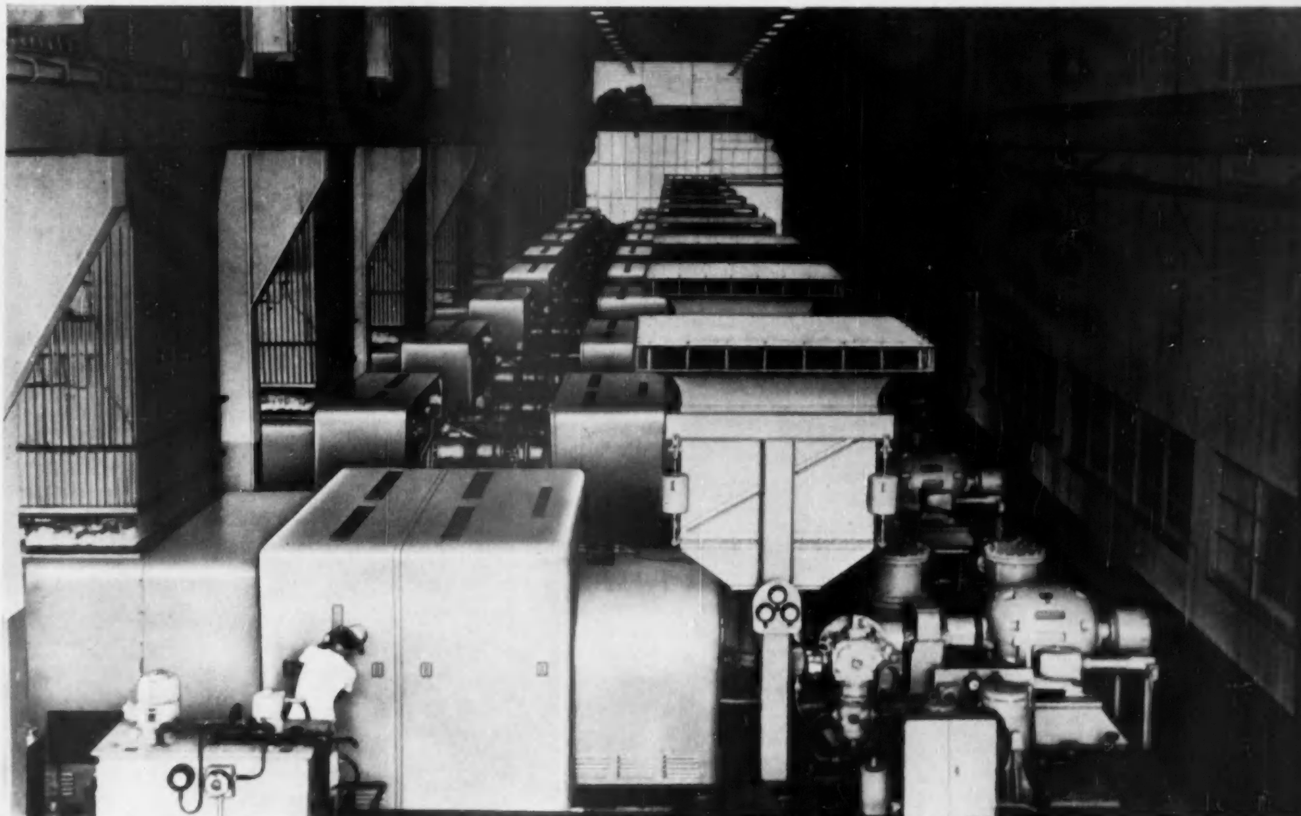
KNOWING EFFICIENCY AND PLOTTING EQUAL-DENSITY LINES PERMIT COMPUTING VISIBILITY.

In the past, the performance of any particular streetlighting installation was judged by a group of experienced streetlighting engineers and based on experience and measurement. Gradually, the considered judgment of a group of average citizens will be incorporated into an improved portable measuring device, thus making more accurate evaluations possible. Field measurements of total light on the road, the distribution of the light, and to a limited sense the visibility can be obtained with today's instruments. Although not as accurate as laboratory photometry, field photometry is essential to know how an installation will perform in actual situations faced by drivers and pedestrians.

Streetlighting's Future

More and more, streetlighting will be engineered and installed on a city-wide basis to nationally recognized engineering standards, and an over-all streetlighting-installation rating that considers the important physical, psychological, aesthetic, and economic factors may be realized. And better measuring instruments and calculating techniques for evaluating streetlighting are sure to follow.

With growing emphasis on visibility and comfort, more automatic instrumentation and computation will help provide some of the basic data still required to determine how ideal streetlighting can be obtained. Because of the close relationship that exists between lamp advancement and streetlighting, the light source of the future may solve some of today's troublesome problems. Ω



GAS TURBINES OPERATE AS A PRIME MOVER FOR CENTRIFUGAL COMPRESSORS IN AN OIL-FIELD REPRESSURIZATION PROJECT IN VENEZUELA.

Industrial Gas Turbines—Past, Present, and Future

By G. R. FUSNER

Last November marked the seventh anniversary of the first commercially operated industrial gas turbine in the United States. Installed in a demonstrator locomotive, this unit operated in revenue freight service on the Union Pacific, Southern Pacific, Pennsylvania, and Nickel Plate Railroads.

From this humble beginning, the application of these heavy-duty machines has expanded to the point where more than 100 General Electric units now operate as locomotive prime movers, electric power generators, mechanical drives for centrifugal compressors, and air-compressor plants. They have accumulated a total operating time of more than one-million hours, or 114 machine-years, with operating hours being increased at a rate of almost five machine-years per month, thereby establishing the gas turbine as reliable a prime mover as the steam turbine and reciprocating engine.

The gas turbine did not become a success overnight. Many problems, both expected and unexpected, required a solution in order to have a reliable operating machine. Because these problems have been solved, the gas turbine is here to stay, with many new applications in the process of being placed in service and others envisioned.

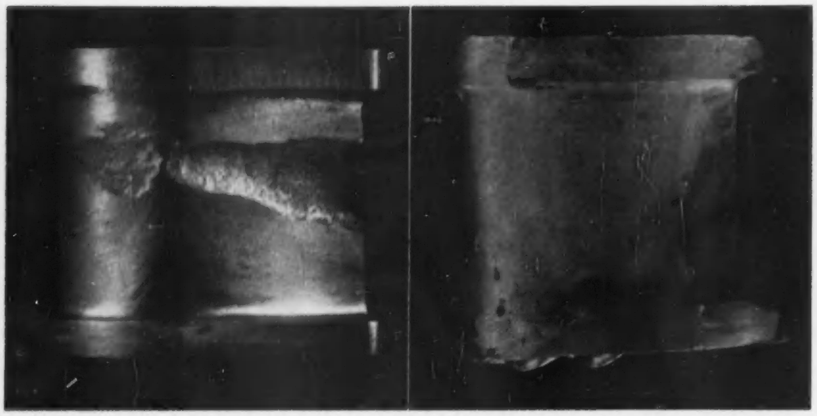
Gas-Turbine Components

The basic internal-combustion gas turbine consists of an air compressor, one or more combustors, and a turbine. Fuel is burned in the compressed air and expanded through the turbine that drives the air compressor and the load. In applications where the load requires a variable-speed prime mover, the turbine is usually divided into two parts, one driving the air compressor and the other driving the load.

Additional equipment can be used in the cycle if a high efficiency is required. For instance, a regenerator placed in the turbine exhaust recovers heat and transfers it to the air entering the combustion system, thus reducing the amount of fuel burned. Sometimes the compressor is divided into two components with an intercooler between them to reduce the work of the second compressor. Introducing a reheat combustor between the turbine stages achieves higher efficiencies.

Engineering Accomplishments

After World War II, the gas turbine established itself as the newest prime mover in the heavy-duty industrial field.



INHIBITOR ADDED TO RESIDUAL-FUEL OIL HELPS LOWER CORROSION RATE OF TURBINE PARTS.

COMPARATIVE MONTHLY COSTS OF FREIGHT-TRAIN SERVICE*

	Steam	Diesel-Electric	Gas-Turbine Electric
Repairs	27.44	16.56	14.45
Enginehouse expense	14.89	3.66	2.24
Fuel	54.99	20.12	22.23
Lubricants	1.47	1.40	0.47
Other supplies	5.65	0.16	0.04
Enginemen	18.28	18.79	14.22
Trainmen	22.42	23.34	15.54
Total	145.14	84.03	69.19
Total for same month (one year earlier)	130.67	85.78	87.32

* Cents per 1000 gross-ton miles (*Diesel Progress*, March 1955).

Much engineering effort went into its development to make it a successful device. Probably the most noteworthy accomplishment is the ability of the gas turbine to burn residual-fuel oil in a small combustion chamber and expand the resultant products through a turbine.

Shortly after World War II, when the temperatures and pressures of steam power plants were increased, some parts in the steam-generating units, such as superheater hangers, rapidly deteriorated in oil-fired plants. Investigation revealed vanadium pentoxide in the oil ash to be the culprit. Up to that time, the same oil had given little trouble, because the metal temperatures were low enough to minimize this compound's corrosive action.

During this same period, gas turbines burning residual-fuel oil were introduced as a prime mover for power generation in the electric utility industry. Gas-turbine buckets and nozzles operate at metal temperatures comparable with and higher than those in steam plants. The gas-turbine materials were also attacked, and an analysis of the corrosive material subsequently revealed that vanadium pentoxide and sodium sulfate were at fault.

Using the facilities available in laboratories, factories, and operating power plants, scientists and engineers developed successful methods of treating residual fuel. One method consists of removing most of the sodium from oil and then using magnesium sulfate, an industrial grade of Epsom salts, as an inhibitor. When a residual fuel is so treated and then burned in a gas turbine, very little ash is deposited, the corrosion rate is low, and satisfactory life is obtained on the parts that are subject to high temperature (photos).

This oil can be treated at the refinery or at the point of use, depending on the quantities involved, plus economic considerations. The gas-turbine locomotives operating on the Union Pacific burn oil that is treated at the refinery. These units have consumed more than 80-million gallons of treated residual-fuel oil, proving its successful use. A New England utility power station has treated approximately six-million gallons of oil and burned it in gas-turbine power plants, thus providing additional proof of its success.

Ideal for the gas turbine, gaseous fuels lengthen the life of the turbine parts, including the combustor liners. Distillate-fuel oil can also give satisfactory life of gas-turbine parts subjected to high temperature. In addition, dual-fuel operation permits changing fuels under load. Progress being made in burning pulverized coal indicates its commercial use in the future.

Although gas turbines operate at higher temperatures than steam turbines, the use of superalloys in the manufacture of gas turbines permits designing components with approximately the same safety factors provided in a steam turbine. Therefore, successful operation has been obtained on the rotating parts of these machines. On units operating in a service requiring frequent starting and stopping, special provisions prevent the parts that are subjected to high temperatures from cracking due to heat shock.

A new method of cleaning the gas turbine during operation is particularly advantageous on machines where the installation doesn't allow adequate filtration of the inlet air or where seasonal compressor fouling may occur.

Gas turbines are finding wide use in the electric utility, railroad, petrochemical, petroleum, and gas-transmission industries.

Industry Applications: Utilities . . .

The present applications in the electric utility industry are limited to gas turbine-generators. So far, the units that have been built in the United States for this service have normal ratings of 5000 kw and below. However, machines now being manufactured for this service range up to 16,000 and 21,500 kw. Some are used in connection with existing steam stations; others operate as independent units, a number of them being located in stations at the ends of long transmission lines. These units are ready to supply the electric load of the surrounding area if a storm severs the transmission line. Sometimes, when the transmission lines were operating near maximum capacity and could not meet new peak loads, the gas turbines more than justified themselves by saving the cost of new lines.

Other units supply energy during periods of maximum demand in existing load centers. The gas turbine is ideally suited for this type of service because it can be started quickly and placed on the line without any warm-up period. Several gas turbines are being used to supplement hydroelectric units during low-water periods. Again, this application is ideal because the stand-by charges for gas turbines are low and the units can be started quickly and simply after being out of service for long periods.

Because of its success, the addition of a gas turbine to an existing steam station has received wide publicity in technical literature. In such an installation, the exhaust gas from the gas turbine-generator heats feed water for the existing station. In stations that are low in boiler capacity, this arrangement enables the operator to get the most out of existing equipment. The gains resulting from such an arrangement vary, depending on conditions peculiar to each station. The addition of 3500- and 4000-kw gas turbines to the Belle Isle Station of the Oklahoma Gas and Electric Company increased the plant capability 14,000 kw and reduced the station heat rate 2.5 percent. A similar type of installation at the Rio Pecos plant of the West Texas Utilities Company uses a 5000-kw gas turbine to increase the station capacity 6600 kw and lower the heat rate 15.2 percent.

This kind of installation consumes about one gallon of lubricating oil for every 470,000 hp-hr. Operation on the No. 1 Belle Isle unit indicates a maintenance cost of approximately $2 per kilowatt-year. Forced outages of the unit have amounted to less than one percent of the total operating time. At an overhaul after 30,000 hours of operation, only the combustion liner caps of the combustors needed replacement. The remaining liner sections of the combustors, subjected to the highest temperatures in the machine, could continue operation.

. . . Railroads . . .

The gas-turbine electric locomotive has been favorably accepted on the Union Pacific Railroad for freight service between Cheyenne, Wyoming, and Ogden, Utah, a mountainous run that requires large locomotives. Because the units normally operate at either maximum or zero power, a simple-cycle single-shaft gas turbine can be justified.

Let's compare the available operating costs of the gas-turbine electric locomotives with the other types of locomotives operating on the Union Pacific (Table). The over-all statistics on diesel-electric and steam locomotives are average values for the entire fleet operating under various conditions. Statistics on gas-turbine electric locomotives are available from only one division of the railroad because they are operating only in this division, where they are used solely in high-tonnage high-mileage service that is best suited to the characteristics of the gas turbine.

. . . Petrochemical . . .

The only present application of a General Electric gas turbine in the petrochemical industry is a mechanical drive for a centrifugal process compressor. The exhaust gas from the turbine is passed through a waste-heat boiler to generate steam for the process. This application demands extreme reliability from the prime mover because it must operate continuously for long periods of time without shutdown. Gas turbines are competitive with other prime movers in this type of service.

. . . Petroleum . . .

Presently, G-E gas turbines are operating in two applications in the petroleum industry: in electric power generation similar to electric utility service and as a prime mover for centrifugal compressors in an oil-field repressurization project. An unusual application and the world's largest gas-turbine installation, ten 6000-hp simple-cycle two-shaft gas turbines and associated equipment are installed on a platform above Lake Maracaibo in Venezuela (photo, page 49). Seven stages of compression are required to pump the natural gas which is separated from the oil and is available from 5 psi pressure at the platform to approximately 1900 psi for injection into the earth where it helps to increase the petroleum yield of the field. The platform is so designed that it can continue to operate if any unit is out of service. This successful application is the most economical way of doing the required job.

. . . and Natural-Gas Transmission

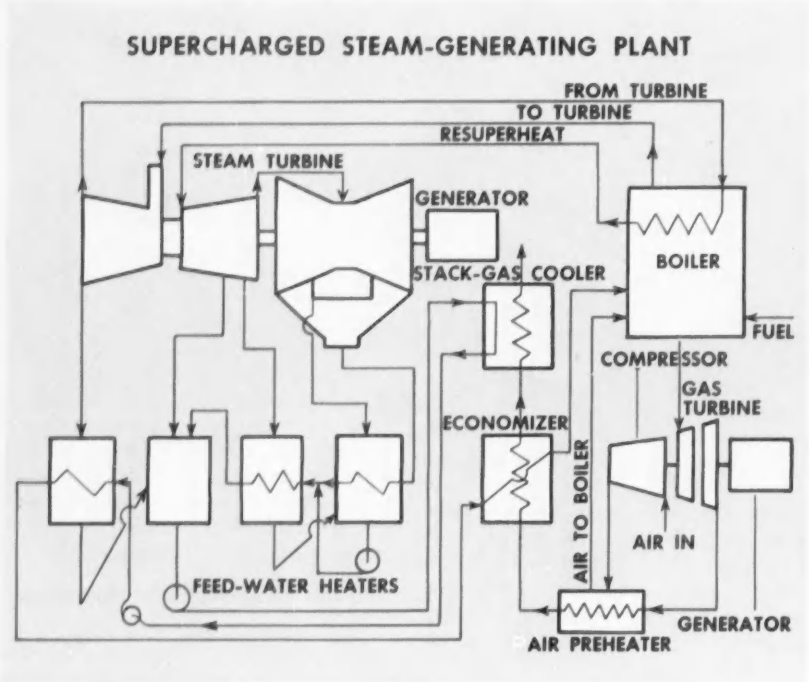
The natural-gas-transmission industry has been the largest user of this new prime mover. Gas pipeline pumping is a natural application for the gas turbine because the ideal fuel for the machine is readily available from the pipeline. Eight major gas-transmission companies have purchased 54 General Electric gas turbines totaling 308,500 hp. These have operated more than 400,000 hours with forced outages totaling only a fraction of one percent of this time, a record establishing the gas turbine as a reliable prime mover for centrifugal pipeline compressors.

In addition to its excellent reliability, the gas turbine has many advantages in this type of application. A pipeline using centrifugal compressors requires less installed power to drive the compressors than is required to drive reciprocating compressors. The gas turbine is ideally suited to drive a centrifugal compressor because the two components can be directly connected to each other.

The gas-turbine centrifugal compressor requires little operating labor, experience indicating that the labor required for a gas-turbine centrifugal compressor station is one fifth of that required for a reciprocating-engine compressor station of the same power. Lubricating-oil consumption of the gas turbine is one tenth of that required for a reciprocating engine of the same rating. Cooling-water consumption of the gas turbine is small. Maintenance costs are low on a gas turbine that burns natural-gas fuel. The customary inspection of

•

Coming with General Electric on the Test Course in 1942, Mr. Fusner has been associated with gas-turbine activities in relationship to industrial applications since the end of World War II. Presently, he is Supervisor, Stress Analysis and Vibration Unit, Engineering Section, Gas Turbine Department, Schenectady.



GAS TURBINE COMBINED WITH A STEAM PLANT SUPERCHARGES A STEAM-GENERATING UNIT.

the gas turbine occurs after its first year of operation, but major overhauls are scheduled following longer periods of operation.

Many factors other than the cost of the basic equipment make installed cost of the gas-turbine centrifugal-compressor station 20 percent less than a reciprocating-engine compressor station of the same rating. Because the gas turbine has a low specific weight and volume compared with most prime movers, the foundations and building can be relatively small. Gas turbines for pipeline service are shipped assembled on a structural-steel base (photo) that forms part of the foundation and contains the lubricating-oil and cooling-water systems, including their reservoirs. Electric wiring is also brought to convenient junction boxes. The gas-turbine stations require less auxiliary equipment and, consequently, fewer auxiliary structures. Further, the small number of operating personnel requires only a few cottages to be located at isolated plants.

Many gas-transmission companies have to pump their maximum capacity during the winter months. The characteristics of the gas turbine are such that extra power is available when the ambient temperature is low. At a temperature of 40 F, 25 percent more power is available than at the 80 F rating point.

In the future, gas turbines will continue to be applied in the same type of service as the units now operating. In addition, many applications are being studied, and others will be investigated as time permits.

Future Applications: Marine . . .

For some years, a gas turbine has been operating as a main propulsion unit on a British tanker. General Electric has built a unit for installation on a rebuilt Liberty ship as the main propulsion 6600-shp turbine, designed to operate on treated residual-fuel oil.

This turbine was built as part of the United States Maritime Administration Liberty Ship Conversion and Engine Improvement Program, which has two main purposes . . .

- Provide a means of evaluating the possibilities of upgrading the Liberty ships in reserve fleets by increasing their power and reducing their specific fuel consumption.
- Develop new types of improved propulsion plants for the American merchant marine.

. . . Petrochemical . . .

A gas turbine can be used as a source of compressed air for a chemical process. Air pressure up to six atmospheres can be extracted from the gas-turbine air compressor up to a certain percentage of the compressor flow, which will vary with each application. When higher pressures are required, low-pressure air can be extracted from the air compressor and boosted to the desired high pressure in a separate compressor driven by the gas-turbine shaft. Inert products from the process, available at a high pressure and temperature, can supplement the unextracted air to produce enough power to drive the compressors. Many times, this is the most economical way to obtain a large supply of compressed air.

. . . Petroleum . . .

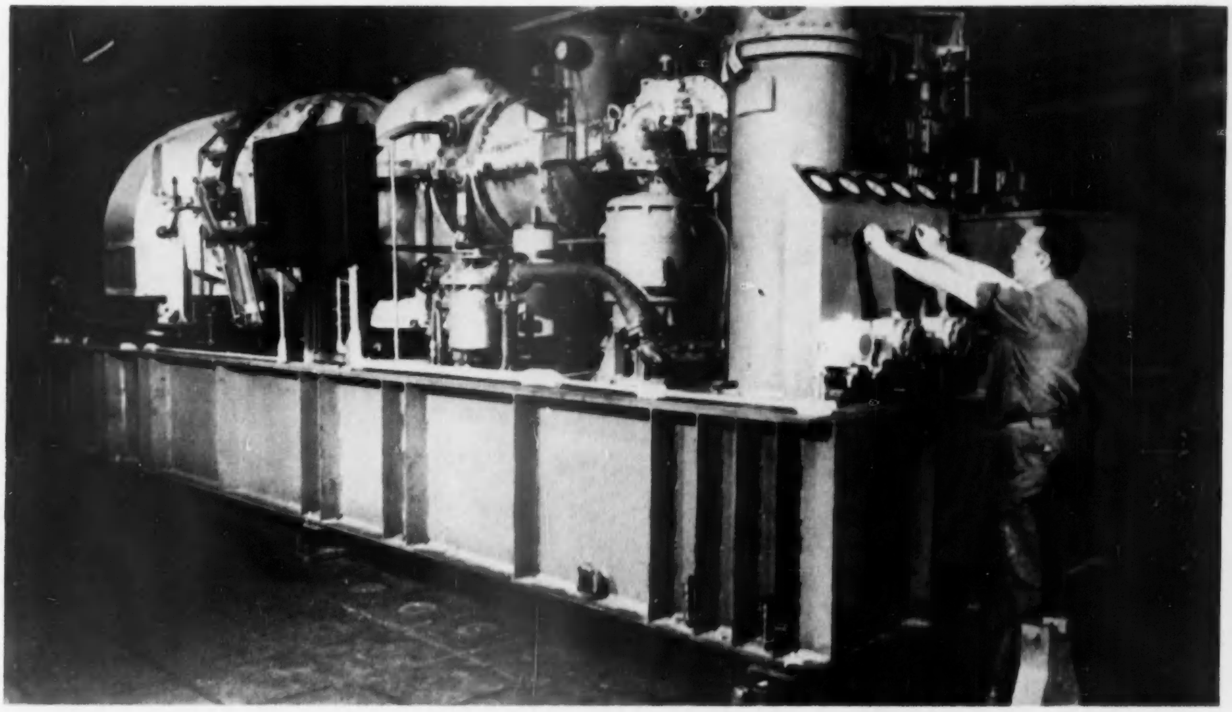
In certain locations, the gas turbine can most economically be used as a mechanical drive for a centrifugal pump in an oil pipeline. As with the gas pipeline, fuel for the gas turbine can be extracted from the pipeline.

. . . Other Processes . . .

The gas-turbine exhaust heat has many potential uses in connection with numerous processes. In the cement industry, the gas turbine could generate electric power, and the exhaust gas could dry the cement in the kiln. The fiberboard industry needs electric power as well as large quantities of heat for drying—two requirements that could be combined into an efficient gas-turbine operation. In the natural-gas-transmission industry, certain chemicals are commonly removed from the gas before it is delivered to a distributing company. Many of these removal processes require refrigeration. Here again, the gas turbine can serve a dual purpose: 1) drive a centrifugal compressor to pump the gas and 2) exhaust to a waste-heat boiler to generate low-pressure steam for steamjet refrigeration equipment.

. . . Utilities . . .

New applications in the electric utility industry will probably be in the form of a combined gas-turbine steam-turbine plant. This combination can be made in a number of ways. One method is to drive boiler-feed pumps with gas turbines and discharge the exhaust into the furnace of a steam-generating unit to furnish a portion of the combustion air. Economically attractive, this arrangement reduces the net station heat rate and increases the net station output for a given gross output. Modern steam



GAS TURBINES FOR PIPELINE SERVICE ARE SHIPPED ASSEMBLED ON A STRUCTURAL-STEEL BASE THAT CONTAINS OIL AND WATER SYSTEMS.

plants operate at increased pressures that demand increased speeds and power from boiler-feed pumps. Therefore, a high-speed high-powered prime mover such as the gas turbine is desirable for direct connection to the pumps. The large power requirements of this application make a motor installation relatively more costly per kilowatt than in low-pressure plants of the same output. The inefficiency of a constant-speed drive at partial loads amounts to a larger percentage decrease in plant efficiency than is common today. Therefore, a variable-speed drive such as the gas turbine has additional advantages as a boiler-feed-pump drive. It also provides an independent self-contained unit that can be quickly started in an emergency when the plant is isolated from the remainder of the utility system.

A gas turbine can also be combined with a steam plant by using the compressor discharge air to supercharge a steam-generating unit (illustration). Combustion products from the steam-generating unit are then expanded through the gas turbine to drive the compressor and an electric generator that produces approximately 15 percent of the steam turbine's output. After leaving the turbine, the gases pass through an air preheater, economizer, and feed-water heater. Such an arrangement shows a calculated gain in station heat rate of five to eight percent over a conventional steam plant having the same rating.

Further, the steam-generating unit's weight and volume are tremendously reduced, as is the volume of the plant building; fans are eliminated on the steam-generating unit; and the plant can be erected faster and with less labor than a conventional installation. The supercharged plant also has another advantage in its ability to start more quickly than existing plants. All these add up to a lower investment.

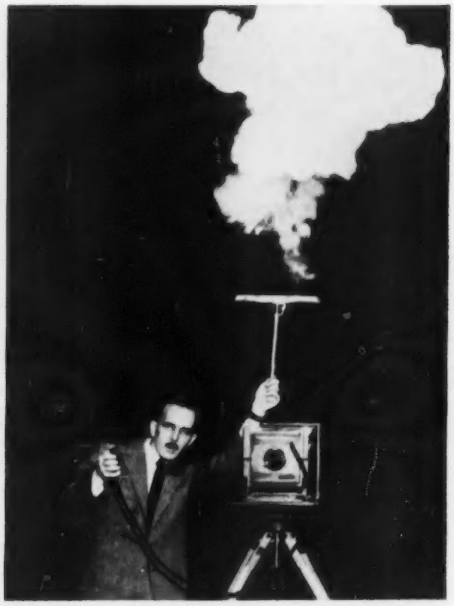
. . . and Railroads

The Union Pacific Railroad recently ordered additional units to supplement its fleet of 25 gas-turbine electric locomotives. This type of locomotive was selected because of its excellent operating record and because it is particularly applicable to the Union Pacific's problem of moving freight trains faster and more economically.

The articulated-cab locomotive will have a gas-turbine prime mover that has a rating of 8500 hp input to the generators for traction at 6000-foot altitudes and a 90 F compressor-inlet temperature. Housed in the leading section will be the operator's compartment, air-brake compressor, dynamic braking resistors, controls, and an auxiliary diesel-power unit necessary to operate the locomotive. The other section will contain the main gas-turbine power plant that will be remotely operated. A tender will carry 24,000 gallons of treated residual-fuel oil, thus assuring an adequate cruising range and minimum change in adhesive weight. The new gas-turbine electric locomotives, like their predecessors, pack much power into a comparatively small space. In terms of length, the 8500-hp locomotive will produce approximately 51 hp per foot (including tender) compared with 35 hp per foot for a modern diesel-electric freight locomotive.

In Summary

Looking at the past, one can see that many problems crossed the path of the industrial gas turbine's development. Because these problems have been solved, today's units are establishing excellent operating records in many diversified applications. The crucial gas-turbine-development period is over; the gas turbine has passed the test of operator acceptance. Many new applications, including atomic energy, make the future look extremely bright for the industrial gas turbine. Ω



ECONOMICAL, EFFICIENT FLASH PHOTOGRAPHY—AMERICA'S FASTEST GROWING HOBBY—REPLACES SMOKY AND NOISY EQUIPMENT.

Photoflash Technology Hits Its Stride

By ROBERT M. ANDERSON

In the early days of flash photography, high-intensity illumination was obtained by burning metal ribbons or powder—usually magnesium—or mixtures of metal powders and oxidizing agents. Flint sparks, fuse, percussion caps, and electric heating ignited flash powder in open receptacles, resulting in smoke, odor, noise, fire hazard, and difficulty in controlling the amount of light desired.

When General Electric introduced the first photoflash bulb in the United States on August 1, 1930, few imagined its terrific impact on American society in the next quarter century. More than two billion flashbulbs have been produced in this country. Production has reached an annual retail value of $65 million, or half a billion lamps a year—about 24 percent of all electric lamps.

Flash photography probably is America's fastest growing hobby. Approximately 19 million of the 68 million cameras in active use in the United States are equipped for flash attachments, and virtually 100 percent of all new cameras are so equipped.

Physically, photoflash lamps have several characteristics of regular incandescent lamps. The lamp bulb simply contains flammable metal and oxygen. By igniting the primer at the inner lead tips when current is applied to it, the filament supplies the initial heat energy to start the flammable metal burning. The light source depends either on the combustion of aluminum foil or the burning of zirconium metal powder placed on the lead wires.

Specific lamp designs depend on the service, type of camera, and the necessary synchronization of flash and shutter opening. An explanation of engineering design requirements of the component parts will show how these various needs are met.

Bulb

The size and shape of the lamp bulb not only govern the maximum quantity of light that can be expected from the lamp but also influence the time rate of combustion of the flammable metal. During the flashing of a photoflash lamp, peak pressures of approximately 25 to 30 psig are developed in some types of shredded-aluminum-foil-filled lamps and about 40 to 50 psig in the primer-type lamp.

Lamps of both classifications are filled initially with oxygen at a pressure below atmospheric. As the burning flammable metal creates high temperatures, these high peak pressures result from the expansion of uncombined oxygen plus a portion of the flammable metal and its oxide reaching their boiling points. In designing a photoflash lamp for a given light output, a bulb must therefore be selected that will withstand the expected instantaneous peak pressures and mechanical shock wave.

Although a glass bulb may resist any of the peak pressures during the flashing of a photoflash lamp, its resistance to the sudden thermal shock is practically nil, making a rupture in the glass likely. Such a rupture might travel up to a maximum rate of one mile per second. To safeguard against such an explosion, bulbs are lacquer-coated and precautions are taken at the factory to keep all glass parts free from strains.

Oxygen

Pure oxygen supports the combustion of the light-producing material in a photoflash lamp. Lamp manufacturing

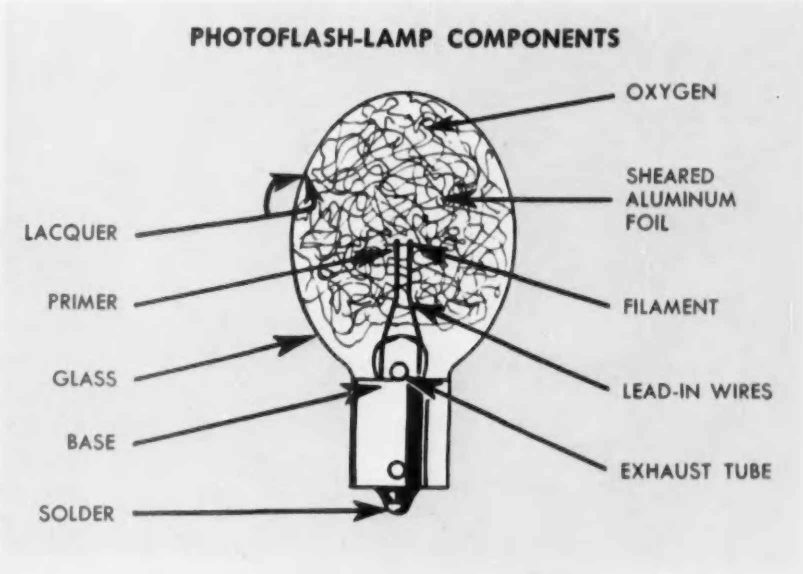
•

Mr. Anderson—design engineer, Photo Lamp Department, Nela Park, Cleveland—began his career with General Electric on the Test Course in 1946. He is responsible for both the design and quality of all GE's photoflash lamps.

techniques, the bulb's resistance to peak pressures, and the quantity of combustible metal to be changed to its oxide, all influence the initial oxygen-filling pressure to be used in a lamp. Should the initial oxygen-filling pressure and bulb volume be fixed, theoretical computations determine the quantity of combustible metal to be used in the lamp. In bulbs of large diameter and volume, the practical and the theoretical amount of metal is approximately the same. However, as the lamps decrease in size, the quantity of metal in the lamp is increased above theoretical.

In small lamps the hot particles of molten metal and its incandescent oxide have less free travel space before touching the relatively cool bulb wall, thus becoming lost to the reaction. The added metal offsets this combustion inefficiency.

For foil-filled lamps, the small quantity of oxygen liberated by the oxidizing agent in the primer doesn't have to be considered. However, the considerable amount of oxygen liberated by the oxidizing agent in a primer-type lamp (SM) must be considered in any theoretical computations.



LAMP DESIGNS DEPEND ON CAMERA AND SYNCHRONIZATION OF FLASH AND SHUTTER OPENING.

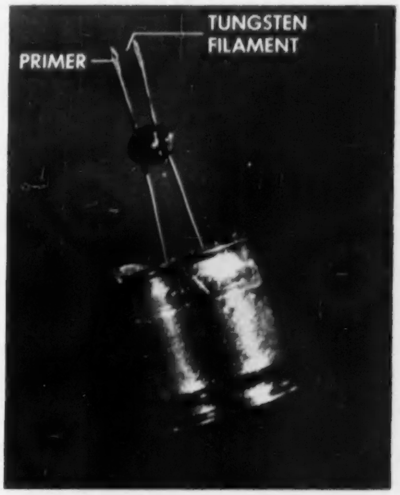
Filament

In most types of incandescent lamps, the tungsten filament serves as the source of light; but in the photoflash lamp, it ignites the primer and, in turn, the shredded aluminum foil. To reduce the amount of electric energy required to flash a lamp, development engineers strive to develop more heat-sensitive primers so that smaller diameter tungsten filaments can be used. The filament today is 0.7-mil-diameter straight tungsten wire—about one third the diameter of a human hair—press mounted to the leads approximately 1½ mm apart. Previously, the filament's diameter was one mil.

For a given filament diameter, two important factors determine the filament length to be used between the inner leads . . .

- If the filament is too short, the minimum amount of electric energy required to flash the lamp must be increased to overcome the cooling effect caused by the heat conductivity of the leads. If a high-current impulse such as that from a capacitor is used to flash a lamp, the lead wires have a negligible cooling effect on the filament. Close inner leads present the danger of coating the filament with a heavy layer of primer during lamp manufacture, which would produce a cooling effect on the filament when a lamp is flashed in a low-energy d-c circuit.
- If the filament length gets too long between the inner leads, an inoperative lamp results; its resistance becomes too great, and the hot spot, or point of filament burnout, occurs too far from the primer to ignite it when current is applied.

Tungsten is used as the filament wire for several reasons: resistivity characteristics; ability to be mounted to other metals by impact; high burnout, or melting temperature; and great tensile strength. The cross-sectional area of any other metal must be approximately twice that of tungsten before it can be handled without excessive breakage in factory production. If this area of a metal wire were increased to obtain the desired total strength, electric energy input must also be increased to heat up the filament of a given length to the temperature required to flash the primer.



FILAMENT IGNITES EXPLOSIVE PRIMER.

Primer

Primer—a layer of heat-sensitive explosive material—coats both inner leads from their tip to below the filament mounting. When a current begins to heat up the filament, the primer absorbs some of this heat energy until it reaches its flash point. In a foil-filled lamp, the flashing primer in turn ignites the foil. The quantity of primer in such a lamp governs the time that the lamp will take to reach its peak light intensity after the current is applied. In the SM lamp, the metal within the primer itself is the light-producing material, and the primer formulation controls its burning characteristics.

Basically, primer is a homogeneous mixture of highly flammable metal powders, oxidizing agents that can be reduced at a relatively low temperature, and a binder that will decompose rapidly with heat and not appreciably slow down the combustion of the metal.

Most of the many types of binders or adhesives on the market today would interfere with the ignition and burning of the highly flammable metal in a primer. Even nitrocellulose—the material generally employed as the binder

ZIRCONIUM METAL POWDER—heat-sensitive ingredient in a primer—ignites readily, resists oxidation in an oxygen atmosphere at normal temperatures and can be handled safely.

for photoflash lamp primer—starts to decompose at 140 C. Thus considerable care must be exercised during lamp fabrication to keep the inner lead tips as cool as possible to prevent the binder from decomposing and the primer from flaking away from the lead wires.

An oxidizing agent used in primer formulations instantaneously supplies oxygen to all metal particles within the primer, thus insuring its rapid combustion. Oxygen released by the decomposition of the oxidizing agent also propels the hot metal particles of primer throughout the bulb. High-density oxidizing agents that readily release large amounts of oxygen per unit weight insure that primer beads do not become large and bulky. Lead peroxide, sodium chlorate, and potassium perchlorate are the three main oxidizing agents used in primer formulations in the manufacture of photoflash lamps throughout the world.

Zirconium metal powder—the heat-sensitive ingredient within a primer—ignites readily, resists oxidation in an oxygen atmosphere at normal temperatures, and can be handled safely if certain precautions are followed. The auto-ignition theory applies when zirconium metal powder is ignited. For instance, if a gram of this material is spread thinly over a large area, its ignition temperature would be approximately 450 C. However, if this same quantity of material is concentrated into a small pile, its ignition temperature drops to approximately 250 C. The color temperature of burning zirconium metal powder in an oxygen atmosphere is 3250 degrees Kelvin, which incidentally makes an SM primer-type lamp nearly a perfect match for all indoor (tungsten-type) color films.

Although magnesium metal powder requires considerably more energy to be ignited than zirconium metal powder does, small percentages of it are used in some primer formulations. For, once ignited, it will burn at a higher flame temperature than zirconium, thus reducing the total quantity of primer required within foil-filled lamps to get correct timing of the peak intensity of light output.

When foil-type lamps flashed, two dark spots would occur on the inside wall surface of the bulb at its maximum diameter. These spots—a deposit of unburned aluminum and primer material—were located in an area perpendicular to the filament wire between the inner leads. By bending the primered ends of the inner leads 90 degrees, but maintaining the same spacing between them (illustration, preceding page), the dark spots occur at the top of the bulb and in the base region of the lamp. This base region does not contribute to the lamp's light output; only the dark spot at the top influences light output. The reduction of darkening on the transparent bulb surface increases total light and peak intensity by 10 to 15 percent. However, because of the nature of the light performance characteristics desired from some types of lamps, straight inner leads are still used in these special types.

Light Production

Aluminum—the light-producing material in all photoflash lamps other than the SM lamp—produces a continuous spectrum of intense white light with a color temperature of approximately 3800 K. Readily available commercially, aluminum is relatively inexpensive and can be handled without danger to factory personnel. Throughout the years, a large variety of other metals has been used as the combustible material in experimental photoflash lamps. However, the light output obtained from a unit weight of aluminum when burned in an oxygen atmosphere far exceeds that of other metals of the same physical dimensions.

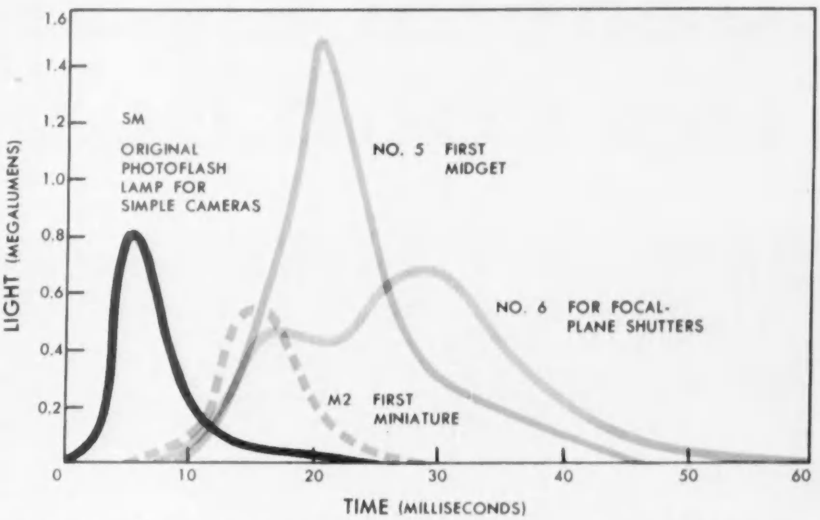
Some metals vaporize more readily than others during combustion within a bulb, resulting in a dense deposit on the bulb wall before final oxidation. Then lost to the reaction, this deposit reduces the light output of the lamp—a pronounced phenomenon when magnesium metal ribbons or powder are used in a lamp.

In the early days of photoflash lamps, aluminum sheet, or foil, was relatively costly, being produced by hammering pellets between goat skins, the goldbeater's method. The thickness of this foil varied from 0.04 to 0.45 mils. Upon ignition in a photoflash lamp, these sheets burned with great rapidity and with high radiant-energy peaks that had poor uniformity of synchronized light output. Unburned sheets near the bulb surface masked some of the light output when the lamp was flashed.

Alco wire, developed to increase the light output of a photoflash lamp above that obtained with foil, is one-mil-diameter filamentary aluminum, produced by drawing a number of heavy aluminum wires, or rods, inside a copper tube and then dissolving away the copper. Evenly distributed within a photoflash lamp, Alco wire gave a longer burning broad-peak lamp with not only an improved uniformity in synchronized light output but also a considerably higher light-output efficiency per unit volume—nearly three times that of sheet foil.

Because Alco wire production was slow, cumbersome, and expensive, a new method was sought for making lamps having the desired long-burning characteristics. Thin strips, or ribbons, of commercially pure aluminum foil were sheared from eight-inch-wide rolls that had a thickness-variation limit within ±10 percent. The foil thickness used in the shredding, or shearing, process depends on the time-lumen characteristics desired from a particular lamp design (illustration). In general, foil thickness used for photoflash-lamp production ranges from 0.5 to 1.2 mil; the sheared width is less than one mil. Also depending on lamp design, a definite number of the sheared strips are vacuum-drawn into the bulb and then evenly distributed by an air jet. Distribution can affect time to peak, peak intensity, and total light.

A photoflash lamp designed for use with cameras that have focal plane shutters gives a light output of long duration with a low uniform peak intensity obtained from two layers of shredded foil. The layer toward the top of the bulb has strands of foil having a relatively large cross-sectional area as compared with the strands in the layer toward the bottom of the bulb and near the lamp igniter, or primer. The light output depends on the time-lumen characteristics of each layer of foil partially superimposed on each other.



ALL PHOTOFLASH LAMPS utilize aluminum as the light-producing material, with one exception. In the SM lamp, the metal within the primer itself is the light-producing material.

Interior . . .

The interior lacquer coating acts as a buffer in protecting the glass from thermal shock caused by the combustion particles when a lamp is flashed. A lacquer must be clear, adhere well to glass, and have a hard but not brittle surface to prevent particles of molten metal from penetrating it and reaching the glass surface. Further, it must decompose slowly enough with heat so as not to interfere with the exothermal chemical reaction taking place in the lamp. The tensile strength appears to be of no significance.

Some plastics that have been used as interior bulb coatings are nitrocellulose, vinylite, cellulose acetate, or combinations of the three. Both nitrocellulose and cellulose-acetate coatings sometimes shrank away from the interior bulb surface and entered into the reaction when the lamp was flashed, thereby making a potential bomb out of the lamp. Although vinylite lacquers adhered well to the interior bulb surface, they did not offer enough resistance to the molten particles of metal traveling toward the glass bulb walls. A blend of nitrocellulose and vinylite plastics fulfills most of the requirements of an interior bulb coating.

Interior coatings can either be sprayed or flushed into the bulb. Spraying keeps the bulb neck free from heavy lacquer material that may interfere with a perfect bond between lamp parts.

. . . and Exterior Bulb Coatings

Cellulose acetate—the exterior bulb coating—has many excellent advantages: high tensile strength and temperature resistance, no appreciable change with age, clearness, easy application, and relatively low cost. Industry also makes increasing use of this material.

Cellulose acetate lacquer is applied to photoflash lamps by the dip process. For uniform lacquer distribution, accurate control is kept not only on the temperature and viscosity of the lacquer but also on the withdrawal rate of the lamp from the lacquer bath.

Many products have been tried as outside coatings for photoflash lamps: polyethylene, polyvinyl chloride, polystyrene, polyacrylonitrile, polyvinyl butral, methacrylates, polyamides, polyesters, cellulose acetate butyrate, and the epoxy resins. These were applied by various techniques—solution, dispersion, or hot-melt. Cellulose acetate still excels other coatings.

The three-sixteenth-inch-diameter neck opening for the miniature (M2) photoflash lamp makes flushing or spraying a lacquer onto the interior surface of the bulb difficult at high production speeds. A new system using two immiscible lacquers on the outside of the bulb protects against shattering the glass bulb when a lamp is flashed and eliminates the need for an interior coating. The lacquer on the glass surface is a heat-absorbing film, and the other a cellulose-acetate lacquer film of high tensile strength.

When an M2 lamp is flashed, the lacquer film in contact with the glass absorbs a large quantity of the heat energy transmitted through the glass bulb wall, thus protecting the outer lacquer film from abnormally high temperatures that may char it or destroy its tensile strength. The heat-absorbing lacquer film will also become thermoplastic and sticky, preventing the fragmentary glass particles from flying should a rupture of the bulb and the outer lacquer film occur.

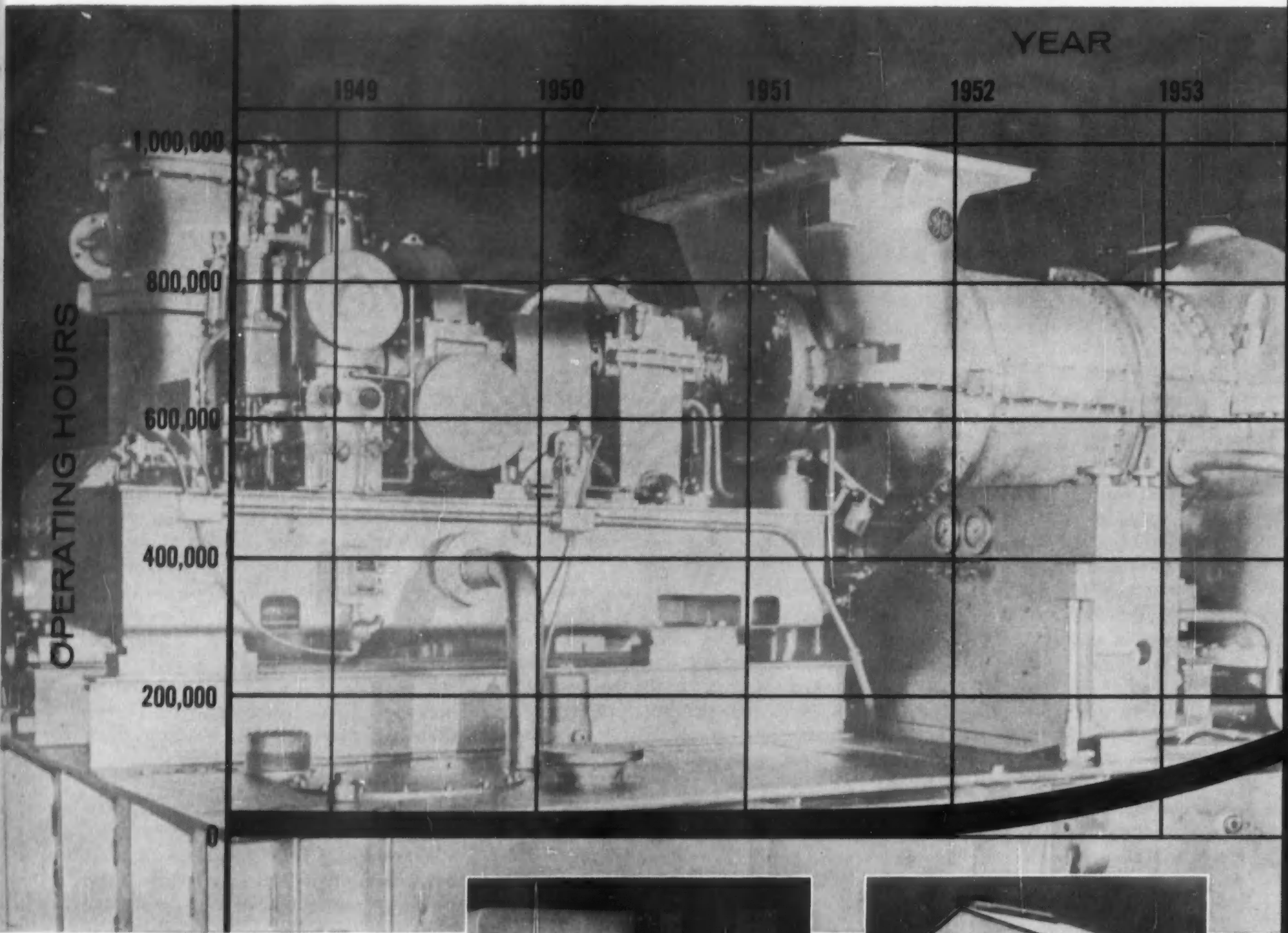
The blue cellulose-acetate exterior bulb coating on some foil-type photoflash lamps filters spectral energy. This corrected distribution permits its use with daylight color film, having spectral-sensitivity response corresponding to that of noonday sunlight plus skylight at Washington, DC. Carefully controlled quantities of fade-resistant blue dyes added to normally clear lacquer accomplish this correction. The spectral-distribution curve of a clear foil-type photoflash lamp approximates that of a black body radiator at 3800 K.

Scientists and engineers constantly strive to improve present designs and develop new ones in the entire field of photo-lamp technology. Ω

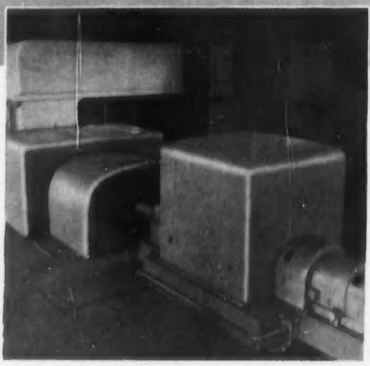
CREDITS

Page	Source
10–21	George Burns
29 (lower)	*Metal Progress*
42	Lens Art Photographers Detroit, Mich.

General Electric Gas top 1,000,000 hours



The Million Hours of operating time shown on the graph above have been logged in applications similar to those shown at right →

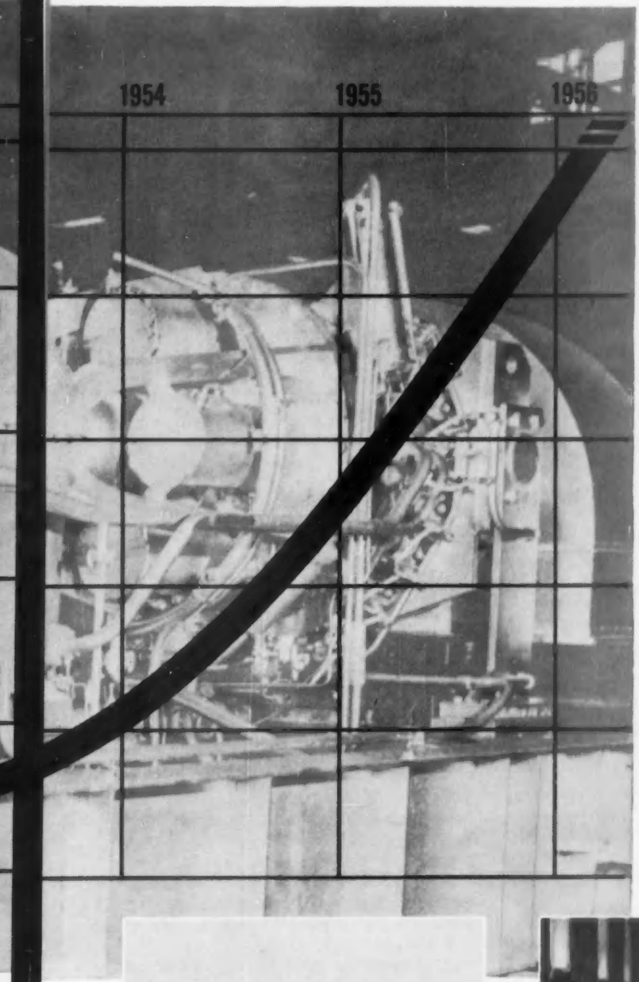


IN POWER GENERATION, G-E gas turbines are continuing to prove an economical addition to steam turbine-generator systems. In one installation, the addition of a gas turbine to the steam station cycle improved the heat rate 15%. Naturally, improvements will depend on existing station conditions.

IN GAS PIPELINE PUMPING, G-E units lower pumping costs. G-E gas turbines are ideal for these installations as they go on the line in less than 15 minutes, can operate virtually unattended, use gas from pipeline as fuel. Little or no water, only a small amount of lubricating oil are required.

Turbines of service

Now, new ratings from 4750 to 28,400 kw promise even wider use of G-E units in electric utility power generation



With an impressive 1,000,000 hours to their credit in varied applications, General Electric gas turbines are now becoming an increasingly important consideration in the selection of power plants for utility power generation. As versatile, low-cost, self-contained power makers, they offer particularly attractive opportunities for use as peak-load and standby units—as well as in small and medium base-load plants, end-of-line generating installations and combined gas turbine-steam turbine cycles.

LOW OPERATING COSTS of General Electric gas turbines have been proved through 114 machine years of service in more than 100 industrial and utility installations. Suitable for remote, unattended operation and containing few wearing parts, a G-E gas turbine power plant requires very little maintenance. According to one user, maintenance costs have amounted to only 0.2 mills per kilowatt hour. In addition, installation cost per kilowatt is less for a General Electric gas turbine-generator station than for other complete power plants of comparable size. Gas turbines up to 9200 kw are shipped and installed on an integral base requiring only a small area and a simple foundation.

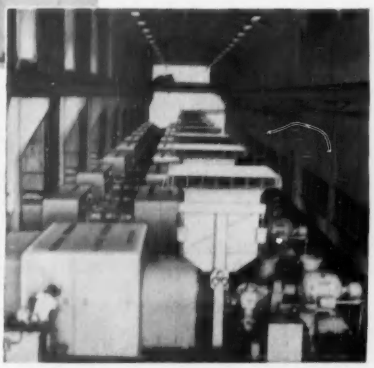
NEW RATINGS FROM 4750 to 28,400 kw promise to open up a broader field of application where the unique features of the gas turbine can bring even greater economies.

Your nearest Apparatus Sales Office will be glad to consult with your engineers and show how the special advantages of a G-E gas turbine can be applied to your operation. Or write Section 261-18C, General Electric Co., Schenectady 5, N. Y.

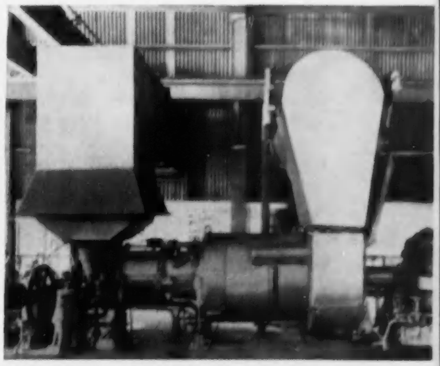
Progress Is Our Most Important Product

GENERAL ELECTRIC

IN RAILROADING, G-E gas turbines have proved their dependability under severe operating conditions. Utilizing low-cost residual fuels, units pack tremendous power for their size and weight. A new G-E 8500 hp gas turbine-electric locomotive can do the work of 5 diesel locomotives.



IN PETROLEUM PRODUCTION, G-E units are used in oil-field pressure maintenance. Driving centrifugal compressors, G-E gas turbines re-inject high pressure gas to oil fields . . . thus increasing petroleum yield. Simplicity of installation, ability to operate with little attention are prime advantages.



IN THE PETROCHEMICAL INDUSTRY, G-E gas turbine is relied upon for continuous 24-hour compressor service. In addition, significant savings are realized by using the hot exhaust gas in heat recovery boiler to make process steam—a good example of the versatility of gas turbine operation.

Carboloy Trends and Developments for Design Engineers...

• How complex permanent-magnet assemblies are built to desired field patterns from simple magnet shapes

G-E Alnico magnets provide unlimited design flexibility

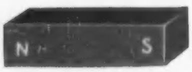
The fundamental problem in designing with permanent magnets is how to provide a specific magnetic flux in a desired field pattern.

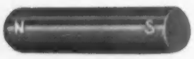
In solving this problem, a designer can choose from seven General Electric Alnico grades, hundreds of styles, weights from a fraction of an ounce to a hundred pounds. He can use magnets with two poles – or many poles; with poles at the ends – or anywhere along the magnetic axis.

This all gives tremendous flexibility to the design of permanent magnets and magnet assemblies. But precisely because there are so many sizes, shapes, strengths, and other factors to be considered, this flexibility can make the designer's job far more complicated.

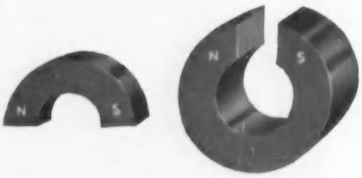
So, to help give a clearer understanding of what can and cannot be done with G-E Alnico permanent magnets, we have prepared this description of basic magnet shapes.

The simplest forms of a permanent magnet are the bar and rod. They are normally salient (i.e., the poles occur at the ends), and may be of any cross-sectional area.

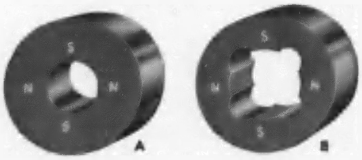




U- and C-shaped magnets are simply bars "bent" to bring both poles to the same plane.



Carry the bending process to its ultimate conclusion and you have the cylinder (see top of next column) with or without the hole. A cylindrical magnet can be magnetized with as many poles as desired on the outside diameter (A), or the inside diameter (B). Not only can the size and shape of the hole be varied, but the magnet can be made salient (B), or nonsalient (A).

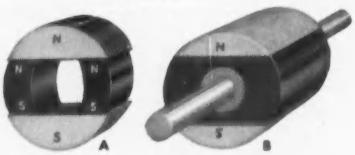


A B

All other forms are merely variations on the original themes, even to such nonstandard shapes as these:

Use of pole pieces adds to design possibilities

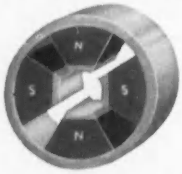
One basic use of pole pieces is to provide a return path for the magnetic flux. Pole pieces may be solid (B), or laminated, like this generator magnet (A).



A B

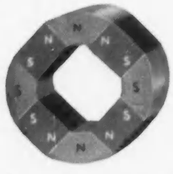
Designers can easily assemble pole pieces and properly shaped permanent magnets to obtain their required field patterns.

One version is this stator assembly, designed to provide inner poles. The

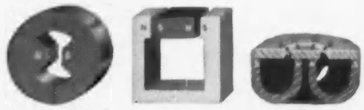


design can be altered in various ways, depending on mechanical, space, magnetic, or physical properties required.

For example, here is another 4-pole magnet using soft steel. It is also possible to construct an assembly with as many poles as required–by using a number of bar magnets or by using one 2-pole magnet.



Perhaps the most important consideration in the design of magnetic assemblies is the amount of flux across the air gap. These air gaps may be single (A), double (B), or annular (C).



A B C

Soft-steel pole pieces are often used to complete the magnetic circuit, allowing maximum flux density though the air gap, with a minimum amount of permanent-magnet material. However, there are a considerable number of variations possible, either with or without pole pieces.

Our G-E magnet engineers have broad knowledge and experience in the design and construction of permanent magnets, pole pieces, and air gaps. They will be more than happy to share their knowledge with you. There is no obligation, and all information is held in strictest confidence. A letter to us will get them to work on your problem immediately.

And keep in mind the Carboloy products that perform a myriad of important jobs throughout industry: *cemented carbides* for combating wear; *Thermistors* for detection, measurement, and control of minute temperature variations; *Hevimet* for high-density and radioactive-shielding applications; and *vacuum-melted metals and alloys*.

CARBOLOY

DEPARTMENT OF GENERAL ELECTRIC COMPANY
11201 E. 8 Mile Road, Detroit 32, Michigan

CARBOLOY CREATED-METALS FOR INDUSTRIAL PROGRESS

General Electric EM* Pumps . . .

Move liquid metals with greater safety and continuity

. . . OPERATE WITHOUT MOVING PARTS, SEALS, OR BEARINGS

General Electric electromagnetic pumps, first designed for radioactive and high-temperature systems, are now used in liquid metal laboratories and industrial processes where minimum leakage and continuous operation are important.

Now designed to pump liquid metals at temperatures up to 1500 degrees F and to move up to 10,000 gallons per minute with accurate control of flow, General Electric EM pumps can be used to move such metals as sodium, sodium potassium, lead, bismuth or mercury.

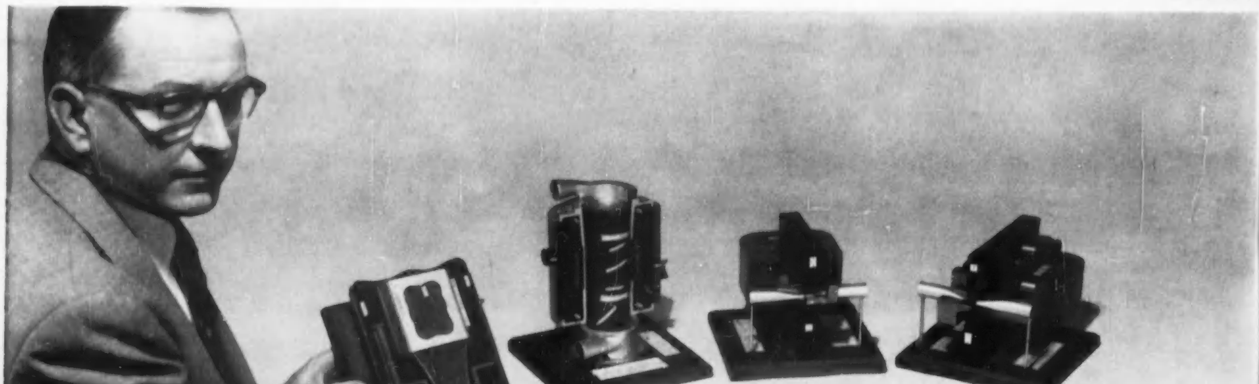
***Electromagnetic**

General Electric offers complete liquid metals pumping systems including EM pumps, magnetic flowmeters, liquid level indicators, pressure transmitters, induction heaters, cold traps, plugging indicators and sodium oxide control stations.

For more information on liquid metals pumping systems and components, contact your nearest G-E Apparatus Sales Office, or Section 193-1, General Electric Company, Schenectady 5, New York. Outside of the U.S. and Canada write to: International General Electric Company, Inc., 570 Lexington Avenue, New York City, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC



FOUR GENERAL ELECTRIC EM PUMP MODELS are shown by J. F. Cage, Manager—Component and Coolant Systems Engineering Operation, Atomic Power Equipment Department, (l. to r.): linear induction, helical flow, d-c, and a-c types. Diagram shows pumps' operating principle: Force is exerted on current-carrying liquid in magnetic field.

LIQUID METAL LOOP tests sodium potassium (NaK) in a G-E electromagnetic pumping system for use as heat-transfer agent. Loop's a-c EM pump (below) operates at 600 degrees F with capacity of 30 gallons per minute. Magnetic flowmeter (left of pump) measures flow externally, providing greater safety.