GENERAL ELECTRIC Review

RADIOACTIVE COBALT SOURCE—SELF-ILLUMINATED

NOVEMBER 1956

NOVEMBER 1956 • VOLUME 59 • NUMBER 6

GENERAL ELECTRIC Review

EVERETT S. LEE • EDITOR

PAUL R. HEINMILLER • MANAGING EDITOR

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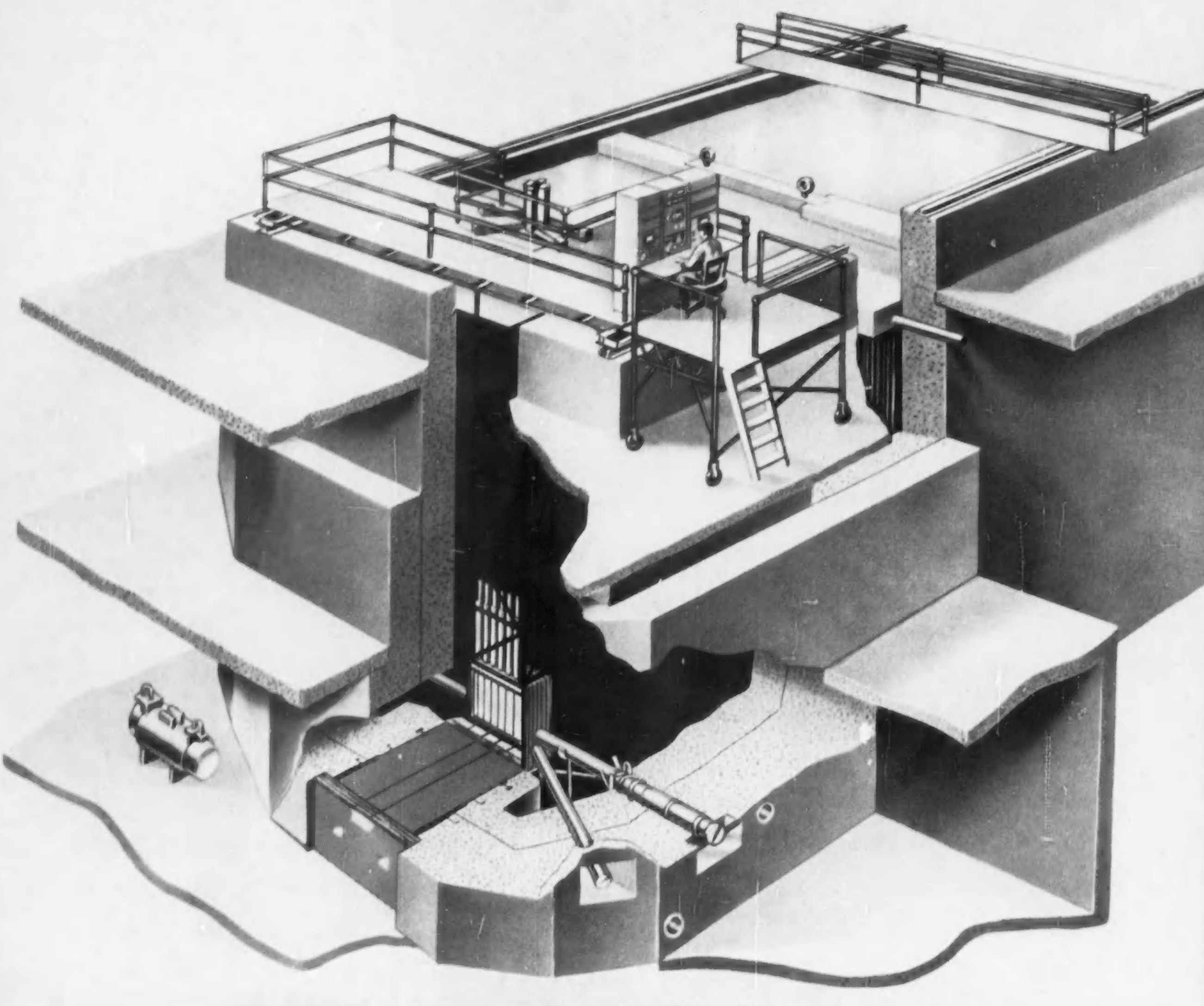
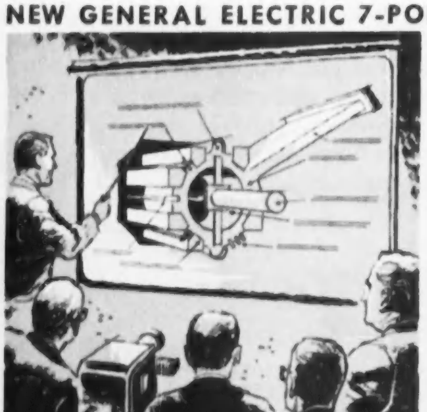
COVER—This 3000-curie cobalt gamma radiation source—illuminated by its own energy—consists of 10 steel-encased rods, shown about one-half actual size. Each rod contains about 300 curies of radioactivity. Shielded in a water-filled concrete pit, the source is used in radiation-damage studies. This facility is located at the Knolls Atomic Power Laboratory, Schenectady, operated by the General Electric Company for the United States Atomic Energy Commission. See article on page 12.

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 details 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.

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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., 570 Lexington Ave., New York, N. Y.

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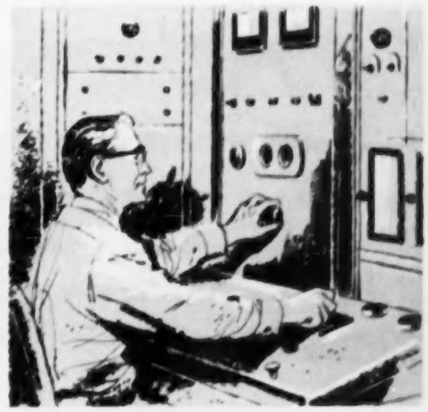
4 MANUFACTURE OF REACTOR is accurately co-ordinated with other construction plans, thereby assuring centralized project scheduling.

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



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

More scope for selection

IN THE FULL LINE OF GENERAL ELECTRIC CABLES

The General Electric line of hundreds of wires, cables, and cords covers just about every possible need. Typical of these are flame-resistant, heat-, moisture-, and weather-resistant types and special constructions to withstand vibration, the electrostatic effects of adjacent power cables —even the effects of atomic radiation. Thus, G-E engineers are never limited to one cable, cord, or wire for a given job, but can suggest the most efficient and economical solution for the particular situation.

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For information on your specific wire and cable application or selection problem see the G-E wire and cable specialist in your locality or write to Section W192-1137, Construction Materials Division, General Electric Company, Bridgeport 2, Connecticut.

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G-E LAMPS GIVE YOU MORE FOR ALL YOUR LIGHTING DOLLARS

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GENERAL ELECTRIC UNIFORMITY IS WHY—G-E 40-watt fluorescent lamps give you all the light you pay for. Their light output is so uniform that you're assured of their performance—even before you put one in a socket. There's practically no such thing as a "lazy" G-E lamp—a lamp that uses full power without delivering its rated lumen output. Less than 1% of all General Electric 40-watt fluorescent lamps are as much as 5% below their average published light output of 2500 lumens.

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REMINISCENCES OF AN ENGINEER

This is the last editorial I will write to my Review reader friends. Since I will be 65 years old on November 19, I will retire from active General Electric service at the end of that month, under the provisions of the Company Pension Plan.

I have had a happy engineering life. I have been privileged to share it with the finest people.

I well remember my first boss, Dr. Louis T. Robinson. He said to me, "Go up on the second floor and where you find them winding a coil for 10 cents, do it for 5." I found no coils being wound for 10 cents, but I soon realized what he meant—whatever you find them doing—do it better. And that, I have found, is the motivation of the engineer. There is always a better way.

I know the thrill of engineering accomplishment. One of my greatest thrills came when Chris Steenstrup told me that he was going to seal a refrigerating mechanism in steel and put an electric refrigerator in every American home. But to do it he needed a parts gage better than any gage then available. So we developed the electric gage that made the refrigerator possible.

Later we applied the electric gage to the steel industry. In that great industry with the design advances in steel-producing machinery, we saw the speed of cold steel strip through the mill advance from 500 fpm in those days to over 7000 fpm today. Without automatic gaging these great speeds would not have been practical. What an engineering thrill that has been!

Oil-filled cable produced another thrill. Paper-insulated power cable—using petrolatum jelly for impregnation—was not satisfactory for 66,000-volt circuit. So we went to work to better it. And paper-insulated power cable filled with low-viscosity oil was the result. We went from approximately 1 inch of insulation at 66,000 volts to ½ inch of insulation at 132,000 volts, and the cable lives on! That was research and engineering at its best. That spells progress any day in good American language.

Our $10,000 masterpiece was another thrill. Lightning had played havoc in the East with 220,000-volt transmission, and we were out to tame it. John Peters of the Westinghouse Company had used Lichtenberg figures to measure the magnitude of the lightning voltage, and we had done this, too. But we needed to know the wave form of lightning and its duration. So we took a cathode-ray oscillograph into the field, set it to catch a lightning shot, and prayed for the lightning to come. It came—and we had the first picture of a high voltage due to lightning on a high-voltage transmission line in these United States. It cost us $10,000 to get that picture, which was quite a sum in those days. But it was worth it. For the characteristics which were disclosed set the standards for years to come. It was as if the heavens opened for just a moment to give us the data we needed. I was accused of making too much of that first picture; but when engineering data comes at $10,000 a throw, you make of it everything you can—especially when it is good data, heaven sent.

In our work in radio and television there were many thrills. At our television station in the Helderbergs, receiving NBC from the Empire State Building in New York was an early problem. While I was in England in 1939, I visited Dr. Hugh Warren (now Sir Hugh), then director of the BTH Laboratory at Rugby. One of Warren's engineers had installed a relay in a tree on his front lawn to pick up BBC from London, 85 miles away. So that night we saw in Dr. Warren's living room the show from London's Cafe de Paris, which I had seen in London a few nights before. It featured a male dancer, and he was good. The reception was good, too. So I sent the constants of the relay to Cap Priest in Schenectady and on my return found that Cap's engineers had set up a relay 1.1 miles from the Helderberg Station. The night I arrived home, they picked up the first reception from the Empire State Building—140 miles away, via relay, at a point 7500 feet below the line of sight. That was another thrill.

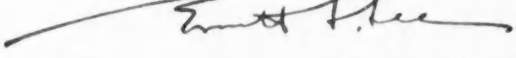
I had an experience in my younger engineering days that made a lasting impression on me. It was just after World War I, and three 30,000-kw steam turbines, designed and built during the war days, had been officially tested for water rates. They were high. The penalties in the contract were severe; the amount General Electric owed the customer based on the official test was $25,000. We were allowed to make an investigation on our own, and I was assigned the electrical output readings. When we finished, we found the water rate to be higher than the official measurement by 0.23 of 1 percent, which boosted the penalty to $50,000 for the three turbines.

Mr. H. H. Barnes, of our New York Office, was in charge. He put us on the spot, checking every detail of our measurements. We answered every question to the best of our ability. The stakes were high. Of course he advised the customer of the increased rate. But later, when the turbines were rebuilt, the contract was such that with expected improvement we would receive back $50,000; with superior performance there would be a bonus. There was a bonus—the check was for $75,000. And the teachings of the Golden Rule shone in all their glory.

Then, as Editor of the General Electric Review, came a new thrill—publishing the wonderful thrills of others in a continuing array of brilliant achievements.

And so it has been lots of fun—and lots of hard work—never ending. And if I had to choose again, I wouldn't choose differently.

Best of happiness to you all.



Editor

In Appreciation . . .

The day-by-day contributions of the engineers and scientists to bring new products into use and to improve existing products never cease. This is the challenge and romance of achievement.

The GENERAL ELECTRIC REVIEW over the years has published such accomplishments in stimulating fashion—to record progress and to keep engineering thought, effort, and concern focused on progress. Thus engineers, particularly General Electric engineers, have been inspired in their careers and stimulated to greater emphasis on professional effort and service to mankind.

Everett S. (Sam) Lee was persuaded to become editor of the GENERAL ELECTRIC REVIEW in 1951. His experience in engineering and his enthusiastic faith in the future provided an unusual quality of leadership. Sam is nationally prominent in the engineering and professional societies and is distinguished in his home community for his leadership in civic affairs. To his new task he brought the background of a long and successful career as a practicing engineer plus a dedicated interest and zest in the profession. During his years as editor, the REVIEW has reflected in the tone and content of its articles the new editorial and circulation philosophies required by dynamic advancing technologies and long-range trends.

Any day's collection of "letters to the editor" symbolizes the REVIEW's outstanding and growing success with its readers—engineers and scientists who are interested in General Electric's contributions and in their own self-development.

Sam Lee retires this November with a unique professional distinction. Impelled by an inner urge, he has set a durable example both as a discerning editor and as a stimulating spokesman for his engineering profession. His has been a performance that will take a lot of doing to equal or surpass.

Clarence Linder

VICE PRESIDENT, ENGINEERING SERVICES

New trends and developments in designing electrical products . . .

How to magnetize permanent magnets to obtain maximum energy product and magnetic stability

According to the domain theory of ferromagnetism, a magnetic material is composed of elementary magnetic volumes called domains. These domains are randomly oriented in unmagnetized materials (Figure 1). Their fields cancel each other, and no external field results.

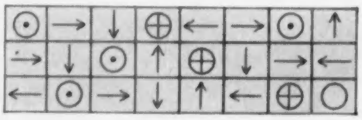


Figure 1—Demagnetized material (domains completely disorganized)

Subjecting the magnetic material to an external field rotates the elementary magnets in the direction of the applied field (Figure 2). In permanent magnets, this orientation is retained to some extent after the field is removed. The magnetic material exhibits poles and an external field.

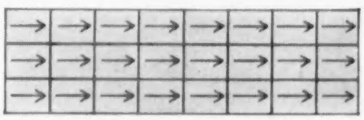


Figure 2—Magnetized material (domains rotated into alignment)

The improvement of permanent-magnet materials has made the elementary domains more difficult to align. Proper magnetization techniques have thus become highly important because of the adverse results of partially magnetized magnets.

Partial magnetization means that the full external field capabilities of the magnet are not realized. And, the magnet is less resistant to demagnetizing influences – hence less stable.

Consequently, General Electric has done extensive work with users of permanent magnets on the problems of effective magnetization.

Modern magnetizing equipment takes advantage of the fact that magnetization is essentially an instantaneous process, and may be achieved with short-duration current impulses. Consequently, direct-current equipment, like generators and electromagnets, are giving way to impulse equipment.

The main advantages of impulse-type magnetizers are lower equipment cost, reduced demand on power supply, and greater flexibility in shapes of fields that can be set up. Impulse equipment generally falls into two basic types:

(1) Half-cycle type, operating from A.C. line (Figure 3). Here, an ignitron tube with suitable control allows current to flow for one-half cycle.

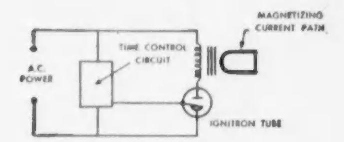


Figure 3—Circuit for half-cycle-type magnetizer

(2) Energy-storage type (Figure 4). Here, a capacitor is charged at a relatively slow rate, and then discharged into the magnetizing circuit. This type of equipment is extremely versatile; tremendous peak currents are possible from low-capacity power systems.

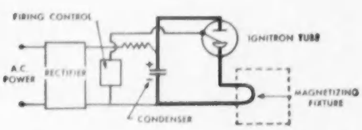


Figure 4—Circuit for energy-storage-type magnetizer

Using this equipment, a simple magnet shape like the "C" magnet in Figure 5 can be magnetized by a single conductor threading the magnet.

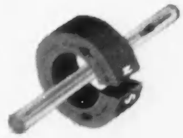


Figure 5—Conductor arrangement for "C" magnet

The "E" shape configuration (Figure 6) uses two conductors arranged to carry current in opposite directions to achieve correct polarity.

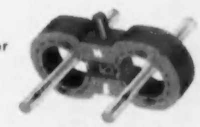


Figure 6—Conductor arrangement for "E" magnet

Multi-pole magnets (Figure 7) require alternate conductors carrying current in opposite directions to establish simultaneous magnetization of all poles.

Figure 7—Conductor arrangement for multi-pole magnet

One of the more recent developments in magnet configurations – the "bowl" magnet – can be magnetized radially by the conductor arrangement in Figure 8

Figure 8—Conductor arrangement for "bowl" magnet

These examples give some idea of the variety of magnetizing problems encountered by users of permanent magnets. Each configuration represents a distinct engineering problem in which such variables as conductor size, conductor arrangement, peak current, and current duration must be accurately balanced.

General Electric magnet engineers have at their fingertips all the knowledge and techniques requisite for efficient magnetization. They are always ready to assist designers and users of permanent magnets in getting maximum-energy product and stability.

For more information on G-E Alnico magnets, or assistance on any phase of your magnet design problem, write *Metallurgical Products Department of General Electric Company, 11201 E. 8 Mile Road, Detroit 32, Michigan.*

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Research chemist Dr. S. S. Jones arrives for typical day's work at the Knolls Atomic Power Laboratory, Schenectady, NY. Engaged in nuclear research for a number of years, he conscientiously follows safety procedures that health physicists have established for his personal protection (photo sequence).

Health Physics: Protecting Man from Radiation

By L. J. CHERUBIN

"Thus far, except for some tragic accidents affecting small numbers of people, the biological damage from peacetime activities . . . has been essentially negative. Furthermore, it appears that radiation problems, if they are met intelligently, need not stand in the way of large-scale development of atomic energy. The continued need for intelligence and vigilance cannot be too strongly emphasized, however."

This statement—an excerpt from the National Academy of Sciences report, "The Biological Effects of Atomic Radiation," released last June—points up the importance of health physicists. This little-publicized group of specialists has been and is quietly fulfilling a vital

1 On entering, Jones picks up badge identifying him and his type of security clearance. Badge also contains film packet sensitive to nuclear radiation.

2 Into change room he carries plant-issue protective clothing that he will don along with a pair of freshly decontaminated rubbers.

3 In a corridor leading to his laboratory, Jones stops at special container, picks up two pencil-like radiation detectors, records his name next to their numbers, and then clips them to his pocket.

function within America's atomic energy industry.

These men began their work during the early years of the Army Corps of Engineers' supersecret Manhattan Engineering District. At that time, a group of physicists and scientists concerned with protecting personnel from radiation coined the term, "health physics."

Why did they choose this name instead of something more descriptive, like radiation safety? Because the secrecy pervading atomic research in those days made any reference to radiation taboo. Even code names signified alpha, beta, gamma, and neutron radiations, as well as units of measurement.

But now with the veil of secrecy lifted, much can be said of health physics and the role it plays in atomic energy operations.

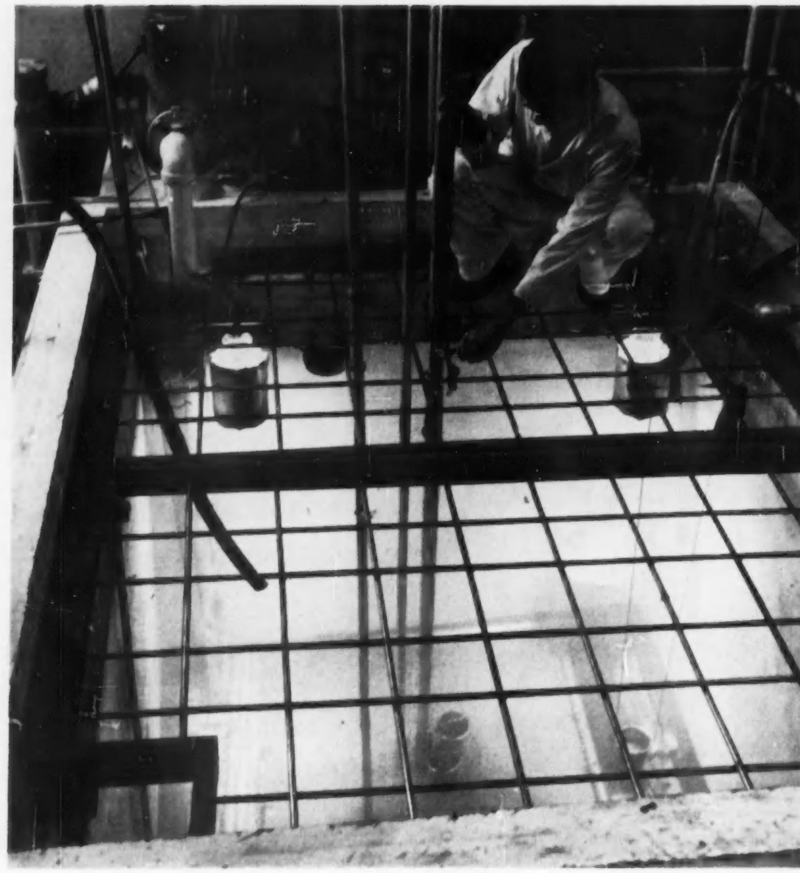
CONTINUED ON NEXT PAGE

4 Once inside his own laboratory, he prepares a solution for irradiation by specific amounts of gamma rays. In this way, Dr. Jones can determine their physical and chemical effect.

5 Attached to diminutive electric mixer, vial containing solution is lowered into place atop portable cart. Storage batteries power the mixer; instruments indicate temperature and mixing rate of solution.

6 Wheeling cart to radiation source, Jones glances at solution's temperature and . . .

7 . . . entering chamber that houses 3000 curies of radiocobalt, he notes instrument reading to determine mixing rate.



8 Over water-filled pit that shields 10 steel-encased rods of radiocobalt (see Cover), Jones moves hollow aluminum tube a prescribed distance from source. When sample solution is lowered to bottom of tube, he leaves the chamber. His total exposure to gamma radiation: about six milliroentgens.

Many-Sided Entity

Radiation connotes many things. But this article confines it to nuclear radiation—alpha, beta, and gamma rays and neutrons—and x rays. X rays are artificially produced when electrons traveling at high speed in a vacuum hit a metallic target.

Actually streams of particles, alpha and beta radiations vary in mass and electric charge. Gamma and x radiations are literally rays differing only in their origin and wave length. Neutrons, nuclear particles, carry no charge.

You'll want to know more about one important characteristic of radiation: absorbed by matter, radiation causes atoms to ionize—that is, release electrons. And this property of radiation—ionization of matter—accounts primarily for its biological implications. Generally speaking, the various types of radiation produce similar biological effects on living tissue to varying degrees.

Organs may vary in their sensitivity to radiation. For example, your skin might possibly withstand twice the radiation level permitted for blood-forming organs. The volume of tissue exposed to radiation also affects biological significance. Again for example, the permissible limit of exposure to your hands, forearms, feet, and ankles is perhaps five times that permitted for the whole body.

How Hazardous Is Radiation?

Excessive exposure to radiation may lead to serious injuries. For instance, a man could experience cancer of the skin and bone; diseases of the blood as leukemia and anemia; and eye cataracts.

The time between exposure to radiation and the onset of injury is called the latent period. With eye cataracts, this period may be a few years. But exposure to several hundred roentgens (definitions, box, page 18) of radiation within a day or less could kill you in a matter of weeks. On the other hand, an exposure of several roentgens in a matter of minutes would probably produce neither an immediate nor a delayed effect.

In most biological effects, tissue recovers and repairs from radiation exposure. This is commonly illustrated by the way a person's skin reddens when exposed to x rays. To produce identical reddening of the skin, two short exposures separated by 24 hours requires a higher dosage than a single exposure.

Natural Radioactivity

Not until 1895 did Wilhelm Konrad Roentgen discover x radiation in a laboratory experiment. The following year Antoine Henri Becquerel accidentally exposed a photographic plate to uranium salts and discovered their radioactive property. Madame Curie, during her celebrated experiments with uranium minerals, isolated the radioactive elements polonium and radium in 1898. And cosmic radiations—their origin is still a mystery—weren't discovered until the period 1910 to 1913 by V. F. Hess and W. Kolhoerster, Austrian-American and German physicists respectively.

The most common naturally occurring radioactive elements include uranium, thorium, and certain forms of carbon and potassium. Radioactive gases released from the soil containing uranium and thorium constantly reside in the earth's atmosphere and surface streams.

The mysterious cosmic radiations from space consist of penetrating gamma radiation. While the earth's atmosphere shields out much of it, the intensity increases with elevation.

Normally, you have a low exposure to natural radioactivity. In Schenectady, NY, for example—average elevation, 236 feet—background radiation from cosmic and natural sources may total 0.3 to 0.6 milliroentgens a day. Of course, your body has a natural radioactivity, too. For human tissue contains radioactive isotopes of potassium and carbon.

To the health physicist, natural radioactivity and natural radioactive elements can be an exasperating nuisance. When he assays human wastes to determine the radiotoxic elements deposited internally, the relatively large amount of naturally radioactive potassium presents some difficulties.

A similar difficulty arises when the health physicist samples the air for highly toxic radioactive elements like plutonium. Here the accumulation of decay products from radioactive gases present in the atmosphere decreases the sensitivity of his instruments to the toxic radioactive elements. For these radioactive decay products attach themselves to dust in the air and collect—along with the radioactive plutonium—on the sampling filter papers.

Hazardous Radiation

You can be injured by exposure to radiation in two ways: external or internal irradiation through the intake—by one means or another—of radioactive materials.

External irradiation presents the most common exposure problem while x-ray machines, particle accelerators, and nuclear reactors are operating. Generally speaking, the accelerators and reactors must be enclosed in heavily shielded cells for safe operation. The shielding requirements of an x-ray machine vary depending on its operating energy.

In any event, shielding is the main protective feature against equipment that produces radiation. Operated remotely and shielded adequately, x-ray apparatus, particle accelerators, and nuclear reactors are safe. The greatest danger would arise if you were trapped in a cell while radiation-producing equipment was operating. (Industry takes elaborate precautions to prevent this from happening.)

Such sealed sources of radioactive materials as radium, cobalt, or iridium—for radiographing or experimenting—are potential hazards. Although stored in heavily shielded casks, these materials might be unshielded while in use. One gram of radium, for example, produces a radiation level of 8400 roentgens an hour at a distance of one centimeter. At one meter the radiation level would be 0.84 roentgens an hour. (The radiation level from a point source decreases inversely as the square of the distance. Thus increasing your distance from a radiation source constitutes an effective safety measure.)

Radioactive materials deposited on your skin or clothing increase the radiation hazard because of close contact.

An exception to this is alpha radiation. Alpha particles can't penetrate the horny, or dead, layer of your skin. Accordingly, it has no biological significance. But even so, you can't ignore alpha-emitting elements such as plutonium; if taken internally, they would damage your inner organs.

You can unknowingly take radioactive elements internally in many ways: through contaminated foods, cigarettes, air, and even through skin absorption. Your hands, if contaminated, can easily transfer radioactive materials by contact.

Air, too, can be contaminated with radioactive materials in many ways: from fires, fabrication of nuclear fuel elements, ventilation systems or inadequate ventilation, ruptured radiation sources, and spills of radioactive solutions. Cuts or abrasions that come into contact with contaminated materials will introduce radio elements into your bloodstream.

Actually, all radiations are potentially dangerous. Strong light, intense heat or sound, and nuclear radiation—all can injure you. Your five senses generally alert you to the danger of light, heat, sound, or poisonous atmospheres. But they fail to set you on guard against subtle nuclear radiation and x rays.

Thus when radiation-producing machines were devised and applications found for radioactive elements, methods to detect and measure these radiations had to be developed. This responsibility,

L. J. CHERUBIN, Manager, Health Physics, checks one of the radiation-monitoring instruments at the Knolls Atomic Power Laboratory, Schenectady, operated by General Electric for the Atomic Energy Commission. Coming to General Electric in 1946, he is now responsible for a radiation protection program that encompasses employee and public protection.

RADIO CHEMIST monitors radioactive solutions beneath exhaust hood during an analysis for traces of nuclear fission products. Note the plastics radiation-detecting rings on his index fingers.

ANALYSIS CONCLUDED, hood is cleaned up and sponge disposed of along with other radioactive wastes. Technician wears face respirator to guard against inhaling any contaminated particles.

along with a host of others, fell to the health physicist (discussion, opposite page).

The employees you find in an atomic energy plant or laboratory are, like all people, exposed to a natural background radiation. Some are exposed to man-made radiation in negligible amounts.

Occasionally, a small number of these people exceed the recommended levels of radiation laid down by the U.S. Atomic Energy Commission (AEC). But the incidence of serious exposure isn't high. In fact, the rate of radiation injuries is considerably lower than the rate of injury from the usual type of industrial accidents.

If facilities are properly designed and safety procedures followed, serious radiation exposure isn't likely. Of course, some low-level exposure does occur: for instance, when employees calibrate instruments with radioactive sources, collect accumulated wastes for packaging and disposal, remove filters from ventilation systems, or perform maintenance work on a reactor. Then too, assembling fuel elements or removing them from reactors also causes low-level exposure. Chemists who analyze radioactive solutions or irradiated specimens also receive some low-level irradiation, as do other scientists in researches on physics, engineering, metallurgy, biology, and so on.

As for protective devices, atomic energy industry requirements don't differ much from those you'd normally expect to find elsewhere. For instance, Army assault masks and fresh-air masks are used where the air is contaminated. The primary use of this respiratory protective equipment occurs when employees perform maintenance in chemical process areas, handle wastes, or weld contaminated equipment.

Scientists at Work

Now let's move from the over-all atomic energy operation into the nuclear science laboratory.

Here you find a research chemist studying the effects of radiation on materials. On entering the installation (photo sequence), he receives a picture badge that identifies him and his type of security clearance. A metallic holder attached to this badge contains a film packet—similar to the one your dentist uses for x rays—that measures radiation dosage.

Entering the chemistry building, he may first remove his clothing in a "change" room; then in another room, he may don plant-issue shoes, trousers, shirt, and laboratory coat. Once in his own laboratory, he prepares a specimen material for irradiation, then moves on to the building that houses the radiation source—a few thousand curies of radiocobalt.

The irradiation facility consists of a pit that holds water to a height of 15 feet, in which the cobalt is immersed. At the top of the pit the radiation level is low—perhaps 10 milliroentgens an hour. A railing around the pit and a metal bar screen that covers it prevent anyone from falling in. (At the railing the dose rate measures about 4 milliroentgens an hour.) As an additional precaution, an alarm sounds should the water level decrease.

After lowering the test specimen into the pit, the chemist leaves during the actual irradiation, later returning to remove the specimen after a given time interval. He wears the same protective clothing. Despite the slightly contaminated water in the pit, his specimen isn't radioactive because the radiocobalt's gamma rays do not activate it. The scientist's total radiation exposure: perhaps six milliroentgens.

Next, let's look in on another chemist engaged in analyzing radioactive samples (photos).

His laboratory—posted as a radiation zone—contains ventilated hoods, lead

TEXT CONTINUED ON PAGE 18

WHO THE HEALTH PHYSICIST IS AND WHAT HE DOES

Prior to the era of atomic energy, human experience with radiation primarily concerned x-ray machines and a few pounds of radium. Then several developments occurred in rapid succession that increased the availability of radioactive materials by several magnitudes.

With these developments came radiation intensities that required shielding. Increasingly larger amounts of radioactive wastes called for new disposal methods, radiation measuring devices for health control were needed, and radiochemical analytical techniques had to be developed.

Originally, radiation protection resided in the province of the nuclear physicist. But before long, chemists and other scientists were recruited into health physics. After World War II, college graduates with degrees in education, biology, psychology, pharmacology, arts and sciences, and geology were also recruited into this field. These people essentially received their training and experience on the job.

For example, the original senior health physicist at the Hanford (Wash.) Atomic Products Operation, operated for AEC by General Electric, received a short but intense training course in radiation protection at the Oak Ridge (Tenn.) National Laboratory.

Today, many of the health physicists employed by private and government-operated atomic energy operations come from the older AEC projects. More will come from the fellowship programs set up by AEC at several universities. These programs are designed to provide a source of technically trained people with a background desirable in the health physics field.

As an important function in an atomic energy plant or laboratory, the health physicist formulates standards for radiation exposure, which are then incorporated into operating procedures. These standards include permissible amounts of exposure to workers on a daily or weekly basis; limits on the amount of radioactive materials that may be retained on protective clothing following decontamination in the plant laundry; and limits on the amount of radioactivity that may be permitted in liquid or solid wastes and stack air released into the environment.

The health physicist also surveys buildings containing radiation-producing equipment or radioactive materials. In areas of probable radiation exposure, he posts warning signs and instructions that explain the precautionary measure required. Among these measures may be the requirement for protective clothing, respiratory protection, film badges, and a radiation count with portable instruments.

He also audits personnel exposure through the use of film badges and other devices.

Film darkening indicates radiation exposure, and suitable standard sources calibrate the degree of darkening. Health physicists commonly use radium and uranium for gamma and beta calibration of film badges and survey instruments. Film badge readings are documented on a personnel record card and filed away with other information containing the employee's history of radiation exposure.

Should the film badge indicate an exposure above the prescribed limit, the health physicist investigates circumstances of the exposure and prescribes corrective measures. These may call for more frequent monitoring, a change in operating procedures, redesign of experimental setups, or perhaps installation of a radiation alert signal.

When a new radiation facility goes into operation, activity increases among radiation-monitoring personnel.

Assume, for example, that a new metallurgical laboratory undertakes the study of irradiated reactor fuel elements. Before actual operations start, the health physicist makes certain checks. He sees to it that there are no radiation leaks in the shielding of casks containing irradiated specimens or in the cell that houses the fuel elements. Additionally, he checks for the proper air-flow pattern between the laboratory, cell, cell hoods, and seating of high-efficiency air filters in the system.

At first, operation of the new metallurgical facility is limited to smaller-size fuel specimens with a low burn-up rate. Then shielding is again checked, air exhaust from the cells monitored for radioactivity, and process-equipment contamination levels established for typical operations—such as cutting, drilling, and grinding.

Naturally, when the cells and equipment are cleaned, radioactive wastes accumulate. This poses another problem for the health physicist. To determine disposal practices, he must establish the wastes' radiation levels. His findings at one level of operation are then extrapolated to the next level. If this indicates acceptable radiation levels, he can further extend operation.

Many other important services fall into the realm of health physics. One of these is providing monitoring services—often on a continuous basis—for such operations as removing irradiated specimens from experimental reactors, removing and packaging air-cleaning filters of radiochemical laboratories, and loading railroad cars with radioactive wastes.

Technically, the health physicist concerns himself with many scientific and engineering disciplines. He may, for example, study the effectiveness of air filters in collecting particles of different sizes, density, and speed. Aquatic life is another field. The health physicist studies the discharge of low-level radioactive liquid wastes into surface streams and its effect on plant and animal life. Or, he may work in a more theoretical field, studying power-reactor safety precautions and possible reactor accident hazards.

" . . . the health physicist has experience . . . to meet the hazard."

barricades to shield samples beneath the hoods, a wall monitor that continuously samples the air for radioactivity, and portable radiation-monitoring instruments. Additional to the standard protective clothing and the film badge, this chemist wears a hand-monitor film ring—a plastics finger ring with dental film contained in its removable top. Such a monitor has particular importance here: the chemical analyst frequently exposes his hands to higher radiation levels than the rest of the body.

To prevent ingestion of radioactive materials in the laboratory, general rules prohibit chemists from smoking, eating, or pipetting liquids by mouth.

Contamination problems arise when handling radioactive materials in a liquid state. If solutions are vaporized, spilled, centrifuged, or agitated, the likelihood of spreading radioactive materials increases. Potentially hazardous to the chemist, too, are self-inflicted jabs from contaminated pipettes or cuts and abrasions from contaminated glassware or metallic equipment.

If you conclude from this that the analyst has a relatively high potential exposure both externally and internally, you will be correct. The degree of hazard, however, depends on the nature and amount of radioactive materials that are present.

For his own protection, the analyst minimizes the radiation hazard in three ways: he limits the amount of radioactive samples processed and carefully monitors his laboratory during the operation. Should radioactive spills occur outside the ventilated hoods, he wears a respiratory mask during the cleanup. Periodically, he submits samples of his urine for audit of internally deposited radioactive materials. And daily, air samples from the laboratory are analyzed to control the airborne contamination adequately.

Now, let's focus on a physicist—one utilizing a low-power experimental nuclear reactor for research. Again, this scientist requires monitoring devices and some protective clothing—but not while the reactor is operating.

Even a reactor of only zero power—one watt or less—is generally located in a concrete cell that contains the radiation. The physicist operates the reactor remotely from a control room. Once it shuts down, however, the situation changes. Then the physicist enters the cell to remove his experimental samples from the reactor. In so doing, he exposes himself to radiation externally as he handles the radioactive materials. Data detected by instruments inside the cell and recorded in the control room tell him the amount of residual radiation after shutdown. This radiation can range up to several roentgens an hour for the reactor, and for the radioactive samples, 100 rads per hour at contact.

Accordingly, upon entering the cell at shutdown, the physicist monitors carefully, limiting his time inside to short periods. Irradiated specimens are handled meticulously, using tongs or similar devices.

How Successful?

The health physicist, through the cooperation of all who work within the nuclear energy enterprise, has been preeminently successful since the early days of the Manhattan Engineering District. Both management and professional workers have helped him immeasurably by their recognition of radiation's great potential hazard.

You'll find typical achievements in radiation-exposure control at the Knolls Atomic Power Laboratory, located in Schenectady, NY, and operated by General Electric for the Atomic Energy Commission. Since its inception in 1946, not a single radiation injury has occurred at the Laboratory.

And the future looks just as promising. For today the health physicist has experience, knowledge, and tools at his disposal to meet the radiation hazard with great confidence. Still, in the development of power reactors, many challenges await him: feasible solutions for confining fission products in the event of an accident sufficiently great to be labeled catastrophic and treating and disposing of radioactive wastes, to name a few.

As the application of radiation and radioactive materials increases in industry, medicine, and research, the demand for health physicists expands proportionately. This need extends to health physicists who direct their efforts not only toward radiation-protection matters but also toward developing nuclear instruments, radiochemical analytical methods, and industrial hygiene. (The formal organization of a Health Physics Society at Ann Arbor, Mich., this past June—with a membership of more than 700—demonstrates the growth of the health physics profession.)

In typical AEC-sponsored laboratories at the present time, the health physics force constitutes from one to three percent of the manpower. They direct research and development efforts toward improving radiation-protection programs, and at the same time they reduce the cost of existing safeguards.

Progress in this field has been significant. You can be certain that wider application of radioactive materials won't be restricted because of the radiation hazard. Ω

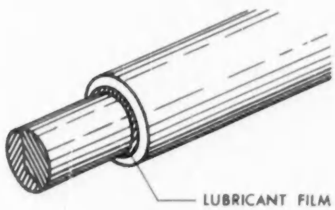
RADIATION UNITS DEFINED

ROENTGEN (R) The quantity of x or gamma radiation that will cause one cubic centimeter of air to emit ions carrying one electrostatic unit of positive or negative electricity.

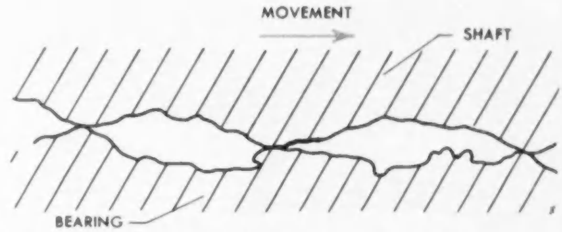
REM An abbreviation of "roentgen equivalent, man" that is a measure of a quantity of any ionizing radiation sufficient to produce the same biological effect as one roentgen of x radiation.

RAD An amount of radiation sufficient to cause one gram of animal tissue to absorb 100 ergs of energy. The amount of energy absorbed by tissue is a function of the tissue's composition and wave length of the radiation reaching it.

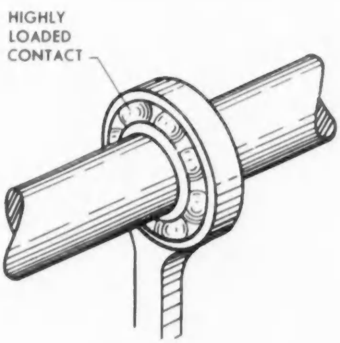
BASIC BEARINGS, FRICTIONAL PHENOMENA, AND LUBRICATION



SLEEVE BEARING
(SLIDING FRICTION)

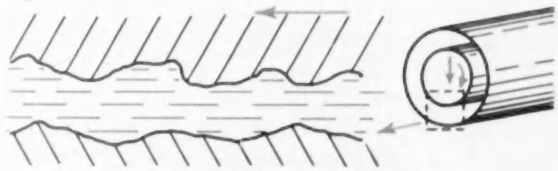


When microscopic hills and valleys in an apparently flat surface come in contact, they enmesh and resist sliding movement; hills collide making unit loads so high that metals in contact weld together.



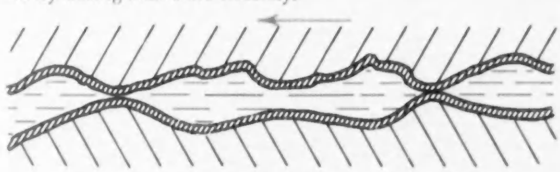
BALL BEARING
(ROLLING FRICTION)

Although these basic types of bearings will continue to be used, new lubricants and novel bearing materials will develop.



HYDRODYNAMIC FLUID FILM

To avoid localized welding, rapid wear, and seizure in the loaded region, two types of film can be used in sleeve bearings. A full separating pressurized film can usually be developed solely through the fluid viscosity.



BOUNDARY LUBRICATION FILM

When microscopic areas of the shaft and bearing collide under high loads or at low speeds, a soft protective boundary layer can be generated by including a reactive sulfur, chlorine, or phosphorus additive in the oil.

Bearings—How They'll Be in the Future

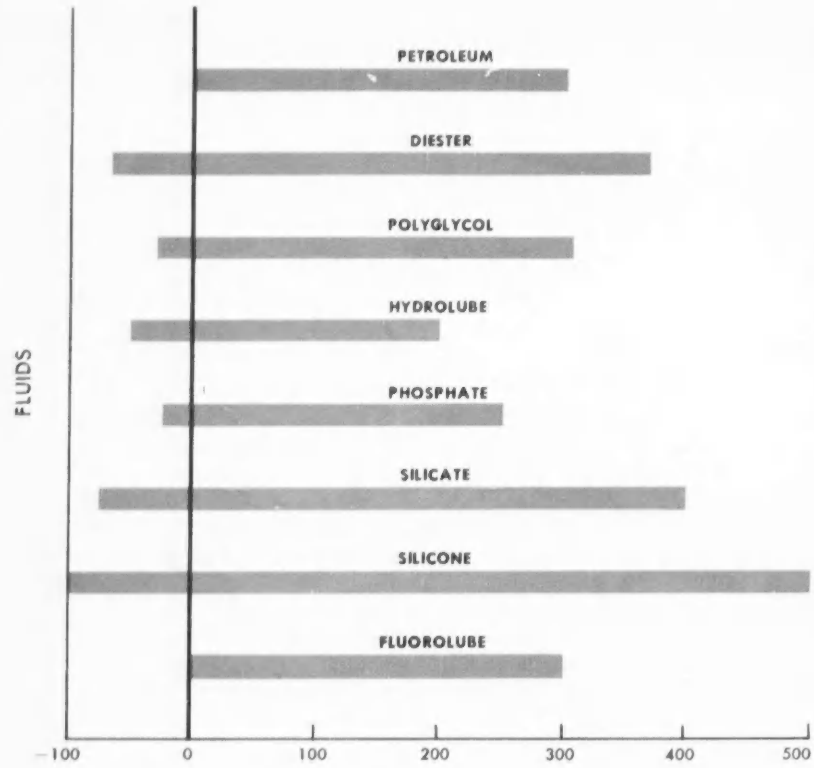
By DR. E. G. JACKSON and DR. E. R. BOOSER

These days the layman can easily conjure up a picture of the technological roadblocks imposed by the heat barrier. Almost a classic example by now is the intercontinental ballistic missile hurtling downward through the atmosphere at speeds on the order of 10,000 mph, its skin glowing white-hot.

But most engineers and scientists encounter more immediate problems than this. Right now, for instance, they are grappling with the problems of 500 F temperatures generated on the surface of piloted aircraft moving at more than twice the speed of sound. For atomic power reactors—particularly airborne nuclear-propulsion types—control motors and other apparatus may be needed that will function at temperatures higher than 500 F or in the neighborhood of 1000 F.

Like nearly all machines, somewhere and somehow these devices depend for their operation on the low-friction movement of surface passing surface. In other words, they depend on bearings. This was essentially true of the first wheel and axle. Today, the extreme loads, speeds, and temperatures of modern technology compound the present situation.

And tomorrow, the demands of an advancing complex technology will be even more exacting.



OPERATING RANGE of conventional bearings has been extended by recent developments of new organic fluids, silicones representing about the ultimate likely to be achieved.

TEMPERATURE LIMITATIONS OF BEARING MATERIALS

Materials	Maximum Useful Temperature (Degrees F)
JOURNAL BEARING	
Babbitt	250
Aluminum	400
Bronze	500
Silver	600
Nickel alloys	1600
Cobalt alloys	1600
Ceramics	2000
ROLLING BEARING	
Special ball-bearing steel	400
Medium alloy steels	600
High alloy high-speed tool steels	800

Combating Friction

Essentially there are only two kinds of bearings (illustration, left, page 19).

The first and oldest—the sleeve bearing—is well-described by its name: the sleeve bearing fits snugly around an axle, as a sleeve fits around your wrist. Either the sleeve or axle rotates. Usually though, the axle moves as with the shaft of an electric motor.

Rolling-element bearings, typified by the ball bearing in the illustration, are more recent mechanisms. Their rolling action reduces friction.

Because sliding friction is the source of most bearing problems, the fundamental phenomenon involved is worth describing.

All surfaces, even the most finely polished, have microscopic hills and valleys that mesh with the hills and valleys of opposing surfaces. Areas of actual contact between a polished shaft and bearing are thus small fractions of the apparent area (illustration, top right, page 19). When the hills of shaft and bearing collide, unit loads get extremely high—so high, in fact, that temperatures reach the welding point. These microscopic welds may be broken as fast as they form, and in the process they may also tear out chunks of metal. Such an effect roughens the surfaces. Quickly this snowballs to catastrophic wearing or welding of the shaft in its bearing.

To reduce friction and prevent these failures, you must develop a barrier of lubrication between surfaces. If all shearing effects can be restricted to this layer of lubricant, no damage to either surface occurs. Accomplishing this calls for one of several techniques.

For one, you could develop a hydrodynamic, or pressurized, fluid film that is thin but thick enough to keep surface irregularities from meshing (illustration, center right, page 19). Such a film requires of its lubricant only that it have viscosity—resistance to flow. Subjected to high rates of shear, the lubricant develops back pressures that support heavy shafts on a thin film of oil.

Another technique is boundary lubrication (illustration, lower right, page 19). Here a chemical reaction at the shaft's surface forms a barrier layer of either oxide or another chemical compound having low shear strength. You can induce this reaction by adding reactive sulfur, chlorine, or phosphorus to the oil. (Inclusion of such additives in automobile lubricants, incidentally, made the spiral-like hypoid gear of your car's rear axle a practical success.)

Sometimes, natural components of the oil effect boundary lubrication. But whether natural or added components, usually mineral oil in some state of refinement forms the base fluid. These oils so well serve an extensive range of products that only a few mechanisms—your watch, for example—require special lubricants. Even now, selected mineral oils lubricate some of America's most widely used jet engines.

Ball, or antifriction, bearings demand less of a lubricant. Still, their requirements must be met. Contact areas between the balls and raceways aren't points as you might suppose: they are ellipses. (Even the hardest materials deform elastically under high pressure.) Over this small area some sliding occurs. Hence you need a lubricant. What's more, between the balls and their separators, or retainer pockets, some sliding also takes place, though at lower pressures.

Limits of Bearing Materials . . .

Presently, the maximum temperature tolerable to bearing and lubricant materials at localized hot spots establishes the maximum loads, speeds, and ambient temperatures for most bearing systems. Many types of bearings reach this upper limit at about 250 to 300 F.

Other limiting factors are the lubricant's chemical and physical stability. They not only fix the upper temperature of a bearing system's operation but also complicate machinery design and manufacture. In short, you must make allowances for periodic lubrication with fresh oil or grease.

Today, in well over 90 percent of industrial sleeve and thrust bearings, babbitt metal constitutes the bearing material. Invented by Isaac Babbitt of Boston in 1839, this material remains unsurpassed for excellent low-friction, antiscoring, antiwelding, and dirt-embedding qualities. (Babbitt metal is a soft alloy consisting largely of either tin or lead.)

The metal's upper temperature limit of 250 F, now being pushed, is reached in some gas turbine, automotive, and diesel applications. Thus you'll find a vigorous search in progress for higher temperature bearing materials. Such bearing alloys as aluminum, bronze, nickel, and also pure silver (Table) are being currently applied in high-temperature applications. As yet though, none has proved as versatile as babbitt.

Conventional steels used in ball and roller bearings have a similar temperature limit of about 250 to 300 F. With special heat-treating procedures, you can raise this limit to about 400 F—still far from adequate in aircraft jet engines. Neither is this adequate for instruments, accessory drives, and other devices in missiles and rockets—nor for that matter, even in industrial units operating at high temperatures.

. . . and Lubricants

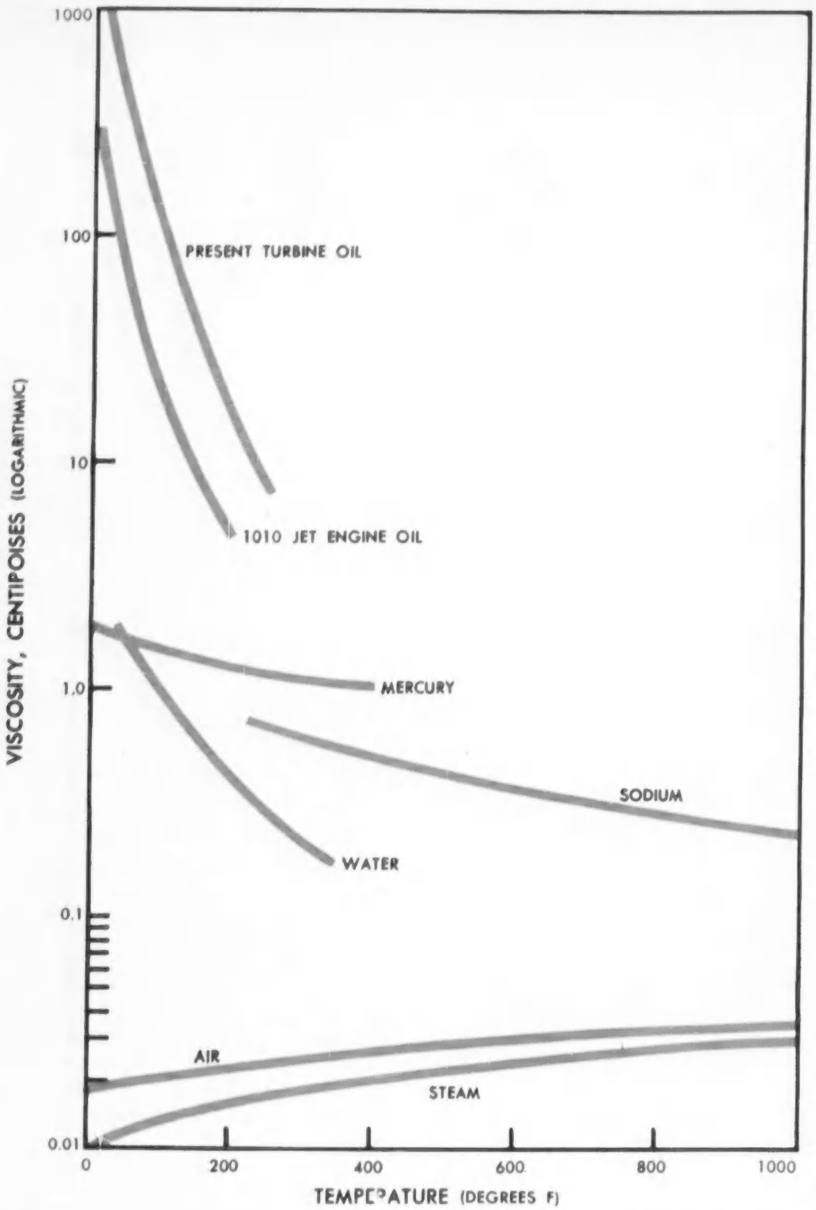
Present lubricants are limited at least as severely as bearing materials. The best petroleum oils you can obtain begin to oxidize rapidly at temperatures above 225 to 250 F. Varnish, sludges, and corrosive agents then form in the oil. What's more, these lubricants usually don't have the needed viscosity for the temperature range of −65 to +300 or 400 F. If they are thick enough at the high-temperature end, then they're too viscous at the low end.

In industrial devices, greases frequently lubricate ball or roller bearings. Greases—simply oil thickened with some gelling agent—such as soap—have the same temperature limitations as oils. In fact, they are even more restricted because both the gel structure and the fluid have to resist heat. Generally speaking, temperature limits of greases used in electric motors, instruments, and appliances are 50 to 100 degrees less than those of the fluid lubricants from which they are made.

A specific application will give you a good idea of the adverse conditions under which bearings and their lubricants must work. Take, for example, the main bearings of a jet engine (photo).

These bearings operate in the vicinity of combustion chambers that reach temperatures of 4000 F. Rotating at 8000 rpm, they generate a quantity of heat internally as well—even though lubricating oil reduces friction. Insulated and shielded from the combustion burner's fierce heat, the bearings are additionally cooled to a more moderate 300 to 400 F—as well as lubricated—by the flowing oil.

BALL BEARING used to support compressors in jet engines is being examined by authors Jackson (left) and Booser after test-running the bearing at a temperature of 700 F.



VISCOSITY of air and steam, unlike other lubricants, increases with temperature. Such gaseous lubricants may be feasible, but many problems remain to be solved.

The oil's temperature is reduced in turn by outside air reaching the walls of an oil cooler. But at 2½ times the speed of sound, outside air hitting the walls generates a temperature of 500 F on the cooling tank. Thus you see that the temperature of the main bearings, though cooled by the oil, will be much higher than the oil.

A fast-moving plane also has on board one other heat sink, or heat-dissipating source—the fuel. On its way to the combustion chambers—or even while still in its tank—the fuel absorbs many Btu's of heat. Already many calls are made on this small resource, however. Electronic equipment, for example, may be immersed right in the fuel to keep it cool. The human pilot, another item in the plane's control system, needs cooling too.

And so unquestionably, bearings and lubricants are needed to function effectively at high temperatures.

"Design of bearing sys t

Many groups throughout the country anticipated this problem in turbojets and other high-temperature engines. As a result, in recent years a number of advances were made in bearing science.

Status Quo

Initial steps beyond natural mineral oils have, in fact, already been taken. The result: synthetic oils. These have raised the limiting temperature of lubricating oils to around 500 F. In the latest jet engines for example, compounded synthetic oils remain stable to 400 F or more. Additionally, their viscosity within the temperature range varies less than that of natural oils (illustration page 20).

Today you can study a number of species of these new synthetics. Chemically speaking, they include polyesters, synthetic hydrocarbons, chlorinated hydrocarbons, polyethers, silicate esters—and most familiar to you, the silicones. All have disadvantages in some characteristics: large variations of viscosity with temperature; instability in the presence of heat, oxygen, or water; or inability to provide the boundary lubrication mentioned earlier. Still, one or more of these synthetics can probably be modified and adapted to carry conventional bearing systems to 600 or 700 F if the lower temperature limits are relaxed.

Known fluids with a temperature range of −65 to +700 F have been about exhausted as far as adapting them to conventional bearing systems. And so, bearing engineering of the future will heed the limits of fluid lubricants.

The advent of new bearing materials has matched the lubricant developments. Jet-engine bearings, more or less the conventional ball and roller types, are now being made of tool steels that maintain the necessary hardness and strength at high temperatures. Engineers have made other improvements, too, by choosing plating materials—silver, for example—that lubricate easily for use on ball and roller separators.

In applications other than flight-propulsion systems, such as nuclear-electric power stations, graphite bearings lubricated with water have been used successfully. True, water has an extremely low viscosity but becomes effective when pumped into a bearing under pressure. Further, it has the ad-

tems will become more flexible with new materials and lubricants."

vantage of being an excellent coolant—often a secondary function of a lubricant.

What about the lightly loaded mechanisms as typified by clocks, instruments, baby buggies, thread guides, and so on? In these applications, plastics bearings are now used widely without any lubrication. Synthetic plastics like nylon are particularly useful in such applications because of their low coefficients of friction.

Modes of Tomorrow

So much for the present. For the future this much is sure: You'll see the same basic types of bearings being used.

Design of bearing systems will become more flexible with the introduction of new materials and lubricants. Then too, design specifications will be modified. By eliminating the requirement that lubricants be fluid at −65 F and by heating the oil where necessary, you'll be able to use lubricants more viscous at the highest temperatures. In other words, it's a matter of cutting off the low end of the temperature range and extending the high end.

These advances at the high end may be achieved by using molten, or chemically stable, materials that remain fluid over a wide temperature range. In either sleeve bearings or ball bearings, you may find metals like gallium and alloys of sodium and potassium as the fluid lubricants.

A few new organic materials also are stable at temperatures as high—and higher—than 1000 F. The oiliness of such fluids may have to be further developed. But their use appears feasible, once engineers stop insisting that lubricants be fluid at ordinary temperatures.

To utilize such fluids, ball bearings need more strength and fatigue resistance. The high pressure—and its cyclic application—that ball bearings are subjected to pose the real problem. Even the high-speed tool steels obtainable today lose strength rapidly at 1000 F. Perhaps acceptable substitutes may crop up among the sintered carbides (used for cutting tools), intermetallic compounds, newer alloys, or even ceramics.

Fatigue presents less of a problem in sleeve bearings. For these you may find that another type of lubricant will be adopted. Where a hydrodynamic barrier—or pressurized fluid film—is utilized, sleeve bearings require of their lubricants only viscosity. And the faster the shaft turns or the narrower the clearance between shaft and bearing, the less viscosity required.

Carried beyond ordinary extremes, you can interpret this to mean that gaseous lubricants are feasible. While air or steam as fluids may be low in viscosity, they have thermal and oxidation stability. Instead of decreasing with temperature, their viscosity improves (illustration, opposite page).

Naturally, the use of steam as a lubricant is highly attractive to engineers designing steam turbines. A readily available product, it reduces fire hazards and problems of sealing. Perhaps one day you may even see an electric motor with its rotor turning and supported in air. The stator would be the only bearing. With heavy loads, the high pressure air from an auxiliary compressor could also be used to float the rotor on air.

These are fanciful schemes. Whether they will prove practicable depends on the magnitude of the technological problems they impose. For example, you can't overlook the possibility that at temperatures of 1000 or 2000 F, air and steam may corrode bearing materials.

The close clearance would require fine alignment. And the failure of the air or steam supply would immediately result in dry welding of the bearing surfaces.

How will these difficulties be surmounted? Perhaps the answer lies in the development of more efficient dry lubricants. With these, in fact, you could well eliminate all your other lubricant problems, such as chemical stability and the changes that occur in viscosity.

Already, dry lubricants like graphite and molybdenum disulfide satisfy some slow-speed applications. However, they do not form self-renewing boundary layers the way fluids do—a principal disadvantage. Eventually this results in loss of lubrication on the worn areas and, inevitably, failure. Needed to offset this disadvantage is an extremely tenacious dry lubricant coating or, lacking that, a means of continually rebuilding the boundary layer.

The first steps toward such lubricants have already been taken. Powdered molybdenum sulfide and graphite dusts, fed into rotating ball bearings by air stream, have successfully lubricated the bearings at temperatures as high as 1000 F.

Other dry materials—one of these, boron nitride—also exhibit lubricity, that is, form boundary layers. A dry lubricant even more effective than graphite will possibly be discovered in the future.

No Magnetic Bearings

Perhaps the most radical suggestion you've heard for a bearing fluid is the flux of a magnetic field. Unfortunately such an idea seems the least practical now. This suggestion has one drawback: you would need extremely high magnetic strengths to carry heavy loads. Coupled to this stands the discouraging fact that magnetic materials lose their magnetism as temperature increases. The magnetic suspension for watthour meters where loads and speeds are negligible has, however, achieved outstanding success.

No Radical Changes

And so, finally, you have to conclude that bearings of the future won't be radically different from today's. Innovations will be generally a switch to new high-temperature bearing materials—perhaps a shift to either gaseous or solid lubricants.

By and large, high-performance machinery of the future will have the same bearing design as the chariots of Caesar's Rome. Ω

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Joining General Electric in 1948, Dr. Booser has carried on development studies of bearings and lubricants for use in jet engines and aircraft equipment, motors, turbines, and household appliances. Presently Manager, Bearing and Lubricant Engineering, Medium Induction Motor Engineering Laboratory, Schenectady, he coauthored the book BEARING DESIGN AND APPLICATION *(McGraw-Hill), scheduled for publication this month. Dr. Jackson—Supervisor, Bearings and Lubrication Unit, Thomson Laboratory, Small Aircraft Engine Department, West Lynn—is concerned with development of bearing and seal designs, materials, and lubrication for small jet engines. He has been with General Electric since 1951.*

Is Latin America really the new land of opportunity? What does an engineer do there? Does language form a barrier for the "foreigner"?

Ed Krieger (photos) spent five years in International General Electric's office in Medellin, Colombia, South America.

He is now back in the States, and on the following pages he gives you his impressions, tells you about some customs, and describes what it's like in the city and on field trips.

Engineer in Colombia: "Arrive by Air, Continue on Foot"

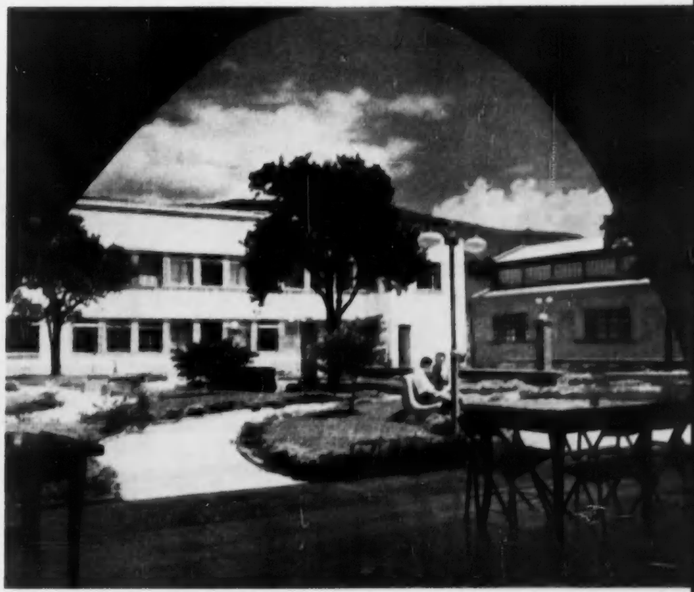
(Story continues on page 26)

In Medellin IGE offices—occupying one wing of a modern building located in the heart of the city—hum with typical office activity. Daily conferences with sales personnel help the Company keep abreast of market trends while . . .



In the Field Jungle trail and mountaintop slow transportation of people and equipment to customers situated in remote locations. Sinking new shaft at a gold mine means both potential sales of pump motors and other electrical business.

. . . completion of morning dictation frees the day for sales calls on prospective customers and Company contacts often involving . . .



. . . luncheon conferences in dining room of local factories. Sometimes business is transacted in restful atmosphere of adjoining patio.

Engineer in Colombia

(Story begins on page 24)

Ed Krieger discussed his experiences in South America with Review *editors. Here's an edited transcript of his remarks . . .*

In the bottom of a saucer-like cup lies the city of Medellin. On all sides the mountains rise abruptly with only a pass to the north beginning at the level of the valley's floor. Flowing through the narrow valley is a river—the Magdalena—that drains out to the north. All airplanes use the pass for their approaches and takeoffs.

Medellin's beautiful climate prompts publicity people who live there to call it the "Land of Eternal Spring." I would say that throughout the year it's about like late April or early May in New York City. We wore wool suits to the office all year round, but we never needed a topcoat—although some nights a tweed coat felt good. The women had no need for a fur coat; they usually wore either a stole or a cape. Sometimes during the heat of the day—say, from 11 am until 1 or 2 pm—it got hot but only in the sun. We quickly caught on to the comfort of walking on the shady side of the street.

Medellin does have one rainy season that lasts for six weeks. It rains almost like clockwork: every day, usually for an hour beginning anywhere from 4 to 6 o'clock. In the morning with a perfectly clear sky, you wouldn't think to take a raincoat. But when you go home for lunch, your raincoat goes back with you to the office. Because just as you leave the office, that's when it starts to rain—and rain hard—but only for an hour.

Of the city's few tall buildings, the tallest has 12 stories. As land has become more expensive and property taxes higher, buildings are now going up instead of out. All of them have been built since World War II—probably within the past few years. In 1951, our IGE office moved into one wing of the new Fabricato Building, modern and comfortable, owned by one of the biggest textile mills.

We had no air conditioning for we didn't need it. We just opened the windows, and everything stayed clean because of so little dust. No one suffered from the heat in the office; in fact, everyone wore a coat. Air-conditioning sales were practically nonexistent. But we sold a few for laboratory use—more to provide clean air than to cool it.

The building trend in South America has changed fantastically in the past 10 years. During the war, these countries couldn't import, but they had acquired a dollar credit as a result of selling products to the United States. With this accumulated credit, they concentrated on building new factories and offices and new homes. Consequently, building has developed and modernized perhaps more rapidly than in the States.

Handling the Language

To learn the language, my wife—Sally—and I used a scheme common for "foreigners": we invited a teacher for breakfast daily for an hour or so of study. In this way, we learned the names of the food and common household items. We did this for six months.

At the same time I had a professor—a teacher, that is—come into the office for an hour three days a week. We concentrated on the technical language I would use in dealing with customers. While this was going on, Sally studied in the local university for women, a well-run and highly regarded educational institution. Many of the professors had studied in Europe, but most of them had come from the United States. This wasn't my wife's first exposure to Spanish; she had attended the University of Mexico with her three sisters while I was overseas. And so she had a predisposition toward the language and enjoyed her studies.

Learning another language is a challenge—it gives you an extracurricular interest in life. Also, you're proud that you can express yourself with relative ease in front of strangers. It's enjoyable to just sit back and relax and carry on a conversation. A person can get a great deal of satisfaction out of that. It's worth all the time spent.

Servants rarely speak English; they make little effort to learn it. Under the circumstances, American wives acquire a peculiar vocabulary of their own. This includes words for all the vegetables, household effects, and similar items—generally seasoned with local slang picked up from their maids. Because of this local vernacular, their vocabulary differs a little from the men's. Fortunately, the wives recognize it as slang and avoid it when they're in proper society. But my wife did surprise me occasionally by using some words I had never heard before.

After Hours From apartment, Kriegers could see Andes . . .

Role of a District Engineer

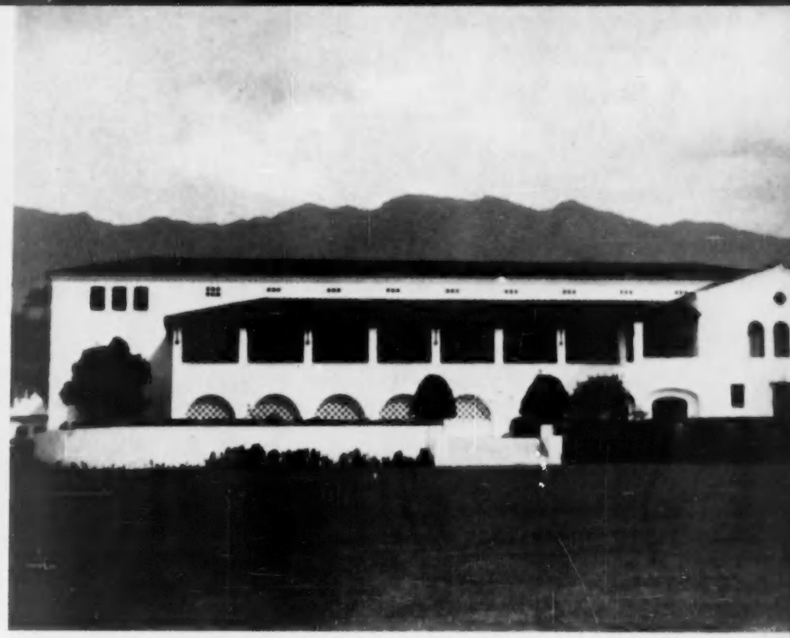
My first assignment in Colombia with IGE was as a district engineer. It gave me an opportunity to become acquainted with the industrial customers. In their preparation for a particular technical field, many of these men have either studied in the States or from English textbooks. For example, in all the factories, electrical engineers usually speak some English—possibly quite a little. Also, the technical vocabulary in Spanish is almost identical to that in English. You could read some technical material of 100 words—volts, amps, watts—and be able to identify 80 of them without any Spanish background. It's an easy, convenient way of starting out with Spanish.

The industries are growing rapidly—perhaps too rapidly. They're anxious to get into electronic controls; their last type of control was something mechanical, let alone electric. Not being properly set up to maintain and operate electronic gear, the customers depend on the district engineer to keep their plants running. And it's quite a job for him.

A Working Day . . . and Night

Our working day differed from yours in the States. We worked from 8 to 6, with lunch from 12 till 2. The two-hour siesta sounds like a wonderful thing, but it has drawbacks: napping after lunch puts on a lot of excess poundage,

. . . and in leisure evening hours they attended gala occasions—for one, annual Orchid Dance—and enjoyed . . .



. . . weekend fun in Medellín's beautiful Country Club where they participated in golf, tennis, and swimming—year-round sports in Colombia.

and the drowsiness lingers on into the afternoon. Many of the Americans go home and relax, read a magazine, and then return to the office early. If you arrived back at 1 o'clock, for an hour you would have peace and quiet in which to get a lot of work done. Sometimes this was a big help. We also worked on Saturdays for four hours, from 8 till 12.

In addition to long working hours, we were obligated to entertain frequently on behalf of business—not only inviting all *our* customers but also accepting invitations from such organizations as the National City Bank and the Royal Bank of Canada and the petroleum companies. Over a five-year period, I think Sally and I averaged two or three nights a week at some business-social event—giving or attending a party. Those evening sessions were probably as important as all our working days put together. And this exposure to business people definitely required polishing up our Spanish.

Those party evenings *were* long. Working till 6, we couldn't conceivably be anywhere before 7 o'clock and the average invitation for cocktails and dinner would be at 7:30 or 8 o'clock. A two-hour cocktail session usually preceded dinner so that guests in Colombian homes were never served before 9:30 or 10 o'clock. With 5 or 6 or 7 courses, we wouldn't finish dinner until well after 11 or 11:30. Guests would then be served coffee and one brandy and go home; it's just automatic to eat and go home. At first we managed this with some difficulty, for sleeping on a full stomach at that late hour can be uncomfortable. But the late hours became a habit, and now we can't adjust back to the 6 or 7 o'clock dinner hour in the States.

The large number of national and religious holidays compensated for the long work week. As I recall, we enjoyed 17 annual holidays. This meant that at least once a month we had a Wednesday or some other day off. Then they also had a "puente"—a bridge—what you in the States call a long weekend. If Tuesday were a holiday, then the employees would like to have a puente—in other words a bridge over Monday. When this occurred, we left work Saturday noon and didn't return until Wednesday morning.

A typical month included several visits to the many gold mines in the territory, a trip to the general office of IGE in Bogota, conferences with industrial customers planning expansions in their fast-growing industries, and frequent discussions with the appliance distributors throughout the territory—far from a monotonous operation.

A Day in the Field

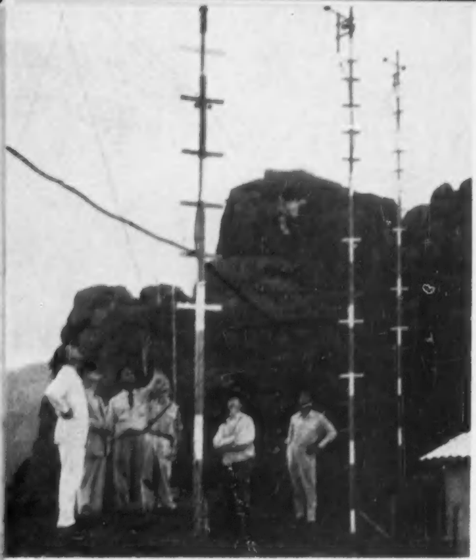
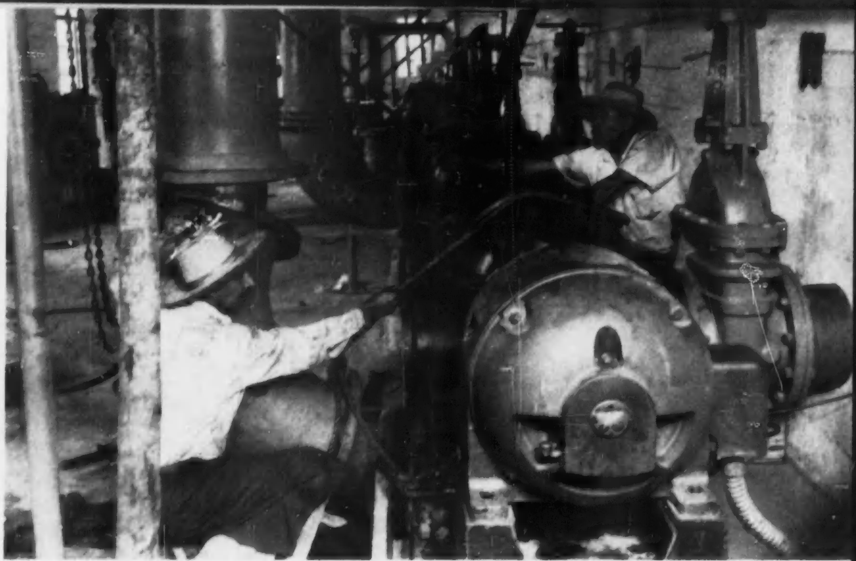
A day's work outside Medellin is another matter. I recall an inspection trip of the FM radio-communication system installed for the oil pipeline running from Puerto Berrio on the Magdalena River and across the central mountain range of Colombia to Medellin. Accompanied by representatives of the State-owned Antioquian Railway (owners of the company operating the pipeline), pipeline specialists, a representative of the U.S. construction company making the installation, and two Colombian IGE electronics technicians, I took an almost typical field trip.

First we traveled on a small rail car over 120 miles of difficult mountain terrain. Then came muleback, jeep, canoe, and finally we traveled on foot, as frequently happens. We checked installations of transmitting and receiving equipment, relays, and remote-control equipment from 10,000-foot mountain peaks to a hot and humid village on the banks of the tropical Magdalena River. I call this an almost typical trip because we did not use the airplane—a form of transportation as familiar and indispensable in Colombia as the subway in New York. On the majority of field trips we would arrive by air, continue on foot, or sometimes wind up in a jeep.

Colombian Businessman

The Colombian businessman has an exceedingly high degree of integrity. Frankly, this surprised me; I had thought he might be a little cagey. But I was wrong. They're shrewd hard-working men.

An energetic, spontaneous person, the Colombian businessman conducts his business similarly to his private life. In the latest issue of *Factory*

Customer Relations

District engineer must solve problems—whether inspecting a frequency modulation relay station high in the Andes or working with local engineers whose handling facilities are not always the best.

he may see a device that simplifies a certain operation. In his eagerness to have the product, even though unprepared to maintain or operate it, he calls and orders it and insists on buying the device. Our job: unsell him on the idea.

The businessman also bargains in a hard-driving manner, even on formal quotations. One time I quoted a transformer at $15,600. The president of the firm phoned and started with nice, friendly small talk. But I soon learned that he wanted to buy the transformer for $15,000. We bargained and finally wound up with $15,350. This typifies the bargaining, whether the item sells for $20 or $20,000.

A man operating a Colombian business probably averages about 10 years younger and works even harder than his counterpart in the States. The average president of a big firm—say, one with more than 8000 employees—is probably in his early 40's, having begun the job while in his late 30's. At around 50 or so he'll retire, be retained, have an office, and act as a consultant. A few years later he really quits and travels with his wife—they may go to Europe for a year. By that time his children are grown up and married. He just enjoys life, having put in 10 to 15 hard years as the head of a company. But he usually remains on the board of directors.

Salaries of Colombian businessmen are normally high, again in keeping with the contrast—you're rich or you're poor. If you work for a living, you either make a mere pittance or a sizable sum of money. There's no middle layer and few men to fill those spots. For you don't become a well-paid man in the middle stratum of management, even in the top of the middle stratum. Once a man enters the influential areas where he makes major decisions, his salary suddenly quadruples; but he has experienced little or no growth.

I needed several men for jobs that paid $400 to $500 a month, but I just couldn't find any. Plenty wanted the job for $200 a month, but they were of $200-a-month caliber. The next bracket of men wanted $800 to $900 a month. Locating good men in the middle ground is a continuing problem there.

If a man lifts himself up, studies to acquire new abilities, and benefits from his experience, he can quickly jump from little more than a clerk to the general manager of a small firm.

American Associates

Our American business associates in Medellin proved to be extremely compatible. Out of, say, 10 couples, we would enjoy close ties and relationships with 7 or 8 of them. In the States, this ratio would be reduced to, say, two or three couples. Although surprising to us at first, this was completely understandable: we'd all been screened along similar standards, we went of our own volition, and we welcomed the adventure and challenge. We formed an interesting group of people, ambitious and independent. They were all willing to take the bull by the horns and do things—as you must do there. Time didn't permit checking back with the home office, and we had no more experienced person to turn to. We made our own decisions and, with practice, the good decisions outweighed the bad ones. Our management always supported and encouraged us.

I liked the stimulating atmosphere: one moment you're discussing some knotty problem in foreign exchange with a young bank president while in the next conversation you're talking steam turbines with a new customer.

The Company urges men to go to South America; and they make it attractive for those who like to accept responsibility—it's part of their development program.

Apartment Living

From our eight-story apartment building, I could walk to the IGE office in five minutes. Nicely situated on the top floor, we looked out over the valley from our large balcony. The mountains stood around us on all sides. Not particularly attractive in the daytime, the Andes—huge but not majestic like the Alps—added to the beauty of the night. The tiny lights flickering in the valley against the mountainous background made a beautiful sight.

During our five years in Colombia we lived in two houses. Then we chose a modern apartment, built by a wealthy coffee owner as a private investment. He really did it up brown: the stainless-steel all-General Electric equipped kitchens included, for example, hot and cold water taps for automatic washers. Each floor had a stainless-steel incinerator chute.

Our apartment had two baths, three bedrooms, and a large 24×28-foot living room with one wall of glass. The relatively small dining room ideally suited buffet serving for large parties.

The maid's quarters included a bedroom and bath. We paid $135 a month for the apartment.

Because of our well-organized apartment, we needed only one servant. Once a week a woman ironed for us, and another cleaned the floors.

Parties in our apartment were normally large—anywhere from 10 to 30 people. We seldom had one couple in for bridge. For large-scale entertaining, the majority for business, we needed lots of space—living areas, space for entertaining, and generous kitchen facilities. We had a 10-cubic-foot refrigerator and a 15-cubic-foot freezer.

Often I would bring someone home from the office or a customer from one of the gold mines who would drop into town out of thin air. I did this on a moment's notice, knowing the maid could easily prepare a dinner from the freezer.

A FEW FACTS ABOUT ED KRIEGER . . .

Edward T. Krieger came with the General Electric Company on the Test Course in 1940. While being recruited by International General Electric, the Army Corps of Engineers called him into active duty.

Upon his discharge in 1945, he began his work with IGE, Schenectady, in the sales section covering Europe, the Middle East, and Africa. In 1946, he was assigned to the South American section dealing with Venezuela, Colombia, Ecuador, Peru, Bolivia, and Chile.

In 1949, Krieger went as a district engineer to Medellin (Med″Ĭĕn′) where he later became district manager. This city, the capital of Antioquia and the industrial center of Colombia, has a population of 350,000. Here he and his wife, Sally—a Phi Beta Kappa chemistry graduate from Wellesley—made their home for five years.

Now back in the States, Mr. Krieger is Manager, Consumer Products Sales, Consumer Goods Export Department, International General Electric Company Division, New York.

All the photographs that are used in this article come from Mr. Krieger's personal files.

Food Differential

Meat costs a little less than in the States, but we couldn't always get it or the cut we wanted. Whenever we could get meat in the cuts we liked, we stocked up and stored it in our freezer.

The Rockefeller Foundation experimented with many agriculture products—especially sweet corn as grown in the States, which is not native to Colombia. The family living below us were local Rockefeller representatives, and they always brought home enough corn for us, too, as well as peas and beans grown experimentally.

Generally, vegetables tasted good and fresh. Anyone who owned a small patch of land in the Andes often came in on a bus carrying over his shoulder a big bundle of produce, which he sold on the market.

Canned goods are really quite a luxury: for instance, 50 cents for a can of Campbell's soup. And mushrooms are not raised there; if you buy a small can, about 1½ inches high—it costs equivalent to a dollar. Local fruits are inexpensive and delicious, but high-priced canned fruits served as a dessert are looked upon as a great delicacy.

Colombia can't boast about its ice cream. They do have ice cream parlors, but the ice cream is either watery and looks like sherbet or it's sour. Milk generally isn't pure there, and so we boiled ours. And from the little I know about cooking, I guess it's tough making ice cream with boiled milk. Our wives usually made ice cream at home, and we seldom bought it.

Commercial refrigeration is not universally used there, and Colombia has no laws to make people properly preserve food. Also, we couldn't drink the tap water; instead we bought 5-gallon bottles of distilled water. They were inexpensive—only 15 cents a bottle delivered to your house.

Entertainment

The Colombian Symphony Orchestra has many members who are displaced Europeans. This excellent orchestra is handicapped by limited facilities. Nearly all the major cities have a well-supported Fine Arts Building, but it's on a small scale, as are the auditoriums and theatres.

During the five years we lived in Medellin, a great many traveling shows came to the city—Xavier Cugat came several times plus Katherine Dunham and Lawrence Tibbet. The South American entertainment field attracts artists who are on their way up or on their way down. It offers a fertile field to either improve themselves or coast along on their reputation.

Generally speaking, the Colombians have had little real art in their history. The native Chibcha Indians had an art in a sense, but little music or poetry has developed. Few painters of any note and only one or two singers have come out of the country.

Social Life

Much of our social life revolved around Medellin's country club with its beautiful golf course. The inexpensive labor is partially responsible for the well-maintained golf courses in the area. And they're scenic because of the mountains and lush growing season. American employees enjoy playing golf when they have time. Oddly enough, it's purely a week-end sport. You work until 6, and 15 minutes later an abrupt twilight settles over the city. Darkness comes in a hurry, as though a shade were pulled down.

South America has an interesting rule: women don't have to join the country clubs—they're all invited. The Latin gentleman makes the grand gesture. Any woman can use the facilities, but clubs adhere strictly to their policy concerning male nonmembers. The clubs really extend the red-carpet treatment to out-of-town visitors, giving them all sorts of attention. This is easily accomplished for a relatively modest club may have 100 to 200 employees.

However, belonging to a club can be expensive because the liquor is expensive: $12 to $15 a bottle. Rum is excellent and relatively inexpensive, but people usually don't want to drink it exclusively.

Dues to join the country club run extremely high. To buy into a country club in Bogota or Caracas would cost about $8000 to $10,000 a share. The Company generally owns some shares, with the membership in the employee's name as long as he resides there. Now here's an unusual thing: the monthly dues are low. In the Bogota Country Club, for instance, they're about $30.

Besides the country club, in Medellin many homes have swimming pools as well as the downtown men's club, the

"The taxis in Medellin baffled me . . . . Everyone is taxi-happy."

Union Club, which has tennis courts, too. We also had a guest membership in the Army Officers' Club.

Educating the Children

For the children in Medellin's foreign colony, the U.S. State Department supports the Columbus School, run by a joint Colombian and American Board of Directors. A beautiful, modern building constructed to New York State Board of Education specifications, the school sits on the mountainside overlooking the valley. It resembles newer central schools in the Empire State. The school uses NY State Regents exams and follows teacher qualification recommendations.

Some of the American companies contributed to the school. For instance, General Electric furnished the lighting and Johns-Manville supplied the roofing. All the foreign concerns own shares, because they bought the bonds.

The school has become a center of interest for the foreign colony. On some evenings the equivalent of bingo and such games are run for the school's benefit.

Usually 15 teachers staff the school, half of whom qualify under the NY State Regents exams. They receive an attractive salary—better than in the States—plus transportation to Medellin. Wives with teaching experience comprise the other half of the faculty.

A child who acquires his secondary schooling there has a unique experience in store. For one thing, he receives plenty of attention, for classes are small—never more than 15. But even more important, he is exposed to children who have lived in all parts of the world. Through this association, the children acquire a breadth of outlook not usually possible in the States.

But when the children reach high-school age, the picture changes drastically. At the local high school, everything is in Spanish. And standards aren't anywhere near Stateside in regard to college-entrance requirements. It presents a problem, and the children have to be sent back to the States. Most companies—including General Electric—stand this once-a-year round-trip expense for high-school and college-age youth. Or, one parent can make the round trip if the child stays in the States.

Influx of Automobiles

Tariffs in Colombia favor lightweight automobiles but not necessarily low-priced ones. More and more, we saw European cars, especially the small ones, coming into the country. Families bring a Porsche or an MG or a Volkswagon because the lightweight cars are practically the only cars you can afford to own in Colombia. This does not hold true in Venezuela, a country rich in dollars. But in Colombia a 1956 Chevrolet would probably cost $5500 or $6000—regardless of whether it was bought there or brought in plus duty. When the first Oldsmobile Fiesta convertible came out, it sold down there for just over $8000.

We took our Ford stationwagon with us, and it proved to be highly convenient. We frequently wandered through the mountains with friends, taking along picnic lunches and driving out to some beautiful mountain springs and through quaint little villages.

At one stage, some political trouble cut down our picnics; but that was a passing thing—sort of like the common cold. They don't bother foreigners, but we did get a little nervous about it.

We paid about 23 cents a gallon for gasoline. Located in the northern part of South America, both Colombia and Venezuela have sizable oil deposits. These countries produce their own gasoline. And this section has a large refinery mostly General Electric equipped and owned by a subsidiary of the Standard Oil Company.

Overland transportation by rail or truck is so difficult that they pipe in practically all the gasoline. Government-owned pipelines spread throughout the country—running up and down and over mountains and across rivers. To lay a 6-inch pipe costs much less than cutting a road through some of the mountains.

Incidentally, the transportation problem can be blamed as one reason why Colombia is so far behind the United States in social and economic development. One city can't make a product and expect to sell it at a reasonable price in another large city some 500 miles away. It costs too much to transport the product. The natives say that Colombia went from the burro to the airplane—and that describes the situation. For they have no road network and a poor rail system. Many millions of dollars are now being spent to improve this condition.

The Magdalena River, which runs north and south, forms the main artery of communication and transportation. It's much like the Mississippi—broad, dirty, and long. The oil companies have barges similar to those on the Mississippi River. But once they get the gasoline up into the mountains, moving it to Bogota, only 100 airline miles away, would probably take another week, were it not for the pipelines.

The taxis in Medellin baffled me. Many are new and you know they cost about $5000. Yet you can take a ride there that costs you a peso—about 35 or 40 cents—while in the States it would cost you a dollar or more.

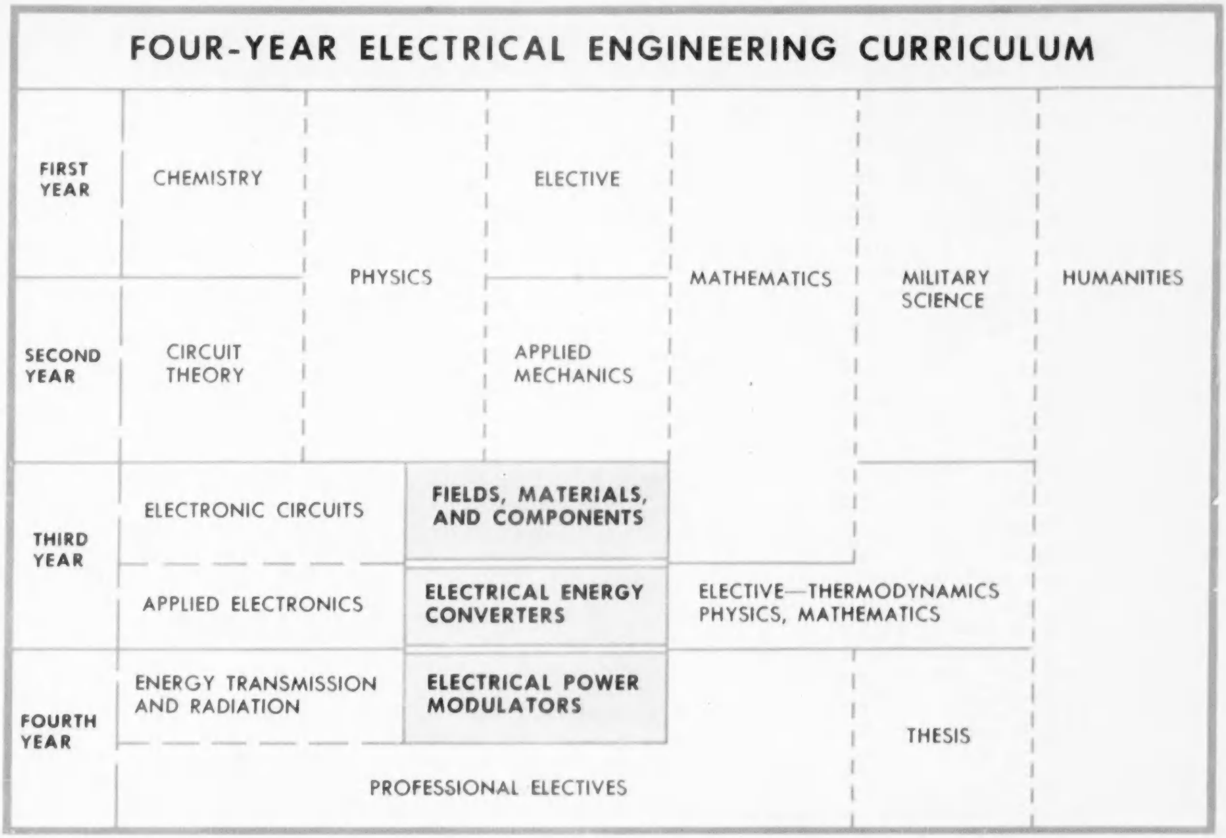
I never understood how they made a go of it; the rates didn't change in the five years we lived there. It surprised me to discover that some of my office employees—clerks working at relatively low salaries—often take a taxi home at night. Two or three fellows who live in the same neighborhood may go together. This way it only costs each of them the equivalent of a dime. Everyone is taxi-happy. We lost one of our best appliance salesmen; he bought a car and went into the taxi business—said he could make more money.

How Our Wives Kept Busy

Some of the American wives formed various art groups. One group specifically studied the history of South America. Every other week they had a tea and a speaker, followed by a discussion—all in Spanish. Sally found it both interesting and educational.

I would have enjoyed doing something similar to that in the men's group. Participating in that sort of thing sets a foreigner apart. If he develops a sincere interest in the country—not merely the mechanics of the language—studies some of its history, and learns to understand the people more, many doors open for him both in business and socially. But, unfortunately, I would say that not many North Americans do this. Some representatives of the bigger firms do because they have had it impressed upon them. Too many of the Americans go through the motions of learning the language, leave it at that, and thus make no real contribution to the country.

To say that Sally and I enjoyed ourselves in Colombia won't come as any surprise after you have read about our way of life there and the interesting activities we pursued. As you can well imagine, our five years passed quickly. Actually, Sally says that *she* was ready to stay fifteen. Ω



Energy Conversion Highlights A New Curriculum

By DR. A. KUSKO and DR. D. C. WHITE

Fundamental revision of undergraduate electrical engineering education at the Massachusetts Institute of Technology led to a promising development—stimulating instructional methods, materials, and techniques based on new concepts of teaching electrical energy conversion.

The new program broke with tradition in every instance where methods based on past heritage no longer advanced with scientific and engineering progress.

The electrical portion of the revised curriculum comprises a group of eight core subjects. Three of them, organized under the broad title of Energy Conversion, provide each electrical engineering student with an understanding of the conversion, utilization, and control of electric energy. Each student also studies a parallel subject sequence—information processing. Not mere substitutes for the traditional a-c and d-c machinery or power transmission subjects, the new program and its contents recognize imaginative processing of energy as a major responsibility of engineers.

The impact of the elements that represent the recent abundance of new materials, environments, energy sources, and calculating machines has increased the demand for scientific competence in tomorrow's engineer. The fields of feedback control systems and automation manifest two of the recent activities that cross the traditional boundaries between the fields of machinery, electronics, circuit theory, and communications.

Briefly, the revised curriculum purposes to adequately equip electrical engineers for advancing electrical technology in any industry.

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Dr. Kusko and Dr. White are Associate Professors of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass. Dr. Kusko specializes in electric machinery, control and regulating systems, and magnetics. Dr. White is concerned with electric energy-conversion systems and magnetic devices. They both act as consultants and work in research related to their respective fields of specialization.

Energy-Conversion Sequence

Within the complete four-year electrical engineering curriculum (illustration), each subject includes weekly lectures, recitations, and laboratory

VERSION, UTILIZATION, AND CONTROL OF ELECTRIC ENERGY

ELECTRICAL ENERGY CONVERTERS

(Offered in the Third Year)

Objectives

Point up the properties of materials and their interaction with fields as they carry out the functions of energy storage, transfer, and conversion.

Emphasize that properties and geometry of materials impose limitations on the energy processed by devices formed from these materials and also determine parameters imposed by these devices on the systems in which they operate.

Subject Content

Energy Storage—determines circuit parameters, the maximum energy that devices can store, and such properties as quality factor of a device, by utilizing the materials' properties and their geometry.

Energy Transfer—utilizes the Poynting vector and quasi-static analysis to show this relationship to energy storage, the chief energy-transfer device being the transformer.

Electromechanical Energy Conversion—covers the simple nonrotating electromechanical devices, excited from a single electric source and dependent on either a magnetic or an electric field for electromechanical coupling. Models demonstrate energy conversion with electric- or magnetic-field storage space as the medium for energy transfer between the electrical and mechanical systems that are coupled by the device. This application extends to transducers with incremental-motion linear operation for converting energy—when the information rather than the magnitude of the energy transfer is more important. Then analog circuits are used to analyze such devices and interconnected systems.

General Energy Conversion—studies theoretical mechanics that apply to multiterminal systems, using generalized coordinates, Lagrange's equations, and similar tools. Finally, the course examines conversion at the molecular level and considers the thermodynamics of the system.

Laboratory

Includes measurement of energy-storage reactors, transformers, and magnetic amplifiers as examples of storage and transfer devices; of transducers as examples of electromechanical energy-conversion devices; and experiments on other converters.

ELECTRICAL POWER MODULATORS

(Offered in the Fourth Year)

Objectives

Recognize and clarify the two major functions of energy converters: energy conversion—interaction of physical systems that cause energy change; and power modulation—dynamics of energy converters formulated as terminal behavior for system operation.

Subject Content

Field and Circuit Concepts for Electromechanical Systems in Relative Motion—considers the interactions of field and matter in relative motion and the formulations of this interaction in terms of energy functions that yield the equations of motion. This leads into special relativity for fields in relative motion and the Hamilton and Lagrangian principles for the study of system dynamics.

Dynamics of Energy Converters—deals with the characterizations and dynamic behavior of electromechanical energy-processing devices, controlled from a signal that modulates energy flow in their respective systems. Present technology experiences two difficulties: analyzing dynamics of nonlinear devices and systems; and determining analytically the dynamic behavior of rotating power modulators. The course explores possible solutions.

Multiple-Excited Energy Converters Such as Power Modulators—derives linear transfer functions where possible and carries out work in these terms. Based on the circuit-transformation approach, the course utilizes the methods of classical dynamics for determining electromechanical differential equations for the machine or system.

Energy-Conversion Systems—centers on feedback-control systems that use energy-processing devices.

Laboratory

Concerns the determination of parameters and transfer functions of energy-processing devices such as metadynes and servomotors when used individually and in feedback-control systems. Also studies the use of an analog computer on nonlinear problems and confirms the results by laboratory investigations.

laboratory should combine prescribed experiments with projects so that the student will treat reasonably diverse material on his own initiative. A creative laboratory also serves to excite the imagination and interest of junior staff members.

• Broaden the subject sequence to include other forms of electric energy conversion—conversion from heat, light, and other media in keeping with the spirit of the new curriculum (illustration, page 34). The present structure emphasizes the electromechanical form, largely because it dominates electrical engineering.

The reward of the over-all program lies in strong student and staff interest coupled with the knowledge that many goals have yet to be realized. Where a dearth once existed, research ideas are now plentiful and funds are more easily obtained. Actually, this phase has achieved the aspects of a large research endeavor: a large quantity of the material is new either in origin or presentation.

work. Outside problem work and reading total twelve hours' study time weekly for each electrical engineering subject. By comparison a student carrying a full load devotes between 45 and 50 hours each week to his studies. About 150 to 200 students comprise each group.

By the end of his second year, a student commencing the energy-conversion sequence will have studied circuit theory for two semesters, basic physics for four semesters, mathematics through differential equations for four semesters, and other related subjects. With a strong background in mathematics and electricity and magnetism as represented by Maxwell's equations, the third-year student studies electronics and advanced calculus, with thermodynamics or atomic and nuclear physics as electives. In synthesizing the sequence on energy conversion, a deliberate effort was made to utilize this background as an intellectual challenge.

Following a broad pattern, the sequence includes field theory and relates it to the microscopic concept of materials, continues through the combination of these materials to perform energy-processing functions, and treats the basic principles of energy-processing devices. The program culminates in the study of energy-conversion systems composed of interconnected devices.

Three subjects make up the sequence: 1) fields, materials, and components; 2) electrical energy converters; and 3) electrical power modulators. The content and objectives of the specific material under each of these subjects in the curriculum are geared to advance the student in the electrical engineering field (box).

Faculty Responsibilities

A specific faculty member nominally carries the responsibility for each of the subjects. However, the development of the central theme into notes, problems, experiments, and lectures results from the efforts of the groups teaching the various sections as well as the whole department. During 1956 each subject was given in seven recitation sections.

The teams of faculty and junior staff teaching the courses in the formative stages are drawn from personnel with varied but pertinent backgrounds, providing depth and breadth. For example, the staff members teaching electrical energy converters have individual backgrounds in feedback control, magnetics, acoustics, physics, power systems, and circuits. Each member contributed to the lectures and notes for the subject portion lying within his particular specialty.

Problems To Be Solved

As this program evolves, many problems remain . . .

• Complete the material sufficiently so that classroom notes and information can be made available as textbooks to assist teaching this material and release key staff for other tasks.

• Coordinate undergraduate subject material for a reasonable transition from subject to subject—presenting a problem of communications among the staff.

• Develop a strong laboratory program to ally with the classroom. Ideally, the

THREE CORE SUBJECTS COVER CON

FIELDS, MATERIALS, AND COMPONENTS
(Offered in the Third Year)

Objectives

Develop field concepts of electrical engineering.

Examine and relate electrical problems from both circuit and field points of view.

Demonstrate electrical properties of materials by study of molecular-level action between materials and fields.

Give a strong background in field theory, the physics of materials, and the interaction between materials and fields—the groundwork of the energy-conversion program.

Subject Content

Vector Analysis—achieves compactness of expression and simplicity of analytical manipulation.

Static Fields—places special emphasis on quasi-statics, particularly in the relationship between fields and the circuit components of resistance, inductance, and capacitance.

Maxwell's Laws of Electromagnetism—uses Maxwell's equations as a basis and develops all further work with stress on the dynamic character of electromagnetism. This approach effectively builds upon work given in second-year physics.

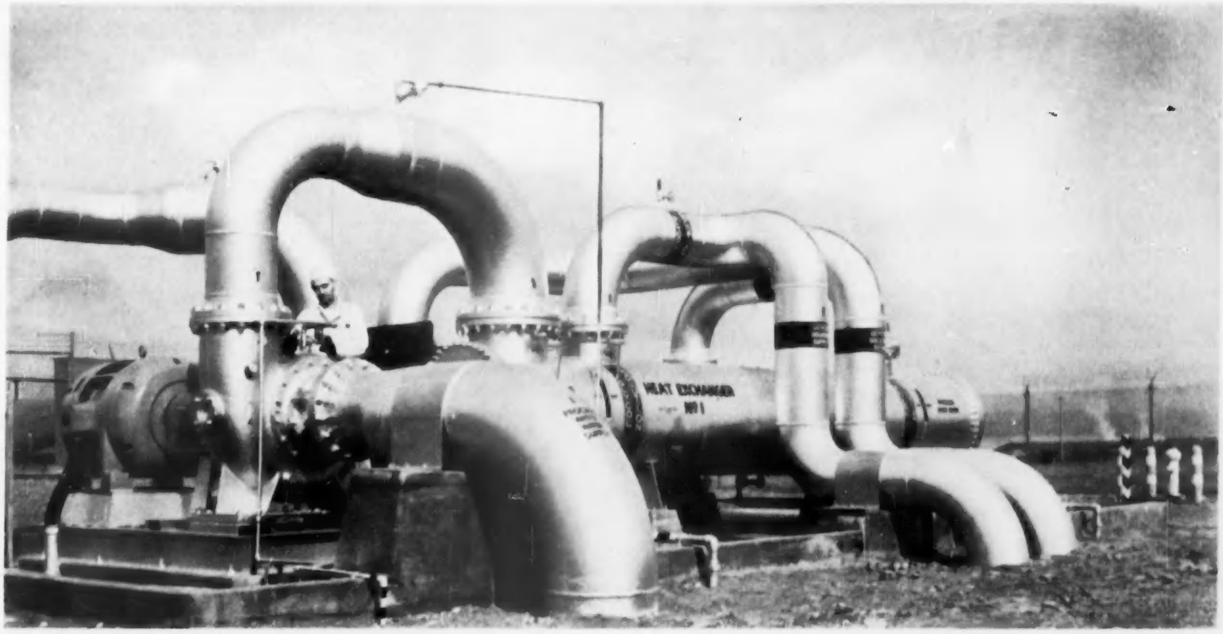
Fields and Circuits—establishes the relationships between fields and circuits by using the Poynting vector to establish power balance between voltages and currents at terminals of a region of space and the electric and magnetic fields contained therein. Concepts of quasi-statics are stressed, and the difference between potential and electromotive force is covered.

Forces, Energy, and Power—develops and investigates field expressions from the Poynting theorem and virtual displacement theory. Forces between material bodies are investigated by considering equivalent models of electric and magnetic dipoles.

Conducting, Dielectric, and Magnetic Materials—bases its study on the development of a level of solid-state physics suitable for third-year students, starting from the concept that matter is a microscopic distribution of charged particles subject to the influence of environmental electric and magnetic fields. Introduces the concept of electric polarization and magnetic moments.

Laboratory

Encompasses field problems, materials, and components. For example, plotting techniques and analog methods solve two- and three-dimensional field problems; principles of duality and reciprocity are applied to fields; and the materials' macroscopic behavior is related to their atomic and molecular structures. Components' equivalent circuits are studied at low frequencies using the quasi-static approach, progressing to frequencies significant for second-order effects.



MAIN HEAT EXCHANGER of space-heating system utilizes heat energy from plutonium-producing reactors for heating Hanford buildings.

Space Heating With the Atom

By S. L. NELSON

The fascinating business of getting motive power from the atom claims so much attention that engineers and scientists generally overlook one important potential: utilizing raw energy as it comes from the atom nucleus in the form of heat.

Heating with atomic energy is relatively simple compared with obtaining atomic power. To provide steam power for a turbine requires high temperatures and pressures—the higher the better. But many materials that work well inside a reactor lack strength at high temperatures, and materials that will stand high temperatures and pressures usually have a high neutron-capture cross section, gobbling up too many neutrons too fast. This requires the addition of more expensive, artificially enriched atomic fuels.

Many materials also become highly radioactive after they have been inside the reactor, making repairs difficult or impossible by ordinary techniques. A piece of equipment that has been exposed to neutron bombardment may, when removed, give off radiation at the rate of thousands of roentgens per hour. Time limits for working on such equipment would be measured in seconds, making ordinary work methods useless. Indeed, certain materials such as stainless steel may become so radioactive with prolonged high-level irradiation that a close approach for even a minute could be fatal. Remote-handling techniques must be devised before any work at such levels can even be considered. The designer of a high-temperature power-producing reactor faces these and numerous similar problems.

Interestingly enough, many of these problems shrink to insignificance if low pressures and temperatures below the boiling point of water can satisfy the designer. While not worth much for driving a turbine, this range of heat does nicely for space heating, as in the new Hanford atomic energy space-heating system.

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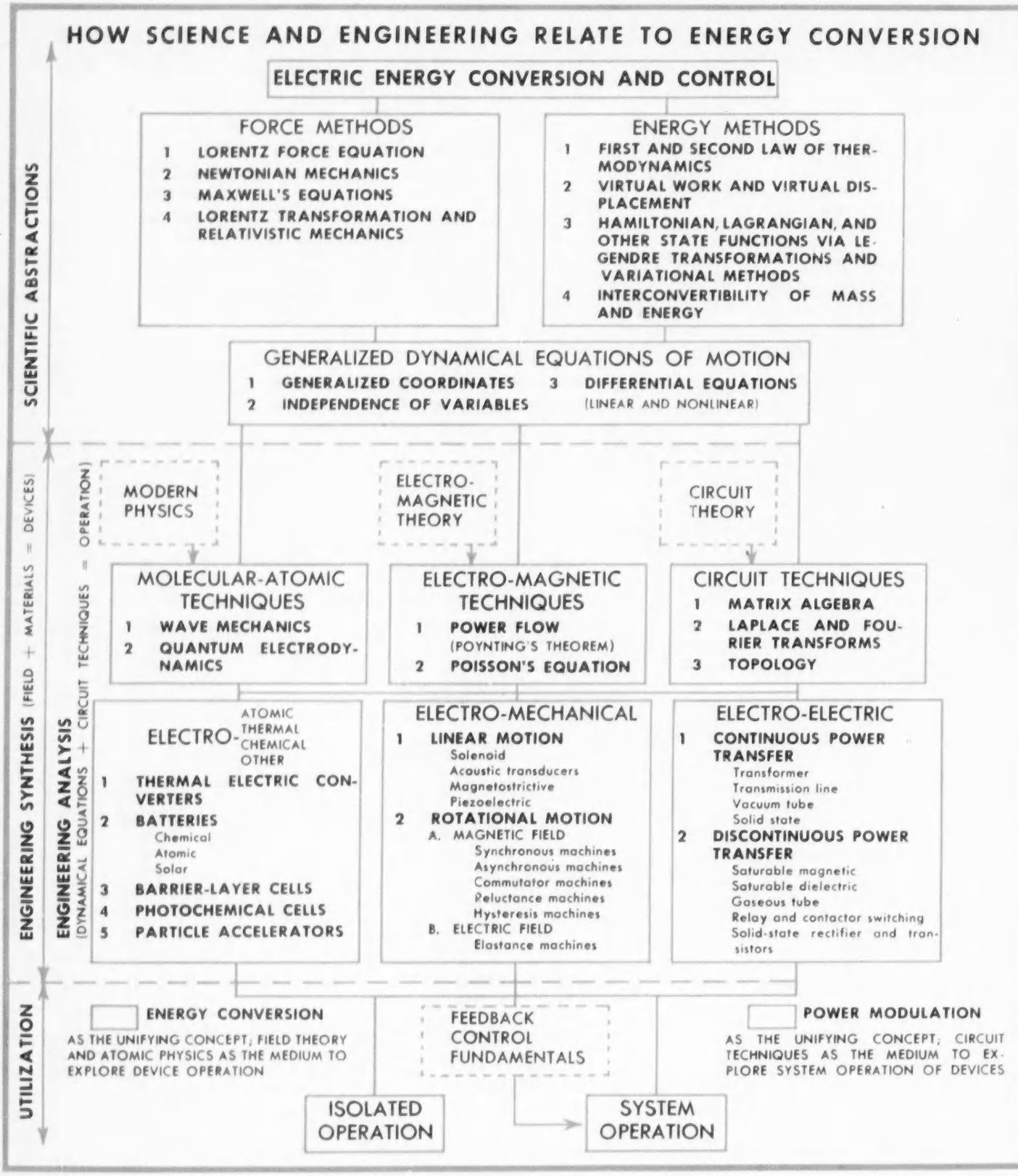
Mr. Nelson first entered the atomic energy field in 1943 as one of the first operations people at Hanford in Richland, Wash. Joining General Electric in 1946 when the Company took over the Hanford operation for the Atomic Energy Commission, he is presently Manager, Processing Operation, F-Reactor Operation, Irradiation Processing Department, Hanford Atomic Products Operation, Richland.

Wasted Heat

For 10 years Hanford engineers sorrowfully watched tremendous amounts of heat energy literally go down the drain. Because the reactors were built to produce plutonium, heat energy became a troublesome by-product requiring the simplest possible method of disposal. And so, it was dumped back into the Columbia River after allowing time for radioactivity decay induced by neutron bombardment of the water molecules passing through the reactor cooling tubes.

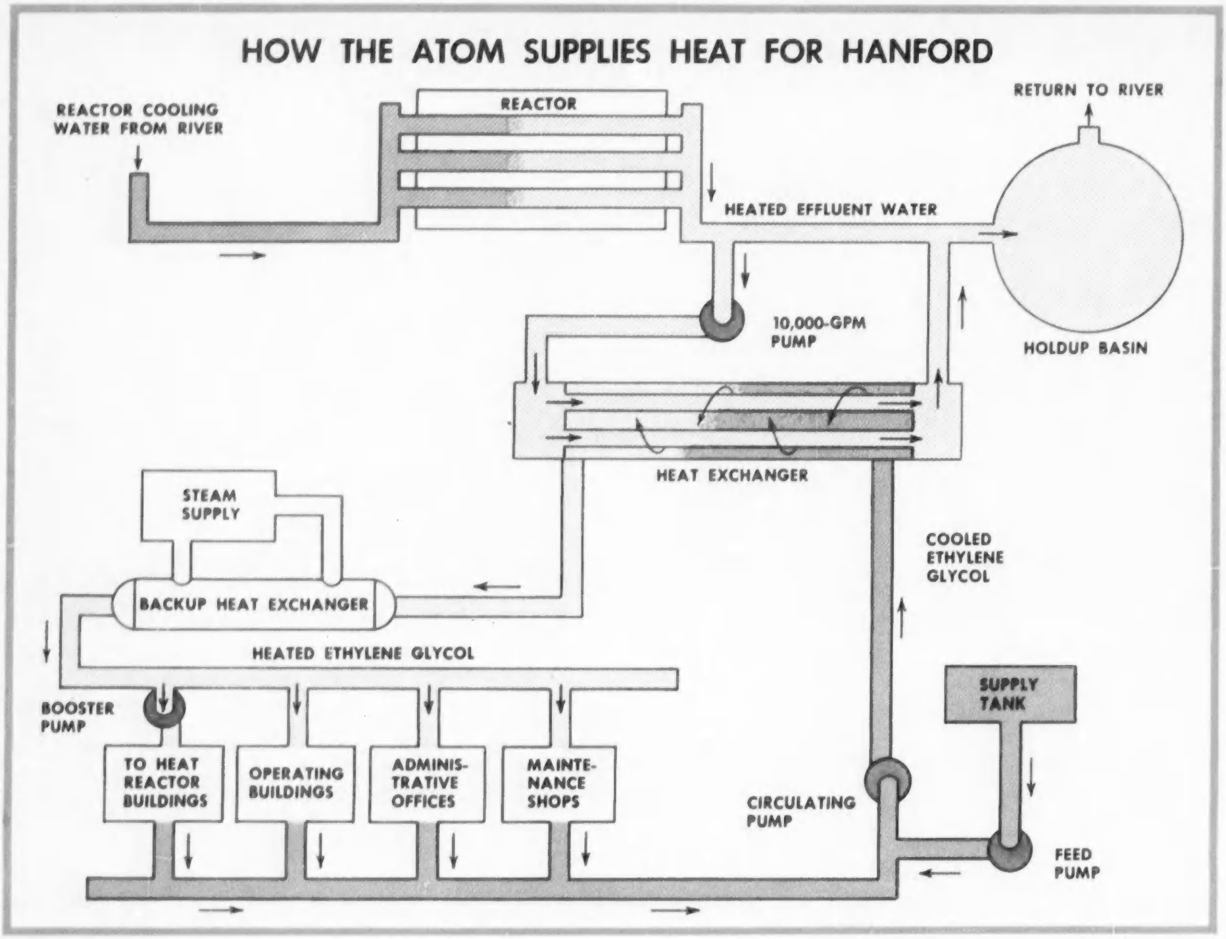
The paradox of running hot water into the river while burning coal to heat plant buildings challenged General Electric engineers. With engineers of the C. T. Main Company of Boston, they pioneered in the design of the space-heating system now incorporated into a construction project at Hanford.



The growing importance of converting energy to electrical form and the possibility that a few key developments may revolutionize the energy-conversion field demands attention. The program recognizes the need for introducing this type of material.

Expanding Program

Based upon field theory and materials, the undergraduate subject sequence was developed to present the important area of energy conversion. The approach continues through the combination of fields with materials to carry out the functions of energy processing, the study of generalized devices, and the behavior of energy-processing systems. And as new and important ideas appear in the world of science, this curriculum will change to reflect the latest thinking and progress. Ω



Design for Recovery

In planning the design requirements, safety and operation reliability were given top priority, and simplicity and operation ease were stressed. Although considered carefully, cost was not allowed to dictate the sacrifice of strength, reliability, and simplicity. Result: a remarkably sound and trouble-free system that operates economically. Although development projects often operate at a loss, this system will make a profit, saving the taxpayers a net of about $60,000 a year after a three- to seven-year amortization.

Many problems had to be solved and numerous choices made: heat exchanger, circulation liquid, pumps, controls, piping system, radioactivity control, prevention of radioactive material from entering the heat-exchange medium, provisions for maintenance work, backup heating system, and radiating exchangers.

The large quantity of hot water being wasted as a by-product made it unnecessary to conserve heat. Although the amount recovered would heat more than 1000 average houses during the winter season, this represented only a small part of the total available heat. Use of a heat pump to increase the temperature of the circulating medium was discarded because it required increased capital investment. Instead, the readily accessible hot water was a strong factor in favor of a simple, direct tube-and-shell heat exchanger.

The Heating System

Three main components (illustration) comprise the system . . .

- A large, outdoor central exchanger that extracts heat from the water after it has passed through the reactor
- A mixture of ethylene glycol and water, heated in the central heat exchanger
- A distribution system that circulates the heated ethylene glycol through the various radiating coils and exchangers used to heat the plant buildings.

The main exchanger is of the tube-and-shell type, with the hot water from the reactor being circulated through the tubes and the ethylene-glycol solution through the shell (photo, page 35). This ethylene-glycol-water solution (34 percent ethylene glycol by weight) is circulated in a counterflow direction through the shell that surrounds the tubes. Baffles inside the shell insure mixing and uniform heating of the solution. Ethylene glycol was chosen as the circulating medium to prevent the building heating coils from freezing, particularly those in the preheaters of the reactor building that are subject to blasts of outside air—at times as cold as −10 or −20 F.

Design specifications call for the transfer of a minimum of 50-million Btu per hour to 5850 gpm of 34 percent ethylene-glycol solution entering the exchanger at 120 F—the heat to be obtained from a portion of the process water diverted from the reactor effluent. An electric centrifugal pump, self-priming and self-draining, pumps the heated effluent through the exchanger and back into the river.

A 5000-gpm centrifugal pump circulates the water and ethylene-glycol mixture. An additional 5000-gpm pump is provided for backup. They can be operated separately or together, if additional capacity is needed. During warm weather, a 600-gpm pump circulates the heat-carrying glycol. These pumps are located in a building some distance from the central exchanger.

Piping is uninsulated and either buried four feet underground or run through existing tunnels. Insulation, condensate drainage, expansion loops, and steam traps are not needed, thus reducing the cost of the system. Although heat conservation is unnecessary, the ground serves as a natural insulator. The more than 30,000 gallons of glycol has a heat-holding capacity so great that it could continue to furnish building heat for approximately an hour, without any heat being added. Long before this happens, however, the backup system would have automatically assumed the heating load.

Backup System

The backup system consists of an auxiliary heat exchanger that floats on the line at all times and automatically responds to heat-load demands, eliminating the need for an operator. Existing boilers that provide steam for generating emergency electric power for the reactor also supply steam for this backup exchanger, making it unnecessary to provide additional capacity.

Radioactivity Problems

Only at the central heat exchanger is radioactive water brought into close association with the heat-carrying glycol. Here only the relatively thin-walled brass tubing separates the glycol from the hot radioactive water. Pressuring the glycol system higher than the process water solves the problem of radioactive water leaking into the space-heating system, should any of the heat-exchanger tubes split open. This prevents a leak into the glycol even if a heat-exchanger tube fails, because the process water inside the heat exchanger is about 25 psi lower in pressure than the glycol solution. Thus any leakage would be from the glycol system into the process water. The only disadvantage: the possible loss of glycol solution. But a regular check would immediately indicate any leak. Repair is made by inserting a new tube in the exchanger or by other standard heat-exchanger repair methods.

Because of the quick decay of almost all the radioactivity in the water, such maintenance work could be performed soon after stopping the flow of process water. If the worst happens and the glycol circulating system becomes contaminated, it could be flushed clean—glycol being the only loss. But the short half life of the radioactive water makes even this unnecessary except in severe contamination.

Experience at Hanford shows that the exchanger does not present operational or maintenance difficulties and can be expected to give long periods of trouble-free service. And the large pump that circulates process water through the exchanger is designed to operate six months or more without any attention.

During operation of the uninsulated and unshielded exchanger, radiation levels are never expected to be greater than 0.4 roentgen at 1 foot or approximately 0.001 roentgen at 50 feet. A cyclone-type fence prevents personnel approaching any closer than 50 feet. Closer approach under regulated conditions with proper monitoring will be possible at times.

Space Heating a Building

During reactor operation, minute amounts of radioactive gas and vapor escape from the reactor system into the building through extremely small openings in the reactor envelope and traps in process lines, sample lines, and other outlets. Although generally not regarded as serious, these gases could become a problem if allowed to accumulate. Some 165,000 cfm of fresh, warm air forced through the building and exhausted up a 300-foot stack keeps the space inside the reactor building swept free of radioactive gases.

Keeping the incoming air properly warmed during cold weather requires a large amount of heat. The heating coils for the reactor building consist of two banks—preheaters and reheaters—capable of warming the 165,000 cfm of air from −10 to +72 F. Circulation rate of glycol through the secondary bank of coils, or reheaters, controls the temperature.

Other smaller units, all utilizing some recirculation of inside air, heat such buildings as maintenance shops and office buildings. Dampering the air so that certain amounts pass through the heating coils or go around them through a bypass duct controls the temperature in these units. Coils are also installed under loading ramps to keep them snow-free. Other units supply heat to chemicals used in the water-treatment process.

A Not-Too-Distant Reality

Using the atom to make bombs; run submarines, ships, and aircraft; and generate electric energy eclipses the less spectacular idea of replacing the old furnace with an atomic reactor. But the significance of the atomic furnace lies in its wide potential application and relative simplicity in design and development.

Of course, this doesn't mean that in 10 or 20 years smokeless atomic furnaces will replace combustion furnaces. It does clearly mean that the use of atomic energy for heating large hotels, office buildings, and other compact areas with large space-heating requirements is feasible now and will become economically practical in the future.

Several things must happen, however, before this can become a reality . . .

- Military needs must be satisfied until atomic fuels become available in quantity.
- A reactor must be designed specifically for low-energy heat production and at the same time offer absolutely safe operation and long maintenance-free service.
- The economics must be made attractive.
- A system must be devised to provide the proper climate for growth and unhampered development of this use but controlled by adequate, workable inspection and safety standards.

Atomic technology is fully capable of producing a long-life low-powered safe reactor, suitable for space heating. Although not enough work has been done on the economic aspects of atomic space heating to make any evaluation, a preliminary glance indicates that for some applications it would be attractive even now. The Atomic Energy Commission has already laid the groundwork for standardization and control.

The remaining problem is fuel. For some time to come, all fuel will probably be channeled into more urgent projects. But within a few decades, city centers, factories, and offices may be heated without a speck of soot, an ounce of ash, or a cubic foot of smog. Ω

What To Expect From An Advanced Educa

By C. F. HIX and D. F. KLINE

What can your company do to make its educational programs more effective in developing engineers and scientists?

In answering this question, first determine the objectives of your educational programs, and then measure your program against these objectives.

To serve both the needs of your company and young engineers, a sound and forward-looking program must meet four requirements . . .

- Conform to a graduate's present investment in education and offer opportunities that provide continuity for future efforts toward self-development
- Impose no great sacrifice on a student's living standards
- Apply realistic problems to classroom work. This approach tests the worth of the educational expenditures and insures a student's satisfaction in the program. Also it continuously applies this test: Does formal study help a student do his job better, whether in research, applied research, advanced engineering, or design?
- Develop individual responsibility for educational advancement. A company can never develop a man; he must develop himself. But the environment, help, and guidance that nurture a man's ability and willingness to reach out must be provided. Moreover, his job should be worthy of his best efforts, continually developing his aptitude and ability.

To show you how one company-wide program fulfills these four requirements, let's take a look at General Electric's Advanced Study Program. We believe that it not only meets these requirements but also, because of its flexibility, adjusts to today's rapidly changing technology.

The building-block idea forms the basis of the Advanced Study Program. A college graduate can select from six individual building blocks—Honors Program, Engineering Design Course, Advanced Technical Course, Advanced Science Course, Creative Engineering Program and Advanced Engineering Program. By examining the contents of each block, turning each around, and arranging them in the most interesting and logical pattern, he can chart the type of career he would like to follow.

Honors Program

Many college graduates find that an academic atmosphere helps them obtain top results in their studies. Recognizing this, the Honors Program provides the opportunity to continue graduate study in technical fields for a select group of qualified men. Rigid standards govern selection. Scholastic records, faculty evaluations, interviews, and layman recommendations must be weighed carefully. Because program participation essentially includes admission to graduate school by a university, academic background must be critically appraised.

Under the program, a student obtains a Master's degree in one and one-half years at a recognized university near a General Electric location. During this time, he works a maximum of 26 hours a week in an operating department. The Company pays tuition, fees, and other academic expenses. And if he works during the academic vacations, the student earns 70 to 80 percent of his normal yearly salary.

Because of the residency rules for advanced degrees, an employee receives all his asignments at one Company location—sometimes in one operating department—until completion of his studies. Assignments compatible with the student's course of study stimulate interest in his selected field.

Throughout the entire Honors Program, a program supervisor appraises the student's progress at school and at work. This supervision guides the student's choice of studies and aids him in maintaining a proper balance between school and work. Watchfulness by a capable adviser insures the Program's success: long-range development of the man.

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Mr. Hix and Mr. Kline came with General Electric in 1949 and 1951 respectively. Mr. Hix supervised the Company's Creative Engineering Program and Engineering Program courses, Engineering Personnel Service, Schenectady, from 1953 to 1956. He is Manager, Component Equipment Design, Army and Fuzing Operation, Missile and Ordnance Systems Department, Philadelphia. Mr. Kline is Supervisor, Honors Program for Graduate Study, Engineering Personnel Service, Schenectady.

After completing graduate study and obtaining his Master's Degree under the Honors Program, the employee may choose to continue his formal education in one of two ways. He can pursue his doctorate at Company expense by beginning his professional career as a permanent member of an operating department. Or he can continue academic work under the Advanced Study Program, taking work assignments in Company locations related to his chosen field.

Engineering Design Course

For college graduates best suited to the challenging work of engineering design, the Advanced Study Program offers a comprehensive course in engineering design. This course analyzes the engineering functions in the evolution of a product from the development, or advanced engineering, stage to a manufactured reality. While the Engineering Design Course doesn't provide mastery of the design field, it strives to fulfill certain major objectives . . .

- Increase understanding and knowledge of the tangible facets of design engineering—materials and processes, shop practices, production methods, and physical principles
- Formulate an approach to the design engineering problem
- Promote an appreciation for the intangibles and background of design engineering
- Describe product development in the Company and the design engineer's role as a member of the business team.

Planned primarily for recent college graduates, Engineering Design includes rotating work assignments that extend the principles studied in class. Employment of the case-history method makes the concept of problem approach easier to grasp; each week's schedule concerns a different product design problem—taken directly from Company departments. Unlike most academic problems, no one correct solution exists in engineering design. Therefore, the instructor, an experienced design engineer from a Company department, evaluates the solutions presented by the students.

By taking this course under the Advanced Study Program, the student gains

tional Program

practical engineering design experience through working full time on rotating assignments. After completing the course and work assignments, most students choose a permanent position with an operating department. Then they continue their education through graduate study or other special courses.

Advanced Technical Course

The Advanced Technical Course, broad enough in scope to include some scientific as well as engineering graduates, creates a favorable educational environment. This course enables the engineer to 1) recognize and appreciate the fundamentals of science and engineering, 2) promote a balance between creative and analytical techniques, 3) organize his mode of thinking, 4) establish an approach to problem solution, and 5) formulate objectives through self-evaluation.

The classes, conducted during working hours, have their material arranged so that it flows easily from topic to topic. This material covers most scientific and engineering fields at a graduate level. Operating departments gear work assignments to the student's growth in class. These assignments—dominantly in creative, analytical, or development areas—make him stretch mentally as well as apply his course instruction.

All classes in the Advanced Technical Course and Engineering Design are synchronized in every Company area. Thus work assignments taking the student from city to city will not interfere with class work.

Advanced Science Course

A course for metallurgists, chemists, chemical engineers, and physicists—comprised of graduate-level scientific and engineering subjects—provides another facet of the Advanced Study Program. The general makeup of the Advanced Science Course appears very similar to the Advanced Technical Course. However, it offers two study options: one emphasizing solid-state physics for people interested in materials work; the other for people interested in process work.

Advanced and Creative Engineering

Graduates of the Advanced Technical Course or those with Masters' degrees may apply for the Advanced Engineering or Creative Engineering Program. Because these programs involve a considerable investment of time by the individual plus time and money by the Company, careful selection determines the candidates best qualified and most likely to benefit from the training. Those selected possess a broad and thorough knowledge of engineering fundamentals. Actual tests, as well as recommendations, school records, and interviews form the basis of candidate acceptance.

Classes are held during the working day, and work assignments are compatible with the course material and desires of the student.

The Advanced Engineering Program requires concentrated study of applied mathematics as a tool for solution of class problems and projects. These involve either actual departmental trouble spots or represent anticipated trouble areas. Solutions of these problems and projects are compared with the recognized departmental solutions. When it seems that a student may have found a better solution, an authority is called in to analyze and judge it.

The Creative Engineering Program aims to increase the individual's ability to conceive ideas, to fortify his technical knowledge that enables him to evaluate his ideas, and to give him confidence in his application of ideas to solution of engineering problems. And the course also attempts to enhance the individual's inventiveness and point out methods of achieving product superiority. An atmosphere of constructive discontent, deliberately fostered in class, incites the student to seek new solutions and have an open mind. The integrated work-class schedule is designed to fully develop creativeness on a sound thinking basis.

Because the development concept must apply to practical manufacturing, neither of the two programs—Advanced Engineering and Creative Engineering—places emphasis entirely on the analytical nor on the completely creative. The students learn that any solution must have a practical application, be feasible for use by the production people, and reckon with cost and performance limitations. By actually specifying the product for manufacture, the class members gain an understanding of cost and performance requirements.

The Creative Engineering Program runs one year, whereas Advanced Engineering is a two-year program. Programmed to stimulate growth in conceptual ability, job assignments also work toward developing practical ability and permitting career analysis by the individual.

Creative Engineering places stress on development of the man as an inventive contributor, particularly emphasizing the synthesis of new products and systems. The Advanced Engineering Program endeavors to develop men who will thoroughly understand a wide range of physical engineering principles and be capable of performing complex analyses.

Other Educational Opportunities

To its engineers and supporting personnel the Company makes available special courses that emphasize single facets of engineering and science subjects. An engineer wishing to study toward a graduate degree on his own time and schedule may do so at a recognized college or university with departmental approval. The department manager can authorize payment up to 100 percent of the necessary tuition. In this way, one or two courses or even the total requirements for a graduate degree may be completed at no expense to the individual. Except for a specified number of work hours, such courses must be taken outside of working hours.

Has It Paid Off?

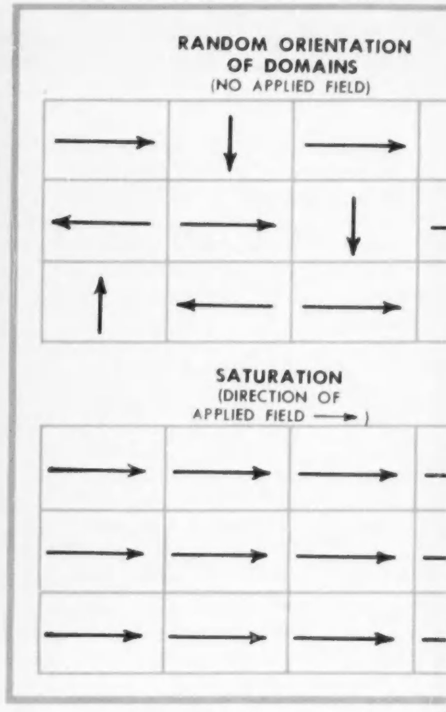
These programs fulfill the need for raising the technical level of General Electric engineers and scientists. They satisfy four over-all requirements of professional men entering the Company: 1) provide the building blocks essential to logical self-development; 2) allow the participant to earn a certain amount of his normal salary—up to 80 percent in one program and 100 percent in all others; 3) offer job assignments in areas that permit the individual to apply the technologies under study; and 4) create the necessary environment for developing the individual's own responsibility.

The employee learns by doing, and by doing he learns. Ω

CREDITS

Page	Source
Cover	G. E. Masters and E. M. Stevens (Daylight Ektachrome film)
9	Percy M. Lee
12–16	Burns Photography, Inc.
56 (left)	Alexander Kerry

Antenna Rod Space-saving ferrite rod held by author Katz (left) sharply cuts size of today's portable radios. By contrast, author Mullen displays former loop antenna, once an essential component.



Domains Fluctuation from zero to saturating field forms the magnetization process.

Harnessing Ferrites for Electronics

By DR. H. W. KATZ and E. B. MULLEN

Developing and utilizing magnetic materials have progressed tremendously in the past 20 years—an insignificant span of time as compared with the several thousand years since the discovery of magnetism. This recent acceleration stems from the growing needs for new magnetic materials plus a better understanding of magnetism itself.

Probably you know magnetism best in the form of permanent magnets. You may also understand the magnetic effects associated with current-carrying conductors, or electromagnets. The underlying principles therein intimately involve the origin of the magnetic behavior of materials and its basic explanations. The magnetic source can largely be ascribed to small circulating currents within a material's atomic structure.

You can usually visualize an atom as a positive nucleus surrounded by a varied number of electrons circulating about the nucleus. Each orbit represents an electric current loop, which behaves as a small permanent magnet. Each electron's direction of rotation determines the polarity of each elementary magnet. If the orbits are so oriented that the magnetic moments do not cancel each other out, the atom will have a net magnetic moment.

Another magnetic moment results from the spinning of an electron about its own axis. This spinning charge produces a magnetic effect similar to that of an electron rotating in its atomic orbit. Thus the atom acquires a net magnetic moment from two sources.

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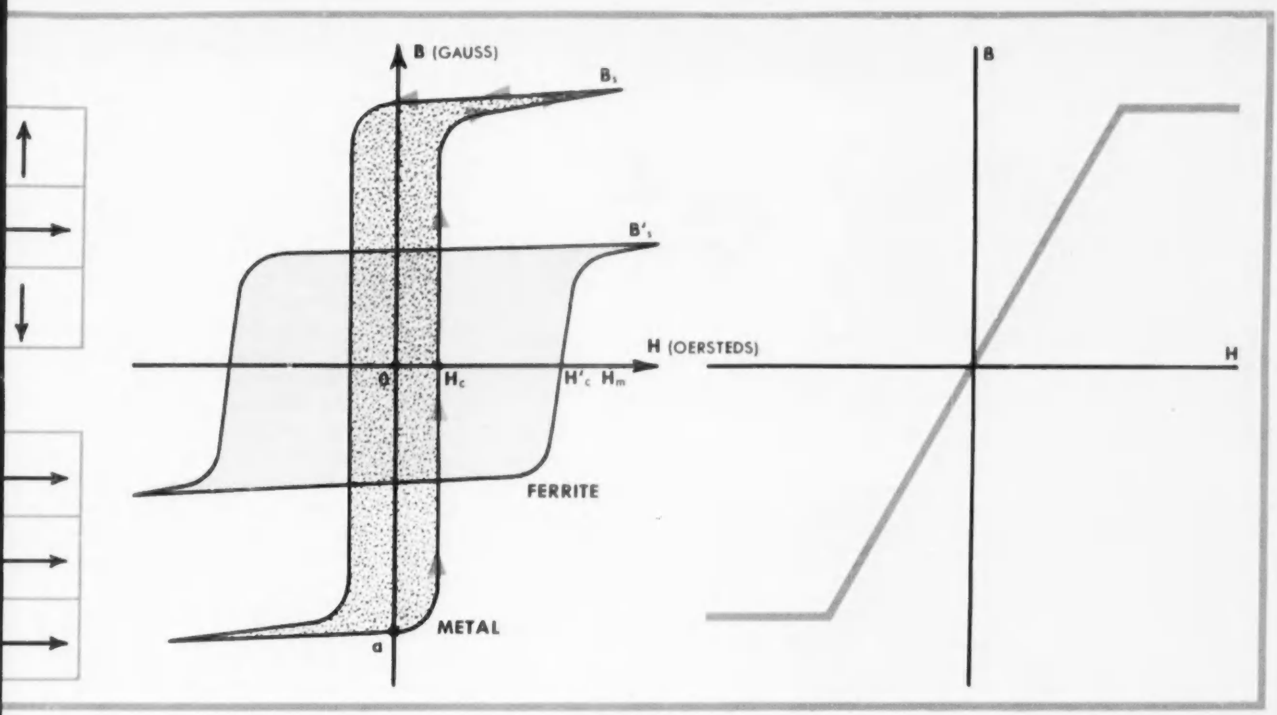
Both Dr. Katz and Mr. Mullen came with General Electric in 1952 and are located in the Electronics Laboratory, Electronics Park, Syracuse. Dr. Katz works principally with ferrite delay lines and magnetostrictive ferrites in the Magnetics and Dielectrics Application Section. Mr. Mullen, a member of the Microwave and Radar Sub-Section, is concerned with waveguide problems, particularly ferrite measurements and applications.

The source of the magnetic effect on ferromagnetic materials—the class of materials discussed here—results principally from the electron's spin about its own axis.

Obtaining the large magnetic effect observed in solids requires some type of cooperative phenomenon among neighboring atomic magnets so that large groups of atomic magnets in the presence of a magnetic field can rotate in unison. This phenomenon, known as the exchange force, compels neighboring spins to align themselves in the same rather than in opposing directions. If you observed a large volume of this material, you would see it divided into numerous domains, or regions (illustration, left).

In each domain the atomic moments align in the same direction. However, in the absence of a magnetic field, all the domains are so oriented that the net magnetic moment is zero. With a strong enough field, all the domains align in the same direction, and the material be-



Metallic Vs Ferrite

Superimposing the respective low-frequency magnetization curves gives a comparison of the two materials. By their nature, these curves also indicate the large irreversibility of the magnetization process. A more ideal material would reveal a somewhat different characteristic (right).

comes saturated. This fluctuation from zero applied field to saturating field forms the magnetization process and supplies the interesting properties exploited for commercial application.

Metallic vs Ferrite Materials

Formerly, the metallic variety comprised the most common magnetic materials for communication purposes. Despite their excellent inherent magnetic characteristics, they suffered from one essential defect: the conductivity was so high that the heating losses due to eddy currents masked the basic magnetic properties, especially at high frequencies. In recent years the discovery of a ceramic magnetic material with a resistivity approximately six to eight orders of magnitude greater than that of the metallic compounds has opened new possibilities for high-frequency magnetic applications.

The chemical composition of this material, called ferrite, varies with the desirable properties. Usually, ferrites are formed by intimately mixing various combinations of nickel, zinc, manganese, magnesium, or cobalt oxide with iron oxide. After pressing, molding, or extruding into the desired shape, the mixture is fired at a temperature between 1200 to 1400 C and then cooled to room temperature. Herein lies the tremendous commercial value of ferrites: they can be fired in the finished form without being laminated as is necessary with the metallic magnetic materials.

Let's compare the metallic and ferrite material by superimposing their respective low-frequency magnetization curves (illustration, center).

The general nature of these curves shows the large irreversibility of the magnetization process. As the applied field H varies from zero to maximum H_m, the magnetization B changes from saturation in one direction to saturation in the reverse direction. However, upon decreasing the applied field back toward zero, the magnetization lags behind the applied field. To return to point a, the direction of the applied field must be reversed completely. A more ideal material would have a different characteristic (illustration, right). In other words it is desirable to have a large reversible change in B for a small change in field H.

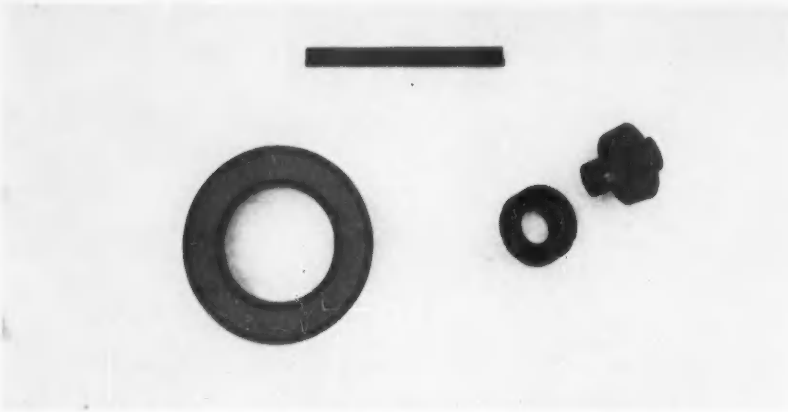
Ferrites can generally be distinguished by the small saturation flux density B'_s and a large coercive force H'_c—defined roughly as the minimum field that must be applied before the saturation can be reversed. Further, the average slope, or permeability, of the BH curve for metals in the neighborhood of the origin greatly exceeds that for ferrites. Thus ferrites do not simply replace metallic magnetic materials. Because of the comparatively low saturation B'_s and the high coercive force H'_c, ferrites probably will not be used at household power frequencies (60 cps). The region of primary interest lies in the kilocycle-to-thousands-of-megacycles range, where the conductivity losses of the metals would be prohibitively high.

Conventional Applications

The application of ferrites can logically be divided on the basis of frequency and on the shape of the magnetization curve. (High-frequency applications appear in the discussion on pages 44 and 45.)

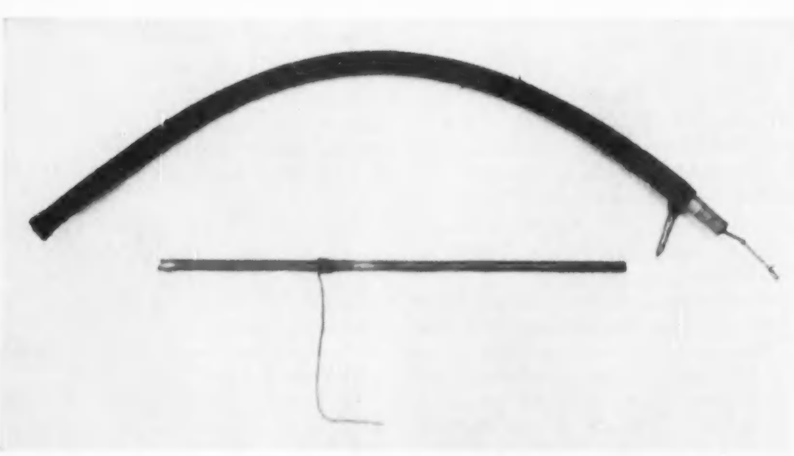
Let's look at the application of ferrites in a frequency range arbitrarily set at a maximum of 100 megacycles. For the magnetization curve in this area, you should have as narrow and steep a curve as possible to provide the high permeability needed in an inductance.

With this type of ferrite you could construct inductors that require fewer turns of wire and smaller volumes than obtained with air inductors. Typical



FERRITE SHAPES for electronics include simple rod, toroid, and cup cores. In television . . .

. . . c-frames offer low eddy-current losses — a valuable ferrite property — while . . .



. . . high permeability delay lines provide more time delay per unit length than other means.

ferrite shapes include the simple rod, toroidal form, and cup cores (photo, top). The toroid confines the magnetic field to reduce coupling with other magnetic elements in a circuit. However, to produce a stable inductance with respect to temperature variations, you must introduce an air gap into the magnetic path. For this effect the cup core (shown disassembled in the photo) seems to be the most feasible.

With the proper choice of raw materials and firing cycles for the ferrite, inductance variations can be made as small as 10 parts per million per degree *C*. These cores find their greatest application in the frequency range of 10 to 500 kc in such areas as communication filters and transformers for broadcast receivers.

The ferrite antenna rod used in most portable radios best exemplifies the rod type of inductance (photo, page 40). Comparable in electrical performance with the familiar loop antenna formerly used, its much smaller volume represents a vital saving so necessary in these days of miniaturization.

Television, another large market for ferrite transformers, needs a transformer to match the high impedance of a vacuum tube to the low impedance of the deflection coil that provides the magnetic field for driving the electron beam across the screen. Because the deflection current contains 15-kc components plus several harmonics, a magnetic material with low eddy-current losses must be used. Again, the ferrite fulfills the proper function. A c-frame accomplishes the deflection (photo, center). Incidentally, the sweep yoke has a ferrite to provide a low reluctance path for the sweeping magnetic field.

Specialized Applications

Many other ferrite properties can be exploited for specific needs. For instance, the ferrite is useful in the construction of electric delay lines (photo, lower). This structure takes a signal at its input and reproduces it at the output after a short period of time, measurable in microseconds. Nearly all color TV receivers require a delay line.

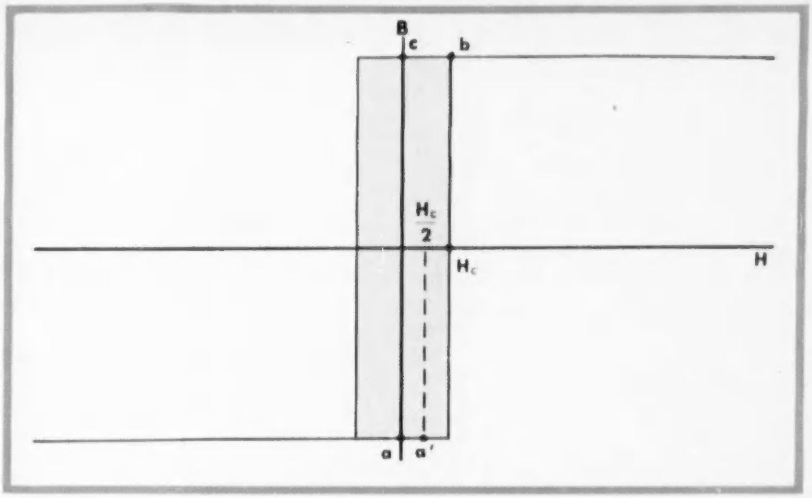
Once more the ferrite's high permeability allows one to construct a miniaturized delay-line component that provides more time delay per unit length than can be achieved with similar air-core configurations. By merely varying the d-c bias applied to the line, the amount of time delay can be varied electrically rather than mechanically. To accomplish the same effect in some lines requires changing the physical length. The variation of permeability with bias current is also used in several commercial inductors for specialized applications.

A particular class of ferrites known as square-loop material departs radically from the linear approximation to the magnetization curve. Three distinct features characterize the idealized square-loop magnetization curve (illustration, top): the material saturates sharply at point *b;* if the material is magnetized to state *a*, a well-defined minimum field H_c is needed before the material will become saturated in the reverse direction at point *c;* after reaching point *b*, and reducing the field to zero, the magnetization goes to and remains at point *c*. The two remanent states *a* and *c* thus provide two stable and well-defined states of the square-loop ferrite. In other words, the ferrite has a built-in memory. Once switched to point *c*, for example, the ferrite remains in this state of magnetization indefinitely without any applied field. Of a completely passive nature, this memory requires no consumption of power to maintain the ferrite in state *c*. An outstanding application of this property occurs in the magnetic memory matrix of large-scale digital computers.

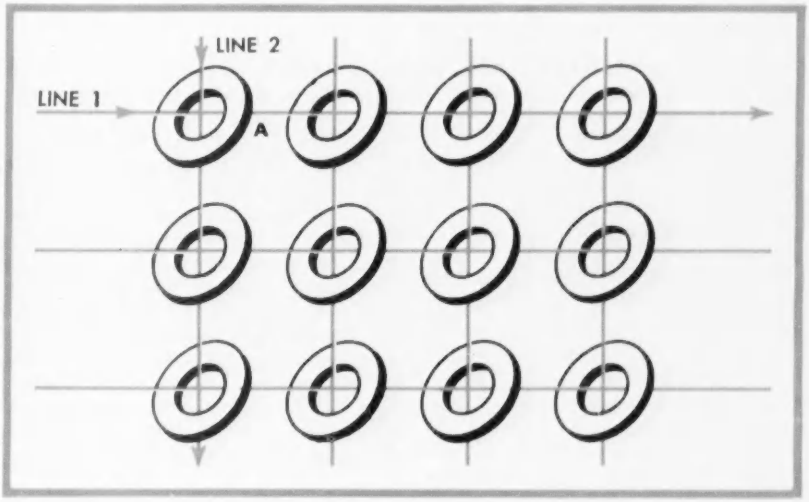
In an array of toroidal square-loop cores with a single wire threading all the cores in a horizontal or vertical row (illustration, center), memory is obtained by setting each core to state *a* or *c*. Information is thus stored in a binary manner. To illustrate, suppose you want to place core *A* into state *c* when already in state *a*. You would place a current corresponding to $H_c/2$ on lines 1 and 2 so that every core in line 1 and 2 except *A* moves to point *a′*. No core changes state except core *A*, which now has a current corresponding to H_c sufficient to move the core to state *c*.

A magnetic memory that operates on this principle is of the coincident current type. Arrays of 100×100 cores are not uncommon with each core having an outside diameter of 0.080 inch an inside diameter of 0.050 inch.

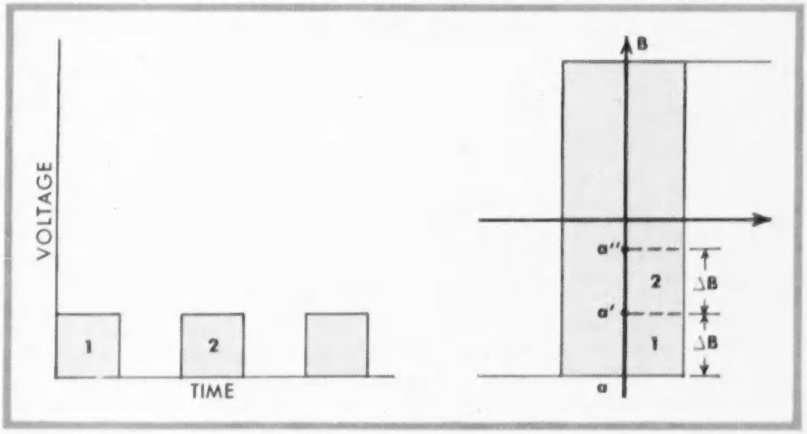
Perhaps a more interesting use of the square-loop ferrite stems from its ability to count digitally and then to store the count. Instead of applying current pulses as in the memory example, you apply voltage pulses. In the memory application you applied a constant current for a sufficient length of time so that the material would completely change its



IDEALIZED SQUARE-LOOP MAGNETIZATION CURVE verifies ferrites' built-in memory . . .



. . . with toroidal cores storing the acquired information in a binary manner. But by . . .



. . . applying voltage pulses, square-loop ferrites count digitally and store the count.

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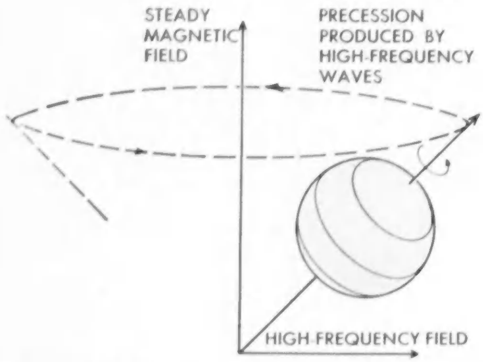
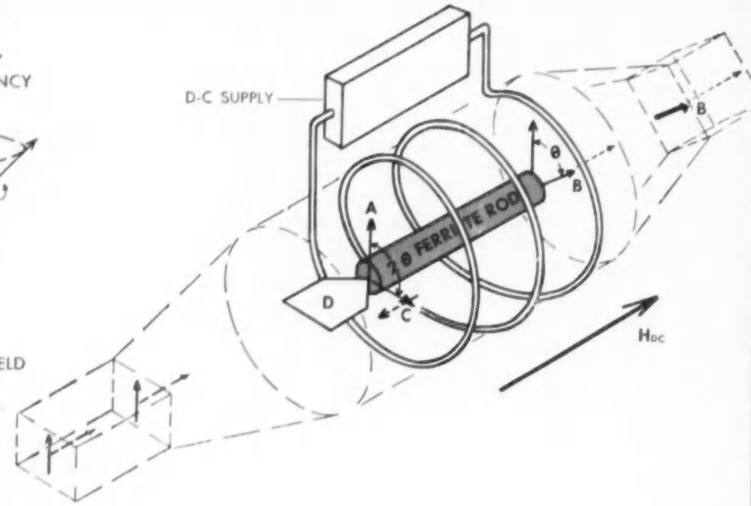




SPINNING TOP simulates the electron spins that occur in the presence of a constant magnetic field (above). First nonreciprocal effects observed were those of the Faraday rotation in a circular waveguide filled with ferrite rod (right).

HIGH-FREQUENCY APPLICATIONS OF FERRITES . . .

High frequencies in connection with ferrites shall mean in this discussion the range where waveguides are customarily used for the short-distance transmission of electromagnetic energy—such as radar and some TV broadcasting. These frequencies would ordinarily be those in excess of a few thousand megacycles per second. At these high frequencies the waveguides or coaxial cables prevent the power that would flow along the surface of a wire or cable from being radiated away.

In such a transmission channel the wave nature of energy now assumes particular significance. By inserting a ferrite of suitable shape, certain changes—analogous to those that alternating current undergoes in passing through conventional circuit elements—can be observed in the wave after it has passed through the ferrite.

The utility of ferrites at very high frequencies stems from a different set of circumstances than do the low-frequency properties. The low-frequency characteristics are based on the properties of domains—small regions of a magnetic material that act more or less as units in magnetic changes. The domain walls can actually be rendered visible by special techniques.

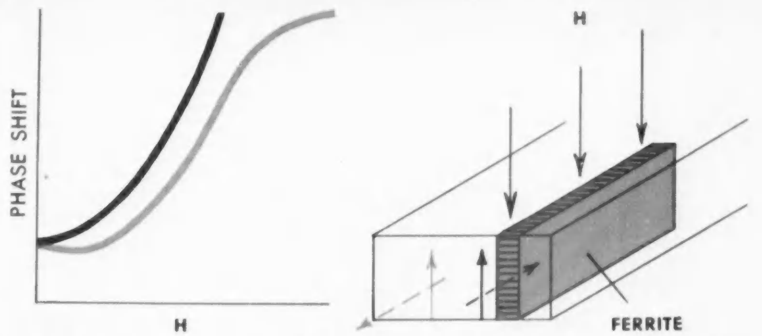
On the other hand, the microwave behavior is based directly on the spins of the electrons themselves. The spins give rise to gyromagnetic effects when the electrons are subjected simultaneously to a large steady magnetic field and a much smaller high-frequency alternating field. This class of phenomenon, enlarged to include nuclear spin effects, has been studied intensively for about 10 years. Its discoverers, Bloch and Purcell, won the Nobel Prize. A whole new field of physicochemical analysis known as magnetic-resonance spectroscopy, has been opened.

The mechanics of the high-frequency wave's interaction with the electron spins that occur in the presence of a constant magnetic field can qualitatively be explained by analogy. Let's use the simple top, where the force of gravity replaces a steady magnetic field and a periodic disturbing force simulates radio frequency (illustration, left). When a spinning vertical top is subjected to a small force at right angles to its axis, it reacts by beginning a precessional motion about the vertical direction. The top's shape and mass and the gravitational force determine this rate of precession. If the disturbing force is made with a periodicity close to that of the precession rate, resonance effects will ensue that tip the top more and more from the vertical position.

With electrons, certain damping effects will decrease the resonance response, which nevertheless can still be large. This mechanism provides a means of coupling the high-frequency energy to the electron spin motion. If the wave frequency is far removed from the electrons' precession rate, as determined by the steady magnetic field, only a slight abstraction of energy from the high-frequency wave will result; however, if the frequency of this wave coincides with that of the precession rate, a large amount of energy will be transferred to the electron.

This gyromagnetic effect at the electron level manifests itself in the high-frequency permeability of the ferrite. A mathematical treatment of the electron spins' interaction with the high-frequency field in the presence of the d-c magnetic field shows that this permeability is a function of the magnitude of the steady field. Herein lies part of the usefulness of ferrites at microwave frequencies: their microwave properties can be controlled or altered to desired characteristics by varying the magnetic field. But more importantly and as a result of the gyroscopic motion, a component of high-frequency magnetization appears at right angles to both the high-frequency and constant magnetic fields. As a consequence the ferrite will also have nonreciprocal transmission properties—waves traveling in one direction through the magnetized ferrite undergo different changes than waves traveling in the opposite direction.

The first of these effects observed was that of the Faraday rotation in a circular



NONRECIPROCAL EFFECTS can also be obtained in rectangular waveguide without rotations of polarized high-frequency waves. By simple modification the ferrite isolator does the modulating job without any attendant frequency modulation.

waveguide either filled with ferrite or equipped with a small ferrite rod along its axis (illustration, right, opposite page). The electric field vector of an incident high-frequency wave generated by a microwave source has a certain direction A and emerges as wave B with its polarization rotated through an angle θ, depending on the magnitude of the longitudinal field H. If now B were reflected back toward the source, the emergent wave would not be A as in the reciprocal medium but rather C, which is rotated through angle 2θ.

This simple device has an immediate application. If H is adjusted so that θ is 45 degrees, then 2θ will be 90 degrees, and C, because of waveguide characteristics, can't emerge from the rectangular waveguide. Such a device constitutes an isolator, for it allows the waveguide energy from the generator to propagate toward the load but prevents reflections from returning to the generator. In practice, the dissipative load D, in the form of a resistive card, is coupled to the cross-polarized wave to absorb this reflected energy. Reflections should be prevented from reaching the generator because, if large enough, they can result in "frequency pulling" as well as reduced power output of the generator.

Nonreciprocal effects can also be obtained in a rectangular waveguide (illustration) but with no rotations of the polarized high-frequency waves. Instead, the nonreciprocity is in the phase shifts experienced by waves traveling in opposite directions through the ferrite. When the differential phase shift is made equal to 90 or 180 degrees, some unusual and interesting microwave circuits can be built.

Through a variety of configurations in both round and rectangular waveguides, new forms for certain microwave devices can be obtained, along with such entirely new types of microwave components as the modulator. In many applications it is desirable to modulate the amplitude of high-frequency-energy output of a klystron by the low-frequency information-carrying signal. Although modulation can be effected by applying the low frequency to a control grid of the klystron, this may lead to undesirable frequency modulation.

With a simple modification the ferrite isolator can do the modulating job without any attendant frequency modulation. Instead of maintaining a fixed 45-degree rotation, a variable amount of rotation is obtained by applying a sinusoidal current to a coil that surrounds the ferrite-loaded waveguide section. Because a fixed magnetic field produces a definite rotation of the microwave field in the circular waveguide, the alternating field causes the microwave field to oscillate about its zero position, and the output rectangular waveguide selects only the component in this zero position. This component is thus the microwave field modulated according to the signal applied to the coil.

If required, a frequency-modulated output can be obtained conventionally by varying the voltage to the klystron's repeller electrode. But this method offers only a limited frequency excursion. Recent work shows that if a klystron with an external cavity containing a ferrite is used, frequency changes about 10 times larger will occur. Of course, the resonant frequency of the cavity containing the ferrite depends on the permeability of the ferrite. This permeability can be varied by means of a coil that surrounds the cavity and is excited by an alternating current.

state of saturation. If you had applied the voltage for only a short interval of time, the core would move from a to a' (illustration, lower, page 43). The change in B is proportional to the area of the voltage pulse. If all the areas are the same, the system can be adjusted to require an integral number of voltage pulses to reach a''.

The core can thus be made to count and remember n voltage pulses. The magnitude of n for a given core material can be 2 to 100, depending on such factors as squareness of loop and switching time. Again, this type of counter requires power only during the time that it changes state but not to remember a given count.

Of the many varieties in the application of square-loop ferrites, all involve some form of counting or storage of information.

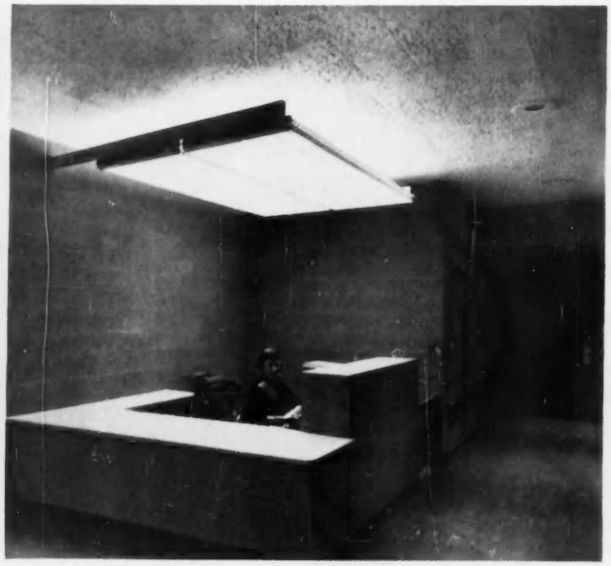
Still another ferrite property is now being exploited: applying a magnetic field to a magnetic material usually results in a change in length—a property called magnetostriction. Fundamentally then, proper electric signals can start a piece of material vibrating mechanically. The losses associated with these resonant mechanical vibrations are much smaller than those of an equivalent electric resonant circuit. Mechanical filters can be constructed that perform the same electrical function as inductance and capacitance, but they will do it in a much smaller volume and with greater selectivity.

And you can fabricate an electric oscillator that uses a magnetostrictive ferrite bar for the frequency-determining element. Although having a physical action similar to that of crystal oscillators, inexpensive ceramic ferrites furnish comparable frequency stability (two to five parts per million per degree C).

Quartz crystals are extremely sensitive to surface contamination, whereas ferrite resonators are relatively insensitive to moisture or surface imperfections. Electromechanical vibrators employing ferrites may thus replace quartz crystals in the 5- to 500-kc range.

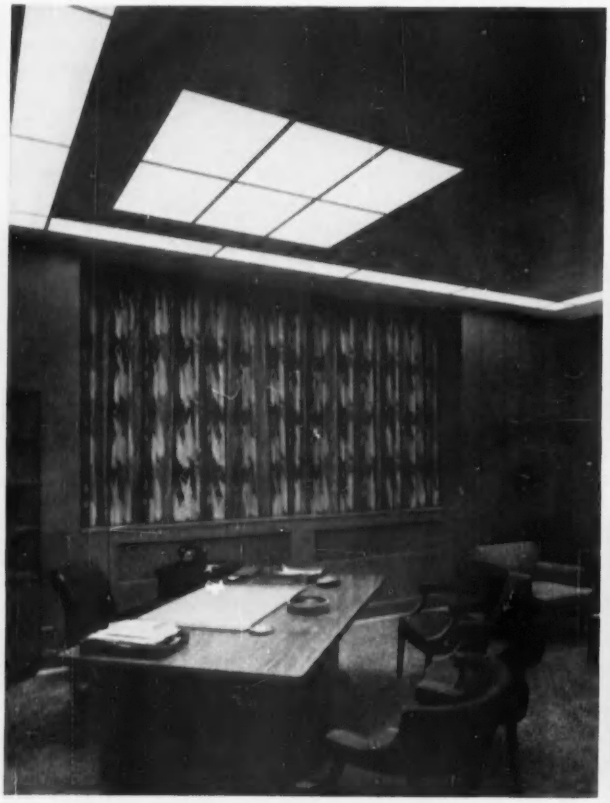
Continuing Development

These examples, chosen from many, indicate some of the uses for ferrites in electronic circuits. Present active development has already resulted in devices that materially aid progress in the constant search toward weight reduction, simplicity, durability, and long life of electronic equipment.

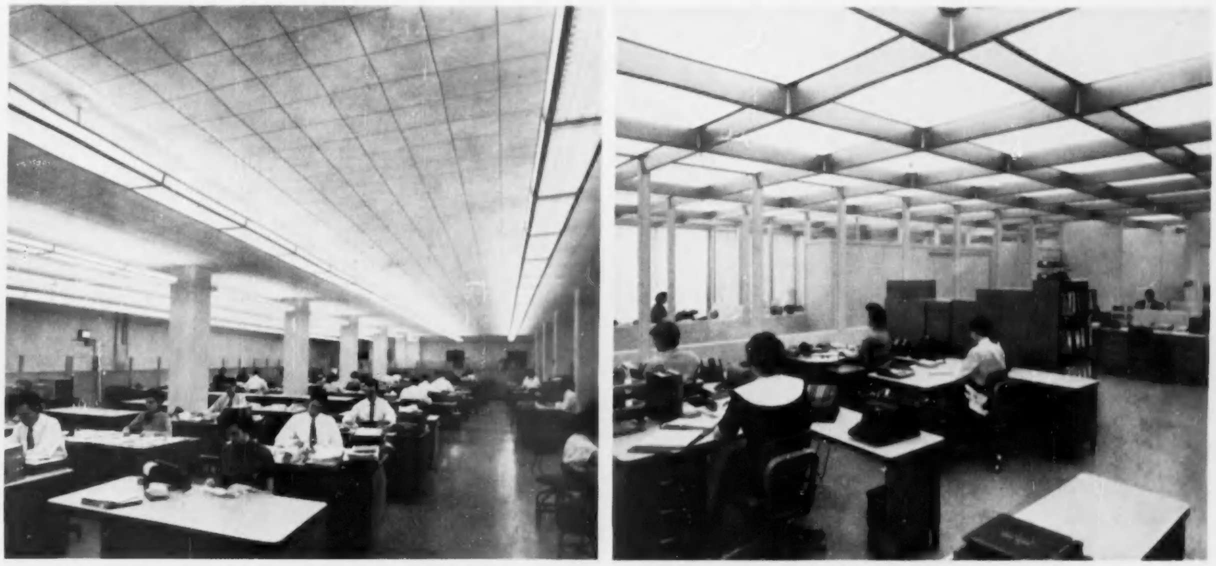
Reception Rooms

Lighting enhances modern design, textures, and appointments and imparts an efficient business-like impression to visitors (left). Two standard "wide" fixtures suspended side by side provide a modern appearance and create a lighting pattern that insures the identification of the area focal point.




Private Offices

Five-foot-square lighting element emphasizes work location as well as gives plenty of desk light. Glass-enclosed troffers light perimeter space, making the room seem larger. Draperies create the illusion of windows (left). Wide fixtures give small offices the appearance of custom styling.



General Offices

Orientation of luminous side panel fixtures and light-color equipment signify good planning (above). Luminous ceiling has environment-control features such as perforated wedges to regulate sound; some wedges introduce conditioned air. High-frequency high-voltage distribution system operates lighting.

New Ideas in Lighting Increase Office Efficiency

By W. S. FISHER

Because the need for clerical workers has increased faster than that for other classes of workers, office space and office personnel have become scarce in our present economy. For example, in 1900 the ratio was one office worker for every 30 factory employees. By 1935 the proportion had increased to 1 to 10. And the most recent data indicate about 2 office workers for every 5 in the factory.

This substantial change in proportion might indicate either that productivity per worker has increased much faster in the factory than in the office or that today's methods of doing business just naturally require more clerical help. Strong evidence exists in favor of the first premise, because the investment in equipment for office workers is only about one tenth that of the average for industrial workers. However, both factors probably exert some influence.

Management knows that office costs are higher now than in the past and that the salaries of their employees contribute more than any other factor to office costs. Thus, managers of modern offices place considerable emphasis on the design concept of creating an environment conducive to efficient production. Creation of this environment involves control of a number of factors such as the lighting, temperature, humidity, noise, and color of room surfaces and furnishings. When properly handled, these factors usually have a favorable effect on worker performance.

Efficient Use of Lighting

Well-planned lighting—a vital ingredient of efficient office environment—increases office productivity and minimizes worker fatigue. And it's inexpensive: adequate lighting costs only about 20 cents a day per employee—a fraction of the worker's salary. Obviously, a small investment made to improve office lighting should return substantial benefits worth far more than the cost.

To experience these benefits, there must be a reasonable amount of light for quick, accurate seeing. The quality of the lighting should aid seeing, not interfere with ~~it. The~~ lighting system and the whole environment should be visually comfortable, with no troublesome shadows and reflections.

Logically you would expect better lighting to produce more efficient office operation. But it's reassuring to have practical, positive proof data. Studies in three different offices of the Federal government where lighting was significantly improved provide this proof: productivity gains were 8, 5.5 and 3.5 percent respectively. To insure reliability, the tests were conducted for extended periods of time, using careful controls. In the tests, increased output paid for the new lighting in a comparatively short time.

With benefits assured and efficient light sources available, great strides are being made in office lighting. Certain equipment, techniques, and data predominate in this lighting progress . . .

- Use of higher illumination levels in many areas
- Application of new data to insure comfortable lighting installations
- Use of light finishes on office furniture and business machines to meet the requirements for good practice
- Extensive installations of large-area lighting elements.

Why Higher Illumination?

We have moved well above threshold limits of visibility in the amount of light supplied for many of our office

Corridors

Valance mounted five feet six inches above floor conceals two rows of fluorescent lamps that light walls and ceiling. This light distribution gives impression of greater width (left). Six-inch-wide recessed troffers equipped with rapid-start lamps and located at each side of the hall brighten walls and suggest space.

tasks. But we are still far below the quantities that make the fullest and best use of our eyes. Certain laboratory research indicates that optimum levels for many office tasks may range between 400 and 500 footcandles. However, present lighting equipment and economics limit the use of these amounts. Most well-planned office environments provide 50 to 100 footcandles, and some installations have over 200 footcandles in service.

Two good reasons for the trend to higher illumination are *people* and *things*. For example, laboratory studies by Guth and Eastman show considerable difference in the individual visibility levels attained for a given task.

Also their testing showed that 95 percent of the observers needed about three times the average footcandle level to achieve the average visibility level. This information indicates that we often incur penalties by basing our lighting recommendations on averages rather than individual variations.

The same could be said for the *things* office workers have to look at. Well-typed original letters may have a type size equivalent to 9-point Bodoni Book type. (The REVIEW is printed in 10-point Bodoni Book.) Carbon copies, although usually poorer than originals, appear more frequently on desk tops today, with the type size sometimes as small as 5-point Bodoni. And often shorthand notes, hand-posted ledgers, poorly duplicated material, drafting tasks, and hand-written script are equivalent to something less than 5-point type. More light provides the simplest, most effective way to magnify their size. This makes the material more readable, thus aiding job performance.

The optimum lighting levels for numerous visual office tasks are far higher than those now used—even in the better lighted offices (Box).

More Emphasis on Visual Comfort

With the use of higher lighting levels, the concept of visual comfort necessarily receives more emphasis. When people experience complete visual comfort, they seldom stop to reason why. But when distinctly uncomfortable, they usually know why. The difficulty arises in the area between extremes where lighting may border on the uncomfortable. Here people often accept the situation even though fatigue and irritation result.

In recent years, much effort has been expended to establish the technology of visual comfort. (A basic paper appeared in the August 1947 REVIEW, pages 31-37.) From this and later research evolved the Visual Comfort Index (VCI)—a method of rating lighting systems. A VCI shows the average percentage of people who find a particular lighting installation visually comfortable.

By referring to visual comfort data, a designer can plan a lighting system confidently—knowing that his scheme and choice of equipment will be acceptable to most of the people who must work under it. And the absence of employee complaints about too-bright fixtures that reduce their production efficiency will provide much satisfaction.

Several factors besides fixture brightness affect visual comfort. These variables include ceiling height, room length and width, fixture orientation, lightness of room finishes, and amount of illumination. Tables of VCI data account for these factors.

Color in the Office

Recently office equipment and business machine manufacturers have made conspicuous progress by manufacturing their products in light colors and nonglossy finishes. You have probably seen the light grays and warm beiges. Some pastel-colored typewriters are even being featured in national advertising. This trend means an important step forward because everything in the office environment affects lighting and seeing: dark objects upset the brightness balance; shiny surfaces present glaring reflections of light sources.

With the expanding use of color, offices look better than ever. Use of one

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Mr. Fisher—Specialist, Office and Drafting Room Lighting Applications, Application Engineering, Large Lamp Department, Nela Park, Cleveland—has been with General Electric since 1947. In connection with his work, he has toured the country with several Lamp Division lighting shows as engineer-lecturer.

of the two deluxe fluorescent colors as a light source gives a particularly attractive appearance to people and furnishings. Also cool-white and warm-white lamps offer the opportunity to create different atmospheres for office areas.

Some floor-covering manufacturers now publish light-reflectance figures for their patterns—a helpful guide to merchandise selection. Thirty percent floor reflectance is practical and improves lighting efficiency as well as visual comfort.

All components of the office environment become important in the final design, especially at high illumination levels. Eye-jarring contrasts that lead to employee complaints and reduce performance levels can be avoided by planning and coordination.

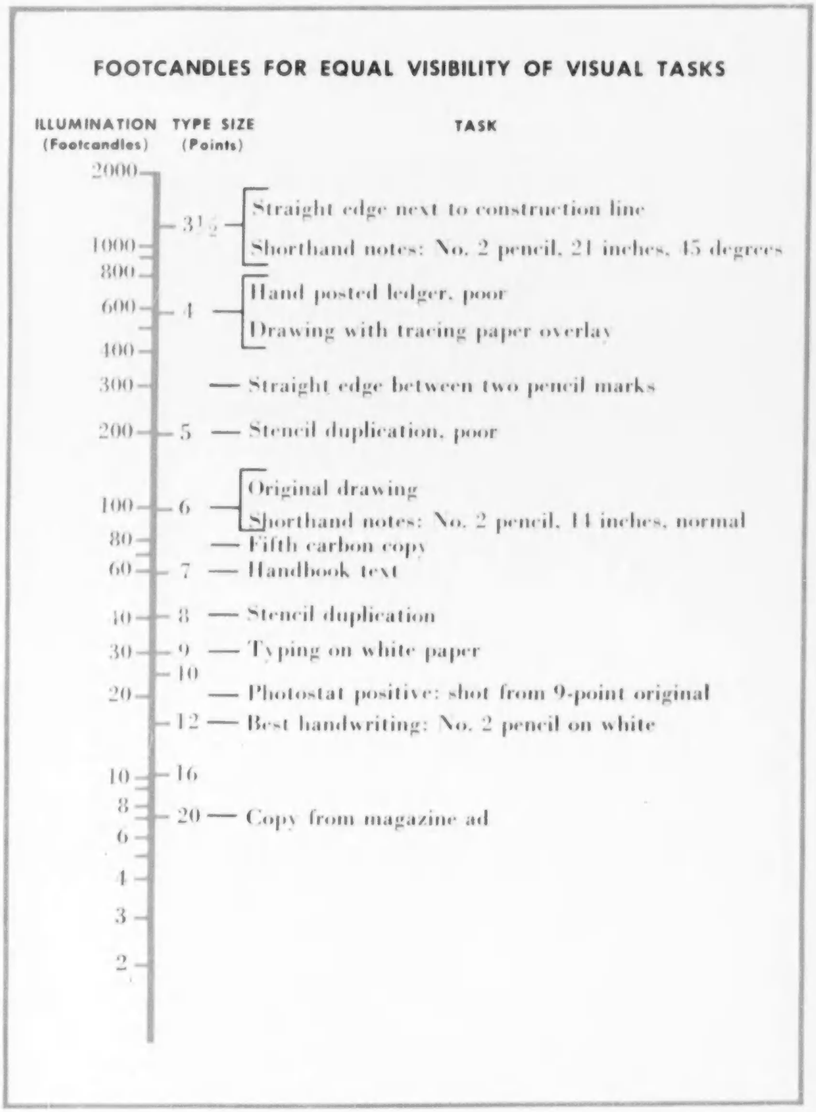
New Lighting Techniques

Along with the adoption of higher illumination has come the extensive use of large area louvered or luminous lighting elements. These eliminate the clutter that would be presented by a large number of conventional luminaires and improve the ceiling appearance. Partial responsibility for this new era in lighting lies with several plastics plus new techniques for fabricating plastics and metal. Of course, fluorescent lamps, which have increased substantially in efficiency during recent years, make this kind of illumination practicable. Neither the eight-foot-long slimline nor the 40-watt rapid-start lamps—often used in new office lighting—require auxiliary starters; yet in effect they give instant starting.

Some interesting variations have been used in large lighting elements. One technique applies units of convenient size in a regular pattern rather than uniform wall-to-wall diffusers. The pattern adds interest to appearance, and it may allow air conditioning and acoustical material to be conventionally installed.

Another variation stops the lighting elements short of the wall, letting them "float" overhead. This simplifies installation, because it eliminates cutting and fitting around pipes, ducts, or irregularities at the room's perimeter. And it contributes to appearance by creating a light, airy touch.

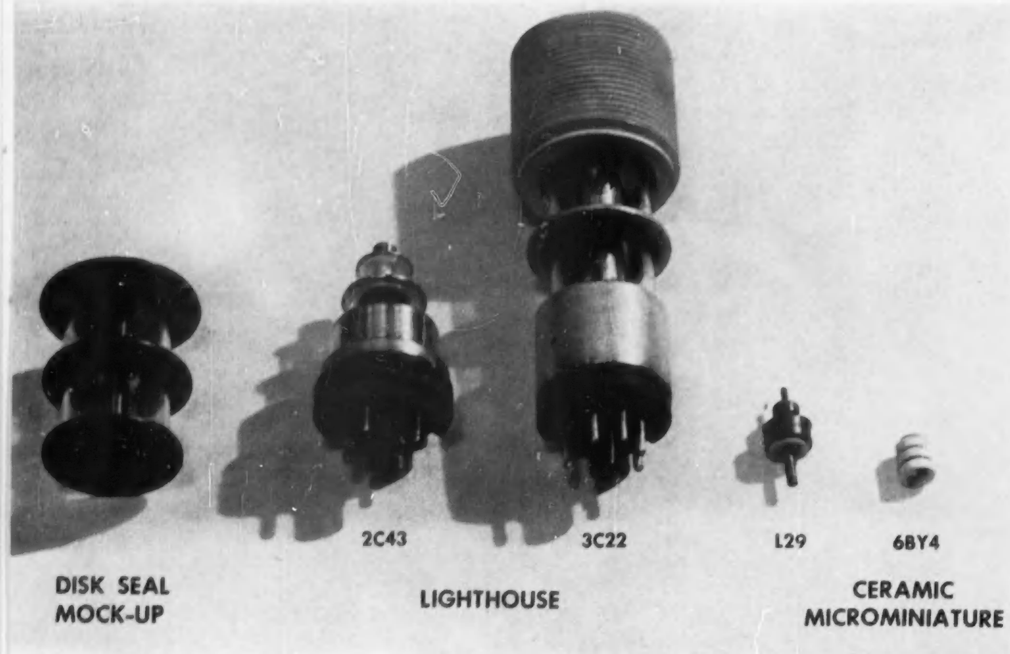
High-frequency and high-voltage distribution systems have much to offer in office properties. At 400 cycles, fluorescent lamp efficiency becomes about 15 percent higher than at 60 cycles. Ballast size, cost, weight, and power consumption reduce substantially. Result: less lighting load on air conditioning. (The frequency converter, which has some power loss, can be located in nonair-conditioned building space.) Already several installations of high-frequency fluorescent lighting operate in the United States, and the benefits interest many building owners and managers. It's a natural companion of the extended-area lighting systems.



Over-All Coordination

The large elements involved in modern lighting necessitate coordination of other building facilities—air conditioning, space partitioning, sound control, and fire protection. After establishing this concept, you can integrate the environment-controlling features of your space into an attractive, comfortable, and efficient office—one with long life expectancy and minimum maintenance.

Use of this new concept of office design brings employee productivity to a new performance plateau and keeps it there. You can more easily go through peak periods of office activity when everyone pitches in with maximum efficiency to accomplish the work. Good business dictates the protection of the substantial investment present in employee salaries. And you will find that lighting which helps instead of hinders performance insures this kind of protection. Ω



Ceramic Tube's Predecessors From original disk-seal tube to ceramic tube represents more than 15 years of development.

Originators

Mc
tha

New Research Concepts Spark Micromin

Review STAFF REPORT

Major scientific achievements today tend to resemble the harvest from an orchard cared for by a staff of highly specialized horticulturists. Often when a particular project bears fruit, the results are the efforts of many men. Such an approach not only draws upon the skills and knowledge of scientists in a variety of fields but also provides a means of conducting the long, complex, and expensive attempts to bring forth new knowledge that characterizes contemporary research.

Evolution of the 6BY4 microminiature vacuum tube—announced by General Electric about a year ago—excellently illustrates this method of operation. Significant research lies behind the tube's development: more than 15 years of progress in related designs and important discoveries by General Electric's Research Laboratory scientists in the fields of chemistry, metallurgy, ceramics, and electronic tubes and circuits. And to this basic work should be added manufacturing skill as well as the knowledge of engineers in other General Electric departments.

Though small in size, this vacuum tube also serves as an eloquent reminder that the individual is not completely eclipsed. Despite all the requisite coordination and collaboration, scientific achievements still reflect the individual scientist whose insight into a problem inspires and channels the efforts of his collaborators and stamps his mark upon the finished work.

In the research that led to the ceramic microwave tube, such a role was filled by two men: E. D. McArthur and James E. Beggs.

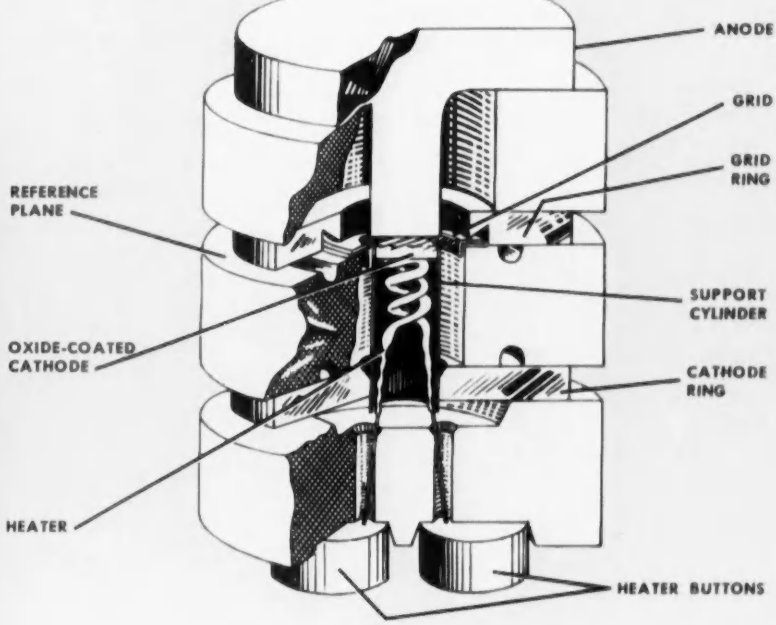
Fathering the Tube

McArthur's concepts concerning the unity of circuit and tube elements in cavity-resonator systems led to his development of the new tube's revolutionary forerunner, the "lighthouse" tube, used in World War II radar. Manager of the Laboratory's electron tube research section for the past six years, he also participated in Beggs' development of the new microminiature-tube design. Beggs took existing concepts, added new ones, and developed new processes. In short, he fathered the tube.

Essential contributions also were made to the series of earlier tubes by the Company's Power Tube Department located in Schenectady, NY, and to the 6BY4's design and production techniques by the Receiving Tube Department, Owensboro, Ky. The success of the 6BY4 and subsequent tubes of similar design will be largely a result of their efforts.

Scientists and engineers created a tube the size of a pencil eraser. And this tube offers high-gain low-noise ability to operate at temperatures above 500 C, displays remarkable shock and vibration resistance, and has a variety of other features. Because it amplifies a television signal more effectively than any other receiving tube known, UHF television can be brought within reach of thousands of homes otherwise out of range.

McArthur (left) developed the lighthouse tube that aided Beggs in creating the new ceramic tube.



Structure Size of a pencil eraser, the new tube offers high-gain low-noise ability to operate at temperatures above 500 C for electronic applications.

iniature Tube

Its small size and ability to dispense with cooling equipment also point to applications in jet aircraft, nuclear reactors, airborne computers, and mobile communications equipment as well as earth satellites and guided missiles.

A great quantity of groundwork prepared the way for the new development. Under the sponsorship of the U. S. Navy Bureau of Ships, the Research Laboratory set out in the 1940's to develop a rugged low-noise amplifier tube for applications at microwave frequencies. The Navy particularly wanted improved receivers to extend the range of early-warning radar stations and for an excellent reason. To identify a target on a radar screen, a pip must be discernible from the smaller irregularities in the trace caused by noise. Thus any reduction in noise makes the pip easier to distinguish. Reducing the noise factor of the receiver by one half would have the same effect as doubling the power of the transmitter. Doubling the transmitter power, say from 5 to 10 mega-

ASSEMBLING THE TUBE

The tube resembles a stack of three metal washers separated by three ceramic insulators, with two metal buttons on the bottom of the stack.

These two heater connection buttons are sealed to the bottom ceramic spacer. Directly connected to the buttons are the heater wires. And on top of the heater insulator spacer lies the cathode ring, shaped exactly like a washer. Welds inside the washer hole attach the cathode support in much the same way as the cathode cover disk is attached to the inside of the cathode support cylinder at the top. The heater—a self-supporting coil—extends into the cathode cover disk. The cathode-insulator ceramic lies on top of the cathode assembly.

Grid Assembly

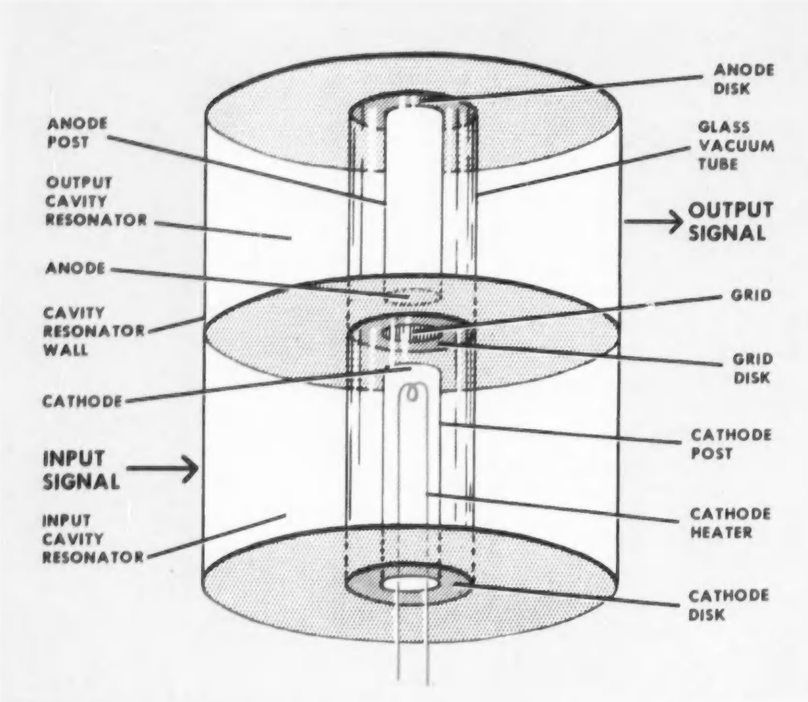
An inner grid support washer and an outer grid ring compose the grid assembly. Virtually invisible under normal room lighting, 0.3 mil tungsten wire is wound and brazed to the inner grid washer at 1000 turns per inch. The recessed outer ring, made of titanium, holds the inner washer and fits on top of the grid-cathode ceramic spacer, with a nominal hot spacing of 0.6 mil from grid to cathode.

Anode Assembly

The grid insulator ceramic lies on top of the outer grid washer. The titanium anode forms a flat disk with a round post rising from the center of one side. The end of the post serves as the working area of the plate. The flat disk rests on top of the grid-insulator ceramic with the post projecting over the grid. The nominal grid-to-plate spacing is 7 mils.

In the finished tube, seals are made between each titanium ring and the adjacent ceramic spacers. The plate is sealed to the grid insulator and the heater buttons to the heater insulator, thus completing the envelope of the tube as one continuous, rigid piece.

The exhaust and sealing techniques used in production of these tubes are unique in the field of vacuum-tube manufacture. The seals remain vacuumtight at temperatures in excess of 700 C.



BASIC LIGHTHOUSE TUBE and forerunner of the microminiature ceramic tube was used in World War II radar. Its revolutionary concepts led to the development of the new tube.

watts, might easily cost several hundred thousand dollars.

McArthur's combination of his cavity-resonator concept with a unique disk-seal design supplied the answer by making tubes virtually self-shielding. Together they made up the lighthouse tube (illustration).

As early as 1938, McArthur experimented with certain metallic enclosures of the pillbox type for use as filters, oscillators, or amplifiers. Although these cavity resonators had great potentialities for high-frequency applications, no tube then available enabled him to take full advantage of their potential. For maximum efficiency, these resonators have to be perfectly symmetrical. Because the electron tube used in conjunction with the resonator ideally forms its central core, the tube itself must also be symmetrical, unlike conventional tubes with the usual anode-grid-plate arrangement.

Forerunners of the Tube

McArthur's approach—finding a means for making the tube elements both symmetrical and integral with the resonant circuit—involved a radical change in viewpoint. It meant combining the electron tube and its attached circuit into a single system.

"The disk tube," says McArthur, "embodies the principle that in the microwave field we could no longer speak of tubes and circuits as two distinct entities."

The tube resulting from this concept shortly before World War II consists of a series of glass or ceramic cylinders closed at the ends by metal disks hermetically sealed at the circumference. Performing three functions, these disks 1) divide the tube into sections that coordinate with the corresponding resonant circuits; 2) contain or support the tube's electrodes; and 3) become—through the ring contacts at their periphery—part of the cavity-resonator's structure that surrounds them, thus making lead wires or prongs unnecessary.

The performance of the first disk-type tube, a transmitting tube operating at 600 megacycles, exceeded all expectations. The frequency was rapidly stepped up to 3000 megacycles. Ralph J. Bondley, associated with McArthur in this development, ingeniously contributed to the physical design and the details of manufacture. These largely influenced the immediate acceptance of the new tube.

Following the successful application of the disk-seal principle to transmitting tubes, the scientists immediately directed their attention toward developing a receiving tube that embodied the same principles. In his efforts, Beggs principally worked out the design details and the method of fabrication. An early model of the lighthouse tube, first used in a naval engagement at Guadalcanal, subsequently played an important role as a receiver preamplifier and as a local oscillator at a 200-megacycle frequency. It was also used with a Navy gun director at 700 megacycles.

Early in 1942 the Radiation Laboratory at Massachusetts Institute of Technology asked for a light, compact medium-power oscillator at 3000 megacycles for pulse service. A tube manufactured for use at 2-kw intermittent power and developed by Beggs met their need.

A combination of these two tubes in a small, simple device became the standard masthead radar unit for PT boats, subchasers, and other small craft. Subsequently modified by the Radiation Laboratory for the airborne gun director, out of this unit came the ARO (airborne range only) system.

Until 1943, efforts were concentrated on these models for radar service. At that time the groups working at Harvard University on radar countermeasures called for high-power tubes. In response to this request, a 50-watt tube—tunable over a wide range of frequencies—was developed for noise modulation.

Late in World War II a demand arose for a still more compact tube for pulse service. In effect the lighthouse tube was turned inside out; the resulting oil-can-type tube combined the advantages of small size and rapid heat dissipation. Instead of getting into the radar program, this tube was used in intership communication.

After the war the application of the disk-seal principle rapidly extended to high-frequency tubes for use in FM radio and in television.

Nearly every successive member of this miniature-tube family is smaller, more compact, and more efficient than its predecessors. To Beggs should go much of the credit for this continued improvement. His contributions include the first practical all-metal tube and built-in antenna for radio receivers, plus those previously described.

Major contributions also came from Bondley. He developed the titanium-hydride method of making ceramic-metal seals, originally discovered by Floyd C. Kelley, and applied it to vacuum-tube envelopes. Bondley later worked on grid-making techniques for the new microminiature tube; his advances in sealing techniques hastened its development.

The ultimate practical value of any tube, of course, lies in its applications. Thus without the work of Norman T. Lavoo on electric circuits, measurements, techniques, and the development of amplifiers, acceptance of the new tubes would probably not have come as quickly as it did. Beggs also helped devise the L29, a tiny tube used with great success in radar. Although setting a new performance standard, this tube—despite its possible usefulness—was too expensive for application in low-priced electronic equipment.

A Successful Search

Beggs thus began searching for a tube that could be mass-produced at low cost, yet offer high performance. Result: the new microminiature design.

The striking assortment of unique features incorporated into this type of tube was largely made possible by a combination of the three "products" of the Research Laboratory: new knowledge, materials, and processes.

. . . *New knowledge* includes original and radical concepts of tube design, some dating from the work on the cavity resonator; new basic understanding of the causes of "noise" in electronic tubes; basic research on low-temperature cathodes with high electron emission; and the uncovering of some surprising fundamental facts about titanium—the wonder metal.

Part of the new knowledge resulted from Beggs' effort to solve the problem of "gettering"—sopping up the gas released during operation—inside a tiny vacuum envelope.

As frequently happens in scientific laboratories, research in another field helped provide the answer. In recent years, titanium had produced many surprises for scientists. And the first hint that this metal might be an unusual electron-tube material came from Beggs, supported by investigations of Dr. Paul Zemany and Dr. Francis Norton. Characteristically, the discovery and its exploitation drew upon the talents of several men. The first experiment to demonstrate its almost unbelievably efficient gettering properties was performed directly by Bondley, and the bulk of numerical data came from the subsequent detailed studies carried out by Dr. Virgil L. Stout and Martin D. Gibbons.

Now accurately measured and applied, this characteristic of titanium ranks in importance with such better known properties of the amazing metal as: strength of steel, weight approaching that of aluminum, and corrosion resistance of stainless steel. Other properties of titanium important in the development of miniature vacuum devices include excellent sealing characteristics, low vapor pressure, and high melting point.

VACUUM TUBE—NO DEAD DUCK

Dr. C. G. Suits, General Electric vice president and director of research, points to the development of miniature ceramic tubes as evidence that the well-publicized transistor will not monopolize future electronic progress.

"Since the revolutionary development of the transistor," Dr. Suits says, "there has been a tendency in some quarters to assume that the vacuum tube is a dead duck. More thoughtful persons feel that research and development on vacuum tubes might become neglected in favor of semiconductor research. But the remarkable achievement of miniature ceramic vacuum tubes, with their exceptional capabilities at microwave frequencies—and their phenomenal high-temperature tolerance—which the transistor cannot even approach, shows that the vacuum-tube art is far from dead."

Researchers at the Laboratory also degassed titanium at 800 C, well below the temperature required for any other metal tested. This property made titanium uniquely valuable for use in tubes employing oxide-coated cathodes. For uniform and consistent emission from oxide cathodes—a prime goal of tube research at General Electric for many years—requires freedom from poisoning contaminants. Thus a significant step toward success was achieved in discovering that titanium can be degassed at a temperature below oxide-cathode activation.

Mass spectrometer measurements showed that degassed titanium will absorb, or getter, a wide variety of gases—some even at room temperature. Equally important, titanium continues as an active getter throughout the life of the tube. Of all the gases gettered, only hydrogen is evolved on reheating to a high temperature. Thus use of both hot and cold titanium resulted in remarkable gettering. Employing titanium not only by using it as the principal structural material in the tubes but also by placing it on the walls of the high-temperature vacuum ovens that bake the tubes utilized these properties to the fullest.

. . . *New materials* in the tiny tubes are ceramics specially designed to match the thermal expansion characteristics of titanium.

For Beggs and his associates became convinced that titanium held the answer to their desire for a tiny, rugged low-noise tube. But one problem remained: finding insulating disks to sandwich between slices of titanium. They needed ceramic bodies with expansion characteristics that matched those of titanium. Because none were commercially available, the Research Laboratory's ceramics section, largely through the efforts of Dr. Alexis G. Pincus and with the cooperation of Dr. Louis Navias, developed a series of bodies having thermal expansion and contraction characteristics almost identical to titanium.

. . . *New processes* were necessary to make an entirely new type of grid and to produce metal-ceramic seals capable of maintaining a vacuum under strenuous operating conditions.

The electronic requirements of tubes for use at very high frequencies dictate that the geometry of the elements should be parallel planes. Grid structures, therefore, comprise a series of equally spaced wires soldered to a flat frame. During operation the grid wires become heated by direct radiation from the cathode and by electric energy dissipated in the grid itself. Dimensional changes that accompany heating of the wires may distort the geometry. To circumvent this difficulty, the scientists developed unique methods of winding the tiny grid wires, mounting them under tension, and nondestructive testing of the completed grids. The advent of smaller tube designs accentuated the problem. This necessitated refinements in further grid-making processes as an essential phase in developing miniature ceramic tubes.

Meanwhile, titanium-matching ceramics allowed soft solders to be discarded in the construction of small tubes. Research Laboratory scientists contributed a unique method of sealing metals and ceramics at temperatures near 1000 C. These seals also have added immeasurably to the ruggedness and consistent operating qualities of the new tubes.

McArthur's leadership in tube design—particularly his successful use of entirely new concepts, as in the lighthouse tube—is well recognized throughout the industry. He and Beggs, and their colleagues have opened areas that hold exciting promise for the future.—WAK eral Technical, Program, Publications, Research, Standards, Admissions, Awards, Education, Membership, and Sections.

The General Technical Committee serves an important function for ASRE. An over-all committee responsible for the technical affairs of the Society, it guides subcommittees related to specific topics. Currently more than 40 such subcommittees exist.

The Standards Committee performs a valuable service. It also functions with subcommittees and is concerned with the numerous standards developed by the Society. Over the years, many of its standards have been widely adopted by the refrigeration industry. Directed principally toward methods of testing and rating equipment, they in no way constitute standards of acceptance or approval. Internationally recognized, ASRE's work presents a continuous program devised in the interests of the industry. And many standards, originally sponsored by the Society, are eventually worked out with the American Standards Association, the National Electrical Manufacturers Association, The American Society for Testing Materials, and others. Certain standards are currently available from the Society (Box).

Differing from other committees to the extent that all Section Chairmen are members, the Sections Committee serves as a direct liaison between the sections and the Society at national level.

Besides the standing committees noted, the president of the Society appoints general committees. These committees, created for special purposes, usually become discharged upon the completion of their assignments. However, some engage in long-term activities and enjoy a semipermanent status.

Staff—A paid staff, employed at Society headquarters in New York City, supplements the activities of the officers, Council, and Society committees. It is divided into several divisions—editorial, publication sales and meetings, advertising, finance, and membership.

Society Sections—To better serve the interests of the individual member, the membership is grouped and represented by local sections, currently 49 in number. These are located throughout the entire United States and parts of Canada. The Constitution states that "the object of a Section of the Society shall be to provide means for promoting the object of the Society by local organization of members who are resident within a given territory."

SOCIETY STANDARDS CURRENTLY AVAILABLE

STANDARD	TITLE
	Methods of Rating and Testing:
No. 14	Mechanical Condensing Units
No. 16-56	Air Conditioners
No. 18	Self-contained Mechanically Operated Refrigerated Drinking-Water Coolers
No. 20	Evaporative Condensers
No. 22	Water-cooled Refrigerant Condensers
No. 23R	Refrigerant Compressors
No. 24	Water and Brine Coolers
No. 25-53	Forced Circulation and Natural Convection Air Coolers for Refrigeration
*ASA B60.1—1950	Refrigerant Expansion Valves
*ASA B38.3—1955	Home Freezers
No. 28-53	Method for Testing Capillary Tubes
*ASA B9.1—1953	Safety Code for Mechanical Refrigeration
*ASA B59.1—1950	Recommended Practice for Mechanical Refrigeration Installations on Shipboard

*Formerly an ASRE standard.

The local sections, patterned in many ways along the lines of the national organization, contain five elective officers and several standing committees such as Executive, Program, Publicity, Entertainment, Reception, Nominating, and Technical. It is evident from the titles of these committees that they operate, in their respective areas, similarly to those of like responsibility in the national organization. The Sections hold 8 to 10 monthly meetings throughout the fall, winter, and spring and frequently conclude the season with a social event. Speakers chosen for their knowledge and ability talk on technical phases of refrigeration or air conditioning. A dinner at which attendance is optional usually precedes the meetings.

Membership

A society consists of participating members who give it life, significance, and continuity. An honor not bestowed lightly nor obtained without effort, membership in a technical society should be accepted by an individual as a privilege. Through his society, he acquires the opportunity to serve his fellow engineers and to further the interests of his own industry.

A technical society concerns itself with professional ethics, thus ASRE has officially adopted the "Canon of Ethics for Engineers" as promulgated by the Engineers Council for Professional Development (ECPD). The Society also recognizes the importance of proper standards for membership qualifications and again follows the recommendations of ECPD.

ASRE has regular membership grades: member, associate member, affiliate, and student member. The grade of Fellow has been established for the recognition of significant contribution to the Society program. And in addition, the Society confers honorary membership on persons of acknowledged professional eminence. Currently, total membership in the Society numbers approximately 7000. The largest portion of this membership resides in the United States and Canada, but 68 American possessions and foreign countries are represented in the Society roster.

National Meetings

At national meetings, held each year in June and December, well-qualified authors present numerous papers on technical and practical subjects and problems relating to such specific fields of interest as domestic refrigerator engineering, new fields for mechanical cooling, air conditioning, and frozen foods. Less formal discussion of pertinent problems occur at forums or group

The American Society of Refrigerating Engineers

By ROBERT C. CROSS

Man has practiced the art of refrigeration for many centuries—long before this modern electrical age. In ancient Rome, Nero built icehouses to store natural ice for domestic purposes. And the use of freezing mixtures such as salt and ice had already been discovered. Moreover, evidence indicates that a method of artificial refrigeration—the evaporation of water or other liquids in streams of air—was known to the people of that era.

The mechanical production of cold possesses a more recent history: the first record of the invention of such a machine occurs in 1755. The inventor, Cullen, devised a method of evaporating water under a vacuum. Subsequent research by Lavoisier, Leslie, Vallance, Gorrie, Carré, and others represents significant progress along the road to modern refrigeration.

Society History

Continued development in this field aroused the interest of leading American refrigeration engineers. On April 2, 1904, a group of these men met in New York City to consider the formation of an organization to promote the study and development of the science of refrigeration and its practical application. They selected a committee to draft a constitution and bylaws, which were officially adopted on December 5, 1904. This date marks the formal birth of The American Society of Refrigerating Engineers (ASRE). On August 30, 1905, a Certificate of Incorporation was filed with the Secretary of the State of New York by 14 of the Charter members.

Discussion at the first Annual Meeting—held in New York, December 4-5, 1905—concerned the principal industries requiring the skill of the refrigerating engineer at that time: ice plants, breweries, and meat-packing plants. The ice-cream industry was still in its infancy. The dairy business did employ refrigeration to some extent, but more dairies used natural ice than refrigerating machinery. And although air-conditioning installations, skating rinks, bakery and candy air-cooling, fur storage, the cooling of drinking water, and the use of refrigeration in manufacturing camera film existed, they weren't in common usage. At that time, ASRE members concerned themselves principally with the design, manufacture, installation, and use of large industrial refrigerating machinery.

The Society had been in existence 20 years before emphasis switched to small equipment and the eventual production of small package units on large scale. Air conditioning interested few members although Dr. Carrier presented his psychrometric chart as early as 1912. Few engineers considered domestic refrigeration; because at the time, general opinion dictated that household refrigeration required little or no engineering.

The next 10 years brought about considerable change. While many members of the Society continued cold storage work and were employed by industrial machinery manufacturers, others began to devote their efforts toward household refrigeration and air conditioning. Although the heavy machinery end of the industry grew consistently, the additional development and interest in the small unit continued. By 1944, papers presented to the Society dealt with such subjects as air-conditioning controls, home freezers, refrigeration in penicillin manufacture, and powdered metallurgy. In recent years, with both refrigeration and air conditioning experiencing rapid growth, a merging of technical interests has occurred in these fields.

With the ever-increasing applications of refrigeration and air conditioning, Society members find themselves engaged in research, design, manufacture, sale, application, and maintenance of many diverse types of refrigeration machinery. Similar activities occur in the numerous component materials and parts that constitute the present-day refrigeration or air-conditioning systems.

The ASRE Constitution states that "the object of this Society is to promote the arts and sciences connected with refrigerating engineering, including refrigeration research, education, design, manufacture, construction, and application in air conditioning, food preservation, industrial processing, liquid cooling, manufacturing, and similar fields." The very breadth of this statement indicates the all-inclusive activities of the Society, naturally resulting in a complex organization.

Organization

Governing Bodies—Four elective officers—president, first and second vice presidents, and a treasurer—administer the over-all affairs of the Society. These officers, leaders in the industry and associated educational and research organizations, are usually selected on the basis of long and valuable contribution to the Society as well as the art of refrigeration.

The country is divided into 16 geographical regions, each with a director. Regional directors also serve as coordinators of the activities in their respective regions and between regions. In addition, they act as intermediaries between sectional, or regional, activities and national activities.

The Council, the Society's governing body, consists of the four elected officers—the three junior past presidents, 12 electors at large, and 16 regional directors. It formulates the policies of ASRE in such a way as to meet the best interests and welfare of the individual member.

Committees—The Council directs several standing committees: Finance, Nominating, Constitution and Bylaws, Gen-

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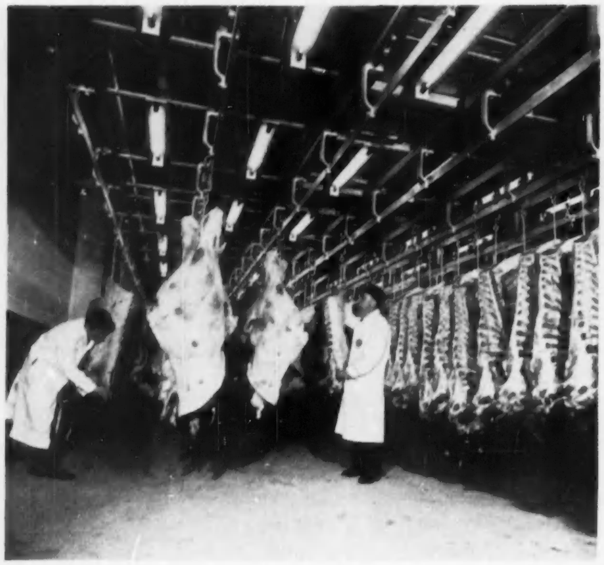
Mr. Cross—Executive Secretary, American Society of Refrigerating Engineers—has served in this capacity since 1951.

SKATING RINK at the famous Rockefeller Center in New York City typifies the diverse application in the field of refrigeration.



MEAT-PACKING INDUSTRY has for many years been one of the principal industries requiring the skill of the refrigerating engineer.

meetings. Recent forum topics included: Defrosting of Low Temperature Evaporators, Contaminants in a Refrigeration System, Rating of Cooling Towers, and Distribution of Frozen Foods.

Various technical and administrative committees of the Society meet during the national meetings, as does the Council. Inspection trips, research exhibits, and similar features add to the technical interests of the meetings. And there is always an attendant social program.

Publication Program

Among ASRE's many activities exists an extensive publication program. It includes a monthly magazine, *Refrigerating Engineering; Air-conditioning and Refrigerating Data Books*, published annually; and a quarterly, *Refrigeration Abstracts*. From time to time, the Society also publishes standards.

Refrigerating Engineering—published monthly for engineers dealing with all phases of refrigeration, air conditioning, and food processing—represents factual accounts of new developments and products by outstanding engineers. And it prints papers presented at annual meetings, permitting widespread dissemination of valuable information. Some of the magazine's regular features include: news items of particular interest to the members and others in the industry, a review of significant achievements in the art, news of people and events, a listing and description of new parts and products, announcements and reviews of new books in the refrigeration field, and a summary review of current refrigeration patents.

Each year, ASRE publishes a *Data Book*—a recognized handbook of the industry—prepared by volunteer members of the Society. Currently a volume on design and another volume on applications, appearing in alternate years, constitute part of the Society's publication program.

The latest edition of the volume on design consists of eight sections: theory, physical data, application design, basic equipment, auxiliaries and self-contained units, operation, tables, and miscellaneous. Full chapters are devoted to such subjects as basic thermodynamics, refrigerants, the heat pump, evaporative condensers, cooling towers, and refrigeration tables and charts.

A recent edition of the volume on applications contains eight sections: frozen foods, refrigeration in food industries, refrigerated warehouse practice, refrigerated food distribution, low temperature applications, industrial applications of refrigeration, comfort air conditioning, and industrial air conditioning. Chapters include such subjects as theories and methods of freezing, candy manufacture, commodity storage requirements, merchant ships, cold treatment of metals, skating rinks, and printing plants.

The Society considers the publication of *Refrigeration Abstracts* a significant contribution to the industry. *Abstracts* is published in cooperation with The Refrigeration Research Foundation. This quarterly contains the systematic classification of summaries from a wide variety of magazines and books. The material includes such subjects as natural sciences, engineering materials, refrigeration media, thermal insulating materials, and refrigeration applications. In addition to its four annual volumes, *Abstracts* publishes a special reference issue with an author and subject index and a list of the actual publications abstracted.

Other Activities

The Society carries on a research program by grants-in-aid to colleges and universities. Presently, 14 projects are being conducted. This program gives assistance to students working on postgraduate degrees and frequently results in the presentation of papers at the annual meetings of the Society. Later these presentations are published in *Refrigerating Engineering*.

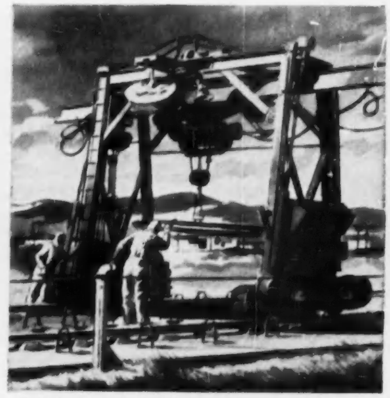
Keenly aware of its responsibility to the engineering profession as well as other engineering societies, the ASRE largely fulfills this obligation by constituent membership in the Engineers Joint Council (EJC). By representation on the several EJC committees, the Society participates actively in the program designed to further the unity and solidarity of the profession.

An active, growing society, ASRE constantly devotes its efforts to the promotion of the arts and sciences connected with refrigeration engineering. Ω

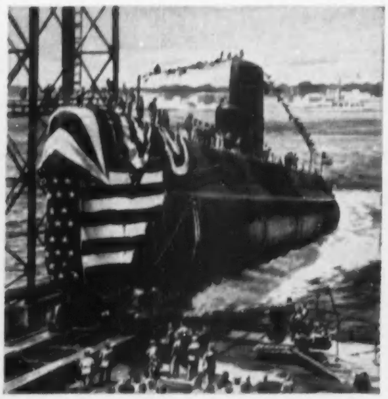
PUTTING THE ATOM TO WORK: *A Progress Report from General Electric*

Prior to 1940 Scientists at the General Electric Research Laboratory were discovering facts about the structure of the atom that contributed to the separation of U-235 from natural uranium in 1940.

1942-45 General Electric developed and produced complex power-supply apparatus and control and instrumentation for the vast *Manhattan District* project that made the first atom bombs for the U.S.



1946 Since the end of World War II, General Electric has been operating, for the government, the giant Hanford Atomic Works in Washington State, producing plutonium for the nation's defense effort.

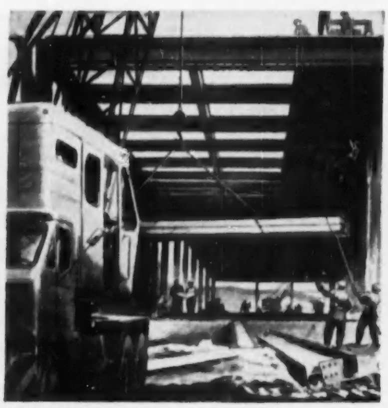


1950 General Electric was assigned the job of developing an atomic power plant at the Knolls Laboratory for the U.S. Navy submarine *Seawolf*. The *Seawolf* was launched in 1955 for final outfitting.

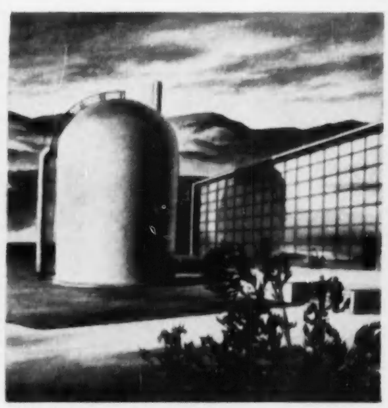
1951 Work on the development of a nuclear propulsion system for aircraft was begun by General Electric for the government at Evendale, O., and is continuing here and, more recently, at Idaho Falls, Id.

1955 After Congress opened atomic development to private industry, General Electric established a department that is designing, developing, manufacturing and marketing atomic reactors and equipment.

1956 In addition to domestic orders, General Electric — through the International General Electric Co. — announced sales of an atomic research reactor for Spain and a power reactor for Latin America.



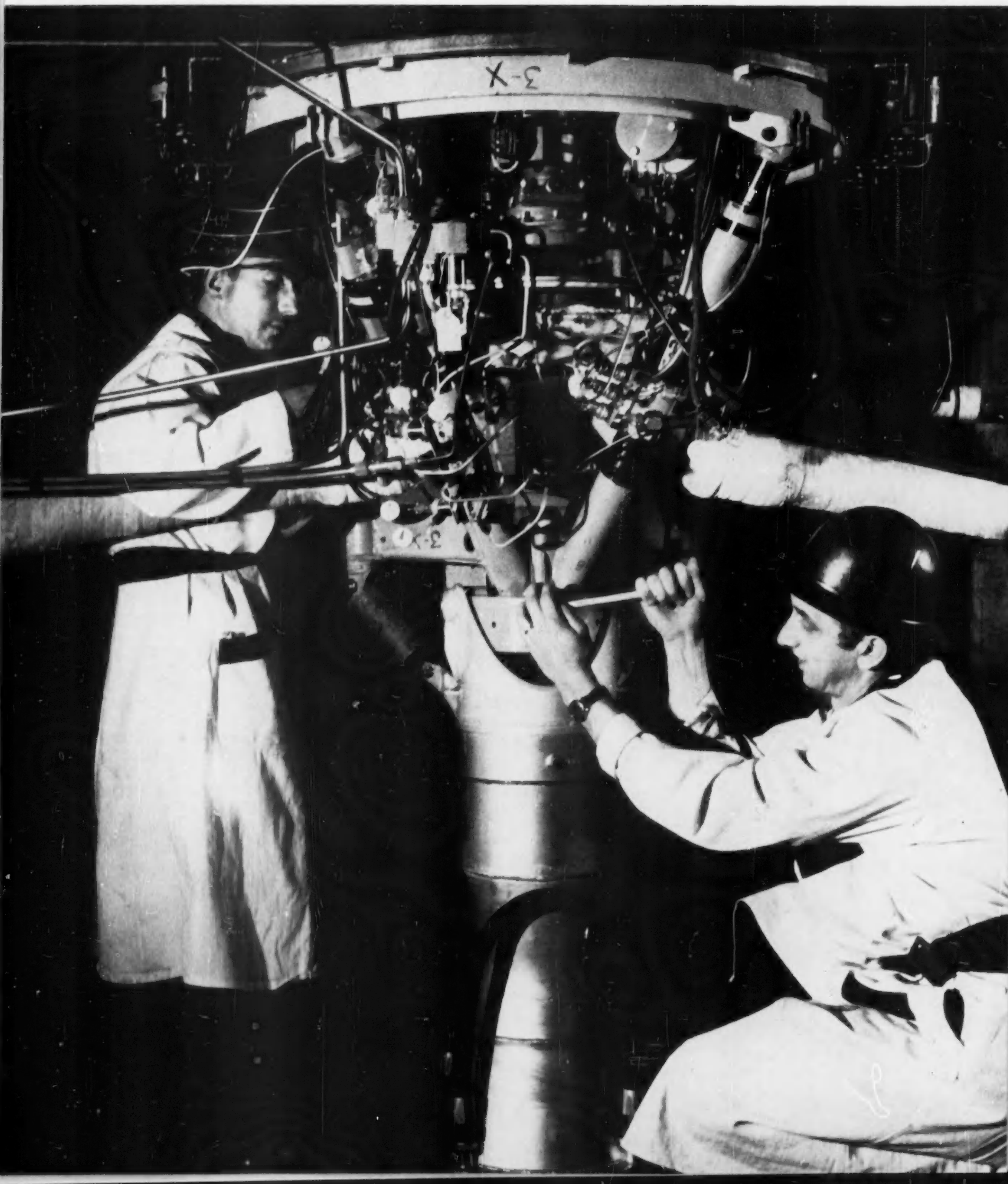
1956 Construction began on the multi-million-dollar General Electric Vallecitos Atomic Laboratory in California. It is dedicated to developing civilian uses of atomic energy, and will be completed in 1957.



1957 A G-E experimental reactor will help bring about 5,000 kw. of atomic power to the San Francisco area. Steam from the reactor will be furnished Pacific Gas & Electric, which will generate the power.

PROGRESS REPORT ON PROJECT VANGUARD

General Electric X405 to



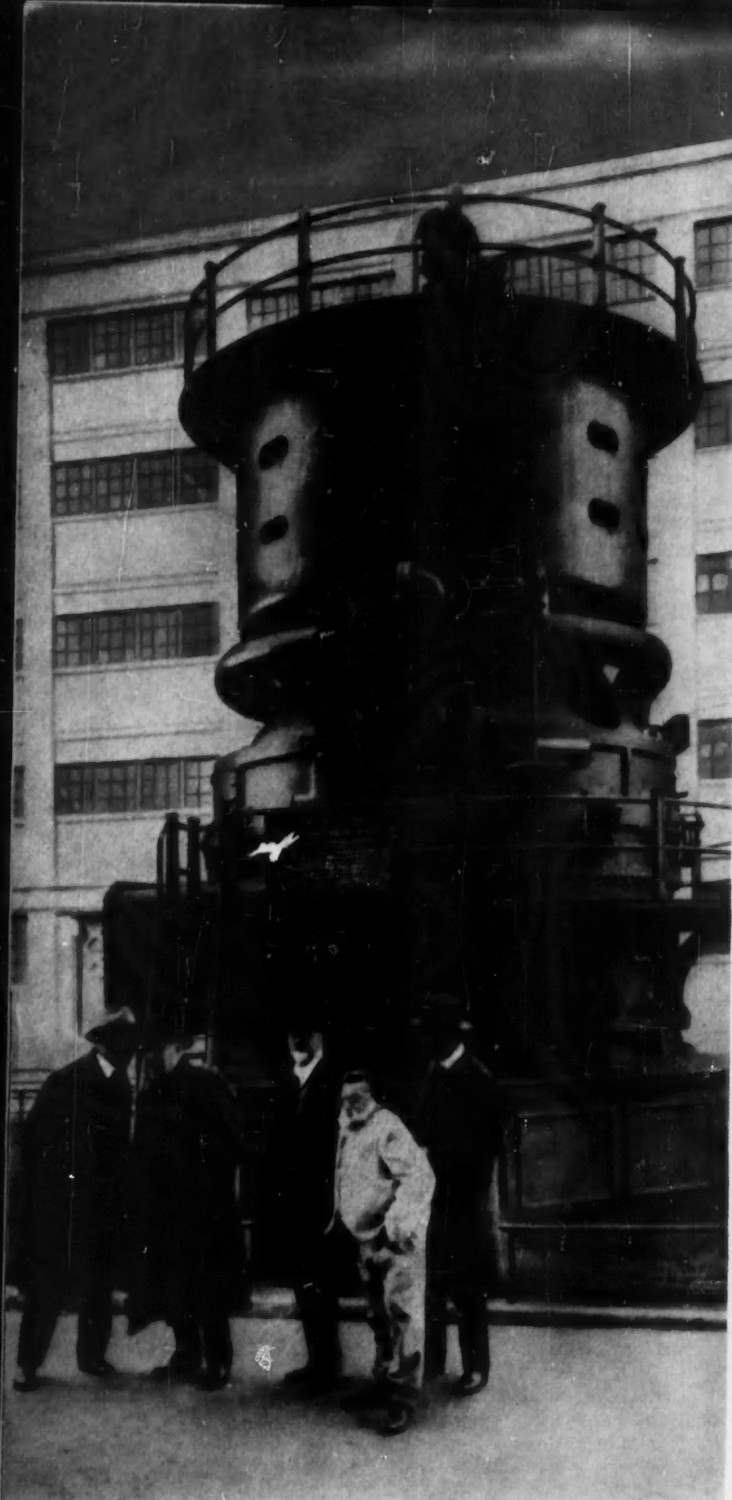
Designing tomorrow's turbine-generator today

5000 to 450,000 KW... a tribute to 53 years of turbine-generator progress

In 1903, the world's first large steam turbine-generator—rated 5000 kilowatts—was installed at the Fisk Generating Station, Commonwealth Edison Company. Advance in turbine-generator design and performance came so fast that after only six years of reliable service, this first large turbine-generator was replaced by a new unit more than twice as powerful. In 1909, the first unit was dismantled, returned to Schenectady and erected as a permanent monument to the skill and engineering genius of the men who built it.

Today General Electric is designing steam turbine-generators rated 450,000 kw—90 times that of this first unit. Fifty-three years ago the total installed electric power capacity of the United States was approximately three million kilowatts. Today it is over 120 million, an increase of 4000%!

General Electric's Turbine-Generator Development Laboratory is another significant step toward the future. Continued engineering developments, financial daring and close co-operation with electric utilities and consulting engineers are making it possible to design the turbine-generators needed for tomorrow's tremendous load growth. Large Steam Turbine-Generator Department, General Electric Company, Schenectady 5, New York. 254-52



"Monument to Courage"—recently rededicated in ceremonies held in Schenectady, N. Y. William L. R. Emmett and Thomas A. Edison (left) and Charles P. Steinmetz (light suit), early pioneers in the electric industry, are pictured before the world's first large turbine-generator.

General Electric's Turbine-Generator Development Laboratory where full-scale tests and measurements, some of which were impossible to obtain before under actual operating conditions, are now being made.

Progress Is Our Most Important Product

GENERAL ELECTRIC