

**GENERAL
ELECTRIC**

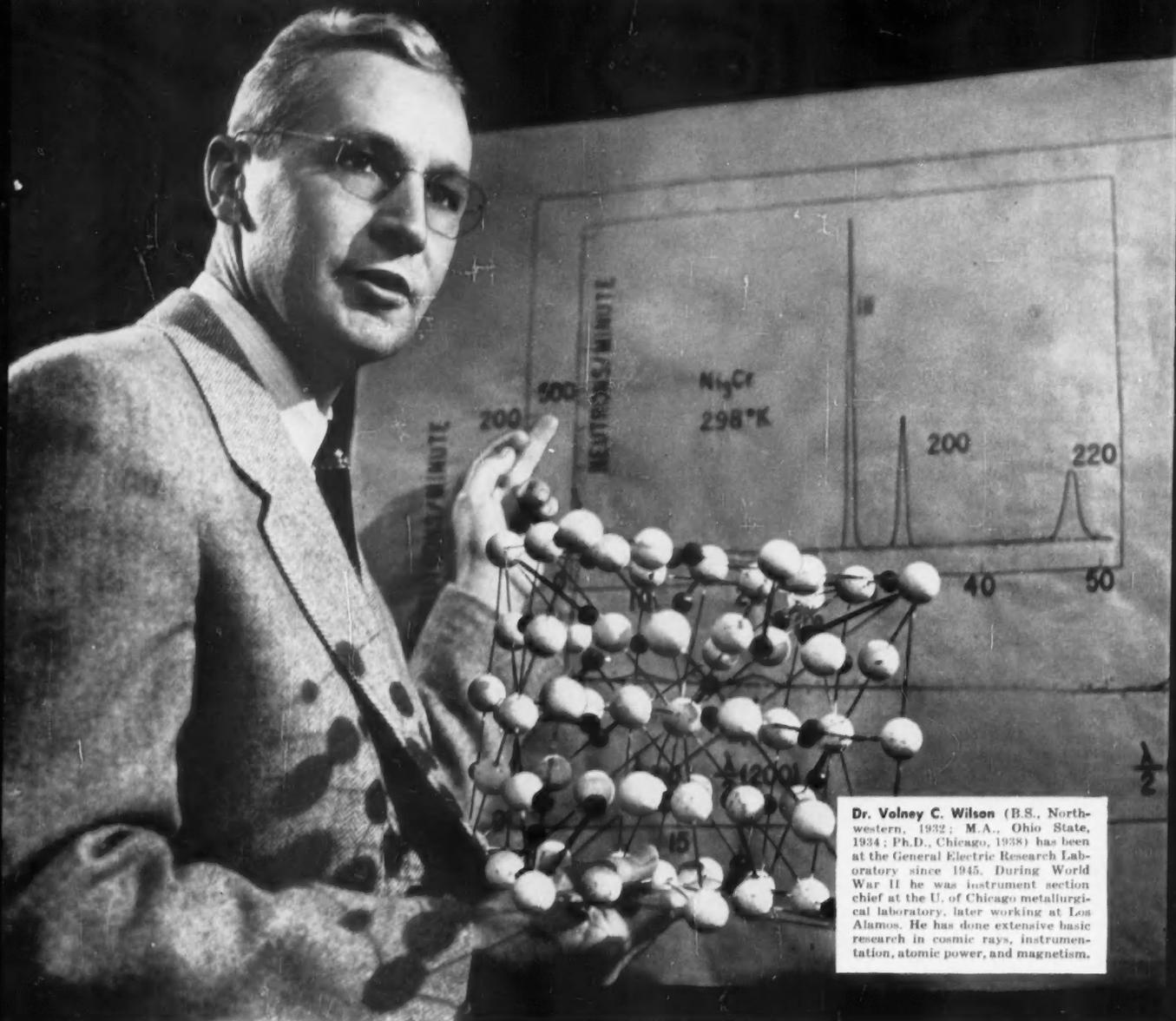
Review



**Research
and
Engineering
Progress
1955**

MAN-MADE DIAMONDS
(Page 10)

**JANUARY
1956**



Dr. Volney C. Wilson (B.S., Northwestern, 1932; M.A., Ohio State, 1934; Ph.D., Chicago, 1938) has been at the General Electric Research Laboratory since 1945. During World War II he was instrument section chief at the U. of Chicago metallurgical laboratory, later working at Los Alamos. He has done extensive basic research in cosmic rays, instrumentation, atomic power, and magnetism.

Why magnets are magnets

General Electric's Dr. Volney C. Wilson uses neutrons to discover fundamental facts for improving magnetic materials

While Volney C. Wilson was director of instrumentation and control for the first atomic pile, under the University of Chicago stadium, Enrico Fermi demonstrated to him and others working on the project that neutrons could be diffracted in the same manner as x-rays. Several years later, when Wilson's interests turned to an intensive study of magnetism, he recognized the special value neutrons would have in revealing atomic arrangements in magnetic materials. Neutrons are not affected by *electric fields*, but—since they are very much like little magnets themselves—they are scattered by *magnetic fields* within crystals.

Accordingly, Dr. Wilson designed and constructed a unique *neutron diffraction spectrometer* at the

General Electric Research Laboratory. It is now in operation at Brookhaven National Laboratory, giving G-E scientists new insight into the problem of why magnets are magnets. Wilson believes that learning new fundamental facts about "atomic-magnetic" structure will result in better magnetic materials—and that even a small improvement in these materials will significantly increase their usefulness in computers, control equipment, and color television.

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Review

EVERETT S. LEE • EDITOR

PAUL R. HEINMILLER • MANAGING EDITOR

RESEARCH AND ENGINEERING PROGRESS • 1955

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COVER—In February 1955, G-E scientists announced the creation of man-made diamonds. The largest diamond produced thus far measures approximately one-sixteenth inch and weighs less than one hundredth of a carat. In imitating nature's work, scientists subjected carbonaceous compounds to combined temperatures and pressures never before attained, producing diamonds suitable for a variety of industrial uses. For more details, see page 10. (Diamonds on cover are magnified 250 times.)

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Engineers foil plant shutdown hundreds of miles away

During a daily switching operation at a utility station, electrical disturbances occurred in a 2500-hp blower motor at a chemical plant several miles away. The electrical equipments involved were products of a number of different manufacturers.

The continuous chemical processing, in which the motor was applied, is interrupted only every eight months for a catalyst change. The chemical company did not wish to incur the loss of stopping production voluntarily by taking the motor off the line; still, they wanted to avoid any possible emergency shutdown later. **Aid from the General Electric Company** at a location hundreds of miles from the plant was requested by the utility and the chemical company. General Electric's experienced analytical engineers set up the parameters of the circuit in miniature on a modern electronic transient analyzer. They proved conclusively that the shutdown could be averted, that the "symptoms" were not critical.

Analytical Engineering like this is one of many services available to you through General Electric's Apparatus Sales Division. Maintenance Service and Field-Service Engineering help protect your equipment investment throughout the life of the equipment. In addition, General Electric Product Development, Application Engineering, and Project Co-ordination assure that you will get the right equipment properly applied and installed on schedule.

Whether you are a *direct user* of electrical apparatus or whether you *incorporate electrical components* in your end product, the local General Electric Apparatus Sales Representative can put these engineering services to work for you. Why not contact him early in your planning? Meanwhile, for the full story on G-E engineering services, write for brochure GED-2244 to General Electric Company, Section 672-19A, Schenectady 5, New York.

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THESE G-E ENGINEERING SERVICES HELP PROTECT YOUR EQUIPMENT INVESTMENT



PRODUCT DEVELOPMENT provides improved equipment to meet tomorrow's increasing demands



APPLICATION ENGINEERING combines latest products into efficient electrical systems designed to meet your specific needs



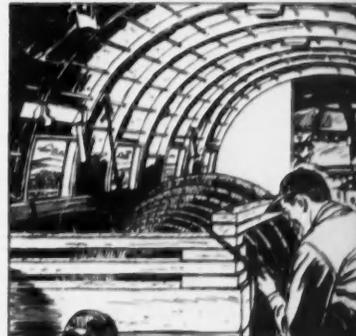
MAINTENANCE SERVICE helps keep your plant electric equipment operating at peak efficiency



PROJECT CO-ORDINATION plans deliveries to simplify purchasing and speed construction schedules



ANALYTICAL ENGINEERING applies skill, latest equipment to solve complex system problems, cuts time used in system design



FIELD-SERVICE ENGINEERING facilitates equipment installation, speeds start-ups, trains personnel



Challenging careers in G-E Sales Engineering

Apply engineering backgrounds to solve customers' electrical apparatus needs

To develop your technical background into the customer-contact career most suited to your interests and aptitudes, investigate General Electric's Apparatus Sales Training Program. Professional career outlets include work in one of the Company's nation-wide district offices in *sales, application, installation and service engineering; headquarters marketing; or specialization in a particular apparatus product.*

G.E.'s training program equips you to work directly with customers to determine what design, new development or electrical system will best serve their need. Here, Jack Byrne, Manhattan College '41, is shown presenting competitive engineering features of G-E distribution transformers. 950-4

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MAIL COUPON FOR FULL INFORMATION

Mr. G. E. Mullin
 Apparatus Sales Training Program
 Building 2
 General Electric Company
 Schenectady 5, New York

Please send me your descriptive bulletin on the Apparatus Sales Training Program, GEZ-515A.

Name

College Degree & Year

Address

THE ROMANCE OF ACHIEVEMENT

Just one year ago this January, I spoke to the members of the Erie County Chapter of the New York State Society of Professional Engineers. I described to them, as an example of the many achievements of the engineers, the day-in and day-out work over the years to generate more kilowatts of electricity with fewer and fewer pounds of coal. I showed that wonderful curve of the decreasing amount of coal required for each kilowatt-hour of electricity, from the *best* station rate of $3\frac{1}{2}$ pounds of coal for a kilowatt-hour in 1905 to that remarkable figure of three fourths of a pound, based on 12,500 Btu per pound of coal.

Without a doubt, I said, this is one of the greatest achievements in engineering history on the part of the engineers and scientists of the electric manufacturing, steam boiler, and electric light and power companies, all working together as teams in engineering accomplishment. It is what has made more electricity available to more people at less cost. It is what has undergirded the superlative industrial output of our country. It is a world-champion curve.

After the meeting, Ray Moore of Niagara Mohawk came to me and said, "Mr. Lee, did you know that we have attained a figure of 0.71 pounds of coal per kilowatt-hour based on our coal?" "Ray," I said, "that is wonderful; you surely know what it means to achieve."

And then I thought of the superlative sum total of achievement in the great engineering profession—in the lives of men dedicated to advancing new and better products, keen in the anticipation of rendering a still greater service. Theirs is the romance of achievement.

Later I learned that Ray Moore had won the Hatfield Pool for 1954 for predicting the nearest to the 472,215,089,000 kw-hr output of the great electric light and power industry in that year. I wrote Ray to congratulate him. This is his letter I received in reply:

"Thank you for your note relative to my winning the Hatfield Pool, also your reference to 0.71 pounds of coal per kilowatt-hour. We have just bought a 200-megawatt turbine for higher pressures and temperatures and hope to run the curve down another point in a short time."

What a letter! Think of the accomplishment in those few lines! That is the language of the engineer. Not a single flourish. But a world-champion accomplishment from the continued, effective, fervent application of the best of engineering talent together with the best of industry contribution in facilities and equipment. After the accomplishment of 0.71, the new 200,000-kw turbine with higher temperatures and higher pressures was expected to run the curve down another point in a short time.

That's the engineer. He never stops producing. That's why progress is our most important product.

Over the years the world has seen engineering and scientific achievements come into being the like of which have never been seen before. The day-by-day contributions of the engineers and the scientists to bring new products into use and to improve existing products never cease. The year 1955 has added its brilliance to the past as the record shows—and some outstanding highlights are recorded in this issue. The romance of scientific and engineering achievement continues to go on.



EDITOR

WILL ECONOMIC GROWTH CONTINUE?

General Electric

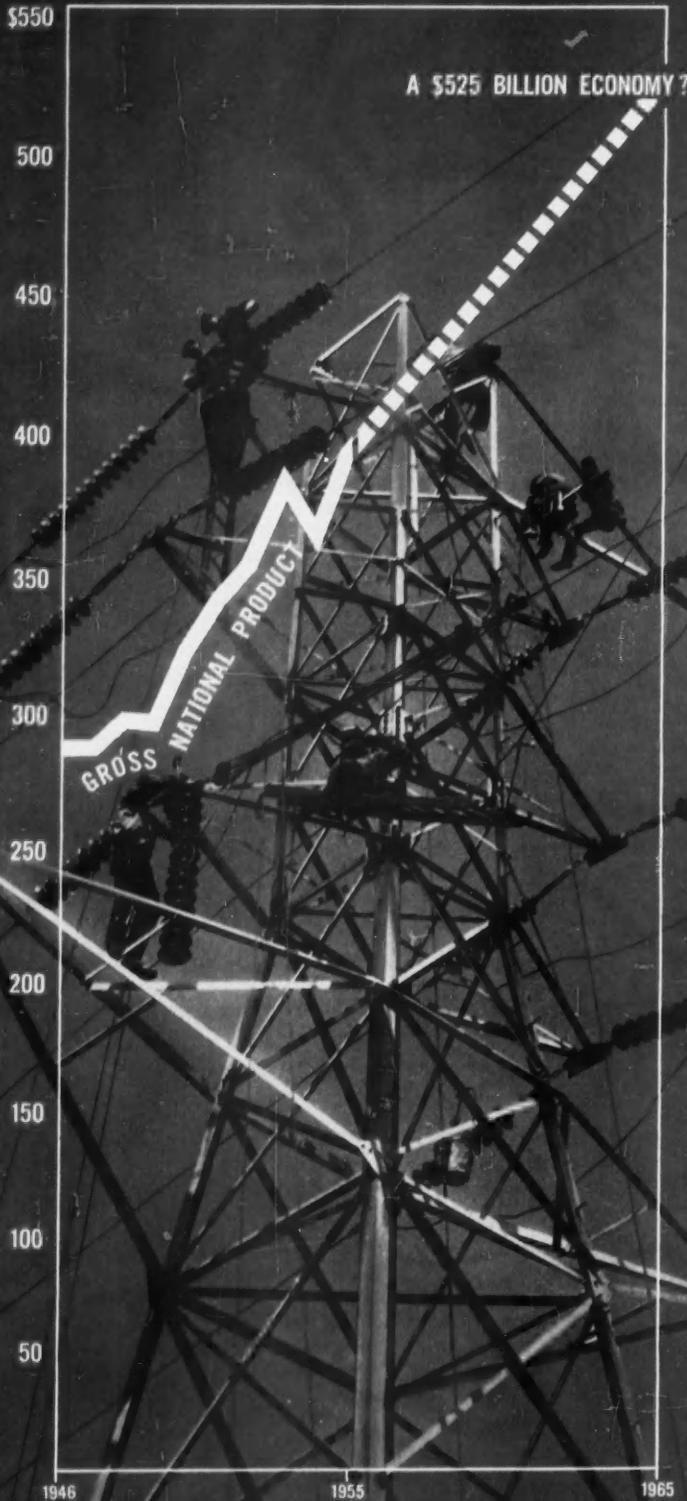
Since 1946 General Electric has invested more than a billion dollars in new plants and equipment to prepare for America's future growth—double that spent in all our previous history

By 1965, there will be 192 million Americans—27 million more than there are today. Forecasts indicate they will demand 40% more goods and services than the country will produce in 1955, and we expect them to want twice as many electrical products.

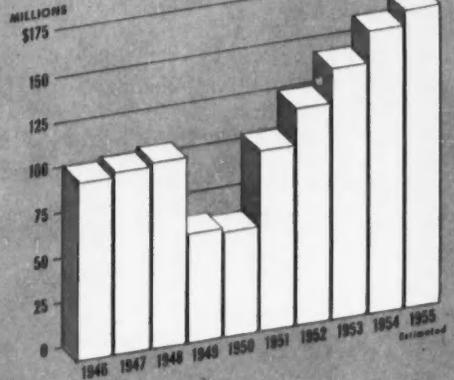
These prospects are encouraging for the nation, but they are challenging, too: there is nothing automatic about prosperity. The \$525 billion economy possible in 1965 will be reached only if there continues to be bold, long-range planning and preparation. In our opinion, American businesses, large and small, have the judgment and initiative needed to meet the challenge.

General Electric, for example, has invested more than \$1 billion in plants and equipment since World War II—\$165 million in 1955 alone. On these pages are some of the steps we are taking to help provide the products, the jobs, and the standard of living hoped for in the next few years.

Billions of Dollars (1955 Prices)



GENERAL ELECTRIC'S INVESTMENT IN NEW PLANT AND EQUIPMENT • 1946-1955
\$1,115,000,000



If you would like us to reserve a copy of our 1955 Annual Report, with an account of our preparation for the future, write to General Electric, Dept. A2-119, Schenectady, N. Y. Your copy will be sent to you early in 1956.

has a billion-dollar belief in U.S. progress



Older plants have been improved. In locations where General Electric has had plants for many years—such as Lynn and Pittsfield, Mass.; Erie, Pa.; and Fort Wayne, Ind.—we have a continuing program of plant improvement. In Schenectady, N. Y., for example, we have completely modernized a 4-acre electric motor factory (above) as part of an \$80 million improvement plan for our plants in that city.



43 new plants have been added by General Electric since 1946, so that we now have manufacturing facilities in 105 cities in 28 states. This investment has resulted in new jobs and new payrolls to dozens of communities. In Anniston, Alabama, for instance, General Electric's new television-tube plant (above) created 2,000 jobs and brought to Anniston its first major industrial payroll since 1947.



2 new laboratories have been opened. In today's technological age, research creates new products and jobs. 70,000 General Electric employees today are working on products we didn't make 15 years ago. One recent example: Man-made diamonds, produced by a 1,000-ton press in our Research Laboratory (above), will mean future jobs at General Electric's Carbonyl Department in Detroit.



Manpower development programs have expanded. Each year, more than 25,000 employees take advantage of Company-conducted training programs. The most recent step taken to assure men of leadership is General Electric's Management Research and Development Institute. (Above, right, Marc A. de Ferranti of G.E.'s Manager Development Consulting Service reviews construction progress.)

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NEW 1000-TON PRESS CAN EXERT 1.6-MILLION PSI ON ONE-SQUARE-INCH AREA TO PRODUCE A DIAMOND (ARROW) FROM A PINCH OF CARBON.

Research

One of the most widely reported non-atomic scientific stories of recent years was the announcement in February, 1955, that a team of G-E scientists had made diamonds in the laboratory. Although the man-made diamonds are not large—the biggest measures approximately one sixteenth of an inch long and weighs less than one hundredth of a carat—they are suitable for a wide variety of industrial applications. Commercial responsibility for their manufacture and sale already has been assigned to a G-E department.

To create the diamonds, scientists subjected carbonaceous compounds to temperatures and pressures never before attained. Before announcing the achievement, the scientists conducted exhaustive tests to prove that man-made diamonds were identical to natural diamonds in hardness and chemical composition. The most conclusive test, involving x-ray diffraction, found the "fingerprints" of the diamonds to be the same as those of natural diamonds. To further confirm the results, two independent groups of scientists from other departments repeated the work with success.

In subsequent experimentation, combined pressures and temperatures of

5000 F and 2,700,000 psi have been achieved and maintained for long periods of time. As a result, great new experimental areas were opened for super-pressure research.

One of the year's interesting scientific sidelights was the demonstration of how nature makes garnet. Natural hornblende was transformed into garnet by simultaneously dehydrating it, heating it to about 2200 F, and subjecting it to pressures of more than 375,000 psi.

New Facilities

Dedication in August of a new Metals and Ceramics Building at Schenectady was an important step in the Research Laboratory's current \$15-million expansion program. Described as the world's most complete metals and ceramics processing laboratory, the \$5-million building gives tangible evidence of the growing significance of metallurgy and ceramics as sciences. Its objectives are to 1) ascertain and analyze the areas of most critical need for materials and processes; 2) develop new processes for new businesses; 3) develop new materials to improve products; 4) study existing materials and obtain a better understanding of their properties and processing; and 5) operate pilot plants

and obtain pertinent economic data.

Virtually completed and now in use is the new \$1.8-million Combustion Building that houses facilities for combustion and vibration damping studies, as well as a small gas-dynamics laboratory. Two 800-hp and one 200-hp air compressors were installed.

Light Amplifier

Demonstration by scientists of direct amplification of light independent of electronic tubes, created new interest in the study of solid-state amplification devices. Experimental phosphor screens with an electric field applied to them give off many times as much light as that projected on them. Because the amplification is nearly proportional, the device can be demonstrated by projecting a picture on the screen with an ordinary lantern-slide projector. The projected image is brightened not by altering the projector's lamp or lens but by "turning on the screen." Applying an electric field does not of itself cause the thin phosphor film to give off light. Ultraviolet energy falling on the screen causes a faint glow. Amplification occurs only when the electroluminescence is "triggered" by light striking the screen.

Semiconductors

A revolutionary new method of producing the crystal "hearts" of transistors was announced during the year. Germanium transistors made by the meltback process operate efficiently at frequencies five times higher than ordinary transistors, at the same time showing greatly improved power-amplification characteristics. Less interlayer diffusion in meltback transistors permits the use of thinner layers, increasing their operating frequency. Use of thin wire-like crystals reduces cross section. Thus the meltback process which produces alternate layers of p- and n-type material can be accomplished quickly and with much less migration of impurities from their proper layers. Formerly, even the best commercially available transistors were not useful for many applications above the standard radio frequencies. But now the transistor's advantages of small size and low power requirements can be utilized in television, radar, short-wave radio, and other electronic devices where high-frequency requirements have previously demanded vacuum tubes.

A new kind of power transistor was developed by forming an alloyed junction close to a pair of rate-grown junctions. Although this remote-base transistor has three junctions instead of the usual two, it is easier to construct and has improved electrical characteristics. It may be operated with either polarity of collector voltage. Positive bias leads to stable amplification, whereas a negative bias gives unstable characteristics that are useful for switching applications.

New evidence that supports theories of breakdown phenomena came from studies of the production of light at the p-n junctions of silicon crystals. Spots of light appear at such junctions when a high voltage is applied to them. Studies of this phenomenon furnish the first direct evidence that high-energy carriers are present in the junction region and that breakdown does not occur uniformly. Because breakdown effects limit the working voltage of transistors and p-n junction rectifiers, these studies may contribute to their continuing development.

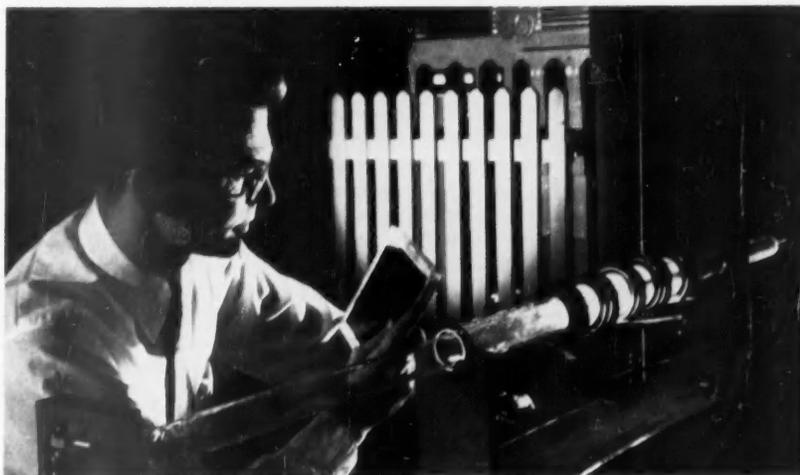
As a result of the additional progress reported in the quest for extremely pure silicon crystals, silicon may now surpass germanium in its importance as a semiconductor element. Although more difficult to process than germanium, silicon has the fundamental ad-



DIRECT AMPLIFICATION of light that is independent of electronic tubes occurs only when electroluminescence is "triggered" by light striking an experimental phosphor screen.



GERMANIUM TRANSISTORS made by the meltback process operate at frequencies five times higher than ordinary transistors and show improved power-amplification characteristics.



ZONE-MELTING PROCESS for production of high-purity silicon consists of successive recrystallizations of silicon as an ingot is slowly drawn through a gas-filled quartz tube.



VOLTAGE-TUNED MAGNETRON, tuned by varying the d-c supply voltage, permits much faster tuning and therefore the use of magnetrons in many new automatic testing devices.

vantage of being able to operate through a greater temperature range.

One of the basic properties of silicon and germanium—optical absorption characteristics in the single-crystal form—was investigated by using a new technique to grind and polish samples to layers as thin as 0.00002 inch. At such thicknesses these materials appear transparent when viewed with the naked eye. The thinnest samples were prepared by polishing one face so that it showed no scratch marks under a low-power microscope. This face was then pressed against a glass plate spread with resin, while the other face was ground and polished until the sample reached the desired thickness.

A total of five additional elements when introduced as impurities were found to produce substantial changes in the electrical properties of germanium. The effects of such doping include changes in resistivity and photosensitivity.

An unusual new laboratory tool is the Army's famous snooperscope, a seeing-in-the-dark device developed during World War II. By using the snooperscope and infrared light, scientists can actually see through crystals of silicon several inches thick, thus spotting contaminants, strains, and crystal imperfections.

Electron Tubes

A variety of previously unannounced research results have been incorporated in GE's new microminiature receiving tube.

A step forward in the development of television picture tubes was taken with

the elimination of the ion trap, once necessary to prevent ions that are generated in the electron gun from reaching the phosphor screen and reducing its efficiency. Recent work makes it possible to eliminate the trap by using a thin sheet of aluminum evaporated onto the phosphor screen. The aluminum is thick enough to stop the ions but thin enough to allow the electrons to pass through to the phosphor. Acting like a mirror, the aluminum also increases the light output of the tube. Studies of electron and ion penetration in aluminum contributed to the determination of the optimum thickness of the aluminum sheet. This simplified construction of the tube eliminates a source of frequent adjustment difficulties.

A new way to construct magnetrons that may be tuned by varying the d-c supply voltage was developed during 1955. Previously, tuning magnetrons over a broad range had to be done mechanically. This presented a major problem because space was limited within the vacuum envelope and because the required mechanical linkage made tuning a slow and cumbersome operation. The new method is entirely electronic, permitting much faster tuning and therefore the use of magnetrons in many new automatic testing devices. Similar electronic tuning methods may be adapted to radar, television, and radio broadcasting.

With a new, extended interface cathode, high thermionic efficiency of oxide coatings in a sturdy mechanical form was achieved for the first time. In

this cathode, the oxide coating is closely interlocked with the base metal. This new technique may have applications in many fields using electron emission from a heated cathode. The scientists continue work aimed at optimizing the application processes so that the full extent of its advantages can be realized.

Polymers

Greater strengths at elevated temperatures, plus other desirable physical characteristics, were imparted to polyethylene by a new process combining the use of fillers with high-energy electron bombardment. Fillers alone in polyethylene may cause brittleness, but combining filling with irradiation results in tensile strengths at high temperatures five to eight times greater than the tensile strengths of irradiated but unfilled products. Ordinary polyethylene melts before it reaches a temperature of 300 F; when filled and irradiated, it can support more than 500 psi at this temperature.

Scientists studying methods of increasing the strength of silicone rubber produced some unusual high-speed photographs showing that a stretched rubber band usually breaks from the inside out. Such basic studies are important because of the similarities that exist between the snapping of a rubber band and the fracture of metals and plastics.

Metals and Alloys

Evidence that a wide variety of perfect metal crystals can be produced by a single process has been obtained since the creation of perfect iron crystals in 1954. By using a high concentration of metal in the gas phase—obtained either by chemical methods or by boiling—perfect crystals of gold, silver, platinum, copper, nickel, and cobalt were produced. The production method was successful with every metal that it has been tried on. Perfect copper crystals have withstood tensile stresses as high as 600,000 psi, in comparison with single imperfect crystals that break at 5000 psi.

More precise knowledge has been gained on the effects of various impurities on the ductility of chromium. Scientists knew that chromium is ductile at room temperature if sufficiently pure, but they lacked the quantitative information as to which were the most critical impurities or how much could be tolerated. Recent experiments demon-

strated the key role of nitrogen in causing brittleness in chromium. Carbon's influence was also clarified, while oxygen and sulfur were shown to have less effect on chromium ductility.

Progress in the search for novel methods of producing new alloys, particularly those intended for use at high temperatures, occurred with the introduction of a multipurpose inert-atmosphere arc-melting furnace. The new furnace, making use of direct current and either a consumable or nonconsumable electrode, can handle ordinary metals, such as copper and iron, or materials previously considered too refractory for commercial production: chromium, niobium, tantalum, tungsten, titanium, and zirconium. Meanwhile, the work continues on the construction of a new consumable-electrode furnace that is capable of operation to one hundred-millionth of an atmosphere, achieving temperatures up to 12,000 F.

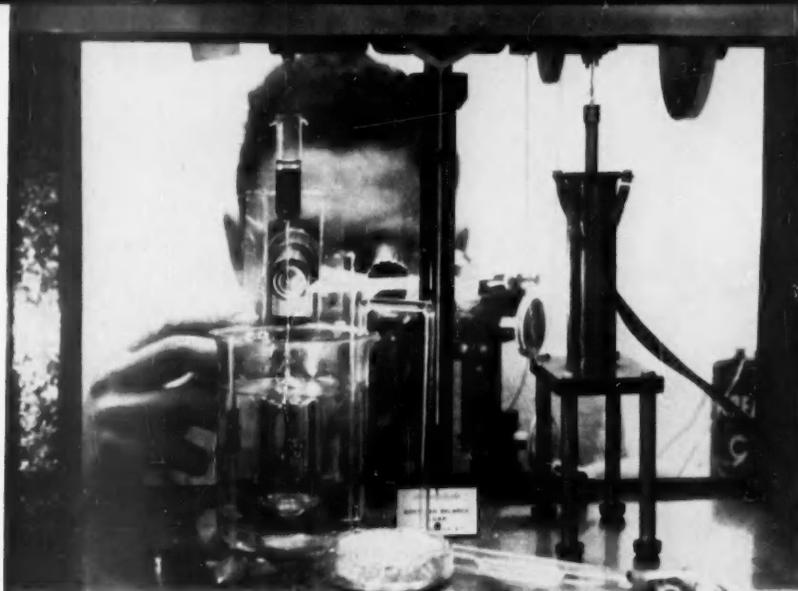
Magnetic Materials

In continuing their work on the general theory and understanding of magnets, G-E research scientists have developed theories to explain in detail the properties observed in small-particle magnetic materials.

A new high-permeability core material was a further development of a soft nickel-iron magnetic material to which two percent of molybdenum was added by using special techniques. Although nickel-iron alloys with molybdenum added are not new, the elements as combined and processed form a magnetic material superior in many respects for use in magnetic amplifiers and other electronic control devices. The new material retains its good magnetic qualities at higher temperatures and, consequently, may prove valuable under the severe operating conditions that are demanded by many of the military applications.

Other Developments

A new ionization gage twice as sensitive but only one tenth as large as conventional types was developed. Such gages measure the pressure in vacuum systems by ionizing some of the residual gas and collecting the ions. The size of the resulting ion current gives an indication of the pressure in the system. Conventional gages are bulky and made of glass. The smaller new gage is made of metal and ceramic. Consequently, it can be heated to high temperatures, an



PERFECT COPPER CRYSTALS, without the usual irregularities in atomic structure, have sometimes revealed strengths almost 1000 times more than those of normal crystals.

advantage during the manufacture of ceramic tubes.

During 1955, progress was reported in studies of the sterilization of food and pharmaceuticals by irradiation with high-energy beams. Aims of the present project are to 1) determine the nature of breakdown products from irradiated proteins; 2) synthesize polypeptides of single amino acids for irradiation studies; and 3) determine by chemical masking what amino acids are involved in odor and flavor production.

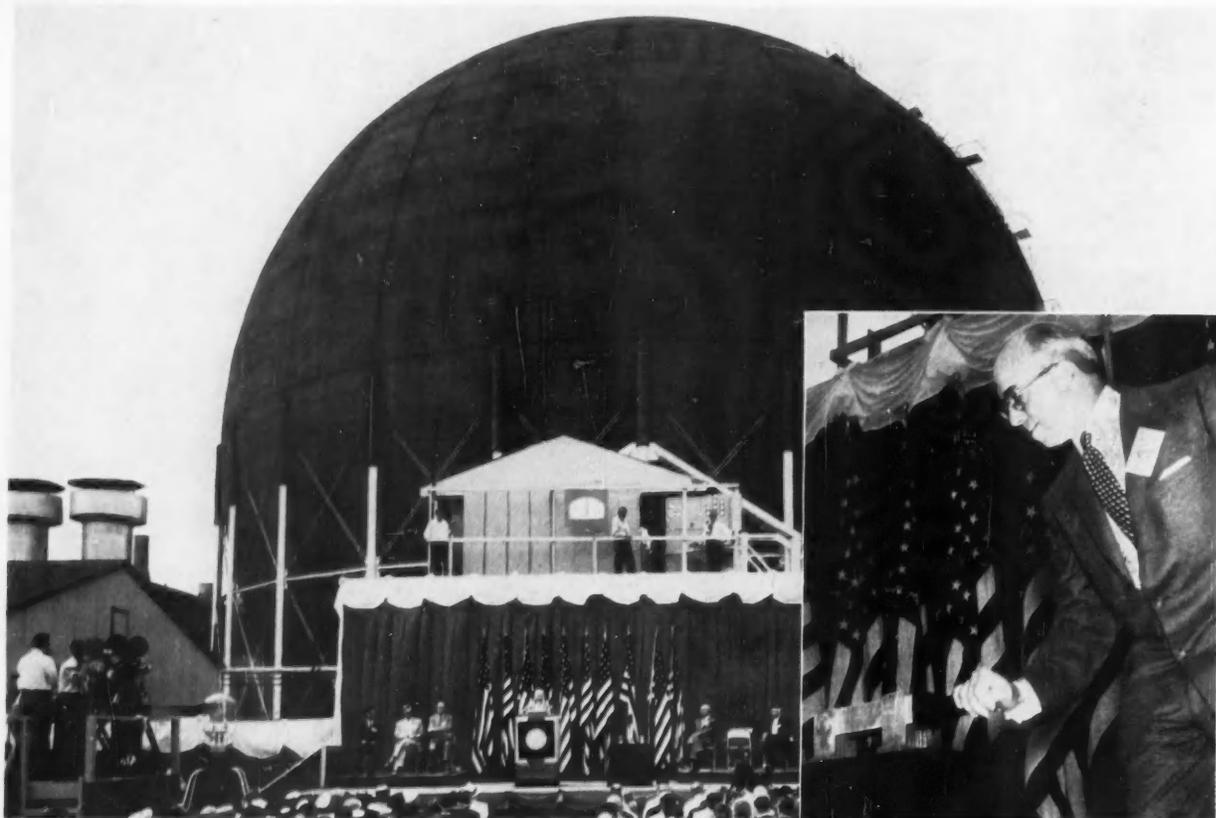
A bloodwarmer, a unique new heat-exchanger device, was developed for use during the famous exchange-transfusion operations performed on Rh-factor babies. The device lessens the shock that newborn infants may otherwise encounter when undergoing the operation of substituting new blood. Preheating the blood is not practical because it may cause coagulation, but the new device heats the donor's blood to the baby's body temperature seconds before it enters the needle and the umbilical cord.

Demonstrated during the year was a novel method of mounting stones in diamond tools, with reductions of up to 90 percent in the size of crystal required. In a conventional mount, as much as 90 percent of the diamond used may be buried in the tool to gain rigidity and prevent loss of the stone. In the new method, a considerably smaller diamond is mounted in a shallow cavity on the surface of a single-point wheel-dressing tool. The process involves use of titanium hydride as a wetting agent plus a solder such as silver copper. The

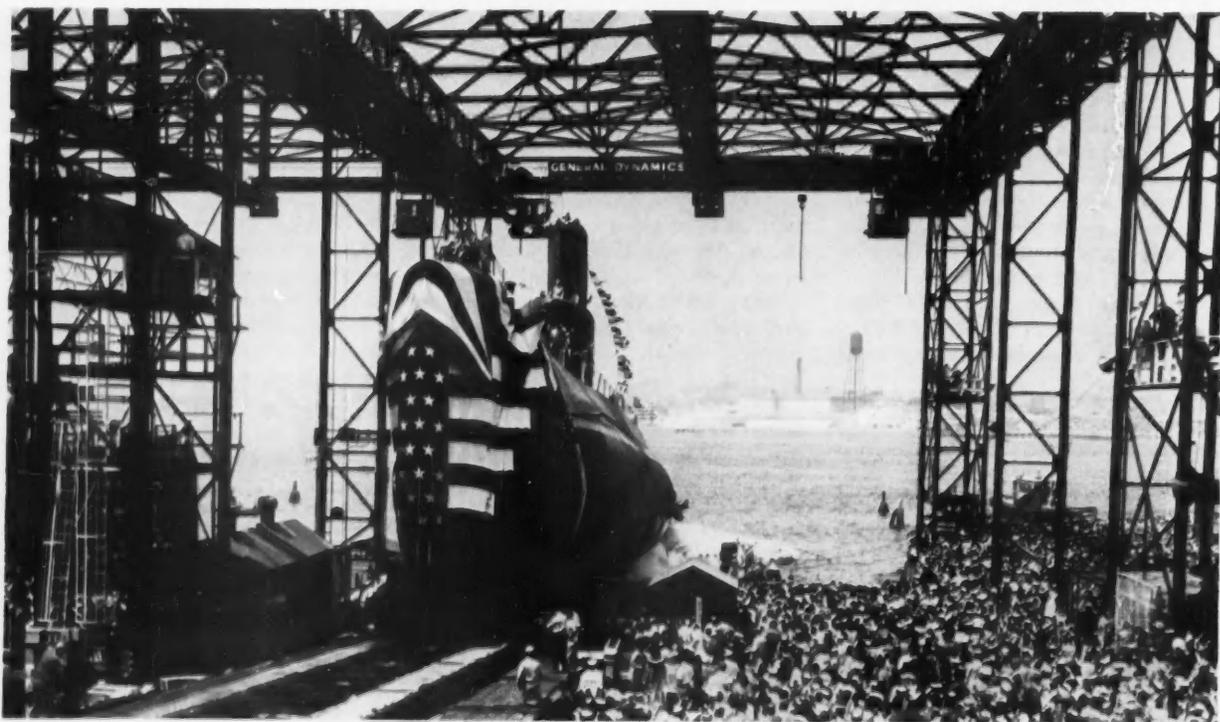
parts are brazed by induction or radiation heating in a high-vacuum system or in an atmosphere of pure argon or hydrogen gas.

A truly dry battery was developed using a plastics sheet as an electrolyte instead of the aqueous solution that is found even in so-called dry cells. The function of the usual electrolytic solution is performed in this solid-state battery by a plastics ion-exchange membrane. As a result, rechargeable and more simply constructed batteries only a fraction of the size of conventional types can be produced. Low internal resistance also helps to provide a larger current for a battery of a given size. Applications in flashlights, hearing aids, and many types of transistor circuits are possible.

A study on the friction of polytetrafluoroethylene blocks sliding on each other verified that the low coefficient of friction for this system holds only when low sliding speeds and newly prepared surfaces are used. At high sliding speed, the nature of the surface is irreversibly changed, and subsequent sliding at low speed reveals a two to threefold increase in the friction coefficient. Reversible changes in the coefficient of friction depend partly on temperature. As the temperature of the material is increased from below room temperature, a sharp and pronounced increase in the coefficient of friction occurs at about 20 C. The existence of a phase transition at this temperature indicates a close correlation between the frictional and the structural properties of this material.



AEC'S LEWIS L. STRAUSS THREW SWITCH AT WEST MILTON, NY, ON JULY 18, MARKING THE FIRST COMMERCIAL DISTRIBUTION OF ATOMIC POWER.



PRIOR TO SEAWOLF'S LAUNCHING AT GROTON, CONN., ITS REACTOR PROTOTYPE AT WEST MILTON OPERATED FOR THE EQUIVALENT OF 2250 MILES.

Nucleonics

Long active in the development of atomic energy for the nation's defense needs, General Electric officially entered the commercial peacetime atomic field in 1955.

On March 15, a new department was established to design, manufacture, and market a full line of reactors and allied equipment for research and for generation of atomic power. One month later, a new reactor design was announced before the American Power Conference at Chicago.

Called the G-E dual-cycle boiling-water reactor, the new design is an advance from the direct-boiling principle. Scientifically speaking—and from the practical side as well—this reactor design helps to take industry past the pioneering stage in the development of practical means for harnessing the atom to the production of useful electric power.

During April, GE announced that it would design and build the world's largest all-nuclear power plant for Commonwealth Edison of Chicago. This 180,000-kw plant will use the dual-cycle boiling-water reactor. It will be located on a 750-acre site near the confluence of the Kankakee and Des Plaines Rivers, 47 miles southwest of Chicago. Scheduled to go into operation in 1960, the \$45-million project will be financed entirely with private funds.

Two months later, four types of nuclear research reactors were announced for industrial, educational, and research organizations: a 30-kw nuclear test reactor, a 50-kw water-boiler reactor, a 1000-kw swimming-pool reactor, and a 5000-kw heavy-water reactor.

Three significant events marked the month of July. On July 18, at West Milton, NY, 18 miles from Schenectady, America's first commercially distributed atomic power went out over utility lines to area farms, homes, and industries. This power was generated through the use of excess steam from the prototype of the submarine *Seawolf's* nuclear propulsion plant. The system's Submarine Intermediate Reactor (SIR) was built by GE at the Knolls Atomic Power Laboratory (KAPL) under contract with the Atomic Energy Commission (AEC). Power generation equipment was manufactured and installed by GE at no cost to the government.

Lewis L. Strauss, Chairman of the AEC, throwing the switch that turned on the atomic power, said, "What we are about to do may well stand as a symbol of our hopes and aspirations for the day when the atom will serve only as the servant of man. . . ."

Three days later, on July 21, at Groton, Conn., the atomic submarine *Seawolf* was launched. The land-based prototype of her nuclear power plant at West Milton had already been operated long enough to have propelled the ship 2250 miles, nonstop and fully submerged.

On July 22, GE and Commonwealth Edison formally signed the official contract for the nuclear power plant.

During August, the United Nations International Conference on Peaceful Uses of Atomic Energy was held at Geneva, Switzerland. Attending were 19 G-E scientists, engineers, and officials, who presented 14 papers before the historic conference. In addition, General Electric sponsored an atomic display at the U.S. Industries' Exhibit, held simultaneously with the Conference.

In September, a contract was signed with the Kaiser Engineers Division of the Henry J. Kaiser Co. for the design of the reactor core, controls, instruments, pressure vessel, and other equipment of an Engineering Test Reactor (ETR) to be built by Kaiser for the AEC.

(Complete details on the dual-cycle reactor, Commonwealth Edison's nuclear power plant, and nuclear research reactors, plus a pictorial chronology of General Electric's 16 years of activity in the field of atomic energy can be found in the November 1955 REVIEW.)

Hanford Atomic Products Operation

During 1955—General Electric's ninth year of operating the plutonium-producing Hanford Atomic Products Operation (HAPO) at Richland, Wash., for the AEC—gains were made in all phases of plutonium research, engineering, and production.

Much of Hanford's fuel-element technology is now being developed at a new fuel-element pilot plant. The 30,000-square-foot facility consolidates in one location equipment for fabricating uranium cores, jacketing experimental and

prototype fuel elements, and supporting quality-control laboratories. The main objective is to improve fuel elements so that they will be less susceptible to dimensional changes and to failure in reactor environment.

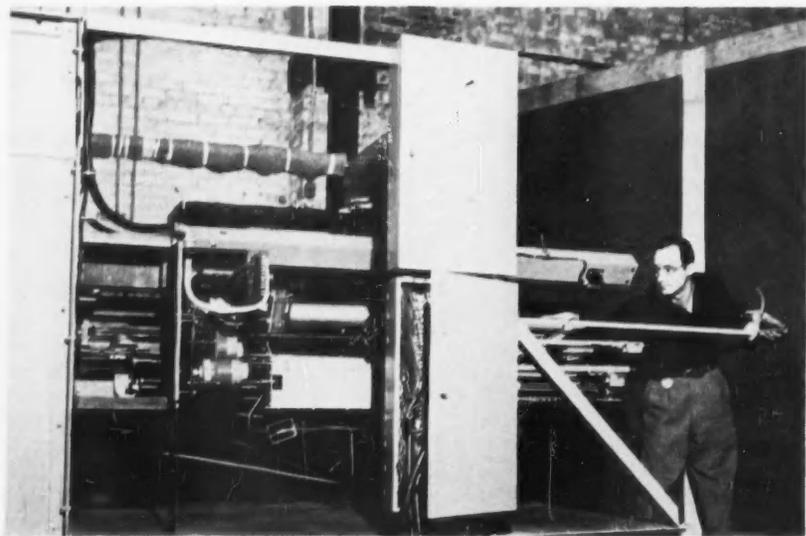
Another experimental laboratory that went into operation at Hanford has equipment for the development and testing of improved treatment methods for Hanford reactor cooling water. The water treated is piped through individual process tubes; its corrosive effects on both tubes and fuel-element jackets can be observed. Results from these tests will determine the best treatment methods to cut down on the corrosive qualities of the cooling water and thus increase reactor production.

An expansion now under way at the laboratory will provide four high-temperature high-pressure in-pile recirculation loops to further the technology of high-temperature reactor cooling systems. Information will be gathered on how this recirculating system will affect process tubes, fuel elements, piping, valves, pumps, and all other components of a reactor cooling system.

Supplementing the in-pile cooling studies is a full-scale reactor-tube mock-up that consists of a 2000-psi recirculation system, a water make-up system, and a water-treatment unit. Heat-transfer studies can be conducted at pressures from 500 to 2000 psi and with inlet water temperatures ranging from 100 F to a few degrees below saturation over the entire pressure range.

Recently completed, a major chemical processing facility employs a new process that will provide higher capacity operation and lower unit cost than any of the older processing facilities. An unusual feature is the use of industrial closed-circuit color television for viewing the working zone.

Because intensely radioactive solutions are processed, the facility is operated by improved remote-control centers. Two cranes span the canyon part of the facility where the process tanks are located, each operating its own track, with one crane riding at a higher level than the other. They handle normal process operations and also remove and replace worn-out equipment. The lower crane is operated from behind a concrete parapet wall that shields the



A 30-KW NUCLEAR TEST REACTOR IS ONE OF FOUR COMMERCIAL TYPES RATED UP TO 5000 KW.

cab operator from radiation, and in this cab is the color television receiver. Both crane operators view the operating zone through periscopes.

A new facility for examining irradiated fuel elements, located in an 18-foot-deep pool of water, allows routine examination of 120 elements a day, plus 35 nonroutine examinations.

The fuel elements are chemically cleaned; photographed; weighed to an accuracy of ± 30 mg; measured for length, diameter, and warp to an accuracy of 0.002 inches; measured for radiation intensity; and visually examined. If the operator desires to examine the uranium piece, the aluminum can is removed chemically. For visual examination of minute areas of both canned and bare slugs, the facility has an underwater microscope. Unique photographic equipment gives an optically flattened picture of the cylindrical surfaces.

Many of Hanford's new developments to obtain better and more economical chemical separations will now be tested in a laboratory-scale chemical separations plant. It can duplicate many of the chemical process steps that occur in the large separations plants, including dissolving irradiated slugs, chemically treating the resulting solution, and separating the desired products—uranium and plutonium.

The majority of Hanford water plants was redesigned, increasing reactor productivity and reducing operating costs. This improvement will increase the attainable rate of reactor coolant flow, resulting in a proportionate gain in production capability.

A small experimental water-treatment plant for process control was put into operation at Hanford. This 5-gpm-capacity plant simulates the chemical mixing, flocculation, settling, and filtration processes of the larger facilities.

Physical Constants Test Reactor

A specially designed reactor, the Physical Constants Test Reactor (PCTR), was constructed and placed into operation at Hanford. It will largely replace slow, expensive exponential piles and permit additional experimental measurements.

The reactor is a rectangular stack of graphite blocks with a large central cavity in which fuel elements and moderator sections can be placed in experimental geometrical arrangements. The reactor is made critical by a ring of highly enriched fuel elements surrounding the cavity and by similar elements in the rear and movable front walls.

In-Line Analytical Instruments

In-line analytical instruments developed at Hanford are putting the analytical laboratory right in the process pipes. One of these instruments, eventually destined for chemical process control in Hanford production plants, is now undergoing extensive field testing. Another, a total beta monitor, is being used with other instruments to accurately assay Hanford reactor cooling water before it is returned to the Columbia River.

These instruments stamp a continuous roll of heavy aluminum tape to form counting cups and then deposit a precise quantity of solution in a cup.

The sample is advanced to a dryer for evaporation and then to a radiation detector for measurement. After the information is obtained, the tape is chopped off and the cup dropped into a removable container.

Waste Storage and Processing

The storage of highly radioactive wastes in underground tanks is a continually increasing problem and one of the most expensive items in the Hanford separations processes. Millions of gallons of these wastes must be stored yearly.

A major milestone was passed when the volume of waste from one of the Hanford separations plants was reduced by approximately 63 percent, representing an annual saving of nearly \$1 million.

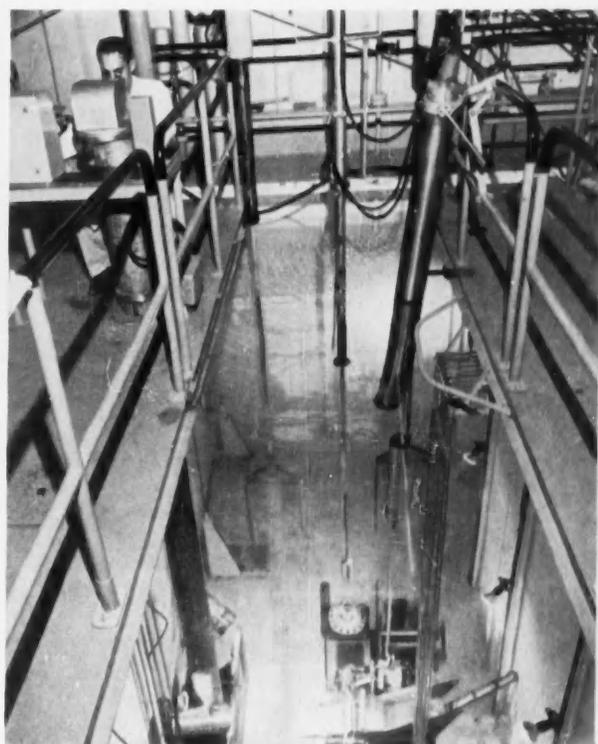
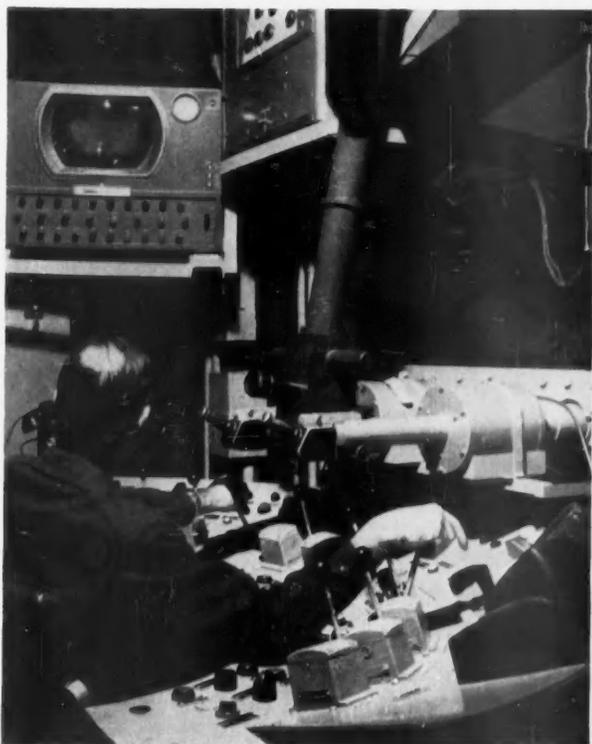
Much of this reduction in waste volume was accomplished by process modifications that permit the return of waste streams, which normally would have been stored, for re-use in earlier stages of the separations process. This technique of back-cycling chemicals not only reduces the waste volumes that would require an increased number of new storage tanks but also significantly reduces the consumption of essential raw materials.

Other economies are resulting from this back-cycling technique, most important being a threefold to fourfold reduction in the over-all loss of uranium and plutonium to waste. An additional annual saving of nearly \$500,000 results from recovery of these products through back-cycling.

The underground tanks that hold Hanford radioactive wastes are constructed of concrete with metal liners. Because the liners prevent the solution from leaking into the ground and eventually into the air and water, the tanks must be replaced before the liners corrode.

To predict the life expectancy of metal liners, a corrosion test facility, consisting of a number of perforated tubes inserted through the dome of a waste tank, was installed in an underground tank. These tubes, nearly reaching the tank bottom, hold specimens of existing liner material and samples of candidate materials for future construction.

Over a 10-year interval, specimens will be removed in periodic stages and taken to remotely operated radiometallurgy facilities for examination and evaluation. Corrosion rates collected in



COLOR TV VIEWS WORKING ZONE IN CHEMICAL FACILITY. UNDERWATER TANK PERMITS SAFE EXAMINATION OF IRRADIATED FUEL ELEMENTS.

this manner will provide the necessary information for estimating the service life of the Hanford waste-tank liners. With the former method of laboratory experiments, actual storage conditions were difficult to duplicate and practically impossible to maintain for more than a year.

As soon as the program for the recovery of uranium from underground storage was initiated, the need became apparent for a continuous process of converting uranyl nitrate to uranium oxide. During the early part of this program, a batch process was workable even though much hand operation was necessary to fill the individual agitated pots for heating the molten nitrate and for subsequent unloading with a large vacuum cleaner.

After consideration of many factors, an agitated trough calciner was developed. Finished uranium trioxide is heated and agitated in the calciner, and then molten uranyl nitrate is introduced directly onto the bed of hot powder. The resulting reaction produces nitric acid and water that is discharged from the calciner, and new oxide is formed on the surface of the heated powder particles.

Initial work on this method was done

in a small 4-inch-diameter vat and scaled up to a 16-inch-diameter semiplant scale for further testing. Approximately 200,000 pounds of uranium trioxide were produced during this test program.

Continuous Monitoring

Continuous monitoring instrumentation was installed to obtain temperatures in each of the process tubes in some of the Hanford reactors. The system employs a temperature readout to a recorder, a tape puncher, and an automatic typewriter. The typewriter prints the temperature of each tube on a large matrix map. Readout devices can be automatically switched from tube to tube by telephone-type stepping switches operating at rates of 25, 50, 100, or 200 steps per minute.

Another safety device for Hanford reactors was developed. Scintillating crystal gamma-ray spectroscopy, originally developed as a research tool, was applied as a monitor of reactor cooling water for evidence of fission-product release. This system can quickly determine fission-product radiations even in the presence of intense variable-background radiation and positively identify a fuel-element failure within the reactor.

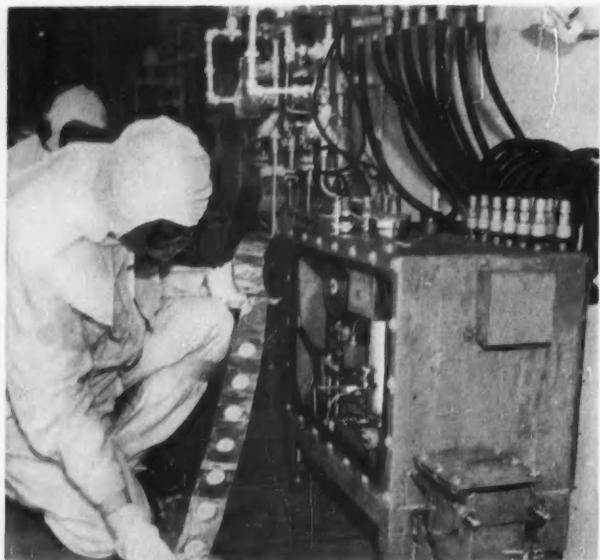
Water Filtration

Hanford engineers achieved filtration rates of reactor cooling water two to three times higher than previously possible, being among the highest ever achieved in this country on a continuous basis. This was accomplished through careful selection of water-treatment chemicals and filter-bed media (a change from sand media to hard-coal filter) and after conducting extensive plant-scale testing.

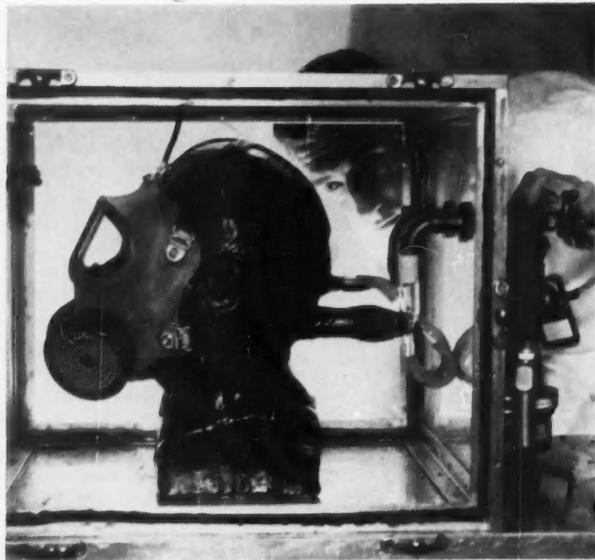
Special Testing Equipment

In the two years that Hanford's Radiometallurgy Laboratory has been in operation, many specialized pieces of equipment have been developed. This equipment allows scientists a more comprehensive study of irradiated materials, while at the same time providing them with maximum radiation protection.

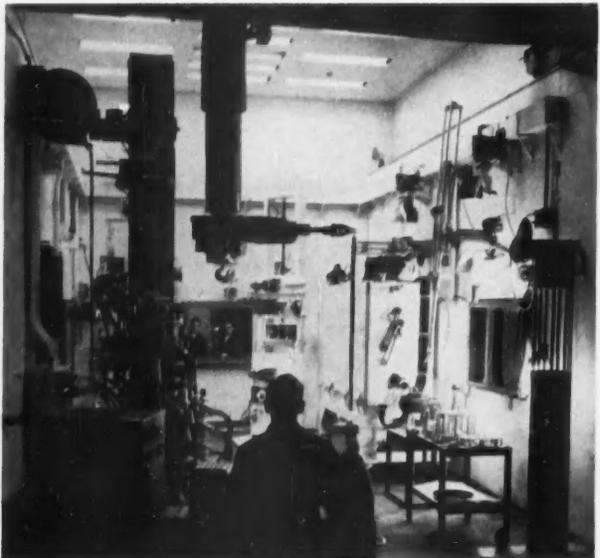
One piece of equipment, a tensile-testing unit for irradiated material at elevated temperatures, consists of a lead-shielded vacuum-sealed furnace mounted on a 60,000-pound tensile-testing machine. To prepare the specimen for testing, lines are scribed on platinum strips welded to the metal specimen. During the testing, optical equipment measures the movement of



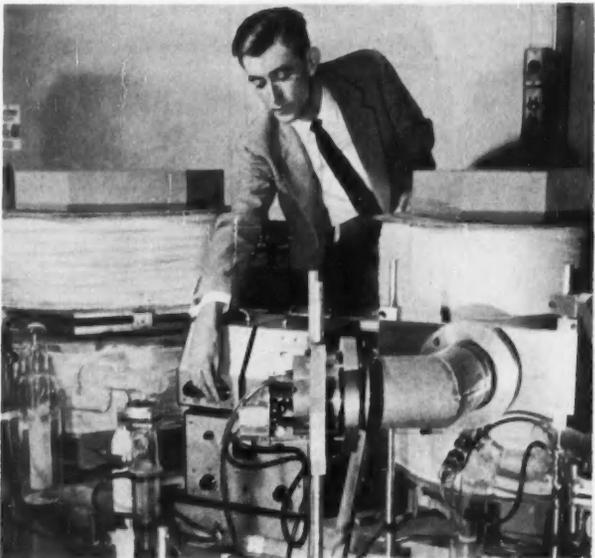
ANALYTICAL INSTRUMENT STAMPS COUNTING CUPS IN ALUMINUM TAPE.



MOBILE UNIT PERMITS CAREFUL TESTING OF PROTECTIVE DEVICES.



SPENT FUEL ELEMENTS TESTED INSIDE CELL ARE CONTROLLED OUTSIDE.



MASS SPECTROMETER AIDED DISCOVERY OF ISOTOPE OF TANTALUM.

the lines through quartz windows in the furnace to determine the elongation of the piece.

Chemical and electrochemical etching techniques, generally used in preparing metal specimens for microscopic examination, are unsatisfactory in etching irradiated metals. As a remedy, Hanford scientists developed a remotely operated vacuum-cathodic etching unit mounted in one of the radiometallurgy cells. The sample to be etched is placed in an in-cell vacuum chamber so that it also becomes the cathode during the etching cycle.

Corrosion Studies of Aluminum

Extensive intergranular corrosion studies of aluminum extended the useful temperature range of this reactor material. The resulting higher temperatures mean greater efficiency for Hanford reactors and may lead to efficient, economic aluminum power piles.

Respirator Tester

Hanford scientists developed and built a mobile testing apparatus that has a special manikin head mounted in the test chamber for testing respiratory protective devices. The head con-

sists of a plaster-base skull of human proportions with a soft latex covering to permit the same respirator contact as in normal usage. Tubes connect the nasal area of the head with a set of breather pumps that inhale and exhale air through the respirator being tested. Any desired test atmosphere can be introduced. In addition, the apparatus can be moved into actual contaminated plant atmospheres.

Graphite Studies

The properties of artificially manufactured graphite make it a highly

suitable material for use in a nuclear reactor, both as a moderator and as a structural material. Its advantages are its mechanical strength, moderating properties, low neutron-absorption cross section, refractory and heat-conducting properties, and availability in large quantities at low cost.

However, irradiation in a reactor produces basic changes in the crystalline structure of this graphite resulting in large changes in its physical properties. Of particular engineering interest are the doubling of mechanical strength, the fiftyfold reduction in thermal conductivity, the linear physical expansion in excess of three percent, and the accumulation of more than 500 calories of stored energy per gram.

A graphite, developed at Battelle Memorial Institute and tested extensively at Hanford, was found to be physically stable under neutron bombardment at room temperatures. This new graphite will allow a much greater flexibility in the operating conditions of future graphite-moderated reactors.

Cobalt-60 Gamma Source

Wherever intense radiation is encountered in Hanford operations, both process chemicals and construction materials may be greatly affected. To more conveniently investigate these effects, as well as to study fundamental processes that occur when matter is subjected to radiation, a high-level cobalt-60 gamma source was installed in a Hanford laboratory. Radiation levels approaching one-million roentgens per hour are possible with the apparatus.

Fuel-Element Replacement

By adapting techniques that permitted the introduction and removal of neutron-absorbing materials from reactors during operations, a method for replacing fuel elements without shutting down the reactor was satisfactorily demonstrated at Hanford on a limited number of reactor fuel tubes.

Atomic Submarine—KAPL

A fuel-element service cell for use during test operation of the prototype SIR at KAPL, operated by General Electric for the AEC, was installed at the West Milton site. Equipment within the cell is used to handle hot and partly burned atomic reactor fuel elements and to prepare them for chemical processing.

Because the spent fuel elements are highly radioactive, all the intricate

operations performed on them must be done by remotely controlled apparatus. Six-foot-thick concrete walls surround the cell, and the operations are viewed by means of five periscopes or through one of eight six-foot-thick windows that contain a solution of zinc bromide to absorb harmful radiation. Two mechanical hands that extend through the walls are operated from outside the cell. A general-purpose manipulator inside the cell is controlled electrically by a movable control board that can be plugged in near any of the windows.

Isotopes

New knowledge was gained by KAPL scientists in the general field of isotopes. An advanced mass spectrometer is capable of monitoring transmutations as small as one atom in 10 million. The equipment has been applied to such problems in reactor physics as a precise determination of the capture-to-fission process in uranium and plutonium for neutrons of intermediate energy; relative abundances of the isotopes of elements heavier than plutonium; and detection and identification of new isotopes in nature. With this new equipment, a naturally occurring radioactive isotope of tantalum, Ta-180, was discovered. This is the first natural isotope to be discovered since 1949, when vanadium, V-50, was found.

Aircraft Nuclear Propulsion Progress

During 1955, four years of work on the development of a nuclear propulsion system for aircraft were completed under contracts with the Air Force and AEC. During these years, significant progress has been made in aircraft nuclear propulsion. Facilities at the National Reactor Testing Station (NRTS) for this project are nearing completion. They include an administrative and service area, assembly and maintenance area, and an initial test area. An increase in the staff and facilities engaged in this research and development program is planned for the future.

New Laboratory

Extensive new facilities were established in the General Engineering Laboratory at Schenectady during 1955 for radiation studies. The new hot lab will be used primarily for investigation by physicists and chemists of radiation effects on various materials; development of new analytical techniques; applications of radioactive isotopes for industrial uses; design of radiation

shielding; and development, testing, and application of different types of particle accelerators.

Equipment of the facility includes a 15-million-volt betatron; a high-voltage heavy-particle accelerator; a 1000-curie cobalt source; and several laboratories for the handling, testing, and analysis of radioactive materials.

Engineers and chemists applied activation analysis (irradiating samples) to measure extremely minute amounts of impurities in samples of fruit trees, vegetable and flower plants, human blood, and such materials as germanium and silicon used as semiconductors. Other projects included application of radioactive isotopes to the solution of industrial problems such as erosion of molds used in forming plastics; testing the efficiency of filters; and measuring mechanical wear of various moving parts, tools, and dies.

Turbine for Small Atomic Plants

During 1955, an order was received for a 2000-kw turbine-gear-generator set to be used as a prototype for small atomic power plants. The turbine will be of multistage, condensing, sectional valve gear type, designed for high efficiency. The casing will support the condenser which will have a long axis perpendicular to that of the rotor.

X Ray for Radiobiology Research

Mounting interest developed in two types of x-ray therapy apparatus for their value in the AEC-sponsored Radiobiological Research Programs.

X-ray machines rated at 250,000 volts were in active daily use at such major locations as the Oak Ridge Institute of Nuclear Studies, Los Alamos Scientific Laboratory, Yale School of Genetics, and Banting Institute, Canada. Special 100,000-volt x-ray machines were in use in such centers as the University of Maryland and the Argonne National Laboratory.

Pressure Transmitter for Reactors

Pressure in liquid metals circulated at high temperatures as the means of heat extraction in nuclear power reactors can now be measured and transmitted with a double-diaphragm pressure transmitter. Prototype units have operated with good accuracy at temperatures up to 1000 F and have continued to operate with the same accuracy after being subjected to high impact shock, severe vibration, and system pressures from vacuum to 200 psi.

Power

Many of the technical problems confronting electric utilities were vigorously analyzed and studied during 1955.

Digital computing machine methods were used to determine the short-circuit current caused by a feeder fault in a low-voltage system for 2200 conditions. Digital computing machine methods were also developed to 1) calculate the self-impedance and mutual impedance for a fairly large section of an electric power system, 2) study the problem of emergency bus transfer at a central power station, and 3) calculate certain steam-turbine heat cycles.

A significant answer to the problem of voltage control on a distribution system was obtained. Main conclusion of the study is that economic voltage control requires both regulators and capacitors. The results provided electric utilities with a guide to the best regulator-capacitor relationship.

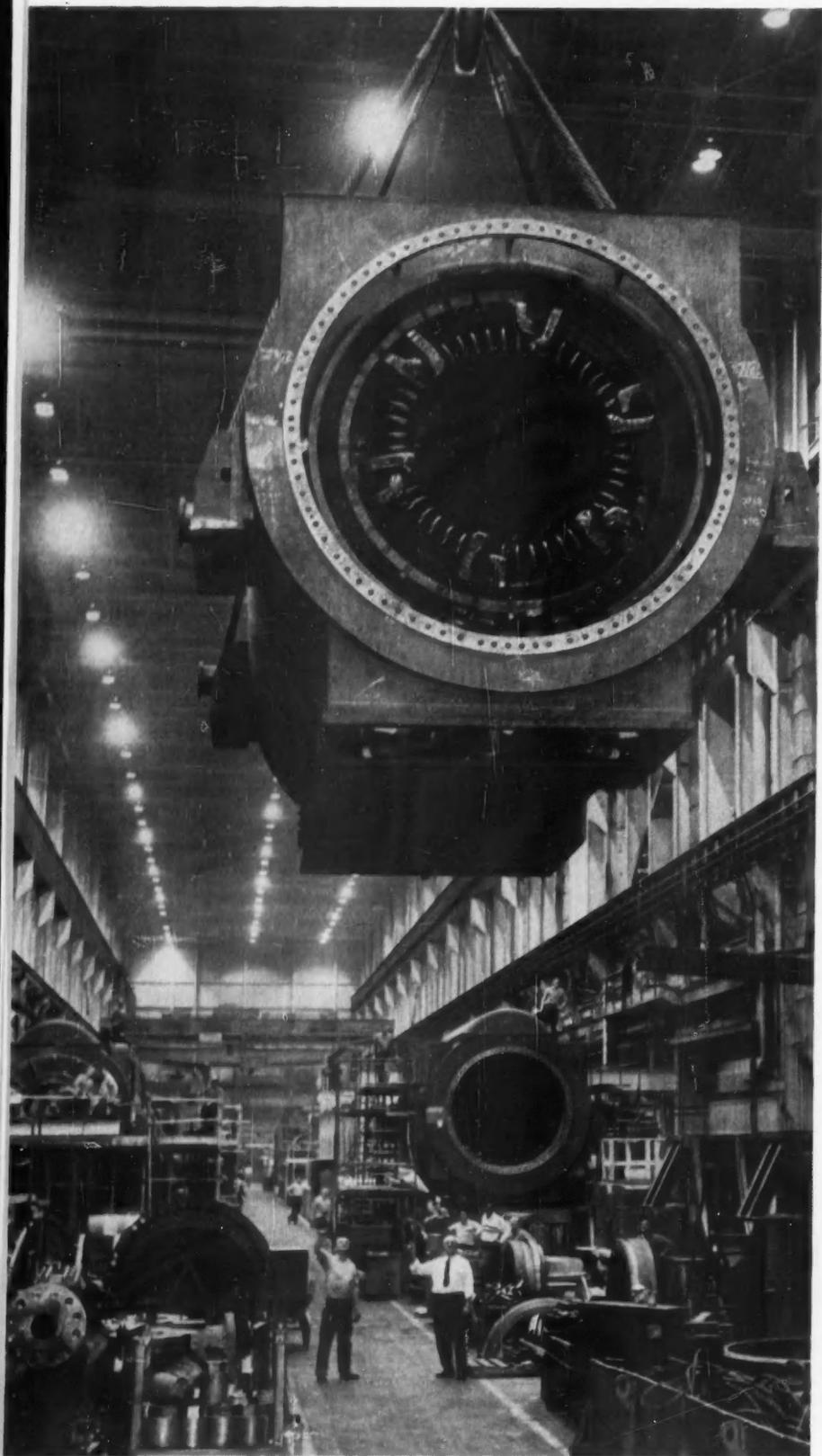
An automatic dispatching system developed for electric utilities determines the most desirable distribution of a power load among available sources of generation within a given electric power system. It also initiates the action to ensure this distribution. No manual adjustments for economic loading are required as the total system load changes throughout the day.

Turbines and Generators

During 1955, maximum steam pressures reached into the supercritical region, and ratings of large steam turbine-generators set new records.

The largest turbine-generator in the world was shipped to the Detroit Edison Company last September. Its rating is 260,000 kw with initial steam conditions of 2000 psi, 1050 F, and reheat to 1000 F. The turbine is of the cross-compound type with a 3600-rpm high-pressure element and an 1800-rpm double-flow low-pressure element. Similar steam conditions are specified for a 300,000-kw turbine to be delivered to the Consolidated Edison Co. in 1957.

The first commercial supercritical-pressure turbine now being readied for shipment is rated 125,000 kw with initial steam conditions of 4500 psi, 1150 F, and reheat at 1050 and 1000 F. Its reheat and low-pressure sections are conventional, but the 26,000-kw high-pressure section incorporates sev-



CONDUCTOR-COOLED GENERATOR ARMATURE HELPS TO INCREASE RATING TO 260,000 KVA.

eral novel features such as steam cooling, individual control-valve bodies, multiple steam pipes, and simple throttling control, all contributing to the reduction of the amount of high-alloy steel required. For example, steam cooling and heat shielding of the inner shells and rotor are employed for the first time by circulating cooling steam at 960 F around the nozzle boxes, through the packings at the high-pressure end, and between the inner shell and thin liners in the high-temperature regions.

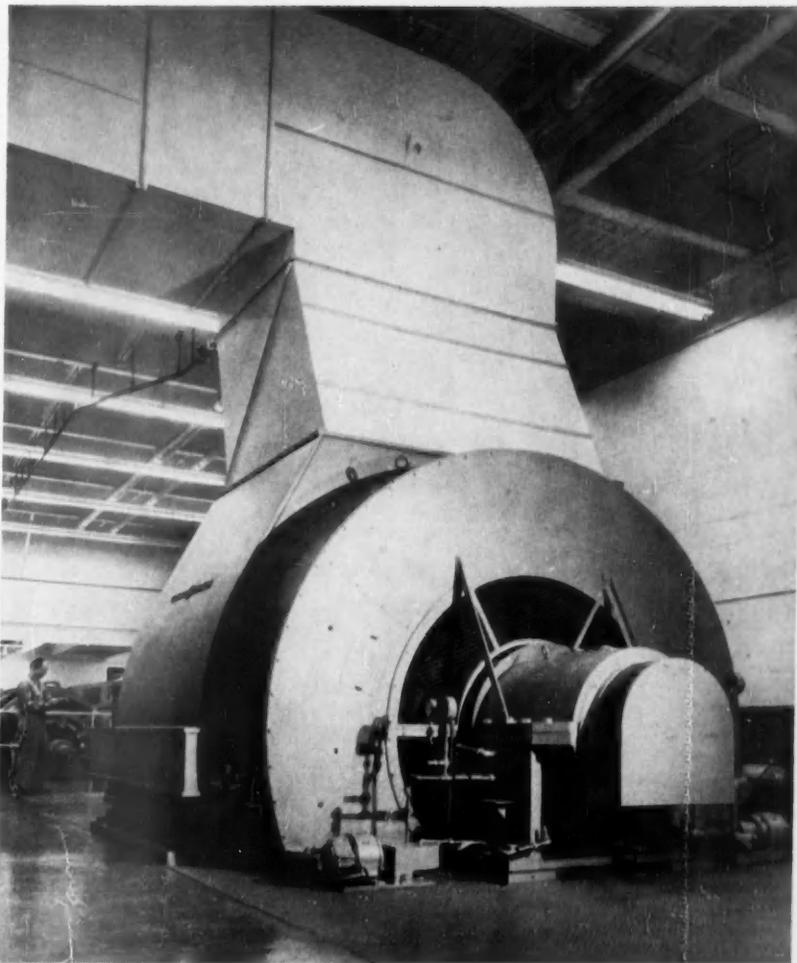
More processing plants are finding it economical to buy process steam from public utilities. Two 25,000-kw extraction turbines for the Tidewater Oil Company, Delaware, and two 225,000-kw extraction turbines for the Public Service Electric and Gas Company of New Jersey are designed for such reciprocal agreements. Public Service Company will furnish steam extracted from its turbines to a nearby refinery of the Esso Corporation and will in turn receive residual oil for fuel.

The Dow Chemical Company has on order a 40,000-kw extraction turbine-generator for its Freeport, Texas, plant that produces magnesium from sea water. Total steam flow of this double automatic extraction unit will be almost 1,000,000 pounds per hour. Each of its automatic extraction openings will deliver 400,000 pounds per hour. Initial steam conditions are 1250 psig and 950 F; extraction is at 475 and 235 psig.

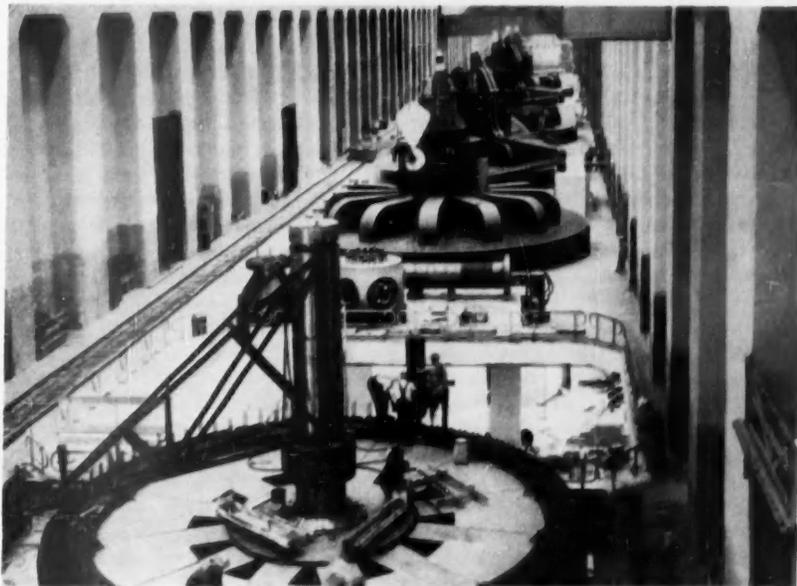
A new and longer bucket was used on a turbine delivered to the Commonwealth Edison Company. The new bucket provides a 25 percent larger annular area that permits increased turbine ratings without increasing exhaust losses. This bucket is intended for extensive use in turbines of 250,000 to 400,000 kw.

Phase changes that are responsible for lower ductility and strength in turbine-bucket alloy steels after long exposure to high temperatures were discovered by electron microscope and x-ray diffraction techniques. These findings make it possible to select or develop high-temperature steels in which such phase changes are less likely.

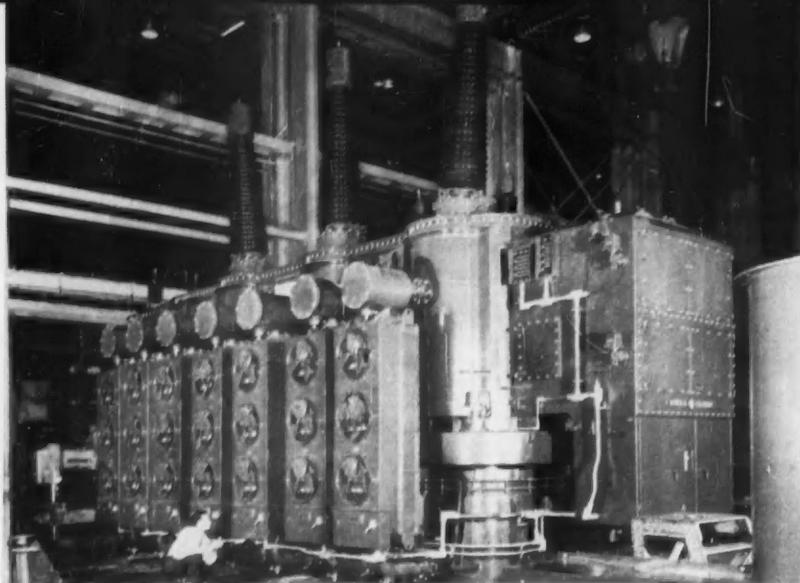
Vibration of turbine buckets received much attention in 1955. A gage was designed to measure vibration through changes in capacitance by sensing devices mounted on the periphery of the stator. Because the gage interferes very little with steam paths, it can be used in service on loaded operating turbines.



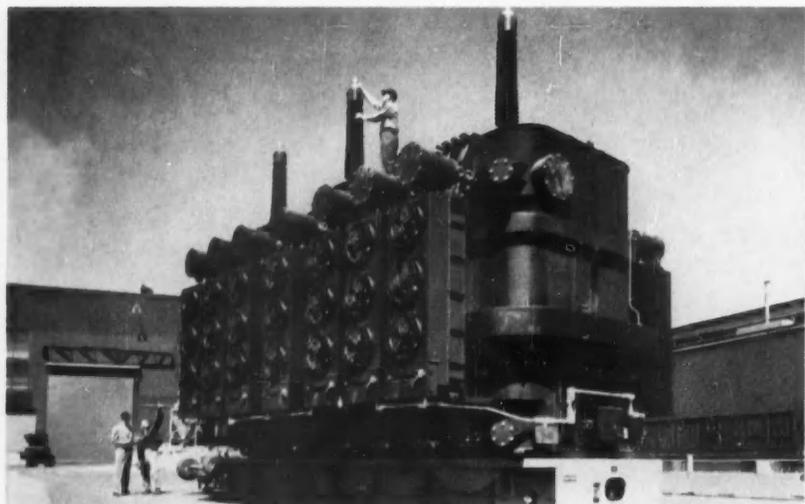
NEW TEST CENTER HAS VARIABLE-FREQUENCY POWER FOR MOTOR AND GENERATOR TESTS.



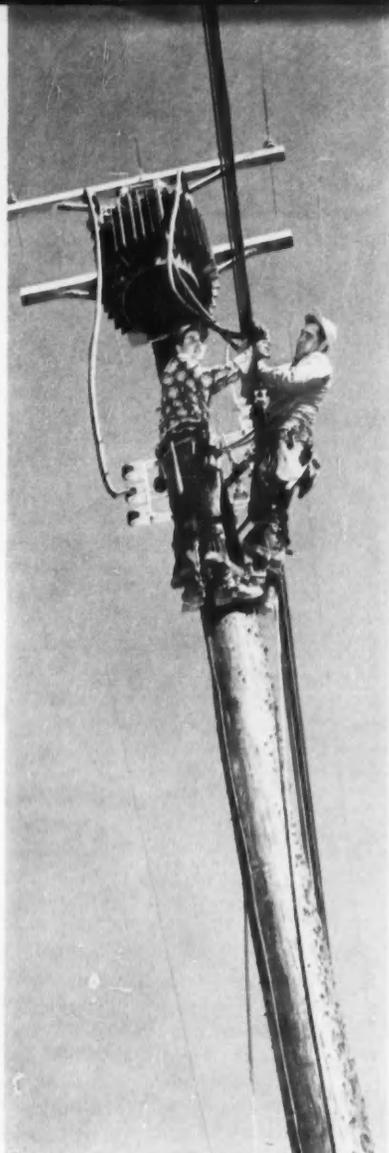
TWELVE 73,684-KVA HYDROGENERATORS FURNISH GENERATING CAPACITY FOR McNARY DAM.



TWO FOUR-WINDING 185,000-KVA AUTOTRANSFORMERS WEIGHING 260 TONS SET SIZE RECORD



EXTRA COOLING CAN RAISE RECORD TRANSFORMER RATING OF 300,000 KVA TO 315,000.



DISTRIBUTION TRANSFORMER SAVES SPACE.

A new vibration design technique was evolved especially for use in small ultra-high-speed turbine wheels and in small auxiliary and mechanical-drive turbines. It reduces probability of turbine-bucket failures by determining and confining exciting frequencies to so-called quiet zones.

Two new 3600-rpm turbine-generators of 156,000 and 260,000 kva employ novel cooling methods. The armature of the 156,000-kva generator is gas cooled; the armature of the 260,000-kva unit is liquid cooled.

A high-pressure centrifugal fan at the collector end of the gas-cooled generator circulates a small flow of hydrogen through rectangular stainless steel tubes inside each armature bar. An axial-flow fan at the coupling end

forces hydrogen through the ducts in the magnetic core and under the retaining rings to the ends of the field windings. This superior cooling makes possible a rating 50 percent higher than conventional machines of the same size.

Oil supplied by an external system of pumps and coolers is circulated through hollow strands that make up the armature bars of the liquid-cooled generator.

The conductor-cooled field windings of both generators are composed of channels forming passages that the cooling gas is circulated through. The gas enters at several locations on the length of the rotor and is discharged at other locations along the same length.

A new million-dollar test center for large rotating electric equipment was

dedicated in Schenectady during June, 1955, to provide facilities for making tests on the factory floor that are difficult or impossible after installation.

At the heart of the test center is a 60,000-kva synchronous generator that is driven by a variable-speed d-c motor to provide test power of any desired frequency. Essential switchgear, exciter sets, and a motor-generator set for d-c power are also located in the generator room. Machines are tested in the assembly area and supplied with test power through underground lines. The tests will supply data for accurately predicting performance under operating conditions. The new equipment permits testing hydrogenerators and synchronous condensers up to 70,000 kva. The first use of the new center was to test a

50,000-kva hydrogen-cooled synchronous condenser for the AEC. A 69,000-kva hydrogen generator will be the largest of its type ever completely assembled and tested in the factory.

Sixteen 60,000-kva hydrogen generators, the largest number ever sold in a single contract, will be installed on the U.S. side of the Barnhart Island Power House of the St. Lawrence Power Project. Work on the first unit will begin this year, with the last to be finished in 1959. Canadian General Electric Company will make eight similar generators for the Canadian side.

Eight hydrogen generators of 82,105 kva were ordered by the U.S. Army Corps of Engineers for the Dalles Dam in Oregon, downstream of McNary Dam on the Columbia River, where 12 73,684-kva generators will be installed by the end of this year.

During 1955, shipment of 14 50,000-kva hydrogen-cooled synchronous condensers to two locations of a single customer was completed. A significant size reduction was accomplished by relocating the starting motor between the surface gas coolers.

Gas Turbines

A 21,500-kw gas turbine operating at 3285 rpm and two 16,000-kw units for 3600-rpm operation, all of the simple-cycle single-shaft type, represent the largest units ever ordered in the United States. The general arrangement of components is conventional, the 15-stage axial-flow compressor being directly coupled to the two-stage turbine.

Between the compressor and turbine is the combustion section where individual combustion chambers—16 in the 16,000-kw units—are located. The 21,500-kw unit is geared to the generator, and either 50- or 60-cycle operation can be obtained by merely switching the pinion and bull gears. The 16,000-kw units are coupled directly to and the aft end of the turbine is supported by the generator, thus eliminating the gear and a main bearing.

Three 5000-kw gas turbines with an average gas-inlet temperature of 1500 F at the Rutland plant of Central Vermont Public Service Corp. now have a total of over 12,000 hours of operation on residual fuel oil. A new system of treatment is used to prepare the fuel; the oil ash is modified by removing sodium and calcium compounds from the fuel oil and by adding magnesium compounds to inhibit vanadium corrosion in the turbine.

Transformers

The largest transformers in physical size yet built by General Electric were shipped last year to the Sacramento Municipal Utilities District, Calif. Weighing 260 tons, these two 185,000-kva four-winding autotransformers will supply the city. They will step down voltage from 230 kv to 120 or 78 kv, with substantial overload capacity provided by forced oil cooling.

A shipment of two 300,000-kva 161-kv transformers set a G-E record for capacity. The units, shipped upright and in their own tanks, weighed 225 tons each. Additional cooling can raise the capacity to 315,000 kva.

The largest regulating transformer ever built, weighing 471,000 pounds, was shipped upright in its own tank, despite the extra weight of the side-by-side arrangement of its two core and coil assemblies.

Larger than any other in the United States is the forced-oil water-cooled transformer rated 275,000 kva and weighing 442,500 pounds. It will step up the generated voltage of 17,000 to 132,000 volts.

Load concentration in residential areas led to a demand for a light pole-mounted 167-kva distribution transformer. Better utilization of materials made the product 33 percent lighter, 15 percent shorter, and of 25 percent smaller plan area. Further improvements on other units in the line led to other reductions in height, a valuable contribution to reducing congestion on utility poles.

Suspension mounting was used to install a new network transformer designed in cooperation with the Consolidated Edison Company of New York. In the design, special attention was given to reducing height. The combined features allow a clear space of 8 to 10 inches over the floor, thereby facilitating floor cleaning and protecting the tank from corrosive sediment.

Vault-type transformers now have a vertical brace that also acts as a radiator header. Wing-like radiators welded to the header reduce the surfaces where dirt can collect and require fewer welds into the tank. Subway-type transformers have panel radiators with plain vertical radiators on which dirt cannot collect.

The design of two revolutionary 2000-kva 69-kv gas-insulated transformers for the Consolidated Edison Company of New York was completed, a single-phase prototype tested, and construction of the units themselves nearly

finished. To be placed in service this spring, these transformers will use sulfur hexafluoride gas as a coolant and insulator.

Forerunners of a projected line of transformers, two new germanium-rectifier power transformers have a secondary winding for very low voltage and high current and are intended for use with 65-volt 15,000-amp rectifiers.

Seven new ratings of feeder voltage regulators double the range of the line. The higher ratings have all the features of smaller regulators, including ± 10 percent regulation in 32 steps of five-eighths percent each.

For all generator currents and voltages, new current transformers having high relaying and metering accuracy were designed to keep abreast of advanced generator design. They are cast in low-shrinkage epoxy resin inside an aluminum housing with an integrally cast terminal box.

A standard line of current-limiting cast-in-concrete reactors with aluminum conductors was introduced in 1955. These reactors are available in ratings of 100 to 700 amp with resistance from 0.1 to 1.6 ohms for circuits of 4160, 7200, or 14,400 volts.

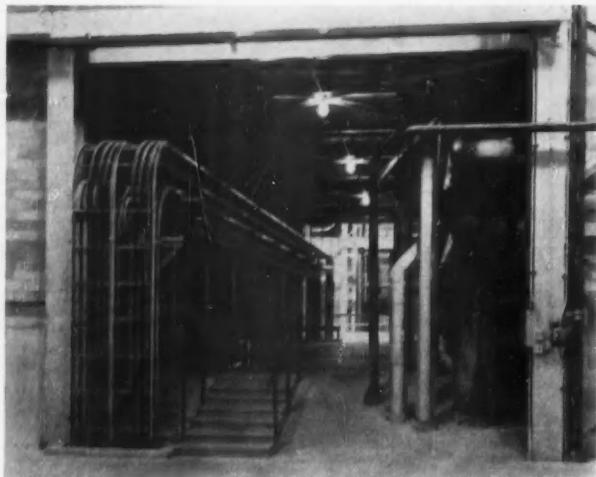
The Card Programmed Calculator (CPC) was expanded by a five-digit plug-board system that cuts in half the time needed for transformer design. The calculator analyzed transformer leakage-flux fields, aided proposition and requisition design of concrete reactors, and demonstrated that larger capacity mobile substations up to 10,000 kva can be built without exceeding highway restrictions.

Recent laboratory work contributed to understanding of transformer problems. An inexpensive, nonflammable fluid for testing leaks replaces more hazardous liquids. Welding repairs can now be made in the presence of the test fluid.

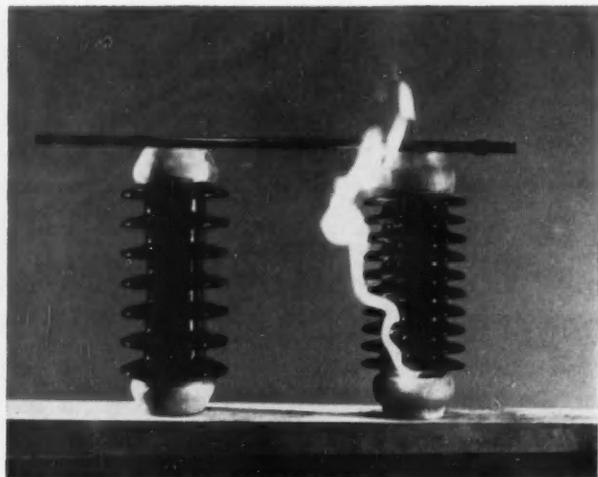
Effects of thermal aging on the shear modulus of thin sheet insulation were measured by a torsion pendulum. Such determinations are important in estimating the shear strength of insulation during short circuits. Impregnation and coating with silicone greatly improved the dielectric and mechanical strength, principally by increasing the moisture resistance. The new insulations are suitable for spot temperatures exceeding 200 C.

Switchgear

The increasing use of direct current in industrial processes has created a



VARNISHED-CAMBRIC INTERLOCKED ARMOR CABLE RESISTS CORROSION.



POST INSULATOR WITHSTANDS HIGH VOLTAGE IN DRY FLASHOVER TEST.

need for d-c circuit breakers and contactors built to more exacting standards. To provide testing facilities for d-c switching apparatus, two large motor-generator sets and the associated controls and instruments were placed in operation. The new installation can produce short-circuit currents as high as 100,000 amp at 700 volts, or 40,000 amp at 1400 volts.

Time-consuming and repetitious detail engineering and drafting of control switchboards for generating stations and substations were reduced by a method of standardizing basic circuit equipment. Reduced to pre-engineered components, 11 basic circuit equipments with provision for options can be rapidly assembled into the desired switchboard. This method shortens procurement time and provides the user with early and accurate knowledge of the requirements of floor space and conduit arrangement.

The lenticular-tank impulse-interrupter oil circuit breakers originally developed for 330- and 230-kv transmission lines are now available for 138- and 161-kv service with interrupting rating of 10,000 mva, a continuous rating of 1600 amp, and a three-cycle interrupting time.

A new outdoor oil circuit breaker—designed for use in rural and suburban circuits of 14.4 kv where interrupting requirements are less than 250 mva—interrupts in less than five cycles compared with eight for its predecessors. Faster breaking permits the use of smaller conductors and provides better coordination with branch fuses.

Normal switching of high-voltage circuits is aided by an attachment for standard 34.5- to 138-kv outdoor ver-

tical-break disconnecting switches that permits their use for interrupting rated load, transformer magnetizing, or line charging currents. The attachment, an auxiliary interrupting blade, bypasses the main contact at the beginning motion of the main contact. As the main contact moves on, it releases a spring that opens the auxiliary blade rapidly enough to ensure positive interruption of the current.

Usefulness of metal-clad switchgear was broadened by a 13.8-kv power circuit breaker that has an interrupting rating of 750 mva compared with a previous rating of 500 mva. The units, although higher and deeper, retain the 36-inch width.

Closing magnetic power circuit breakers of more than 100 mva achieved by a charged-spring mechanism makes the breaker independent of control power. The spring is automatically reset either by a small universal motor or by hand each time the breaker closes; it also closes the breaker with sufficient speed and force to ensure latching against even full-rated momentary current.

A new glass laminate possessing increased fire resistance and greater strength was introduced in metal-clad switchgear.

Maximum ratings for buses that carry power from generators to transformers were raised from 8000 to 10,000 amp without size increase. This was accomplished by a new design of isolated buses that forces a thermostatically controlled air supply through the enclosure to remove heat. The air circulates in a closed system of air-to-water heat exchanger; a filtered intake makes up leakage. Metal baffles deionize any gas that might be

ionized by a fault in the center phase before it reaches the outside phases. This prevents a ground-to-phase fault from developing into a phase-to-phase fault.

Capacitors

Tubular capacitors of tantalum foil designed for continuous operation in ambient temperatures of -55 to $+125$ C were introduced in 1955. Designed with axial leads, they incorporate an improved double-seal technique using polytetrafluoroethylene and synthetic rubber. The tubular capacitors, especially adapted to the assembly requirements of many applications, were made available in limited quantities.

The trend toward high-kilovar-rated power capacitor units continues. At mid-year, production began on a capacitor rated 25 kvar at voltages of 12,470 and 13,800. It is only 20 percent larger than the previous standard rating of 15 kvar at these voltages. More recently, a 50-kvar capacitor for 2400 to 7960 volts has been developed. The increased rating has created wide interest among utilities as a means of providing a more compact kilovar supply.

Cable

A solid dielectric cable insulated with silicone rubber was introduced for power circuits in wet or dry locations, either exposed or in a conduit. Withstanding high temperatures, the cable can operate as hot as 125 C at ratings up to 5000 volts. Ozone resistance of the cable's silicone insulation surpasses that of the best grade of rubber.

The continuing demand for larger interlocked armor cables, both indoor

and outdoor types, resulted in the installation of new production equipment that can produce such cables up to four inches in diameter. Other new equipment applies the corrosion-resistant jacket on large-sized cables. These cables, rated from 600 to 15,000 volts, were installed in corrosive atmospheres of paper and steel mills and chemical plants.

Aluminum as an impervious cable sheath found some applications on power and control cables. Lighter in weight and on a par with the latest high-temperature insulations, aluminum-sheathed cables can be installed in industrial plants with a minimum number of supports.

Arresters and Cutouts

Line-type lightning arresters introduced early last year provide a 20 percent lower discharge voltage than their predecessors. Additionally, they have 10 percent lower sparkover and handle lightning currents up to 100,000 amp. Their voltage range was expanded to include ratings from 3 through 121 kv. Of these ratings, the porcelain-top arresters rated 3 through 15 kv are particularly useful on small switchgear where space is limited.

A new open-dropout fuse was also introduced. Rated 15 kv at 100 amp and having a 4000-amp capacity, it supplements the previous model that has a 2000-amp interrupting capacity.

Insulators and Bushings

A new station post insulator, rated 7.5 to 69 kv, incorporates a number of new features, including an improved seal to prevent infiltration of moisture into the unit's inner cavity. Improved terminal hardware and wider spaced external corrugations allow more effective leakage distance and better natural cleaning action.

When loaded transversely, a new alumina composition has almost twice the mechanical strength of ordinary porcelain. Thermal shock resistance of the new composition is many times that of porcelain, while its electrical characteristics are approximately the same. The new material can be glazed to retard surface dirt accumulation.

Put into production during 1955 was a new high-voltage bushing for oil circuit breakers and for power, distribution, and instrument transformers. An oil-impregnated wrapped-paper core with printed-on stress equalizers provides more complete control of voltage dis-



GERMANIUM RECTIFIER DELIVERS 1950 KW OF DIRECT CURRENT AT 94 PERCENT EFFICIENCY.

tribution, thus increasing the bushing's radial dielectric strength. Void-free insulation in the new bushing eliminates radio noise.

New packaging methods for shipping huge, fragile high-voltage bushings utilize rubber shock mounts for support. Replacing highly flammable excelsior, the new mounts have greatly reduced shipping damage.

Rectifiers

Pumpless ignitron rectifiers for large aluminum pot lines mark a significant advance in the art of power rectifiers. Ordered during 1955 were 24 pumpless ignitron rectifiers, each rated 6000 amp at 750 volts, that will serve two new 72,000-amp pot lines. Rated 6667 amp at 650 volts, 18 more of the units will serve a single 120,000-amp pot line. Pumpless ignitron rectifiers are now widely used in general industrial, rolling mill, and electrochemical services.

Many advances were made in the application of germanium power rectifiers during the year. The largest single installation—1950 kw at 3000 amp and 650 volts d-c—was applied to a hydrogen-oxygen plant. It has an over-all efficiency of approximately 94 percent. Still larger installations, one rated 2730 kw at 42,000 amp, 65 volts d-c and another rated 5850 kw at 90,000 amp, 65 volts d-c, are on order.

A new line of selenium rectifier components, available in three cell types, was announced in 1955. Features include 63-volts peak inverse rating per cell, life expectancy of 80,000 hours, and 130 C ambient operation. New miniature designs were added to the line, as was a new type of stack design

embedded in a protective potting component for military application.

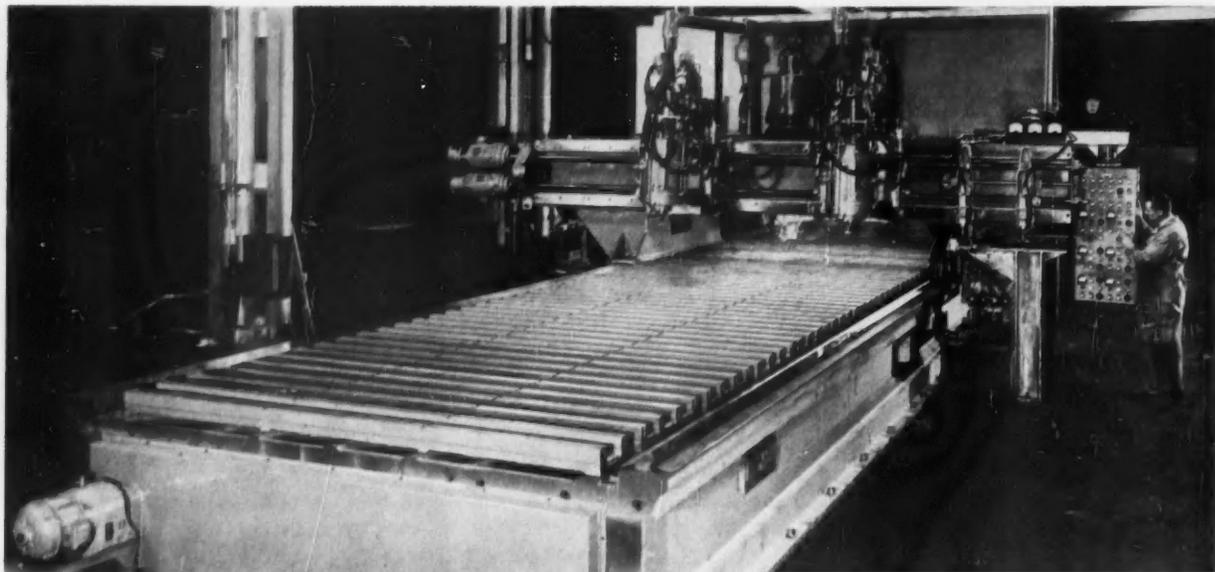
Distribution Systems and Busways

Developed in 1955, an electric power busway has reactance values 8 to 23 times those of conventional feeder busways. A distribution system with this high-reactance busway as the basic element provides an economical means of utilizing standard switchboards, control centers, panelboards, and other proved distribution components in installations having high short-circuit levels (200,000 amp). The system provides for the use of current-limiting fuses in combination with molded-case circuit breakers and other devices to raise the short-circuit ratings above those of the individual devices.

New plug-in busways, developed for applications requiring higher short-circuit rating than normally available in standard equipment, incorporate rugged porcelain-block insulators and can be used on systems with short-circuit levels up to 50,000-amp rms asymmetrical. Available in ratings from 400 to 1350 amp, it can be furnished with a 100 percent neutral.

Newly developed multipurpose switchboards use a minimum of floor area in industrial, commercial, and institutional applications. Their modular construction permits rapid additions or alterations. Two types of modular cubicles are interchangeable within standardized vertical sections.

A new service-entrance cubicle contains main service circuit breakers and mounting provisions for meters and current transformers in one compact enclosure.



TRACER CONTROL GUIDES A CONTOUR PROFILE MACHINE THAT ACCURATELY AND ECONOMICALLY MAKES DUPLICATE SPARS FOR B52 BOMBERS.

Industry

During 1955, American industry took several more giant strides toward higher operating speeds and more automatic controls.

In the field of metal working, for example, standard business-machine cards direct the movement of an 80-ton press as it punches holes in one-quarter-inch steel plate. Tracer control regulates a machine that turns out spars for a huge military aircraft. The steel industry—one of the protagonists of mechanization—has a cold reduction mill that produces finished tin plate at speeds in excess of 7000 fpm.

Motors

The prime mover of increasingly greater industrial productivity remains the electric motor.

In the field of d-c motors, a new insulation system was perfected after a long period of research and development, offering for the first time Class H insulation in a complete line of d-c armored motors. Silicone resin played a key role in making this insulation system practical. Used for field-coil impregnation and final dipping coats, the resin can be cured at low temperatures. Installed in an armored motor, the new Class H insulation system maintained excellent operating condition under

severe overloads that produced motor temperatures as high as 200 C.

During 1955 a line of fractional-horsepower motors was built for the tough jobs encountered by machine-tool builders and other heavy-duty industrial applications. The motors are designed to meet the strenuous requirements of frequent plugging and start-stop service.

Designed to drive machine-tool coolant pumps, a totally enclosed non-ventilated fractional-horsepower motor can be mounted vertically or horizontally. A snugly mounted dripcover provides easy cleaning and keeps the motors free of accumulated metal and dirt particles.

More than 20 electromagnetic pumps with capacities of 60 to 5000 gpm were supplied to atomic energy installations during the year. These pumps circulate the liquid-metal coolant through reactors, such as the Submarine Intermediate Reactor (SIR). Canned motors and motor pumps rated up to 1250 hp were also supplied.

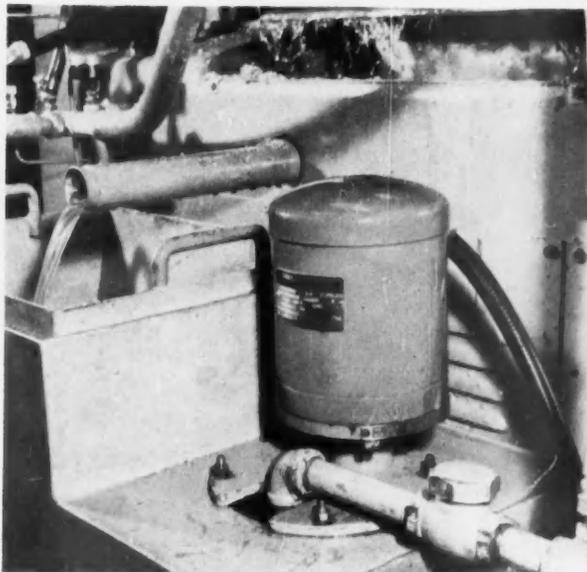
Forty synchronous motors each rated 4500 hp at 720 rpm will supply power for a pumping operation at an Atomic Energy Commission (AEC) installation. Each motor will drive a centrifugal pump with a flywheel and a speed-increasing device between the motor and

pump. An amortisseur winding permits full-voltage starting and acceleration of the motor and flywheel (90,000 hp-seconds).

To meet the rapidly growing needs for smaller oil-burner components, a "vest-pocket" motor rated 1/12 hp was designed and manufactured. The new motor, suitable for application in two out of every three small furnaces, weighs only about 9½ pounds and has the full starting torque of a standard 1/8-hp motor.

Other small component motors introduced during the year provided the consumer and industrial markets with a broader, more versatile range of products. In aircraft and electronics, for example, a new 1¼-inch-diameter motor capable of operating a number of tiny actuators has the same performance as motors up to one-quarter inch larger. More performance per pound can be supplied by a new four-pole specialty induction motor used for typewriters, calculators, and similar desk-top electric equipment. A reversible shaded-pole motor, 5½ inches in diameter, is also available for manufacturers of electrically reversible window fans.

Several new designs were added last year to the line of medium induction motors. These include a dripproof ver-



DRIPCOVERS PROTECT MOTORS FOR MACHINE-TOOL COOLANT PUMPS.



NEW MULTISHAFT GEAR-MOTORS OPERATE AUTOMATIC PIN SPOTTER.

tical motor with either hollow- or solid-shaft construction for use in irrigation pumping.

The most complete line of highly efficient fan motors ever developed for the air-conditioning industry was introduced during the year. Of the permanent split-capacitor type, they allow both room and central air-conditioning units to be rated 90 percent power factor or more when working in conjunction with improved compressor motors.

A recent air-over motor, mounted in a duct so that air passes over its shell, brought about an increase in ratings for totally enclosed motors. By increasing the air velocity, increased continuous power is obtained.

Automation of bowling alleys also increased last year with the advent of a $\frac{1}{3}$ -hp gear-motor to drive an automatic pin spotter. The gear-motor with its three shafts operating at 288, 75, and 48 rpm drives the bowling-ball lift and the tenpin distribution mechanism. Two double-shaft brake-equipped gear-motors operate the table and sweep-arm device.

Control

A new plant for motor starters, push buttons, limit switches, solenoids, and other general-purpose control items moved into full production during 1955 at Bloomington, Ill. Located on a 66-acre site, this plant occupies 382,571 square feet and presently employs 1500 people.

In Waynesboro, Va., another new plant began production of control equipment ranging from aircraft electric systems to complex programming systems for automatically controlling machine-tool operations. Covering an area of 190,000 square feet, it has more than 800 employees and an annual payroll of about \$3 $\frac{1}{2}$ million.

A new combination program timer eliminates the need for a separate sequence timer, undervoltage relay, and program timer in oil-well pumping starters equipped for automatic sequence restarting. The new timer provides undervoltage protection, timing of the pumping cycle, and automatic sequence restarting after power failure with restarting controlled by a momentary contact in the timer.

Mechanically held relays and contactors, designed to maintain continuity of sequencing in the event of power interruptions, were introduced during the year. Because these relays and contactors eliminate the need for continuously energizing the coil, they silently maintain a circuit. Multipole relays are available in 10-amp 600-volt maximum ratings.

A new vertical lift magnetic motor starter, designed for motors up to 100 hp, is 40 percent smaller than the previous model. The new starter with either vertical or horizontal mechanical interlocks is also available in reversing, multispeed, and combination forms.

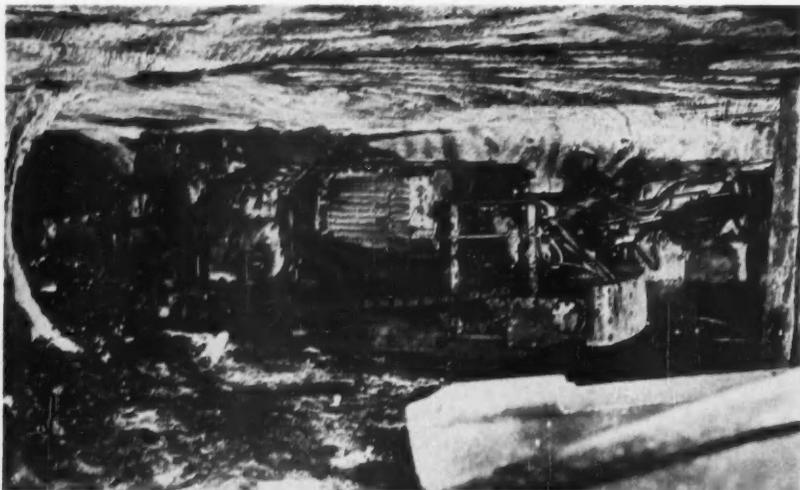
Through the use of new materials

and a novel method of frame-size designs, a new line of control transformers up to 40 percent smaller and lighter was introduced last September. The new transformers can be used for machine tools, general-service voltage applications, and general-control circuits. These units are available in a wide variety of voltage combinations within each frame size.

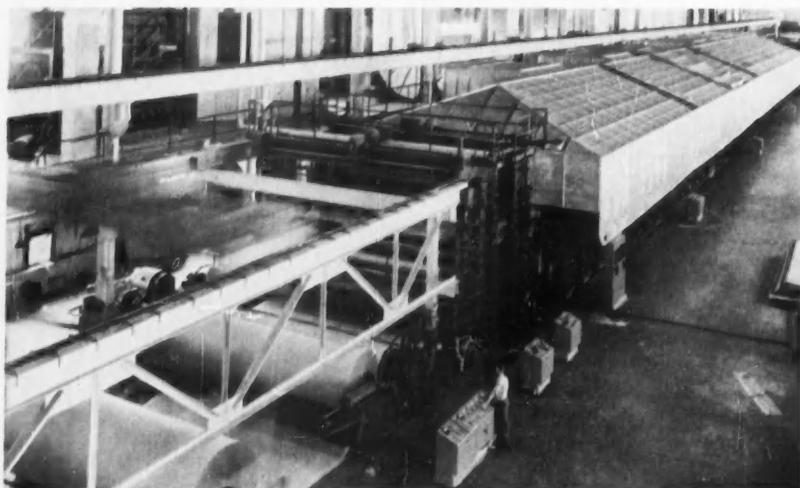
Full-wave electronic adjustable-speed drives with printed circuits and simplified control systems were introduced during the year—the initial entry of printed circuits into a motor-control system. Offering a wide speed range and close speed regulation, the new design comes in two ratings: $\frac{3}{4}$ to 1 hp and $1\frac{1}{2}$ to 3 hp.

High-voltage controllers, front-wired and front-assembled, were developed with a standard depth of 30 inches. Mounted back to back or against a wall, they conserve floor space. For ease of installation with a maximum of wiring space, the line contactor can be rolled out and the auxiliary panel swung out. The roll-out feature also facilitates inspection and repair.

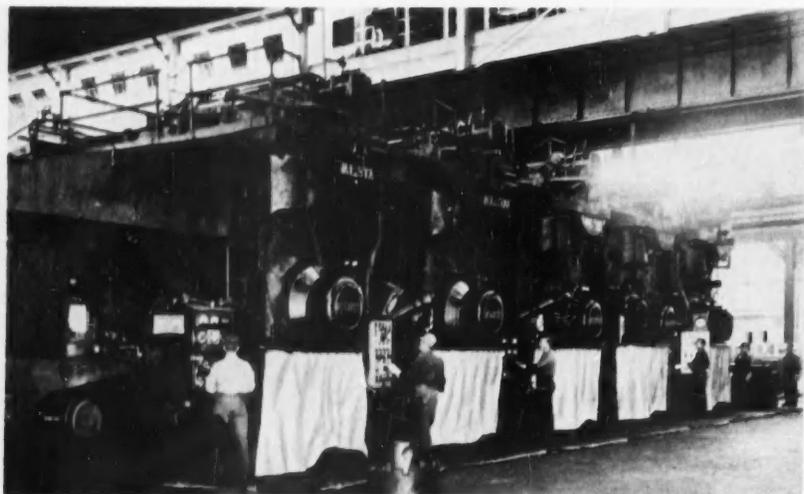
A new line of adjustable-voltage d-c dynamometer controls with amplidynes to excite the generator and dynamometer fields was evolved. Controlling the amplidyne fields are electronic pre-amplifiers. The control maintains armature current proportional to dynamometer speed or to the square of dynamometer speed.



COAL MINING APPROACHES AUTOMATION WITH 100-HP D-C CONTINUOUS MINING MACHINE.



PAPER-MAKING MACHINES HAVE GREATER POWER TO COPE WITH INCREASED PRODUCTION LOAD.



AUTOMATIC GAGE-CONTROL SYSTEM PERMITS IMPROVED ACCURACY IN ROLLING OF TIN PLATE.

Protective Breakers

For the first time, separate 480-volt a-c interrupting ratings were established for molded-case circuit breakers. The new interrupting capacities range from 15,000 amp for the 15- to 100-amp size (F-frame) to 35,000 amp for the 125- to 600-amp size (L-frame).

A higher a-c interrupting rating was also established in the 240-volt 125- to 600-amp circuit breaker (L-frame). The new interrupting rating is 50,000 amp—25 percent higher than the former a-c interrupting rating at this voltage. (Approximately 90 percent of the industrial uses for molded-case circuit breakers are on circuits 480 volts and below.)

Another molded-case circuit breaker (E-frame), in production for the first time, has a 100-amp continuous current rating for 120/240 or 240-volt a-c service and 125/250-volt d-c service.

A two-pole common-trip circuit breaker introduced in 1955 cuts off both sides of the line when a short occurs on one side. This line of breakers has both thermal and independent magnetic trip units.

New interchangeable raintight hubs simplify ordering, stocking, and installing safety switches and service-entrance devices. Installation simply involves selecting the desired size to match the conduit and then screwing the hub into the top of the raintight devices.

Simplicity of selection also highlighted the application of molded-case circuit breakers. New published material describes a simplified method for determining short-circuit currents in low-voltage systems. Based on NEMA procedures, this new method eliminates complex engineering calculations.

Industrial Heating

A new line of hermetically sealed heaters utilizing a brazed ceramic-to-metal seal will withstand terminal operating temperatures of 1000 F, severe thermal shock, and pressures to 2000 psi. The hermetic seals protect heater insulation and resistance wire from short-circuiting and wire oxidation.

Welding Products

Important savings in the manufacture of welded electric conduit were effected with a welding-current control developed in 1955. Measuring the thickness of metal to be welded, the control stores the information for a few seconds and then properly adjusts the welding temperature. Seam welded, the conduit is formed from a continuous strip of

steel. An electro-lytic gage measures thickness of the steel strip within an accuracy of one mil.

Carbon dioxide used in consumable-electrode gas-shielded welding of mild steel promises to reduce the cost of gas-shielding to one tenth that of inert gases. Bare electrodes fed at high speeds and high currents are used in the process. Carbon dioxide is especially suited for automatic welding; its visible arc makes possible full control of the weld quality.

Mining

In recent years, mechanization of the mining industry has reached the threshold of automation. For example, without previous drilling and blasting, the continuous coal-mining machine digs coal out of the solid face of a mine. Powering a recently designed machine of this type is a G-E explosion-proof motor, rated 100 hp, 1030 rpm, and 230 or 550 volts d-c. Already 43 of these special-purpose motors have been supplied for this application.

The increased mechanization of the coal-mining industry has created a need for larger power-distribution systems and voltages. During 1955, the first installation of a 15-kv distribution system was made in underground coal mines. Insulated with geoprene rubber, the primary supply cables for the system are the three-conductor mine-power type with ground wires.

Another development of 1955 was an automatic a-c motor drive and control system for mine hoists. Utilizing two motors, one with d-c dynamic braking, the system automatically accelerates, runs, slows down, and stops the hoist at the correct location.

Paper and Printing

Production developments in the paper industry during the past 10 years have required corresponding developments in electric equipment for paper mills. For example, in Finland a 2500-fpm newsprint machine has the world's largest single-motor line-shaft multiple-roll drive—a 2000-hp 1000-rpm d-c drive motor. In addition, more than 800 hp of regulated auxiliary d-c motors were needed to operate the huge machine. An electronic amplidyne speed-regulating system maintains machine-speed within one tenth of one percent.

On order for a paper mill in this country is a 40,000-kw turbine-generator set, the largest in the paper industry. Providing process steam as well

as power, the turbine will operate at a higher steam pressure and temperature—1450 psig at 1000 F—than any paper-mill turbine yet installed.

New drift-free a-c amplifiers combined with electronic speed-regulating systems have provided the paper industry with ultra-accurate speed-regulating systems. They were used with great success for paper-processing machines that operate through a wide range of speeds.

Six 6000-hp 240-rpm synchronous motors for driving pulp grinders in a paper mill are presently on order. Rated 13,200 volts, they are believed to be the largest motors of this voltage rating for such service in America.

In the field of printing, a new press to produce *Life* at speeds up to 2000 fpm will be powered by an electronic drive. Two 350-hp d-c motors powered by a 600-kw adjustable-voltage ignitron rectifier operate the huge press. Electronic drive is already installed in 56 different plants.

Steel

The steel industry is an outstanding example of mechanization. Higher speeds, greater production, and larger machinery require increased automation and greater precision in the automatic process control.

One of the most significant developments took place in the art of cold-rolling tin plate. A new tandem cold reduction mill is capable of finishing tin-plate gages in excess of 7000 fpm. Its five stands and winding reel are powered by a total of 28,000 hp—over 6000 more than any previous mill. The mill utilizes a completely new drive system, faster in response as well as more accurate and automatic than previous systems.

Supplementing another tin-plate mill's basic drive system is an automatic gage-control system that controls thicknesses to closer tolerances than previously possible. It is the first automatic system with a complete complement of auxiliary inspection and reset functions integrated with the over-all drive system. Free of vacuum tubes, the system was designed around transistors and magnetic-amplifier components.

Improvements in automatic control systems have also contributed to an increase in utilization of hot-strip finishing mills. Utilization has risen from about 50 to 90 percent.

On a hot-strip mill in the Midwest, load-ratio transformers are used with

pumpless rectifier unit substations for continuous operation down to 60 percent of rated d-c voltage and optimum power factor. A new amplistat regulator provides improved transient and steady-state voltage regulation.

The level of electrification of auxiliary drives also increased, resulting in improvements in flexibility of operation and reduction in down time and maintenance expense. The new Midwest hot-strip mill placed in operation last year is also the first to have complete adjustable-voltage table drives from the slabbing mill through the reversing roughing mill and the finishing mill to the strip coilers. Even more significant is the increased application of individual motors to each roll of the mill tables. Individual motors power each table from the reversing-mill approach table through the finishing-mill runout tables.

For the first time in this country, a reversing hot mill is being powered by a rectifier drive. Rated up to 500 kw, the drive has normal peak ratings for blooming-mill service. Experience gained from this application will probably extend the use of rectifier drives in metal-rolling and processing industries.

Having a sensitivity five times greater than the model it supersedes, a new pinhole detector for strip steel detects holes down to one mil diameter. It does this in opaque strips measuring 10 mils or less in thickness. The unit functions with maximum sensitivity at strip speeds up to 2000 fpm.

Furnished for a large tandem cold-strip mill was one of the longest and highest capacity motor-generator sets ever built for this application. Consisting of six 2000-kw generators driven by a 15,000-hp synchronous motor, the unit is almost 69 feet long and weighs 385,000 pounds.

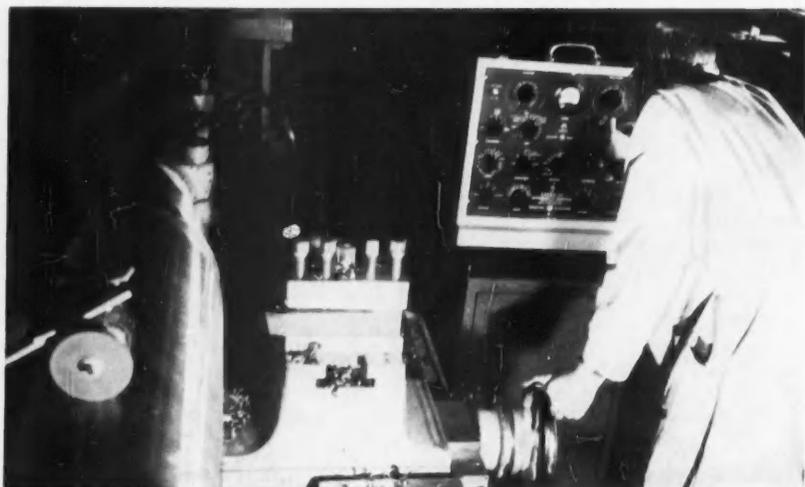
In an unusual example of design, a 2250-kw d-c generator furnished for a steel mill is used as a spare. It is required to operate in any of eight different locations in two different motor-generator sets. The unit must operate not only in parallel with either of two groups of generators having different ratings but also in either of two directions of rotation.

Metalworking Industries

Highlighting developments in the metalworking field is a contour machine that automatically produces integrally stiffened spars for B52 bombers. Tracer-control systems regulate the huge



STANDARD BUSINESS-MACHINE CARDS NOW DIRECT MOTIONS OF LARGE ROTARY TURRET PRESS.



MACHINABILITY COMPUTER SUBSTITUTES FOR RULE-OF-THUMB IN CALCULATING MACHINE SPEEDS.

machine. Six motions of the machine are controlled by six one-dimension units: two mechanical tracer and four selsyn tracer types. Duplicate spars for the high-flying B52 are turned out accurately and economically.

The first commercial application of the revolutionary record-playback control was demonstrated on an aircraft skin-milling machine. In a normal record-playback operation, a skilled machinist runs the machine manually or with tracer control to produce the first work piece. Translated into electric signals, these motions are then recorded on magnetic tape. Parts can then be duplicated by playing back the tape recording.

The year also saw the first production-line installations of numerical positioning control—a system whereby standard

business-machine cards automatically control many machine tools. Consisting of a control and a card reader, numerical positioning control operates through a system for command and pick-up elements directed by the punched cards. In service on a punch-press application, the new control allows, on the average, a hole to be punched once every three or four seconds—about triple the speed of a manually operated machine.

In two minutes a new machinability computer solves machining problems that normally take hours of computation. This self-powered analog unit correlates a vast amount of knowledge from the shops, with basic theories proved by research. The computer will consider 15 operational variables, including grade of carbide, speed, feed,

depth of cut, tool life, and work-material alloy and hardness.

A majority of large broaches used in automotive and jet-engine manufacture are now electrically driven. D-c drives that give smooth, fast reversal for a maximum number of cuts at high speed have brought about considerable savings in machining time. As a result, smaller broaches are being similarly equipped.

Automation of many press lines has also accelerated the use of adjustable-speed drives for air-operated friction-clutch flywheel presses. Many adjustable-speed drives up to 75 hp were furnished during the year.

Chemical Industries

During 1955, orders were received for two squirrel-cage induction motors rated 4000 and 2500 hp to drive centrifugal compressors in a new anhydrous-ammonia plant. Making fertilizers is the principal use for anhydrous ammonia. Reciprocating compressors at this same plant will also utilize about 9500 hp of synchronous motors.

Materials Handling

The old railroad bridge across New York City's Harlem River was replaced with a twin vertical lift bridge in 1955. For the first time on bridges of this type two independent power sources are used—one on each side of the river to raise and lower the spans. To keep them level during operation, a selsyn positioning system controls their adjustable-voltage amplidyne systems.

More than 100 adjustable-speed conveyors were installed during the year at GE's Appliance Park plant in Louisville, Ky. They are so controlled that production will be a given number of units per hour. Basically, the control consists of a small synchronous motor driving a reference control selsyn through an adjustable-ratio gear train. Another selsyn control is geared to the conveyor to feed back the actual conveyor speed. The operator sets the gear train for the desired number of units per hour, and the system produces them as accurately as an electric clock keeps time.

Textile Industry

A synchronous motor was developed for the textile industry in 1955. For the first time it provides small motors with the desirable electrical characteristics of large machines. Used for synthetic textile spinning, this motor is an improvement over previous reluctance-

type motors, because it requires only one fourth to one half the kilovolt-amperes for the same power. Substantial savings reflect back through the power system.

The clutch-brake loom motor, the culmination of five years' development work, contains a clutch, brake, and flywheel within the motor frame. It has fast, accurate braking; constant picking speed; reduced speed fluctuation; and lower maintenance cost. The clutch automatically disengages from the flywheel and rotor when a warped thread breaks, removing inertia; and the brake brings the loom to a quick, accurate stop.

The textile industry uses 14 percent of all industrial motors. Developed for this important segment of industry was a totally enclosed fan-cooled motor for operation in the lint-laden atmospheres of textile mills. Room air cools the motor as it goes through the large passages in the end shield made to prevent clogging with lint and continues along the exterior length of the motor's frame. For such atmospheres the new motor is expected to replace the screenless-type open textile motor.

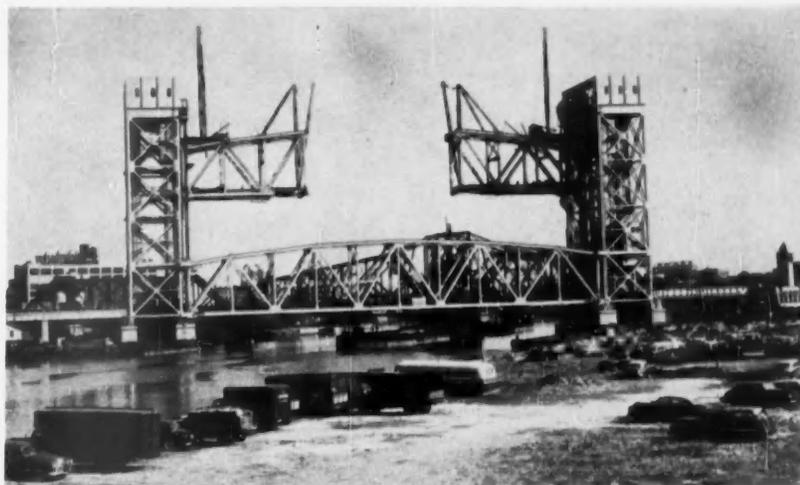
A new drive for machines that print colored designs on cloth utilizes an amplistat regulator. The complete drive includes an adjustable-speed power unit containing the motor-generator set to supply direct current to the individual motors and control panel. An operator can adjust cloth speed over a 3 to 1 range to obtain the best speed for a given set of operating conditions.

Industrial X Ray

An image amplification system promises daylight fluoroscopy without the need for either darkened rooms, dark-adapted eyes, or high x-ray intensities. This relatively simple system intensifies, enlarges, and relays the image to remote stations.

At 70 kw the brightness intensification factor is 10,000 times greater than with conventional fluoroscopy. From the x ray, this system directly produces a latent electric charge pattern on a photoconductive lead-oxide layer and displays the image on a conventional TV picture tube. Because the image is intensified electronically, the original x-ray intensity, and voltage can be decreased. This not only reduces hazard to patients but also minimizes the need for x-ray protection to industrial fluoroscopists.

Photofluorography, previously confined to the medical field and a few low-



SELSYN CONTROL MAINTAINS LEVEL OF INDEPENDENTLY POWERED TWIN LIFT-BRIDGE SPANS.



IMAGE OF INSPECTED PART APPEARS ON TV SCREEN FAR FROM SOURCE OF DANGEROUS X RAYS.

voltage industrial installations made a significant appearance on the industrial scene. A new technique involving million-volt x rays and a new mirror-type 70-mm photofluorographic camera was developed in conjunction with the Naval Ordnance Laboratory. It brings to the industrial field a fast, economical method of inspecting radiographic procedures and permits the inspection of items having thicknesses above the range of normal fluoroscopy.

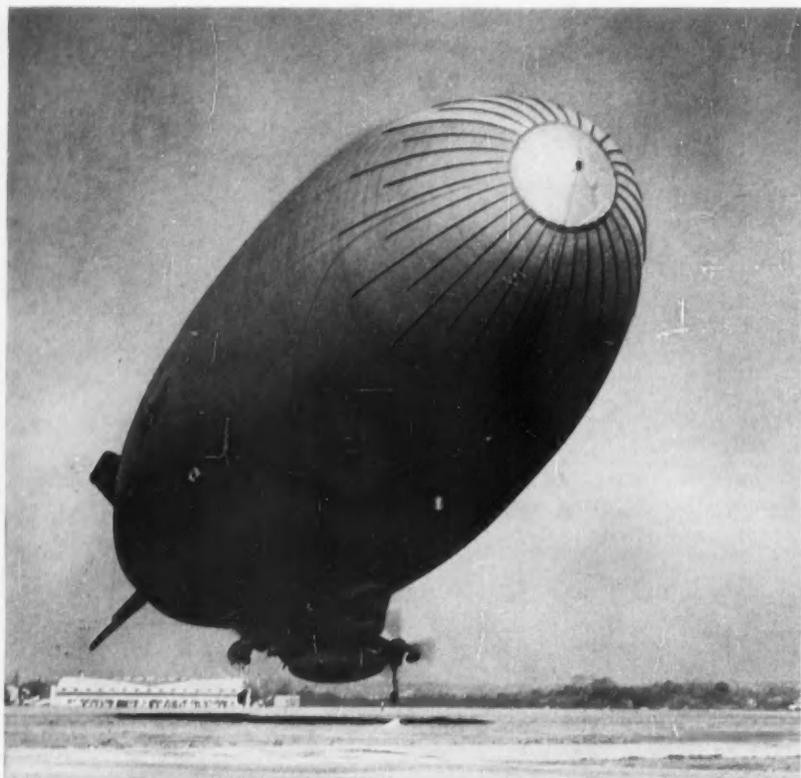
Fluorescent screens have increased the range of voltages for industrial fluoroscopy to one- and two-million electron volts. Improved photofluorographic cameras, designed to use mirror optical systems, enhance the quality of the picture by registering contrast and details necessary in industrial inspection. Recording the results on 70-mm

film also reduces cost of materials and processing equipment.

Cable

Bus-drop cable insulated with polyvinyl chloride and used in industrial plant applications was listed by the Underwriters' Laboratories, Inc. It is the first cable with a thermoplastic insulation ever used as a bus drop. Such cables provide a flexible, easily installed wiring system for supplying power to machine tools from an overhead plug-type distribution bus.

Silicone nonleaded heating cable developed in 1955 dissipates 67 percent more heat than conventional cables at the same surface temperature. Additionally, the silicone insulation has twice the moisture resistance of high-grade rubber insulation.



NEW LINK IN RADAR NETWORK, NAVY PICKET BLIMP CARRIES HIGH-POWER SEARCH RADAR.

Electronics

Television broadcasting in 1955 moved toward the highest transmitting powers permitted by the Federal Communications Commission (FCC). High transmitting power insures the clearest pictures to the greatest number of viewers in a TV area. Accordingly, many transmitting equipments of higher power outputs were pioneered during the year.

Television Broadcasting

One development in high-powered TV broadcast equipment is a high-channel transmitter with a power output of 10 kw. Utilizing improved tubes and circuitry, this transmitter is designed to meet the exacting requirements of color TV. When operated to drive two 50-kw amplifiers in parallel, the system provides TV broadcasters with 100 kw of power.

Ultrahigh-frequency TV broadcasting equipment costing a half-million dollars will make WGBI-TV of Scranton, Pa., the world's most powerful TV station. The equipment will increase the station's

present effective radiated power of 250,000 watts to two million. The 45-kw transmitter combined with a 50-gain helical antenna will produce the power.

Serving over a million people in the Scranton-Wilkes-Barre-Hazleton area, the station will begin operating with the new equipment early next spring. Associate TV stations at Williamsport and Sunbury, Pa., will pick up the two-million-watt signal and rebroadcast it locally.

Exactly one year ago, ultrahigh-frequency (UHF) television transmissions of one-million-watts effective radiated power were inaugurated by WILK-TV in Wilkes-Barre, Pa. The station utilizes a 45-kw UHF transmitter, the most powerful ever built.

When broadcasting is centered in one building, television antennas placed end to end on the same tower require twice their normal over-all height. To offset this disadvantage, two antennas can be interlaced. Helical antennas, interlaced for experimental purposes, give good

radiation patterns and are practically unaffected by one another. No additional filters are needed at the transmitters.

Symbolizing progress in the television industry is GE's 14-inch portable TV set. Using 13 tubes, the set weighs only 32 pounds. Five years ago, a TV set with a 14-inch screen required 22 tubes and weighed more than 100 pounds.

Automatic TV Operation

Early in 1955, automatic operation of a TV station for smaller communities was demonstrated with a color film and slide center. The center consists of two movie projectors and a slide projector; a tape recorder supplies audio programming. Presently, development is aimed toward an economical punched paper tape for the control function.

A simple automatic gain-control amplifier was designed to hold constant the outputs of networks, microphones, and turntables. Additionally, it has many other uses—in public-address systems and communication facilities, for example. Recording studios report that this simple automatic amplifier fills most of their needs.

Convertible to color, a low-cost version of the color-film scanner for monochrome TV was developed in 1955. Cost reductions were also made in substantially improved color-TV studio equipment. A color-film scanner with a continuous projector, introduced two years ago, was proved superior to other systems.

Besides these cost reductions in 1955, the space required for many d-c power supplies used in typical TV stations was reduced 50 percent, as was heat radiated from the units. Germanium rectifiers increased efficiency of the units.

Industrial Television

To meet the demand for television equipment in industry, a high-quality TV-camera channel with a vidicon camera tube was developed. It consists of a camera monitor and control units. A complete line of accessories includes remotely controlled pan-and-tilt head, lens iris, optical focus, and electronic view finder. For application in severe atmospheres, explosion-proof enclosures and housing are also available.

Another development is a prototype facsimile recorder that utilizes a high-grade direct-recording electrolytic-type paper. Frequency drift of the recorder's oscillator over a period of two years is less than 11 parts per million. The recorder can operate unattended.



HELICAL ANTENNAS, interlaced for experiment, give good radiation patterns.



PORTABLE 14-INCH TV, symbolizing TV progress, uses 13 tubes and weighs 32 pounds. Five years ago, a 14-inch screen required 22 tubes and weighed more than 100 pounds.

Radio Receivers

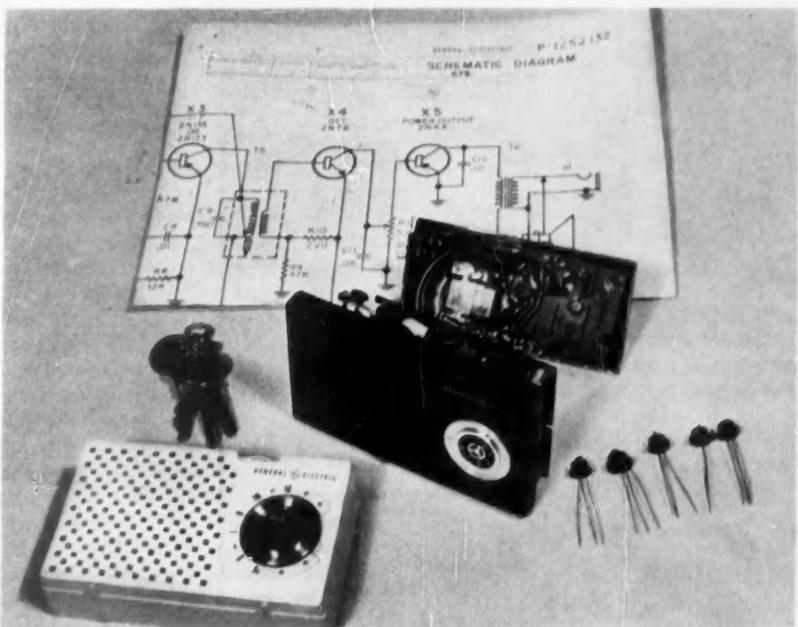
The 1955 design award of the Industrial Designers' Institute went to a G-E clock and portable radio. Built in separable units, it can be operated as an alarm clock and battery-operated portable radio; together, it is a power-line-operated clock-radio. A simple switch at the back of the set locks the units together and transfers the radio power source from line to battery.

A pocket-sized portable radio utilizing transistors instead of vacuum tubes was introduced early in the year. Built around a five-transistor printed-circuit chassis, the radio has unusual sensitivity and power output. A special circuit arrangement extends battery life; the power dissipation in its output stage decreases with decreasing volume setting.

Hi Fi

New high-fidelity components include a 20-watt amplifier engineered around a dual chassis. It can be used as a single cabinet-enclosed unit or as two separately installed units. Seven control knobs are located on the panel of the new amplifier. One of these, the selector, has eight positions: five compensate for variations in record characteristics, one is for radio, and two are for television and a tape recorder.

Earlier in the year, styli in the variable reluctance cartridge were made individually replaceable. The new design also allows hi-fi fans greater flexibility in



POCKET-SIZED PORTABLE RADIO, utilizing transistors instead of vacuum tubes, has unusual sensitivity and power output. A special circuit arrangement extends battery life.

selecting the styli combination best suited to their record collections.

Electronic Tubes

A microminiature receiving tube for UHF-TV, less than one-half inch long and about five-sixteenths inch in diameter, allows the design of UHF tuners that incorporate a stage of r-f ampli-

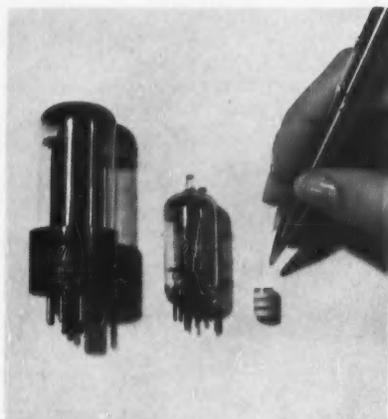
fication. Made of metal and ceramics, the tube has a noise factor of approximately 8.5 decibels at 900 megacycles. It has a power gain of about 15 decibels at this frequency with a band width of approximately 10 megacycles. Development of the new tube followed several years of fundamental work by G-E research scientists.



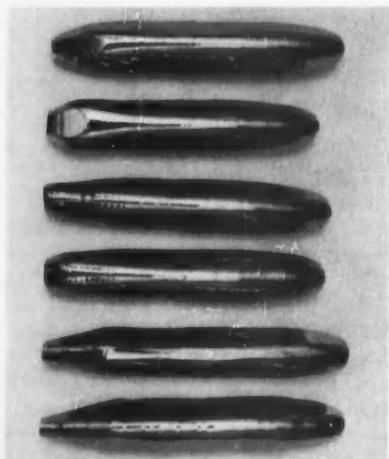
TRANSISTOR micropower audio-frequency amplifier can operate for three years.



METAL-AND-CERAMIC high-frequency tube of the lighthouse line can deliver two kilowatts of peak power at 3500 megacycles and can be pulse-operated up to 4000 megacycles.



MICROMINIATURE RECEIVING TUBE climaxed several years of fundamental research.



SEMICONDUCTOR FURNACE of most recent design grows single-crystal germanium.

Also introduced during the year was a specialized series of tubes for mobile communications equipment. They are designed for applications involving excessive on-off cycling and extreme variations in supply voltage.

New multisection tubes provide the TV circuit designer with another degree of freedom in laying out simplified, compact receivers. Several of the new tubes contain a triode and a pentode as electrically independent sections in the same envelope. Another type is a twin pentode with separate suppressor grids and plates.

Additional types were added to the line of tubes designed for use in 600-ma series-string receivers. All tubes in this series have a uniform heater warm-up characteristic that minimizes voltage surges during the receiver's warm-up period. Thus economies in set manufacture can be achieved without sacrifice in heater reliability.

Two new types were added to the series of tubes for computer application. These tubes are an outgrowth of a specialized design for military and commercial airline use. Many have been in operation for more than 15,000 hours. One computer manufacturer with more than a million of these tubes in use reported a failure rate of only about 0.2 percent per 1000 hours.

A new addition to the lighthouse line of high-frequency tubes is less than three inches long. It can deliver two kilowatts of peak power at 3500 megacycles and can be pulse-operated up to 4000 megacycles. Shock-tested to 300

Gs, the tube, of metal-and-ceramic construction, can withstand envelope temperatures up to 175 C.

Production of the first in a line of G-E television camera tubes began in 1955. Known as image orthicons, they require more than 250 separate parts in their complex assembly. All manufacturing operations are conducted in an air-conditioned and air-filtered plant.

During 1955, progress continued in development of a three-gun picture tube for color TV. The tube is known as a post-acceleration type, because electron beams, directed at vertical color-phosphor strips inside the face, are accelerated after passing through a grille located close to the phosphor screen. Development models of the tube exhibit a higher degree of brightness than other color-TV tubes available.

Utilizing a new non-ion-trap gun, a 21-inch cathode-ray tube does away with the need for an external ion-trap magnet. The straight low-focus-voltage electrostatic-focus gun requires no tilting to compensate for beam displacement produced by ion-trapping fields. It is available with deflection angles of 90, 72, and 70 degrees.

High degree of resolution is provided by a new single-layer type of phosphor developed for cathode-ray tubes. A single-layer phosphor is only 2 mils thick compared with 10 mils for the conventional double-layer phosphor.

Cathode-ray tubes for black-and-white TV continued their trend toward 21-inch tube size with aluminized screen, electrostatic-focus gun, and 90-degree deflec-

tion angle. Improvements in the electrostatic-focus ion-trap gun provide equal or better performance over tubes using magnetic-focus guns.

In the field of power tubes, three new gaseous-discharge devices that are pencil-like in appearance were introduced during the year. They can replace switching tubes of older design where higher power levels are required. The new tubes are used for polarization or branching-type duplexers in radar systems.

The frequency range of 960 to 1215 megacycles is covered by a new three-resonator tunable klystron tube with a peak power output of 22 kw. Forced-air-cooled, the tube features mechanically tuned integral resonators.

Semiconductors

Major advances took place in the field of semiconductor devices during 1955.

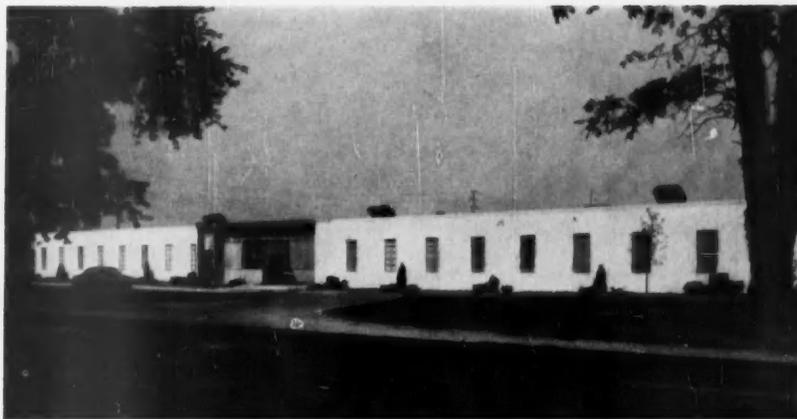
A silicon high-frequency transistor operates up to six megacycles in ambient temperatures as high as 120 C. Thin-base regions of the transistor yield collector-to-base current gains of 10 to 50 times, with high-frequency power gains as great as 15 decibels.

Another development is a silicon double-base diode. Basically, it operates as a microsecond switch that has a regenerative switching action between its two stable points. It can also be used as the prime element in multivibrators, counters, oscilloscopes, phase or amplitude detectors, regenerative pulse amplifiers, and sawtooth generators.

Developed from the rate-grown transistor was a new line of germanium high-frequency n-p-n transistors that will replace many vacuum-tube functions. The use of these units will result in higher efficiency, lower maintenance costs, and smaller size. Included in this new rate-grown family is a commercially available triode, plus a developmental triode and tetrode. All units were designed to meet rigorous military testing and standards.

The p-n-p high-frequency transistor extends the useful operating frequency range of the alloy junction-type transistor to the home-broadcast band. Useful gains at radio frequencies are attained by reducing the germanium pellet thickness, indium dot size, and base resistance path of the low-frequency series.

A transistor d-c to d-c converter, used to obtain medium- and high-voltage direct current from a low-voltage d-c source, was developed during the year. Characterized by long life, small size,



SYSTEMS CENTER FOR HEAVY MILITARY ELECTRONICS EQUIPMENT WAS DEDICATED AT SYRACUSE.



MICROWAVE LABORATORY IS ENGAGED IN APPLIED RESEARCH AND ADVANCED ENGINEERING.

and superior efficiency, it is capable of high power output and is relatively insensitive to shock.

Developed also was a transistor d-c to three-phase a-c inverter to take over the switching function on airborne d-c motors, formerly done with brushes and commutators. Low-voltage direct current supplied to the inverter is converted to three-phase alternating current.

A transistor micropower audio-frequency amplifier with a self-contained power supply of 1.5 volts was introduced in 1955. Power requirements are so small that it can operate continuously for three years. Frequency response of the amplifier is flat within ± 3 decibels from 20 to 20,000 cycles, and it has a power gain of 5000. Temperature range of operation is from -25 to $+75$ C.

Developed for the Air Force, a 50-amp silicon rectifier will be available commercially late this year. Small in size, the rectifier has a peak inverse rating of 200 volts.

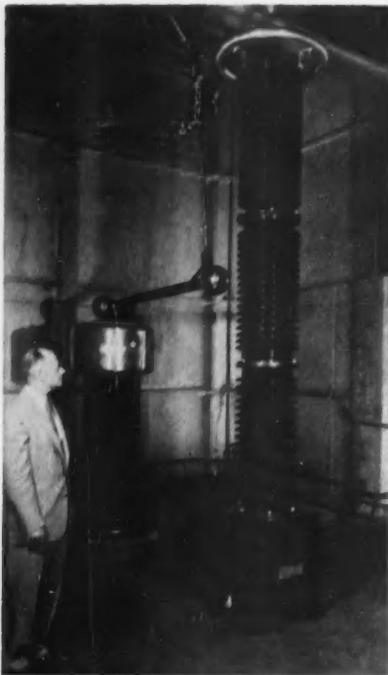
Based on transistor feedback princi-

ples, a standard amplifier was developed that is utilized 33 times in an airborne navigation system. By merely changing external networks, it can be used as a resolver driver, computing element, or mixing amplifier.

Transistorized instrumentation and control circuits developed for the Submarine Intermediate Reactor (SIR) include a log amplifier, derivative amplifier, and d-c amplifiers. These components compute reactor power level and power changes and trip the safety rods that govern the reactor's operation.

Significant strides were also made during the year in refining, purifying, and growing single-crystal silicon and germanium.

The latest furnace designs remove the human element from the growth cycle of single-crystal germanium after the splice is established between the seed stock and the molten germanium. Similarly, rate-grown germanium can be reproduced well, both mechanically and electrically.



COUPLING CAPACITORS of high capacitance were put into production during the year.

Large quantities of hyperpure needle-form silicon were processed during the year. Single-crystal material was generated having lifetimes in excess of one millisecond.

Thin filaments of semiconductor material are melted back in a new process to generate high-frequency high-gain transistor material. Highly reproducible transistor bars, generated in both silicon and germanium, yield higher frequency-response and higher gain devices.

A typical semiconductor pilot production line now produces 720 transistor assemblies of the rate-grown type per hour.

An inexpensive transistor, distributed at a cost below two dollars, was designed for radio amateurs, hobbyists, and experimenters. Types include i-f and r-f p-n-p transistors made by the fused-junction process, as well as r-f n-p-n transistors made by the new melt-back process.

Military Electronics

Automatic assembly of components and more functional requirements per unit volume of equipment distinguished the field of light military electronics in 1955.

The design of tube sockets developed for printed wiring boards is based on a standard incremental pattern so that socket holes can be punched with an

automatic programmed punching machine. Narrow enough for components to straddle them, tube sockets have indexing locations for automatic placement.

Multiple-layer printed wiring boards, consisting of stacked conventional printed boards separated by thin layers of insulation, solved the problem of getting more conductors on a board. After four months in a cycling oven, the new boards show no sign of failure.

An electronic control circuit, designed to withstand 25 Gs of vibration, operates up to 400 F. Part of the circuit is a magnetic amplifier incorporating four toroidal stacked cores.

Constructed during the year was a subminiature capacitor that is variable between 0.8 and 13.5 micro-microfarads. It occupies space three-eighths inch in diameter and one-eighth inch high.

The application of a transfer servo-valve, actuator, and electronic servo-amplifier in a closed-loop positioning system provides remote tuning and sweeping of magnetron frequency according to a wide variety and combination of input functions. Using a 400-cycle carrier frequency in the servo-amplifier avoids the inherent instability problems of d-c amplifiers.

Highly specialized electronic equipment, part of a system of controlling and coordinating fighter intercept missions from an airborne combat information center, was supplied the Navy during 1955. Previously done from land- or ship-based radar stations, this is a new concept in aerial defense.

Extremely high-power airborne search radars were supplied for the Navy's new ZPG-2W radar picket blimps. It is the most powerful airborne search radar yet developed, about equal that of heavy land-based search radars. Printed wiring extensively used in the new equipment reduces weight.

During 1955 a systems center for heavy military electronics equipment was dedicated at Syracuse, NY. The new building contains 100,000 square feet of floor space. Major programs of heavy military electronics are in the fields of air defense, ground warfare, communications, antisubmarine operations, strategic air operations, missile control, radiation instrumentation, air navigation, and traffic control.

Magnetic Circuits

Two new magnetic circuits were developed during 1955. One is a magnetic voltage reference based on the satura-

tion flux density of core materials exhibiting a rectangular hysteresis loop. It is magnetically compensated against temperature variations and includes a frequency-compensating network. The circuit is superior to permanent-magnet, gas-tube, and other conventional references.

The second circuit is a magnetic amplifier, essentially a d-c controlled ferroresonant a-c voltage source. Insensitive to changes in source voltage and frequency or load current, the circuit is used as a regulator in d-c power supplies.

Microwave

Shipped during the year were the first "Quadriphase" microwave relay stations. A new concept in time-division multiplexing, they provide 25 communication channels for telephone, telemetering, supervisory control, and many other services.

Space requirements for microwave equipment were substantially reduced. For example, a 25-channel Quadriphase terminal station now needs less than half the floor space of previous equipment with essentially the same function.

Similarly, a one-third reduction in vacuum tubes has improved the reliability of microwave stations. Vacuum tubes were completely eliminated from power supplies by using the long-lived industrial selenium rectifier.

New high-speed switching systems at the receiver output provide better service for high-speed teletype, power-line relaying, and similar functions.

Improvement in the microwave radio-frequency system has made it possible to supply the same transmitter and receiver to users in both government and commercial frequency bands. With increased transmitter output and receiver sensitivity, the spans between microwave stations can be either lengthened or shortened.

GE's Microwave Laboratory at Stanford University is engaged in a comprehensive program of applied research and advanced engineering. Engineers at the laboratory have already completed a development program leading to a broad-band 100-watt continuous-traveling-wave tube, the most powerful of its type yet achieved.

The new Microwave Laboratory also completed a series of studies on new methods of focusing long electron beams, such as those encountered in traveling-wave tubes. Applications of

the findings will mean significant improvement for microwave equipments where packaging and weight are factors.

Another development is a four-cavity reduction klystron cascade amplifier that operates on a pulsed basis. It supplies output power exceeding 15 kw over a frequency range of approximately 15 percent. Power gains in excess of 60 decibels are obtained. The gang tuner permits simultaneous tuning of the four cavities by a single master control knob.

About 10,000 square feet of floor space was added to the Microwave Laboratory at Stanford, and the number of employees has doubled since operation began in 1954. Rapid advances in the application of microwave electron tubes and new microwave techniques in communications and radar are responsible for the expansion.

Carrier Current

For power-line protective relaying, a transmitter-receiver unit is equipped with quartz-crystal frequency control. Maximum possible selectivity consistent with the required speed of operation permits a power system to carry more communication channels without mutual interference in the range of 30 to 200 kc.

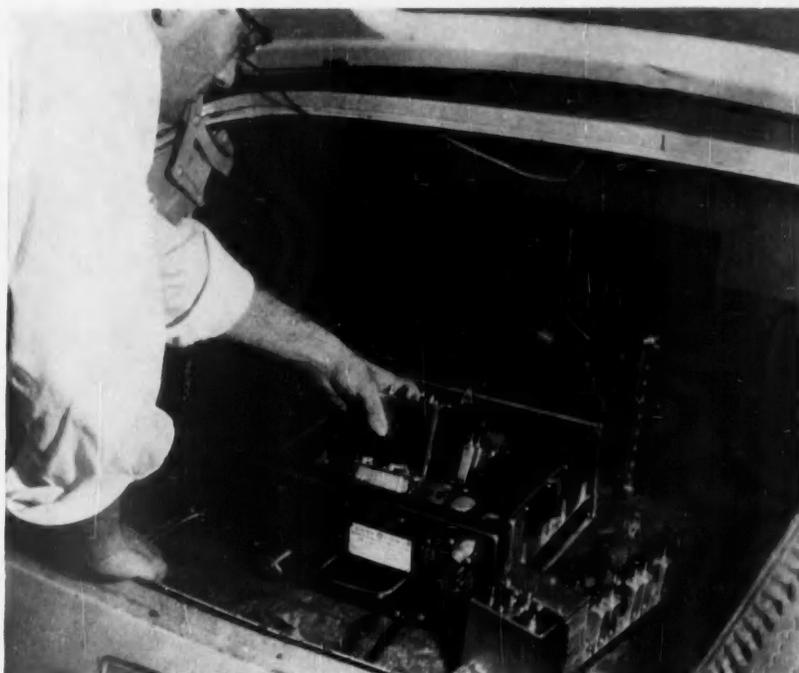
High-capacitance coupling capacitors were put in production last year. They connect standard carrier-current transmitters and receivers to high-voltage power lines with lower coupling losses. Broad-band coupling networks can be used to simplify the simultaneous transmission of several carrier frequencies.

Mobile Radio

Two entirely new lines of two-way radio communication equipment were supplied for mobile installations in the new 25- to 54- and 144- to 174-megacycle bands. These lines carry improvements in transmitter, receiver, power-supply circuits, and packaging. Units composing a complete installation can be assembled in a mobile mounting rack.

Part of the new communications equipment is a 100-watt 25- to 54-megacycle mobile unit. Transmitter input power is delivered by a dynamotor supply that operates from either 6 or 12 volts. The new unit opens up new coverage areas for the police and highway systems in the Middle and Far West.

Paralleling development of the new equipment is a small but convenient base station. Desk high, the new station has complete controls in ready reach of the operator.



TWO-WAY RADIO EQUIPMENT shows improvements in transmitter, receiver, and power supply circuits and will open new coverage areas for police and highway systems.

Terminal Equipment

Introduced during the year was a new series of audio-frequency range-tone signaling equipments that permit greater flexibility in control of the level, duration, and response characteristics of the tone signal. The units are practically immune to false operation induced by voice and noise signals.

Terminal facilities using tone-modulated radio links were developed for controlling traffic lights. Sirens for civil defense are also controlled by radio tone.

Ultrasonics

A newly developed mechanical handling system provides for automatic punching of core laminations, automatic loading of the laminations, ultrasonic cleaning of individual laminations, and delivery of clean laminations to an annealing furnace.

Infrared Scanner

Developed during 1955 was an infrared scanner that reproduces a scene with the fidelity of a commercial television receiver. Using a lead-sulfide detector, the scanner has a resolution capability greater than that of a radar system. An immediate application of the equipment is in showing the heat distribution in and around reciprocating engines, turbojets, and boilers.

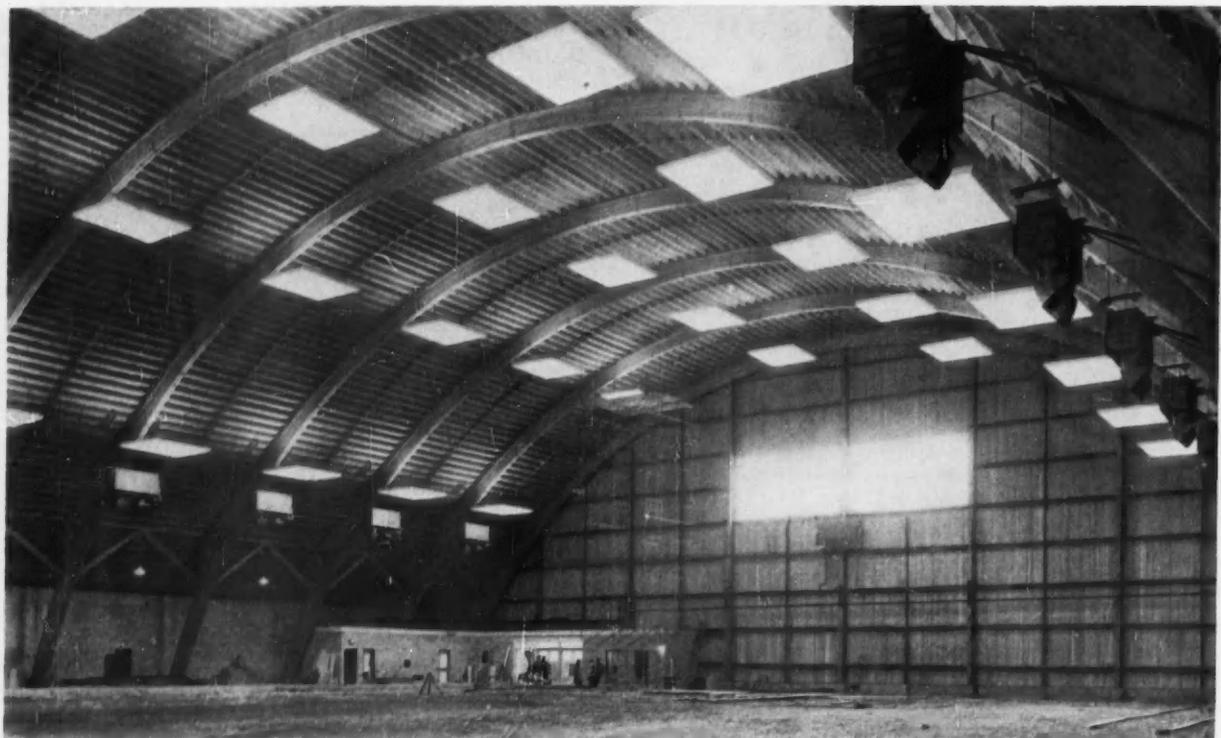
Transformers and Capacitors

An encapsulated transformer introduced in 1955 gives the electronics designer a choice in specifying the exact degree of encapsulation to be used. Uses of the transformer range from military applications to industrial and commercial applications. The tailor-made encapsulated transformers combine many of the proved qualities of hermetically sealed, metal-clad, and open-end transformers.

New design techniques resulted in a substantial reduction of size and weight of oil-filled transformers used in radar sets. One typical power supply, for example, was reduced by 61 pounds.

During 1955, alumina bushings began replacing glass terminals on oil-filled transformers and inductors. Terminals of this kind are less susceptible to damage from thermal shock because of their tough ceramic construction. The bushings have excellent electrical characteristics.

Microminiature capacitors were developed to meet demands for transistorized electronic circuits. Used for such applications as hearing aids, capacitors only 0.095 inch in diameter and 9/32 inch long were developed. They represent a reduction of almost 50 percent in volume over the smallest capacitors previously available.



BRIGHTNESS OF UNION COLLEGE ALUMNI MEMORIAL FIELD HOUSE EXCEEDS THAT OF ALL OTHERS WITH ITS 400-CYCLE FLUORESCENT LIGHTING.

Lighting

August 1, 1955, marked the 25th anniversary of General Electric's introduction of the photoflash lamp in this country. The entrance of that revolutionary lamp marked the end of a colorful era in photography and the beginning of an even more promising one. Professional and amateur photographers immediately accepted the smokeless photoflash lamps, creating an immense new market in photography. For the cumbersome and dangerous flash-powder equipment—notorious for smoke, odor, and noise—was replaced with practical, speedy, artificial light for indoor and outdoor photography during the day or night.

In recent years, flash photography has become one of America's fastest growing hobbies. Half a billion photoflash bulbs, nearly a quarter of all electric light sources produced, were made in the United States in 1955.

Meanwhile, notable forward steps in other lamps were taken during this silver-anniversary year. The recent lamp developments were divided rather evenly

among such classifications as large, miniature, and photo lamps.

Facilities

Indication of a steady increase in the number of future lamp and lighting developments by General Electric was the completion in 1955 of two major research and development facilities in the Cleveland, Ohio, area. One was the new \$2-million research and pilot plant at Nela Park.

Another project of almost equal scope but unique in its activity was completed in the nearby suburb of Euclid. Known as the Refractory Metals Laboratory, it is the only facility of its kind in the world devoted exclusively to the refractory heavy metals and related products. When completely staffed, more than 75 scientists and engineers will study the metallurgy, chemistry, and physics of tungsten, molybdenum, and similar materials. The Laboratory also includes pilot plants for the development and engineering of new extractive and processing techniques.

High-Frequency Lighting System

A modern, efficient, general lighting system—seen as a forerunner of many large industrial, commercial, and institutional lighting installations—went into operation at Union College's Alumni Memorial Field House, Schenectady, NY. The system is the first application of high-frequency fluorescent-lamp operation for the general lighting of a large area.

A total of 490 eight-foot slimline fluorescent lamps is operated on 400-cycle power. Increasing the frequency to 400 cycles from 60 cycles is accomplished by two 30-kw rotating frequency converters.

The 44,000-square-foot area of the field house is illuminated to a level of 45 to 50 footcandles—more than twice the amount of light provided by typical field-house installations. High frequencies permit operation of the lamps at light levels from 20 to 50 percent higher than the same lamps operated on 60 cycles. Ballasts are about one fifth the size and weight of regular ballasts.

The system costs approximately 15 percent less to install than an incandescent-mercury lighting system originally considered for the field house. In addition, the 400-cycle system offers an estimated 50 percent saving in annual operation and maintenance cost.

Lamp Improvements

Improvements in design will increase output of incandescent lamps by at least 6 percent for household sizes and 15 percent for industrial and commercial lighting—300 to 1000 watts. An improved filament for household lamps will be mounted axially; high-wattage bulbs for the first time will have an axial, doubly coiled filament. First lamps to have the improved construction are the 750- and 1000-watt sizes. Other lamp sizes during the next few years will benefit from this principle, believed the most significant incandescent lamp improvement since the development of the gas-filled bulb in 1913.

Light output of the 400-watt color-improved reflector mercury lamp was increased 5 to 12 percent. Other improvements provide better light maintenance and longer lamp life. In the lamp construction, silver-plated wire replaces metal bands in the framework of the mount and supports the mercury element inside the outer bulb. The silver finish reflects light previously absorbed by the dull metal bands, and the wire framework releases more light than the old bulkier construction. Further, a new method of making electrodes not only virtually eliminates impurities but also reduces tube darkening.

The 96-inch high-output rapid-start fluorescent lamp, first introduced in 1954, was further perfected during the year. A design change increased output an additional seven percent, and deluxe cool-white and deluxe warm-white versions of the lamp were made for use where improved color rendition is desirable.

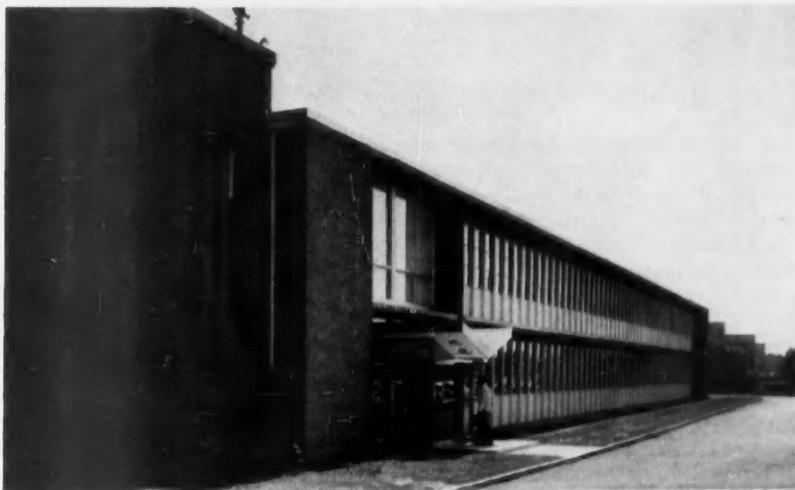
Bulbs and Lamps

A group of five decorative lamps, known as deluxe pink bulbs, was introduced during 1955. These bulbs enrich colors and complexions, add luster to polished furniture, soften shadows, and reduce glare. A "holiday pink" Christmas-tree lamp was also introduced for the first time.

A full line of controlled-beam PAR lamps was completed with the listing of three standard-voltage 500-watt sources



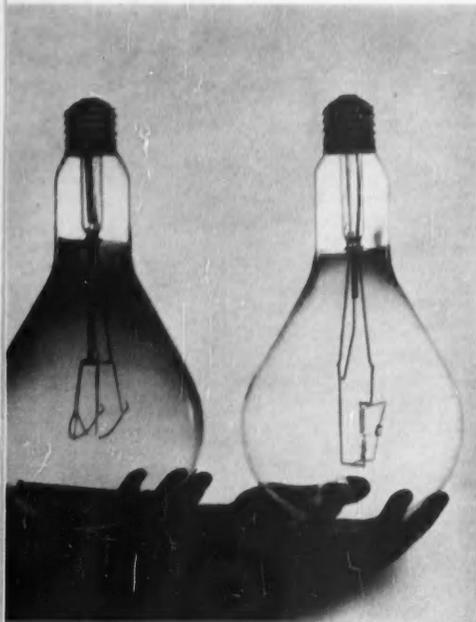
NELA PARK LABORATORY PROVIDES STAFF WITH SPACE FOR RESEARCH AND PILOT PRODUCTION.



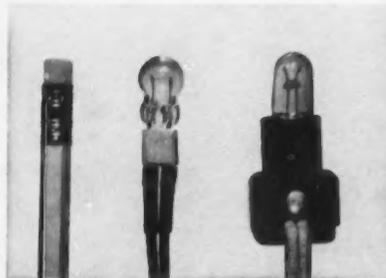
TUNGSTEN AND MOLYBDENUM METALLURGY IS STUDIED IN REFRACTORY METALS LABORATORY.



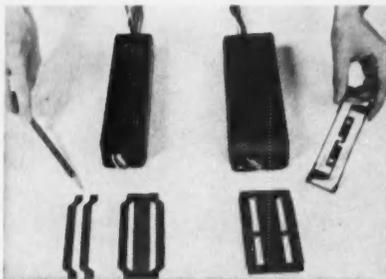
THE WORLD'S LARGEST FLUORESCENT STREET LIGHT YIELDS INTENSE LIGHT FOR MAIN STREETS.



AXIAL FILAMENT INCREASES LIGHT OUTPUT.



TWO-PIN DESIGN RESISTS HIGH TEMPERATURE.



NEW, SMALLER BALLAST HAS SCRAPLESS CORE.



HAND EASILY TRIPS NOVEL LIGHT SWITCH.

in narrow-spot, medium-flood, and flood patterns, plus a 300-watt flood lamp, bringing the line to eight. The controlled beam differs from the customary circular-beam patterns in that it approaches a rectangular beam.

A 750-watt high-voltage lamp similar to the 500-watt lamp widely used in steel mills, foundries, welding shops, and railroad car shops was designed during the year. It will help to solve the lighting problems of industrial plants with high bays, dust and dirt, and a 230- to 250-volt power supply.

A new bulb designed to improve the performance of portable floor and table lamps that have three-way switches contains two filaments: one 30 and one 200 watt.

Omitting the intermediate stage of conventional three-light bulbs permits a single turn of the switch to instantly change the lighting level from low (30 watts) to one high enough for good lighting (230 watts).

Miniature Lamps

Two miniature lamps consisting of a small glass bubble sealed around a coiled filament with two rigid pins protruding at the base were developed last year. One of the lamps will be used for radio-panel lighting. Because it withstands a temperature almost twice that of conventional miniature lamps (600 vs 350 F), the lamp is expected to be widely used on waffle irons, casseroles, toasters,

and other hot electric appliances where indicator lamps were previously impractical or costly. Lamp pins will plug into appliance sockets like electronic tube sockets in a radio receiver. The other lamp will be used for coin machines and similar applications.

A 12-volt truck headlamp, designed to withstand unusual shock and vibration, was also introduced. The lamp is for use only on certain heavy trucks, usually diesel-powered, having vibration that could damage filaments and cause premature burnouts. Four lead-in wires are threaded through a small shock-absorbing ceramic block that keeps them separated and in exact position. This prevents filaments from touching and shorting under any excessive vibration.

Street Lighting

A highly versatile mercury-vapor street-lighting luminaire has five different lamps and two different reflectors that may be used within the same unit. The glassware, reflector, and lamp can be removed and replaced without tools. The tilted optical assembly provides the luminaire with better uniformity of pavement brightness and a higher utilization efficiency.

Another luminaire was designed for operation with a 100-watt mercury lamp in residential areas.

The world's largest fluorescent street light, designed in 1955 for areas requir-

ing a high level of illumination, uses 12 six-foot rapid-start lamps. The new luminaire will find its principal use on American main streets.

A completely redesigned street-lighting controller, lighter and smaller than the unit it replaces, handles all primary voltages up to 7620 volts.

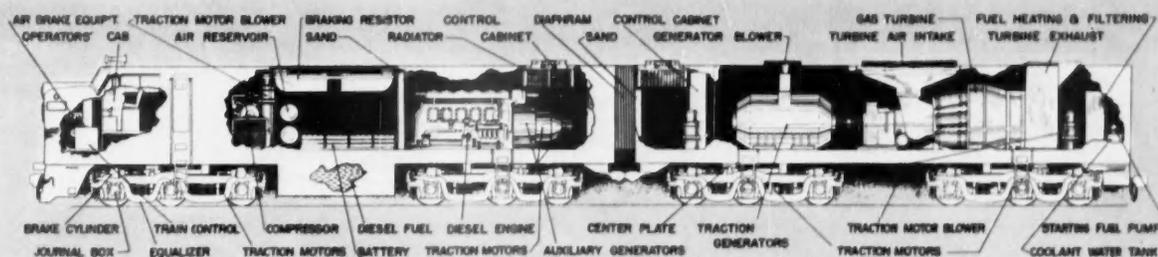
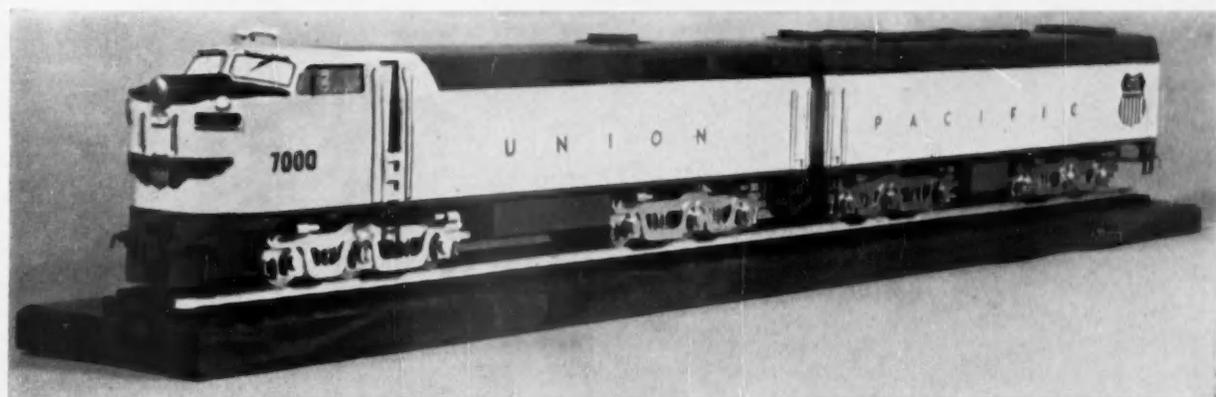
Fluorescent Ballasts

A redesigned core and coil structure of the ballast for a pair of two 40-watt rapid-start fluorescent lamps resulted in considerable saving in material and a reduction in case size. A new core punching with virtually no scrap allows a reduction of 28 percent in the case cross section.

Electronic Switch

Last summer, an impedance-operated electronic switching device for portable lamps in the home was introduced. Compact enough to be mounted in the lamp's base, it provides maximum convenience by requiring merely a touch to turn the lamp on and off. The basic elements of the circuit are a rectifier, capacitor, triode, and relay.

The rectifier charges the capacitor to a potential below the ionization voltage of the tube. The touch surface is connected to the control grid. When this grid is bridged by the hand, the triode fires and discharges the capacitor through the relay coil, causing the relay points to open or close.



FIFTEEN 8500-HP GAS-TURBINE ELECTRIC LOCOMOTIVES (MODEL) WERE ORDERED BY THE UNION PACIFIC FOR DELIVERY IN 1957.

Rail

The development of the gas-turbine electric locomotive passed through a year of decision in 1955. Twenty-five 4500-hp units were produced in 1952, 1953, and 1954 for use on the Union Pacific's mountainous area between Cheyenne, Wyoming, and Ogden, Utah. Throughout this period these locomotives turned in an enviable mileage record for a new form of motive power. Today, performance exceeds the highly developed diesel-electric locomotive, and maintenance costs are competitive.

To more fully realize the inherent advantages of the gas turbine as a prime mover, the Union Pacific late in 1955 ordered 15 new 8500-hp gas-turbine electric locomotives for delivery in the spring of 1957. The highest horsepower per ton of any internally powered locomotive yet built, they will have a simple-cycle gas turbine. The Union Pacific intends to purchase 30 additional units in the two years following the delivery of the initial 15.

Rectifier Locomotives

In March, 10 high-speed streamlined rectifier passenger locomotives were delivered to the New Haven Railroad. The

brightly striped 174-ton 4000-hp units were the first rectifier passenger locomotives built in the United States. They operate from 11,000-volt a-c trolley or 600-volt d-c third rail with equal ease.

The Virginian Railway placed an order in August for 12 rectifier-type freight locomotives with delivery scheduled to begin in October, 1956. These locomotives will operate from an 11,000-volt a-c 25-cycle single-phase overhead trolley on the 130-mile electrified division between Roanoke, Va., and Mullins, W. Va. In appearance, they will resemble the diesel-electric road switcher having hood-type equipment cabs and an operator's cab located toward one end. Approximately 70 feet long, each locomotive will weigh 394,000 pounds. Each unit will be rated 3300 hp continuously with about double that capacity for short periods. To obtain greater power, the units may be operated in multiple.

Export Road Locomotive

A year ago last fall, a four-unit diesel-electric locomotive went into mainline freight service on the Erie Railroad, operating some 400 miles between Marion, Ohio, and Hornell, NY. De-

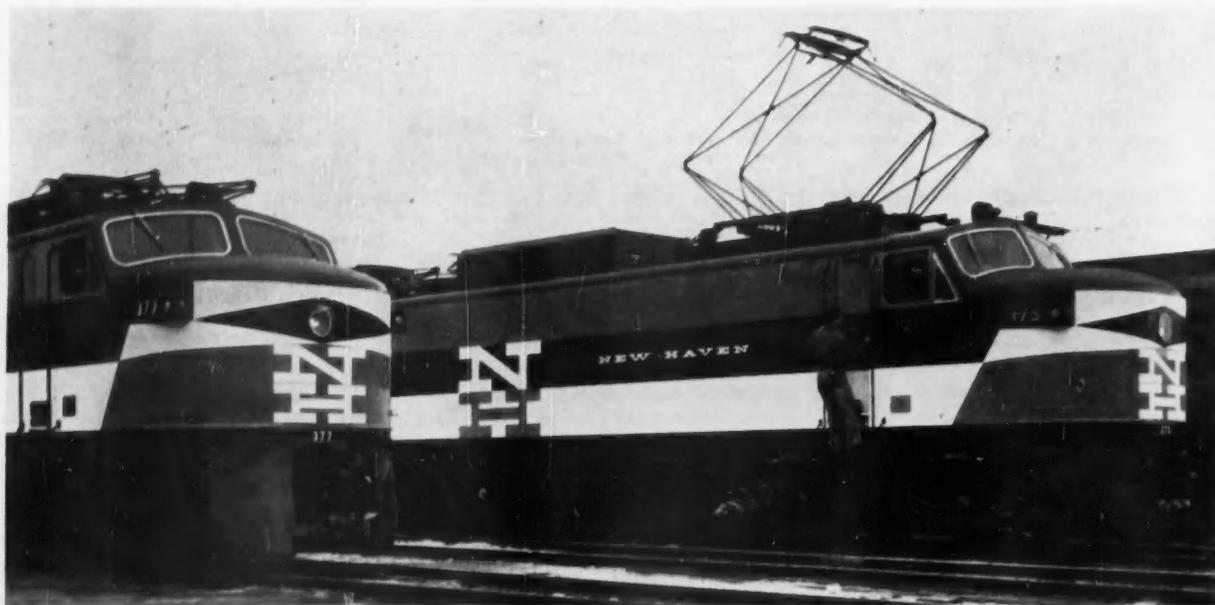
signed primarily for the purpose of evaluating components to be used in locomotives for the export trade, these units are basically the same as the conventional diesel-electric locomotive so well known on U.S. railroads. In purpose, however, they are rolling laboratories where the service performance of equipment in both the mechanical and electrical fields is carefully watched.

The four units make up a 6000-hp 212-foot-long 490-ton locomotive. The cabs are of the usual box-type structure, except the side sheets are fluted rather than flat. They give a pleasing appearance and, more importantly, save weight. Two of the cabs are equipped with Cooper-Bessemer V-type 12-cylinder 4-cycle 1800-hp turbosupercharged diesel engines. The other two have similar 1200-hp V-8 engines. The newly designed static-excitation scheme is used on all four d-c generators. Each of the two-axle trucks is powered by a pair of traction motors of a type widely used on domestic diesel-electric locomotives. They have a maximum speed of 65 mph.

After a year of service on the Erie Railroad, this locomotive had run a total of 120,000 miles and consumed



A ROLLING LABORATORY, THIS FOUR-UNIT DIESEL-ELECTRIC LOCOMOTIVE EVALUATES COMPONENTS FOR USE IN THE EXPORT TRADE.



TEN STREAMLINED RECTIFIER PASSENGER LOCOMOTIVES, RATED 4000 HP, WERE DELIVERED TO THE NEW HAVEN RAILROAD IN MARCH.

nearly 870,000 gallons of fuel, hauling freight trains averaging approximately 5000 tons including the locomotive. Although some equipment failures occurred, road delays chargeable to them totaled only three hours. This record establishes it as the equal of any other locomotive operating in the same service.

Locomotives for the Philippines

An order placed by the Manila Railroad Company for 40 diesel-electric locomotives of three types represents a major step in the dieselization of this system comprising almost 800 miles of 42-inch-gage track.

Ten of the locomotives are of the industrial switcher type, rated 500 hp and weighing 52 tons each. Powered by a Caterpillar V-12 engine, the unit has four double-reduction-g geared d-c traction motors for heavy pulling at low speeds. Maximum speed is 40 mph.

Twenty newly designed 1200-hp 96-ton modified road-switcher locomotives will handle the majority of freight traffic. The power plant for these locomotives will consist of a Cooper-Bessemer turbosupercharged V-8 engine driving a d-c traction generator. Each of the six axles will be driven by a universal traction motor recently designed for world-wide locomotive application.

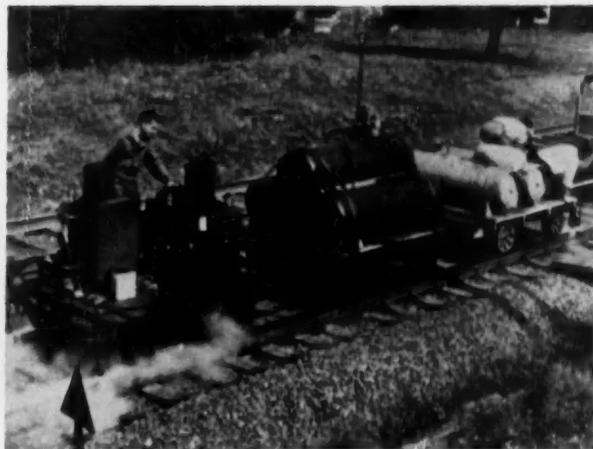
The remaining 10 locomotives for passenger service will have box-type cabs and the same internal arrangement and equipment as the 20 freight locomotives. Weighing 91 tons each, these units will have a maximum operating speed of 60 mph.

Standard Export Locomotives

With an eye on the bright future of the world market for diesel-electric locomotives, a line was developed that has a maximum number of interchangeable components between all the models. With this basic design, the widely varying requirements of the world's many railroads can be met with a minimum



IMPROVED DESIGN of control and motors gave lightweight rapid-transit cars more horsepower per pound at little weight increase.



WHEEL-SLIP STUDIES indicated that water-propagated oil films can be reduced by the application of rail-conditioning materials.

amount of alteration to the basic model.

To determine the number of models for inclusion, three prime criteria—horsepower, tractive effort, and weight per axle—were carefully balanced. Horsepower will range from 400 to 1800; tractive effort ratings will generally exceed those of comparable locomotives now on the market. Because of the track and bridge restrictions on most foreign railroads, these locomotives will have considerably less weight per axle than current domestic designs.

Each model is being designed to suit the composite requirements of the world's railroads. Such factors as external clearance restrictions, track gage, brake systems, draw gears, location of operating station or stations, wheel type and diameter, steam-generator application for train heating, dynamic-braking equipment, and number of axles can be varied with little or no change to the basic locomotive.

Rapid-Transit Car Equipment

An 82 percent increase in horsepower with little increase in weight and none in size resulted from the motor and control improvements on two sample high-performance rapid-transit cars now operating in Chicago. The major key to this advance—more power per pound—is aimed at improving the performance of lightweight rapid-transit cars, allowing them to compete with modern automobiles on an expressway. The sample cars were made up by using standard lightweight rapid-transit cars and replacing the existing control and motors with new equipment of improved design.

The new traction motor rated 100 hp has a top speed of 6500 rpm; its prede-

cessor was rated 55 hp with a top speed of 5000 rpm. The improvement was achieved by better mechanical design, especially in the commutator, and the use of a multiple armature winding. The multiple winding provides satisfactory commutation, even in dynamic braking at 80 mph when each 100-hp motor is generating a peak of 250 hp.

A new all-electric control provides series-parallel acceleration with field shunting in both positions and gives dynamic braking at all speeds up to 80 mph. The previous control provided rheostatic acceleration with the motors connected in parallel and gave dynamic braking up to 48 mph. The greatly increased performance is achieved by a new resistance network circuit, new method of resistor proportioning, better resistor heat distribution, new control-positioning scheme, and improved circuits to gain better power-switch utilization.

Subway Car Equipment

Passengers of the Broadway-Jamaica line of the New York City Transit Authority subway system now enjoy smooth acceleration and braking provided by new G-E control equipment. During the year, 100 cars equipped with truck-mounted motors and all-electric control were put in service—marking an advance in passenger riding comfort. And 200 more are being delivered for service on the Pelham Bay line, with additional ones currently on order.

Radically different from the traditional pneumatic control equipment, this new system is entirely electric. Two motor-operated cam-actuated controllers form the heart of the system. For this

heavy-duty service, wearing parts were made easily accessible for inspection and renewal. Sliding covers provide quick, easy access to the main control package that houses all the propulsion control apparatus except the line circuit breakers.

Wheel-to-Rail Adhesion Tests

The potentially high tractive effort of modern electric-drive locomotives emphasized the importance of maintaining high-friction coefficients between the driving wheel and the rail. Laboratory investigation pointed to water-propagated oil films as the cause of a large percentage of locomotive wheel slip. Extensive tests in cooperation with a major railroad substantiated this, and corrective measures were indicated. Results obtained during 1955 indicate that coefficients in excess of 26 percent can be maintained during train operation by applying certain materials that condition the rail surface—nearly a 45 percent increase in the accepted average for railroad operation.

Slip Rings

Mercury slip rings small enough to mount in the armature shaft of a locomotive traction motor were developed. These rings permit measuring armature stresses while the locomotive is operating under regular service conditions—previously impossible because of space restrictions and application limitations. A set of rings can transmit signals from 10 different strain gages to instruments in the locomotive cab. These low- and stable-resistance rings operate at speeds of 15,000 rpm and perform reliably in service for periods up to a year.



DEFENSIVE FIRE-CONTROL SYSTEM PROTECTS B66 OPERATIONAL BOMBER BY USING COMPUTING TECHNIQUES TO IMPROVE LINEAR PREDICTION.

Aviation

Initiated in 1955 was an undertaking of world-wide significance: the United States's earth-satellite program, known as Project Vanguard. In October the Defense Department announced that GE would build the first-stage engine of the three-stage rocket that will launch this satellite.

The announcement came as GE prepared to enter its 12th year of missile activity. On February 24, 1949, a GE-launched two-stage rocket reached an altitude of 244 miles, still an unbroken record.

One of the world's largest solid-propellant-missile test vehicles was revealed during the year. GE and other industrial firms developed the missile designated RV-A-10 in collaboration with the U.S. Army. For certain uses, solid propellants are more reliable, easier to handle, and cheaper than liquid fuels.

Liquid propellants, oxygen and alcohol, were used in the GE-developed missile designated A-1. With a sea-level thrust of 10,000 pounds, the missile has an over-all length of 25½ feet and a 10-inch diameter. A series of these missiles was launched to evaluate missile-guidance systems, to gather data on

aerodynamics and structures, and to observe operation of the propulsion system.

Smokeless propellant charges for starting jet engines are being developed in collaboration with several propellant manufacturers. With a longer storage life at higher surrounding temperatures, the new smokeless charges should cost only about one fourth as much as their predecessors.

Jet Engines

As J47 jet engines—several of which operated 1000 hours without overhaul—set new service marks by collectively running up 5½-million miles daily in 11,000 flight hours, FIAT Works in Italy became the first foreign manufacturer to be licensed for J47s. FIAT, a supplier of fighters to countries belonging to the North Atlantic Treaty Organization (NATO), will also build spare parts and overhaul the J47, the first U.S. engine licensed abroad.

Utilizing punched cards in conjunction with an electronic data-processing machine, engineers can now speed up and improve the design of jet aircraft. Information quickly obtained includes

such data as engine power and rate of fuel consumption over entire flight paths. The new method will save aircraft manufacturers thousands of hours of calculating time on every proposal.

One of the most important measurement techniques—a magnetic tape and data-reduction system—came into use in 1955. It simultaneously records 28 data signals and reduces data in multiples of 12 channels. A 28-channel tape recorder stores data, while special pre-amplifiers adjust transducer input signals to the proper level. Many tests conducted during the year demonstrated the system's ability to record, reduce, and concisely present data, as well as simulate actual tests by replaying data.

A unique digital recorder installed during 1955 procures main-log data of jet-engine test results. It eliminates laborious reading of instruments. Results obtained are also more accurate and easier to read. In one minute, 54 variables of 10 different factors—such as speed, flow rate, temperature, and pressure—are recorded within an accuracy of one-half percent.

With an integrated electric control system perfected during the year, a

pilot can operate the engine of his J47-powered F86D *Sabre Jet* with a one-hand thrust selector. The pilot selects a percentage of available thrust, and the control automatically regulates main and afterburner fuel.

Development and testing of a new hydromechanical control for a 10,000- to 20,000-pound-thrust turbojet were completed in 1955. Its production version will weigh about 50 pounds. A speed regulation of one-tenth percent can be obtained with limited override trim.

Development and design also began on engine-control systems for ramjets, turbojets, turboprops, rocket motors, and nuclear engines. Engine controls for several small and large engines should begin production during this year or next.

Initial engine testing began at a new outdoor jet-engine testing center in Peebles, Ohio, near Cincinnati. Provided at the new center are facilities to investigate acoustic techniques that will minimize noise problems possibly resulting from jet aircraft operating in populated areas.

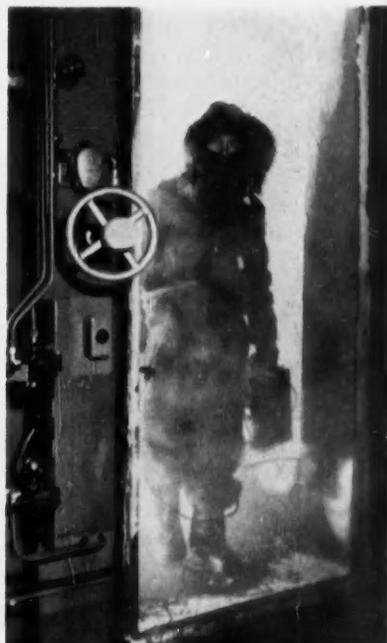
Armament and Guidance

During the year, the Air Force's three principal operational bombers were equipped with G-E defensive fire-control systems. They are the Strategic Air Command's B47 *Stratojet* and B52 *Stratofortress* and the Tactical Air Command's B66. Significant feature of the armament systems is the use of computing techniques to modify the first derivative of a straight-line predictor. The development of equipment to mass produce precision-wound potentiometers also contributed to the success of the system.

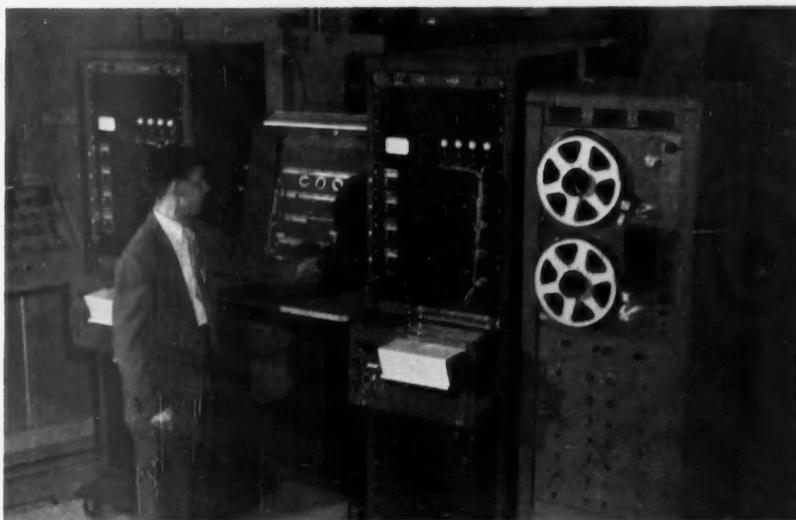
To evaluate complete airborne, armament, and missile-guidance systems, a dynamic accuracy tester was developed. It evaluates a system under fully simulated flight conditions, including firing at a target. The tester can accommodate a variety of air-duel courses and flight conditions.

Environmental Testing

Work continued during the year with extensive testing equipment used to simulate environmental conditions of military specifications. Conditions simulated include vibrations up to 500 cycles; temperatures cycling between -100 and $+250$ F; shock, sand, and dust; humidity; and sustained acceleration. One large walk-in chamber simulates a 120,000-foot altitude within 15 minutes.



SOLID FUELS PROVE RELIABLE MISSILE POWER. CHAMBER SIMULATES 120,000-FOOT ALTITUDE.



DYNAMIC ACCURACY TESTER SCORES MISSILE-AIMING AND AERIAL SYSTEMS WITHOUT GUNFIRE.

Small Gas Turbines

Progress continued in developing a small gas-turbine engine for Navy helicopters. A contract with the Air Force calls for a small turbojet designed primarily to power drones and pilotless aircraft. A five-year expansion of facilities required for the development testing of small gas turbines was planned.

High-Altitude Progress

New cored-type carbon brushes were put into production to meet the increasingly severe conditions of higher alti-

tudes. They are designed for high-performance rotating electric machines. With the cored-type construction, there is less heating at the contact surface because of lower electric resistance. The cored brushes have operated well at the altitudes specified for military aircraft.

Turbosuperchargers continued to set new operational endurance records during 1955. As a result of carefully planned cooperation with commercial airlines, maximum overhaul service of turbosuperchargers can now be safely extended.

Temperature Measurement

A resistance-type temperature detector for jet engines was developed and is currently being evaluated by the jet-engine industry. Among other advantages, it is completely sealed against contamination by moisture and fuel.

Separate signals for indication and control of jet-engine exhaust temperature are provided by a new dual-junction thermocouple. It replaces two separate thermocouple systems, providing improved accuracy while simplifying installation and maintenance.

Wind Tunnels

One of the more complex control systems analyzed during the year was a wind-tunnel fan drive. Two parallel wound-rotor induction motors made up the drive. To study various load and speed disturbances, the complete transient performance of the system was represented on an electronic differential analyzer.

Four large adjustable-speed induction-motor drives, described in the REVIEW one year ago, began operation during 1955. All drives were built for laboratories of the National Advisory Committee for Aeronautics (NACA). These four drives are the largest adjustable-speed wind-tunnel drives in operation today.

Small in size, a precision diaphragm-operated strain-gage pressure transducer instantaneously measures varying pressures in supersonic wind tunnels. The transducer can measure absolute or differential pressures as low as 10 mm of mercury absolute to an accuracy of 0.1 percent. Output of the transducer is a convenient d-c voltage.

Aircraft Generators and Drives

A 20-kva version of the hydraulic constant-speed alternator drive for aircraft weighs only 35 pounds—about 20 pounds lighter than other constant-speed drives of the same rating. Operating at a constant output speed of 8000 rpm, the drive has an input-speed range of 3900 to 8300 rpm. It is continuously rated 32 hp with short-period overloads.

An electric load-division system allows parallel operation of four 60-kva turbo-alternator drives. Each unit of the system, a closed-loop type, has a self-contained discriminating circuit. All four machines are interconnected to divide loads within plus or minus five percent of the average load per unit.

Completed during the year were development and testing of a static regu-

lator exciter for 60-kw generators used in military ground-power applications. This exciter is being evaluated for applications involving guided missiles.

Two other excitation systems for generators rated 125 and 250 kva were put into production during 1955. The generators will supply power for military computing equipment.

Six test-stand drives that closely simulate the actual aircraft-drive system went into operation at the Naval Air Development Center (NADC) in Johnstown, Pa. They are rated 100 hp over a 3000- to 8000-rpm speed range with provision for overspeed to 11,000 rpm. Ignitron rectifiers were used for high accuracy and speed of response.

In 1955, a static regulator was developed for aircraft alternators rated up to 90 kva and ambient temperatures of 120 C. Exceeding all performance specifications, the device greatly improves voltage regulation and recovery time.

Compass Transmitter

Developed specifically for thin-wing airframes was a remote-indicating compass transmitter. Providing magnetic-heading information, the transmitter can be installed in a space where headroom is only 2½ inches. Hermetically sealed, it can operate in a surrounding temperature of 125 C.

Electric Components

Now in late stages of development, a high-voltage energy-storage capacitor will help aircraft designers push back the thermal barrier. The capacitor is designed for jet-engine ignition systems where ambient temperatures may reach 200 C. Key to its development is the use of silicone fluids and mica mat (reconstituted mica sheet).

Developed to meet requirements of future aircraft was a new high-temperature high-performance carbon-pile regulator. Having closer voltage limits, the new regulator operates in ambient temperatures ranging from -90 to +120 C.

A microminiature relay for electronic equipment is small, light, and highly reliable. It measures 350 × 785 × 875 mils and weighs only 0.35 ounce. Designed to give high-contact rating at high temperatures, the hermetically sealed relay operates rapidly and resists shock and vibration.

Another development in electronic components is a double-pole subminiature relay weighing only one ounce. Its ability to operate continuously in

high ambient temperatures qualifies it for rugged airborne applications.

An unregulated transformer rectifier rated 100 amp at 28 volts is capable of full-load operation at altitudes up to 60,000 feet and ambient temperatures to 120 C at sea level. Also introduced during the year was a statically regulated 200-amp rectifier power supply. Rated 28 volts, the unit weighs 76 pounds.

For developing and testing aircraft products, a new Aviation Control Laboratory began operation in Waynesboro, Va. Facilities include a two-generator electric system complete with constant- and variable-speed drives. Oscillographs provide an on-the-spot check of operating characteristics of equipment.

A new protective panel for the McDonnell F101 fighter provides maximum serviceability and accessibility of components. Its complete enclosure prevents the entrance of foreign materials. To facilitate inspection and servicing, electric wiring is accessible from both sides of the panel.

Designed to operate in an ambient temperature of 150 C, silicone-rubber-insulated aircraft wire has excellent flame and abrasion resistance. Two braids covering the silicone insulation withstand temperatures up to 200 C.

Accessory Turbine Instrumentation

Three major advances were made in aircraft accessory turbine instrumentation. A system composed of a magnetic pickup, electronic tachometer, differential circuit, and d-c amplifier records turbine-shaft acceleration up to 200 rpm per second at speeds above 1000 rpm. To give direct-reading pressure differences, a pressure-ratio meter was designed with a range between 1 to 1 and 1 to 20. For rapidly measuring high temperatures in a high-velocity gas stream, a new thermocouple was especially constructed. Operating at steady-state temperatures from ambient to 2800 F, it responds to a change from ambient to 2000 F in 0.2 second.

Fuel and Oil Systems

Newly developed last year, a high-volume mass-measurement flowmeter measures up to 600,000 pounds per hour. It measures the rate of fuel transfer from a flying tanker to another airplane during in-flight refueling operations. The transmitter has 50 times the capacity of the flowmeter transmitter presently installed with each engine of the B47 *Stratojet*, yet it weighs only three times as much.

Marine

Powered by four cross-compound steam turbines combined with four double-reduction gears, the world's most powerful warship—the aircraft carrier USS *Saratoga*—was launched in 1955. Propulsion equipment of the *Saratoga* operates at higher steam temperatures and pressures than those of her sister ship, the USS *Forrestal*. It develops more shaft horsepower than the propulsion machinery of any naval vessel afloat. The new marine power plants were built to meet the Navy's requirements of engineering perfection.

Almost identical with the power plants installed in the *Saratoga* are propulsion steam-turbine gear units ordered for the Navy's latest aircraft carrier, the USS *Kittyhawk*. Similar units are being built for the USS *Ranger* and USS *Independence*.

A "roll-on roll-off" vehicle carrier for military sea-transport service will be powered by two 6000-hp single-cylinder steam turbines. A new concept of a ship, the carrier is the first seagoing vessel to be powered with a single-cylinder design of a propulsion turbine.

Gas-Turbine Power Plant

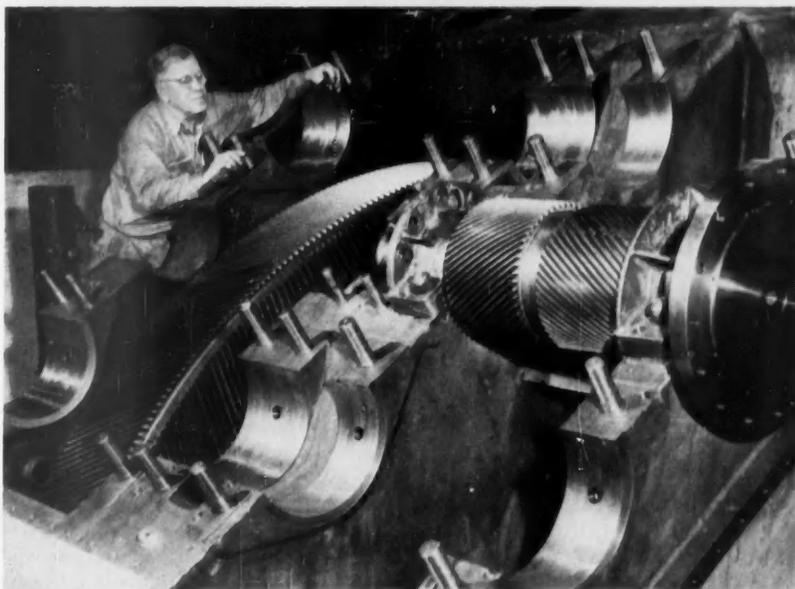
A commercial gas turbine delivered during 1955 will repower a Maritime Administration liberty ship, the SS *John Sergeant*. A two-shaft unit with a 6600-hp maximum rating with regenerative cycle, it is similar to gas turbines used in gas-pipeline pumping applications. Modifications were made for the greatest over-all advantage of shipboard installation. The turbine will drive the ship's controllable pitch propeller through a single double-reduction gear.

Commercial Shipping

Also under construction in 1955 were the main propulsion turbines and gears for two large twin-screw passenger vessels. Additionally, propulsion gears, each rated 26,500 shp, were ordered for two new tankers. These are the largest ship propulsion gears in terms of physical dimensions ever built.

Power Dredge

Electric motors will power a large dredge used to excavate the bottom of San Francisco Bay and broaden the shore line. The equipment, furnished in 1955, consists of a d-c cutter motor, a



USS "SARATOGA," newest 60,000-ton aircraft carrier, develops with four cross-compound steam turbines and four double-reduction gears more shaft horsepower than any naval vessel.

motor-generator set, and large induction pump motor. Rated 1500 hp, the d-c weatherproof cutter motor is totally enclosed, forced ventilated, and equipped with antifriction bearings for operation at a 45-degree angle. The induction pump motor is rated 8000 hp at 360 rpm.

Naval Control and Switchgear

A high-impact shock-type a-c contactor developed for the Navy is characterized by unusual compactness. Rated 100 amp, the new contact has fire-resistant shockproof arc chutes and arc-splitting inserts, plus a considerable blow-out effect. Combined with thermal overload relays, the contactor becomes a compact full-voltage three-phase starter.

A size-0 manual starter introduced for naval applications also meets high-intensity shock requirements. It is intended for use with motors, driving fans, pumps, small machine tools, and other miscellaneous auxiliary motor drives aboard ship. The starter is rated 1½ hp, single phase, 440 volts; 2 hp, three phase, 440 volts; and 1 hp, d-c, 230 volts.

The first high-shock single-pole circuit breaker, type ALB-1 rated 5 to 50 amp at 125 volts ac-dc, was introduced for applications aboard naval vessels. It is approved for lighting-panel applications on submarines and superaircraft carriers. During tests the energized breaker withstood blows of 2000 foot-pounds without tripping.



DOUBLE-ROLL SYSTEM rapidly turns out superior high-bulk-density molding materials with minimum of attention from an operator.



TRANSPARENT SHIELD protects against flying chips as cemented-oxide cutting tool machines steel at phenomenal rate of 7500 fpm.

Chemical and Metallurgical

Interest and demand for nonmelting insulating tapes of irradiated polyethylene increased during 1955. The pilot plant for producing irradiated polyethylene is presently operating on a two-shift basis, with a further increase in production planned early this year. This new concept in electric insulation offers the engineer a lower insulation cost, improved electrical characteristics, and protection against thermal overloads and adverse environmental conditions.

Molding Materials

To satisfy the need created by automatic molding machines, new high-bulk-density molding materials were developed and sold as standard products.

Their development required a considerable investment in equipment. A newly installed double-roll system produces both black and brown general-purpose molding materials, believed superior to any similar molding material available. Using these materials, automatic rotary presses rapidly turn out molded pieces with minimum operator attention.

After two years of development, a one-stage odor-free phenolic molding material now overcomes major disadvantages of previous materials. It neither sticks to molds nor requires any tricky processes to turn out molded parts. Even when odor is not an issue,

the new one-stage material is being used for its rapid curing speed and high finish. It is also used for critical molding processes that previously excluded the use of one-stage compounds.

Resins

A heat-resistant polyester resin developed during the year should greatly expand the application of glass-base laminates. This product exhibits remarkable strength retention and degradation resistance at elevated temperatures. Laminates fabricated from it retain 60 to 70 percent of their original flexural strength after exposure to 260 C for 200 hours. The resin also imparts superior chemical resistance.

In the fast-growing field of foundry resins, a sand-coating technique introduced in 1955 offers several advantages over conventional shell-molding methods. The new process utilizes sand mechanically coated with resin. To accommodate the process, two new phenolic resins were developed for core-blowing applications and for dump-box operation.

Also introduced was a low-cost chemically resistant coating resin with outstanding resistance to humidity. Primer and primer-plus-topcoat films show no attack after 15 months exposure in a standard humidity cabinet. Promising uses of the resin include primers for appliances and heavy-duty industrial

equipment, as well as alkali-, acid-, and solvent-resistant coatings.

Resins played a part in furthering electronics manufacturing technology during 1955. Impregnating TV power transformers with a semirigid polyester reduces their size and cost. The same polyester can be used for potting, encapsulation, or casting.

A process was developed for producing shaped parts in continuous lengths from polyester resins and glass rovings. Data accumulated on the process show the effects of tank length, viscosity, temperature of gelation, speed, and percentage of resin.

Laminates

Another step toward the fully automatic laminated-plastics factory was taken in 1955: an automatic metering-roll controller. Beta-ray gages measure the resin content of the laminate stock. Then the metering controller completes the feedback loop to automatically operate the resin-content controlling rolls. Receiving data on resin content, the controller decides the direction and magnitude of the control action. Further installations of this pioneer development in the laminated-plastics industry are planned this year.

A new product, a fire-resistant polyester-glass-mat laminate, is now produced in molded flat sheets through a range of thicknesses and also in one

size of molded angle. Its initial use was in air circuit breakers. Self extinguishing, it will not burn after removal of the source of heat. The new laminate is approximately twice as strong as the paper-base product formerly used.

Another development overcame the characteristic warp of high-pressure melamine-surfaced decorative laminates. Formerly, warp resulting from unequal shrinkage during cure caused the sheets to curl cylindrically as much as 30 percent. Now, the new laminates will not warp more than five percent under the most adverse conditions.

Two other new paper-base industrial laminates can be heated and bent or drawn to form many useful shapes. Both laminates can be readily fabricated by hot-punching. One application has been a ventilated wiring channel: ventilating slots are punched into the flat sheet, and the slotted strip is postformed into a channel. The lightweight channel—an insulator itself—can be fabricated in the field with tin snips.

Insulation

High-voltage mica mat ground insulation tape developed during the year is now applied to large motors and generators. Its cured, yet flexible, binder has excellent properties at Class B temperatures and withstands high dielectric stresses.

A low-cost mica mat segment plate, based on an entirely new process, is in pilot production. Although well-bonded, the plate contains a minimum of heat-resistant organic binder. It has greatly increased resistance to slippage, and its binder has shown no tendency to ooze under any condition. Several large commutators were successfully made from the segment plate. It is also useful for barriers and separators.

Mica mat combined with glass cloth and having a layer of polyester film on each side provides a superflexible insulating tape with excellent uniformity of thickness and dielectric properties for Class B temperatures. Now in production, the tape is intended for application to conductors and to motor coils as ground insulation and other motor applications.

An extensible flame-resistant tape made from bias glass cloth snugs down well over irregular contours. Treated with a tough flame-resistant binder, it was adapted for use in switchgear. It is suggested for use as an outer coat over regular varnished cloth to confer flame resistance.



TWO AUTOMATIC MINIATURE PRODUCTION LINES INSPECT AND TEST LOUDSPEAKER MAGNETS.

Metals and Alloys

Highlighting the 1955 developments is a cemented-oxide cutting tool, laboratory and field tested at speeds 8 to 10 times greater (7500 fpm) than presently used for machining steel. With a feed of 5 mils and cutting depth of 100 mils, the tool lasted 27 minutes in machining 1045 steel annealed to 170 Brinell. Under development for several years, the new cutting tool may supplement carbides much the same way that carbides supplemented high-speed steel cutting tools about 15 years ago.

A newly designed tool holder for throw-away-type carbide insert blanks allows cutting tools to operate with less overhang, while providing greater rigidity. An indexable seat or pad of carbide supports the cutting insert and protects the steel shank. Requiring only a light tightening torque, the tool holder also serves as a fixed chip breaker to provide uniform chip control.

The 1000-pound vacuum-melting furnace described on these pages one year ago began operation late in May. It will add better than 120,000 pounds of specialized vacuum-melted alloys per month to the nation's capacity. The furnace is presently capable of producing two 1000-pound heats per shift.

Machinability

In another development, a new 125-hp 32-inch lathe, first of its kind, will be used to test machinability of materials with various grades of cemented-carbide and cemented-oxide tools.

Additionally, it will determine tool-material life under all conditions of operation, as well as provide more information on speeds and feeds in machining various metals. Electronic feedback systems are used to maintain lathe speed within one percent at full load.

Magnets

An important advance in magnet technology occurred in 1955. Elongated particles of iron a millionth of an inch in diameter were produced with several hundred-thousand times the coercive force of ordinary iron. When compacted, they provide magnets with energy products greater than 3-million gauss-oersteds. This compares favorably with the $4\frac{1}{2}$ -million energy of alnico V, at the same time exceeding the properties of other commercial alloys. These results point the way toward development of powerful new magnets free of strategically critical metals.

Speaker magnets are inspected and tested magnetically by two newly developed electronically controlled systems in an area of about 16 square feet, where previously 50 square feet were required. Virtually two miniature production lines, the units synchronize the functions needed to sort the end products well within predetermined quality ranges. With the aid of only two operators, they actuate belt conveyors; control drop chutes, hoppers, and magazine feeders; and align pushers, miniature gravity conveyors, and other devices. Every magnet is segregated and counted.

than that of a news photographer's camera. Also vital is an electronic triggering mechanism that turns the x rays on and off in synchronism with the camera shutter, thus greatly reducing exposure of the patient to x ray.

Cancer Therapy

In cooperation with Atomic Energy of Canada, Ltd., major gains were made in installing rotational-type cobalt-60 machines for cancer treatment. Providing three-dimensional cancer therapy, the new units concentrate the effective power of the beam at a designated point inside the patient, thus reducing the x-ray exposure of any intervening tissues.

This same cooperation brought about the introduction of a hectocurie-type cobalt-60 unit designed to use smaller (600 curie) sources of radio cobalt. With it, the cost of cobalt therapy equipment can be cut about 50 percent. Such a unit is best suited to smaller hospitals having limited funds and fewer patients.

Diagnostic Radiology

Introduced in 1955 was a new type of versatile medium-priced x-ray apparatus for diagnostic radiology. Three different types of spot-film devices, as well as three different types of radiographic tube supports, are available for the apparatus. The table can be positioned at adjustable speeds from full vertical to 45 degrees in the head-down position.

Dental X Ray

Radically new dental x-ray equipment promises many gains to both the patient and the dentist in improved ability to diagnose and treat dental ailments. It has a 100 percent increase in x-ray output over previous models of its kind and a 40 percent higher operating voltage. The new equipment was introduced to meet the growing trend among dentists toward the use of high-voltage x-ray devices. It operates in any voltage range from 40,000 to 90,000 volts—without precedent in the field of dental x ray. Exposure times can be varied

from one twentieth of a second to 10 seconds.

Electron-Beam Sterilization

Triple-powered electron-beam generators were developed for sterilizing food and drugs and for producing improved chemicals. One such generator, operating at two-million volts and 1.5 ma, has an output of 2100 watts. With a beam sweeping across a rectangular field eight inches wide, the unit will make it possible to sterilize or treat several times the previous number of products in a given time.

Among the more unusual applications of electron-beam sterilization is the irradiation of human blood-vessel grafts, particularly of the artery leading from the heart.

In the field of food processing, equipment now under development may eventually make it possible to sterilize foods for less than one cent a pound compared with the present cost of two cents a pound.

Air Conditioning

A new line of Weathertron (heat pump) units went into production early in 1955. They average 20 percent smaller and 35 percent lighter, while delivering 40 percent more heating capacity for the same nominal cooling ratings. The refrigeration system is hermetically sealed for reliability, and the entire mechanism can be easily removed from the unit for replacement. Nominally rated for three- and five-ton cooling, the new models have substantial component improvements that increase reliability and greatly simplify the design. Effective standardization resulted in a 66 percent reduction in the number of different parts over the previous designs.

Heating and Cooling of Homes

New oil-fired boilers for residential heating with circulating hot water were introduced in two sizes: 100,000 and 140,000 Btu per hour. The single-purpose design simplified installation and made servicing much easier.

A new arrangement for one size of air-cooled home cooling equipment locates the refrigerating compressor with the outdoor heat-transfer coil. This makes a complete air-cooled condensing

unit. Only the indoor heat-transfer coil, housing, and fan are installed in close combination with the warm-air furnace.

In Tyler, Texas, ground was broken for a \$15-million plant for the production of home heating and cooling equipment. When completed late this year, it will be completely air conditioned, contain 350,000 square feet, and employ several hundred persons.

Announcement was made of a new step-starting accessory to eliminate objectionable light flicker caused by starting 3- or 5-hp air-conditioning motors in homes. It saves on extra costs of heavier lines and transformers ordinarily required to supply full-voltage starting. The utility company also benefits: after a power outage, the starter delays part of the motor current inrush on a distribution system when power is restored.

Horizontal Air Conditioner

Ceiling-mounted packaged air conditioners, including both air- and water-cooled models, were produced in 3-, 5-, and 7½-ton cooling capacities. Primarily, they are for use in stores, restaurants, offices, and factories.

Other Developments

The life of refrigerant compressor valves can now be successfully determined in a matter of hours instead of the previous months or years of testing. A rotating mechanism alternates air and vacuum to simulate operating conditions of automatic spring-loaded or flapper-type compressor-valve designs until a fatigue failure occurs. The valve can be observed in operation during the test. This enables various thorough studies such as the effect of port opening and oil flow by using stroboscopic light and high-speed motion pictures.

Excessive moisture in vapor-compression refrigeration systems has always been recognized as an important cause of failure. Dehydrating procedures scavenge the systems of moisture, but correlating the results of the dehydration with adopted procedures posed a problem. By applying the electric conductimetric measuring principle to testing moisture content, the various results can now be correlated. This provides a better understanding of the moisture problem and gives a solid base for improved quality and more economical processing procedures.



MOBILE XERORADIOGRAPHIC EQUIPMENT, using its own packing case as a support, can be set up in any building for emergency purposes in the event of a civil disaster. This process produces a wider range image density (inset, right) than conventional methods.

Medical

A low-cost high-speed dry technique for developing x-ray pictures on a reusable metal plate highlights developments in the medical field. Known as xeroradiography, it promises to significantly extend the use of x rays in industry and medicine—particularly the medical needs of civil defense and community disaster agencies.

With xeroradiography, x-ray images can be produced on a metal plate in as few as 40 seconds compared with 15 minutes for developing and 45 minutes for drying conventional film. Processing costs are half that of a comparable film, and the metal plates can be used over and over again. During the year, the New York State Civil Defense Commission placed an order in excess of \$500,000 for the apparatus, including special portable x-ray equipment as the x-ray source, two-wheeled trailers, standby generators, and other special items.

Low-Investment X-Ray Generator

An x-ray generating unit introduced in 1955 was designed to aid the physician beginning the use of x rays in his practice. With a low initial investment,

the physician can later add to his x-ray equipment as his patients and requirements increase.

The initial unit operates at 200 ma, up to 100 kv with full-wave rectification. It includes an automatic circuit breaker to protect the system from overload. The physician need only set the "dial-the-technic" control to the desired milliamperage, and the unit automatically establishes proper filament current and selects the proper focal spot.

Components that can be added to this x-ray generator include a separate tube for fluoroscopy, multiple and single phototimers, a spot-film control unit, a switch to shift the tube for stereoscopic radiography, and an exposure counter.

X-Ray Tubes

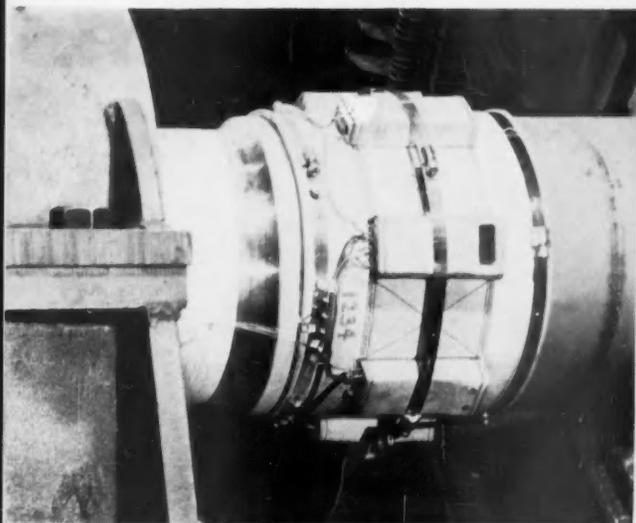
Versatile and lightweight, an x-ray tube that weighs only 24 pounds can be used without counterbalancing problems on all types and makes of radiographic tube supports. The tube offers peak ratings and double focus. Small in dimensions, it is adaptable to both radiography and fluoroscopy.

A new heavy-duty x-ray tube permits the use of higher energy ratings in making x-ray exposures without any increase in tube size. Additionally, it has a greater heat-unit input and a higher rate of heat dissipation. The new tube operates at up to 130 kv and 500 ma.

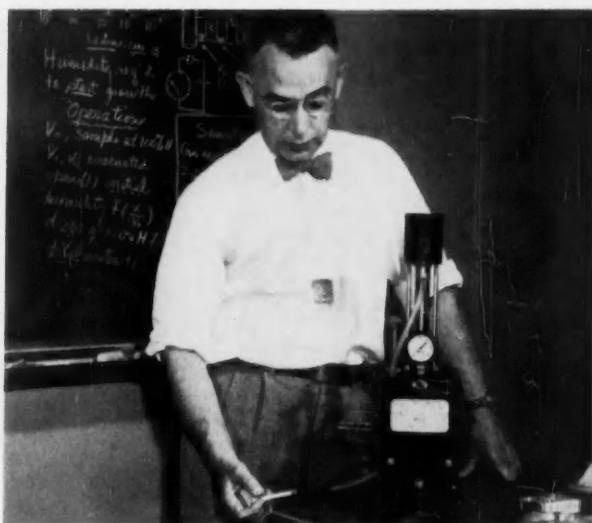
For supporting x-ray tubes, a ceiling-suspended and highly maneuverable support was developed that can be adapted to practically any type of x-ray equipment. Suspended from 9-foot-high ceilings, the support can position an x-ray tube as high as 95 inches above the floor and as low as 34 inches. Overhead mounting allows a completely clear working area when the x-ray tube is in a parked position.

Cinefluorography

The first commercial production in this country of cinefluorographic apparatus for making x-ray motion pictures began last year in cooperation with S. A. Weinberg of the University of Rochester School of Medicine and Dentistry. The heart of the apparatus is an f/0.71 lens, about 30 times faster



TORQUE TELEMETER TRANSMITS SIGNAL TO AN OSCILLOGRAPH.



PORTABLE NUCLEI METER COUNTS MINUTE PARTICLES IN AIR SAMPLE.

installations. The spectroscope and its electrode system weigh less than seven pounds, allowing an operator to support the instrument and view the spectrum with a minimum of fatigue. A 35-mm camera may be attached to the eyepiece tube to make a spectrograph.

Sound Measurements

For making noise studies on fractional-horsepower motors and on transformers, a double-walled anechoic chamber and its associated laboratory area were constructed during the year at Fort Wayne, Ind.

Mounted on springs, the anechoic chamber is a concrete room weighing 500,000 pounds. An accordion-type blanket weave is used for acoustical wall treatment; it folds in and out a distance of three feet from the concrete wall. Tests from 100 to 4000 cycles indicate an accuracy of plus or minus one decibel within six feet from a point source at the room's center. The accompanying laboratory area is well equipped to handle applied research, development, and measurement of industrial noise.

Rapid noise studies can be made with recently developed automatic equipment that measures total sound power radiated from apparatus under test. Sound pressure, or noise, can be calculated for any particular location. A small analog computer receives the microphone signal, then integrates its square. Measurements of noise can be made in free space or in a reverberant room.

Oscillographs

One of two new oscillographs is a general-purpose instrument for static

or dynamic testing of all types of industrial and aircraft equipment. Combined with suitable transducers and amplifiers, it records pressure, vibration, strain, and flow up to 71 variables. It is usable up to 6000 cycles.

The other is an automatic oscillograph that records unanticipated disturbances in power transmission circuits. The new unit's fast-starting automatic record-paper holder enables it to begin recording four milliseconds after a disturbance occurs. Recording stops after a preset interval or after the fault has cleared, whichever is longer. Month, day, hour, minute, and second are automatically photographed at the end of each record.

Strip-Chart Recording

Portable and switchboard strip-chart recorders for the indication and recording of electrical quantities were introduced last year. This line has a throw-away inkwell, reduced servicing of ink and paper, a 60-day spring clock, fast response, and 28 chart speeds. The system virtually eliminates spilling, evaporation, and contamination of ink.

Telemetry

Measurements of torque in large rotating shafts are conveniently made with torque-telemetry equipment recently developed. Mounted on the rotating shaft, an electric strain gage transmits its signal to a stationary wireless receiver. After demodulation, the torque signal is rectified and amplified for recording on an oscillograph. The equipment is packaged in small units in a flexible belt around the shaft.

Pyrometry

Developed for measuring temperature was equipment that compares two radiation intensities transmitted through a quartz rod. The intensity ratio determines the temperature. Only eight mils in diameter, this flexible quartz rod can be used where it would be difficult or impossible to measure radiation intensities optically.

Roughness

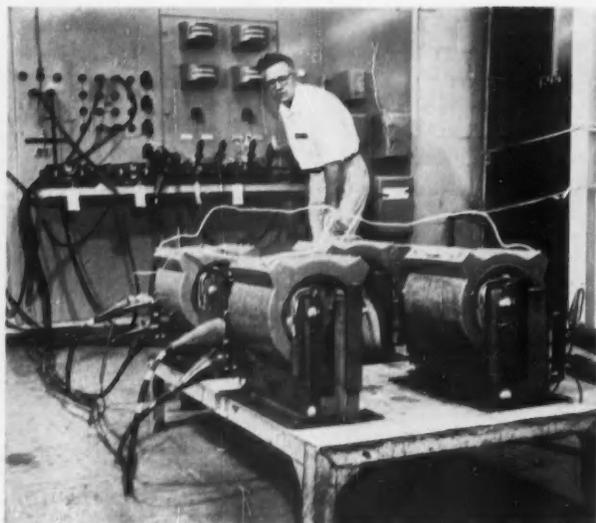
To measure the heights of burrs on metal, a special three-dimensional microscope was developed. Essentially two microscopes in one, it detects differences of one-quarter mil and magnifies them 15 times. Additionally, the instrument measures topographical variations of metal crystals.

Radiation Tachometer

A convenient method for determining the speed of rotating objects was developed in 1955. It utilizes a radioactive source attached to the rotating object and a radiation detector. During rotation the source is alternately exposed to and shielded from the detector, which need not be in direct line of sight of the rotating object.

Condensation Nuclei

Simple and portable, a device constructed in 1955 measures the number and gives an approximate size distribution of particles suspended in normal atmospheres. Such particles may vary in numbers from a few thousand to several million per cubic inch of air. The bulk of the population ranges in size from a few angstroms to about a micron.



CAST COIL TRANSFORMERS OFFER SAVINGS IN SIZE AND WEIGHT.



BLANKET WEAVE PERMITS ACCURATE MACHINE-NOISE MEASUREMENTS.

Testing and Measuring

A notable development of 1955 is a butyl-rubber insulation for molded instrument transformers used in high-voltage outdoor applications. An improved butyl formulation, it completely eliminates arc tracking from electric discharges. This product removes a major obstacle in the use of organic materials as outdoor insulators.

Transformers

Utilizing this nontracking insulation, a butyl-molded current transformer for outdoor service was successfully extended to the 15-kv class. With stainless-steel hardware and mounting base, this transformer should last a lifetime, even under severe atmospheric conditions. Another 15-kv current transformer with conventional butyl insulation was introduced for indoor applications.

A window-type butyl-molded current transformer for indoor and outdoor use at high current levels was offered to electric utilities in 1955. Intended for 600-volt circuits, the new transformer handles currents up to 4000 amp. Its large window accommodates flat or rectangular bus or several large cables.

During the year, transformers redesigned to fit the properties of filled epoxy casting resin were greatly reduced in size and weight. Also cast in epoxy

resin, small three-phase high-voltage transformers easily withstand impulse tests of 65 and 95 kv.

Cast coil transformers with a high basic impulse level, initially designed to provide control power for distribution systems, may prove advantageous in such fields as radio and TV transmission, along with many military applications. Cast coil transformers offer a substantial savings in size, weight, and maintenance.

A line of liquid-filled potential transformers in standard voltage ratings of 24 to 69 kv was introduced early in 1955. Also made available in ratings up to 69 kv were metering outfits that included radically new high-voltage bushings. The multiconductor current bushings consist of porcelain housings that make an integral assembly with the tank and its welded-on cover.

Portable Instruments

Portable a-c instruments developed during the year meet both the one-quarter and one-half percent accuracy classes of the American Standards Association (ASA) over an extended frequency range. Spring-mounted jewel bearings greatly reduce maintenance. Tough, molded windows are designed for high visibility.

Process Instrumentation

A new precision indicator rapidly and accurately scans a number of process variables. Measuring up to 48 circuits, the indicator can be used with a recorder to obtain intermittent records. It is available in either d-c potentiometer or a-c bridge types.

X-Ray Diffraction

Built up from many components, newly developed x-ray diffraction equipment begins with a moderately priced unit having only the essentials for photography. When component after component is added, the apparatus becomes completely equipped for direct-measuring techniques as either a diffractometer or a spectrograph. Two tubes can be operated simultaneously from one high-voltage transformer. Adding a spectrogoniometer and other accessories permits simultaneous filming and direct measurement. A spectrometer and helium-tunnel assembly are required to detect any element down through sulfur by x-ray emission.

Spectroscopy

Modifications of a direct-vision spectroscope permit qualitative spectrochemical analyses on samples located in manufacturing areas, stockroom, or field



ADVANCES IN APPLIANCES INCLUDE AN ELECTRONIC OVEN THAT COOKS AT HIGH SPEEDS, THE ADDITION OF A BACKSPASH CABINET COMPLETE.

Appliances

At Appliance Park, Louisville, Ky., construction was authorized for a \$5-million structure for the production of room air conditioners. In 1957 when this 8½-acre facility is in full production, it will employ about 900 persons. The same modern assembly-line methods will be used in the new building as are used in the other five buildings where refrigerators, automatic washers, automatic clothes dryers, combination washer-dryers, ranges, food-waste disposers, and automatic dishwashers are made.

Expansion of some existing Appliance Park buildings was announced during 1955. The total cost of buildings and equipment for these expansion plans will be \$40 million over a three-year period. Total employment at the Park is expected to reach 16,000 in 1958.

Refrigerators

A significant new feature on all refrigerators is a magnetic door that closes silently and automatically, has no moving parts to wear out, and gives a greatly improved door seal. Because the door

can be opened as easily from the inside as from outside, a child cannot be trapped inside.

Development of the magnetic closure necessitated the solution of many problems. For example, door gaskets in the materials and configurations ordinarily used on spring-latch doors were stiff and needed 60 pounds of pressure to seal them.

The new gasket, which compresses to give eight times the width of sealed area around the door, uses vinyl as a thin outer covering. Glass fibers inside the vinyl envelope provide the recovery, or spring, action. A closing force of about one seventh that required for old-style gaskets accomplishes perfect sealing.

Another feature of the new refrigerators is a compressor unit that utilizes a simple and extremely compact two-pole motor.

Kitchen-Laundry Center

First introduced in 1954, the kitchen-laundry center was modified during the year. A backsplash storage cabinet

complete with radio was made available. The oven was raised and additional storage space added to the center. Appliances included in the center are combination washer-dryer, sink with food-waste disposer, automatic dishwasher, range surface units, and low oven. Mounted under a stainless-steel sink top, the entire center can be installed as a single unit in any style of kitchen.

As optional equipment, a waist-high oven with cabinet can be added for those who desire a high oven. A special 24-inch cabinet can be substituted for the low oven and a special 30-inch cabinet for the combination washer-dryer if separate laundry facilities are desired.

Automatic Dryer-Conditioner

A new automatic dryer control system takes the guesswork out of selecting the proper combination of heat and time for drying various types of fabrics. The user simply sets a single dial according to the type of fabric to be dried.

Operation of the control system is based on the behavior of all fabrics



WITH RADIO TO THE KITCHEN-LAUNDRY CENTER, AND A MAGNETIC REFRIGERATOR DOOR THAT HAS NO MOVING PARTS AND SILENTLY CLOSES.

while drying. In the initial stages of drying, for example, all fabrics have an excess of water available at their surface. The new system dries all types of fabrics at full heat to remove this surface moisture. Thus evaporation takes place at an essentially constant temperature, even though the rate of evaporation varies with ambient temperature, humidity, and line voltage.

Depending on the weight of the clothes load and its moisture content, the temperature begins to rise at a time in the final drying stage when the remaining moisture must migrate from the inner fibers to the surface of the fabric in order to be evaporated. When the critical moisture content of a particular load is reached, a sensitive thermostat responds to the temperature rise in two ways: it begins to modulate the heat input to match the rate at which moisture can migrate from the inner fibers; at the same time, it regulates the progression of the control dial from the selected setting toward the **Off** position. Thus in the final drying stage, the thermostat is automatically adjusting the amount of drying heat and the length of time according to the actual requirements of the particular clothes load being dried.

Electronic Oven

A new electronic oven that will cook meats and foods at speeds surpassing those of conventional ovens by a wide margin will be on the market late this year. A magnetron tube converts normal household power into the high-frequency microwaves needed for electronic cooking. The new oven will brown the food while it is being cooked electronically. Cost of electricity for the new oven will be about the same as for cooking with conventional methods. But speeds will be higher: a three-pound rolled roast normally taking 1½ hours will be done in 15 minutes; a 15-pound turkey will be roasted in 45 minutes compared with a normal six hours. Vegetables will be cooked without water, only in the moisture contained in the vegetable itself.

Room Air Conditioners

New room air conditioners displayed some major reductions in size and weight. Volume was reduced 36 percent and weight 15 to 20 pounds from previous corresponding units. The new models have ratings of ½, ¾, and 1 hp, all with the same exterior dimensions.

Of basic significance is an entirely different method of moving the air from the room, through the machine and the

cooling coils, and back out into the room. Rather than the usual blower-type fan, a special design of propeller-type fan is used that has both axial and radial flow. The fan's action builds up pressure behind the cooling coil, resulting in an extremely even and balanced discharge of air through the coil. The net effect is full utilization of the coil surface, low air velocities for low noise level, and a major saving in total space requirements for recirculating the air.

New cord sets for room air conditioners utilize a special three-conductor thermoplastic oval cord. Available in a choice of colors, this cord is better looking than its bulky predecessor because of its smaller size.

Housewares

A new automatic kettle will boil a quart of water in less than four minutes. It has a capacity of 2½ quarts, a whistle-vent lid that signals when the water is hot, and a heating unit that shuts off automatically if the water boils away.

An all-purpose mixer with 12 mixing speeds and two beaters can be used with its stand or as a portable mixer. The portable portion weighs only three pounds, two ounces.



AUTOMATIC KETTLE boils water in less than 4 minutes per quart; an all-purpose two-beater mixer has 12 speeds; and the coffee maker has a selector for brewing at any strength.



RUBBER-TIRED WHEELS roll a new vacuum cleaner anywhere, even up and down stairs.



CAST-ALUMINUM SKILLET with temperature selector has sealed-in heating element.

A coffee maker has a brew selector for mild, medium, or strong coffee or any strength in between. Capacity is 3 to 9 cups, and the coffee stays hot after brewing.

Made of specially cast aluminum, a new skillet utilizes a sealed-in heating element. On the handle is a temperature-selector dial, indicator light, and cooking-temperature chart.

To switch from baking waffles to toasting cheese sandwiches does not require an extra set of grids in a new automatic grill and waffle baker. The grids are reversible: smooth on one side, waffle shaped on the other. This appliance has a temperature-control panel with six pretested settings and can be used as an open grill for grilling or frying.

Fan Heaters

Fan-forced heat is a feature of two thermostatically controlled fan heaters. One model has a two-tone brown case with a large copper reflector that assures a steady flow of warmth. It also has two heat levels (1320 and 1650 watts), a built-in mercury switch that turns the heater off if it is tipped, an adjustable base, and an indicator light.

All-Purpose Fan

An all-year window ventilator is mounted in a clear plastics panel. The fan unit can be snapped out of the panel and turned around to reverse the action or can be removed entirely and set up as a wall, table, or floor fan. It fits regular and casement windows, circulating 850 cubic feet of air a minute.

Vacuum Cleaners

A new type of vacuum cleaner that rolls anywhere, even up and down stairs, has 12-inch rubber-tired wheels, a large throw-away filter bag, and a detachable cord set. Designed to store easily with hose and wands attached, another, new cleaner rolls around on a four-wheel base. The swivel top on this cleaner rotates in a complete circle and the reversible two-in-one tool cleans both rugs and floors.

Clocks

Introduced on an electric automobile clock was an automatic regulator movement that permits the clock to automatically make a correction whenever the hands are set to the correct time. If the clock is slow, setting the hands forward to the correct time will make the movement run faster; if the clock is fast, setting the hands backward to the correct time will make the movement run slower. As later corrections are made and the time error becomes less, a smaller correction is made each time the hands are set, ultimately resulting in a fine adjustment, with the clock keeping correct time.

A battery-powered electronic clock is kept in synchronism by the 60-cycle power in the home or office. The 60-cycle alternating magnetic field is picked up by a ferrite antenna, and the signal is then amplified in a miniaturized transistor circuit. The amplified signal controls the frequency of a tuned oscillator that provides power to a 60-cycle 3600-rpm motor.

Timers

A new timing motor, smallest ever built by General Electric, is only 55 percent the weight of its predecessor because of size and material reductions. It has improved torque characteristics and lower noise level.

Television programs can now be automatically turned on at the start of a program and turned off after its conclusion with a new electric memory timer for TV. It allows warm-up time so that none of the program will be missed.

The air-conditioner timer introduced in 1954 was further refined last year. The timer not only turns on the room air conditioner in sufficient time to cool the rooms before their occupation but also makes it possible to skip days when the air conditioner is not required, such as on weekends and at other times when the user is away.



A PROPOSED HOSPITAL IN LIMA, PERU, WILL HAVE THE LATEST IN ELECTRICAL SERVICES.

... For Building Construction

A two-level steel underfloor wiring system for commercial, industrial, and institutional buildings, introduced during 1955, consists of two levels of steel ducts that provide complete separation of high- and low-tension services. The lower level of ducts feeds the conductors from panel boxes to the upper level that in turn distributes conductors to the surface outlets. The two-level design increases wiring capacity, provides design flexibility, and allows any number of separate services to be installed in a given floor area.

Service-Entrance Protection

The rapidly expanding 480-volt networks needed to supply 277-volt lighting and heavy air-conditioning loads of large buildings can often produce short-circuit currents as high as 200,000 amp. Circuit breakers available for service-entrance protection in such buildings have a maximum rating of only 100,000 amp at 480 volts. A new service-entrance protector, produced in 1400- to 3500-amp continuous ratings, consists of a coordinated combination of current-limiting fuses and a load break switch with a high-speed charged-spring stored-energy mechanism. The fuses will interrupt and the switch will close and latch against fault currents of 200,000 amp. The switch has adequate interrupting capacity for manual switching of full load currents.

A new building-type switchboard incorporates quick-make-break switches of high interrupting capacity in ratings of 30, 60, 100, and 200 amp at voltages up to 600. In combination with current-limiting fuses, the switch was tested for interrupting ratings of 100,000-amp rms asymmetrical.

Two new lines of service-entrance equipments were introduced during the year, one using circuit breakers as the protective element, the other using fuses. Either type serves electrical needs in homes, apartments, small offices, and light commercial applications. Both provide for three-wire 100-amp service, the minimum needed to handle today's loads.

Circuit-breaker load centers offer a full selection of ratings with 1 to 20 circuits. One design has five double-pole 240-volt branches to accommodate such appliances as ranges, water heaters, dryers, and air conditioners. A sixth double-pole 240-volt circuit feeds 8 single-pole 120-volt branch circuits for lights and outlets. Another design has 12 circuits and incorporates a 100-amp main disconnect breaker; still another is a combination meter socket and load center.

For low-cost service entrance, the new fusible line offers up to five fuse pullers for 240-volt circuits. Both series and parallel designs are available with up to 20-plug fuse branch circuits.

Heating Cable and Control

A new vinyl-jacketed heating cable provides improved performance in soil-heating, roof-deicing, and surface-heating installations. The cable is constructed of a nickel-chromium resistor with nylon covering, a layer of vinyl insulation, a tinned-copper grounding braid, and the extruded vinyl jacket. The vinyl covering protects the cable from abrasion and from the action of oils, chemicals, and water. The control consists of a thermostat with capillary tube and bulb, control setting, and double grounding outlet—all enclosed in a weatherproof die-cast aluminum cover.

Surface Circuit

Additional electric outlets are easily installed in existing wiring circuits with the new surface-circuit wiring devices and cable. The cap, fitted with an adjustable housing that enables the cable to lead out from the cap in any direction, can be plugged into any existing outlet. Caps, outlets, and other devices in the line all have the new pressure-lock terminals. The specially insulated flat-constructed cable has widely separated No. 12 conductors that permit small nail holes to be prepunched at four-inch intervals down the middle of the cable. The cable can be laid along baseboard, wall panel, or molding and then tacked down and painted to match.

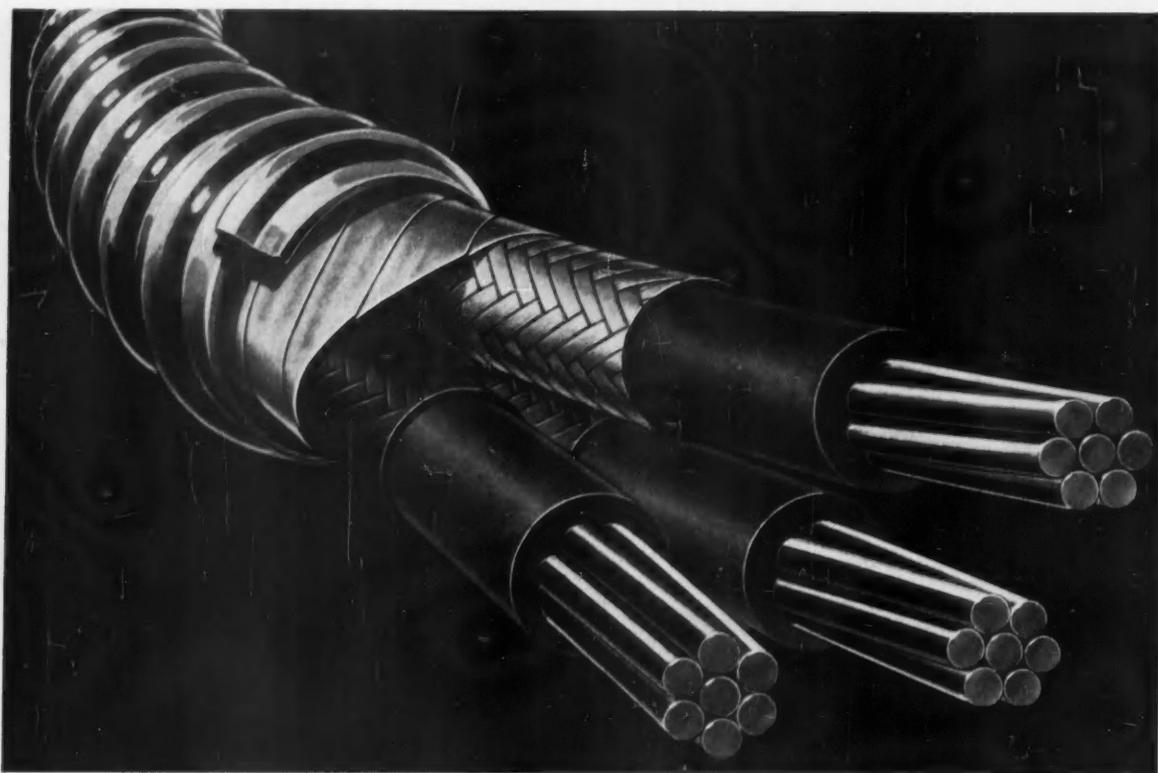
Plastics-Coated Conduit

Rigid conduit and electric metallic tubing is now coated with polyvinylchloride for use in areas subjected to unusual atmospheric conditions. The extruded seamless coating provides uniform nonporous protection over the entire length of the raceways and effectively resists the action of grease, oils, organic solvents, sunlight, and weathering. Tests indicate that 30 or 40 years' service will not age the coating significantly.

A pace setter for all Latin America, the Employees' Social Security Hospital now under construction in Lima, Peru, will have 160 miles of rigid conduit, plus intricate electrical services.

Rubber-Insulated Cable

Continued developments in rubber compounds resulted in an insulation with higher heat stability and moisture resistance for cables used in wet or dry locations at a temperature of 75 C. For wet locations this allows an operating temperature 15 C higher than previous ratings. Ω



What goes into a G-E Silicone-rubber Cable?



Silicone-rubber insulated cable being subjected to 1400°F flame for 24 hours in laboratory tests. Superior materials and rigid testing go into each G-E cable.

How can G-E silicone-rubber insulated cable keep control circuits in operation—although engulfed in flame? Why can this cable operate at temperatures up to 257°F? What gives it the moisture resistance of the best grades of rubber? In short, what makes it an outstanding cable for vital control circuits, for boiler room installations, and for high-temperature processing operations?

The answers to all these questions are the unique properties of the special silicone-rubber insulation—and each vital property has a history of G-E research, development engineering, and testing. Flame tests at 1400°F proved that this new insulation would remain nonconducting even when completely oxidized. Accelerated-aging tests proved that the cable would dependably withstand continuous ambient or conductor temperatures up to 257°F. Silicone rubber was compounded in many different ways and proportions to produce a cable that would retain its electrical and physical properties through prolonged water-immersion tests—and that could be handled and terminated as easily as an ordinary rubber-insulated cable.

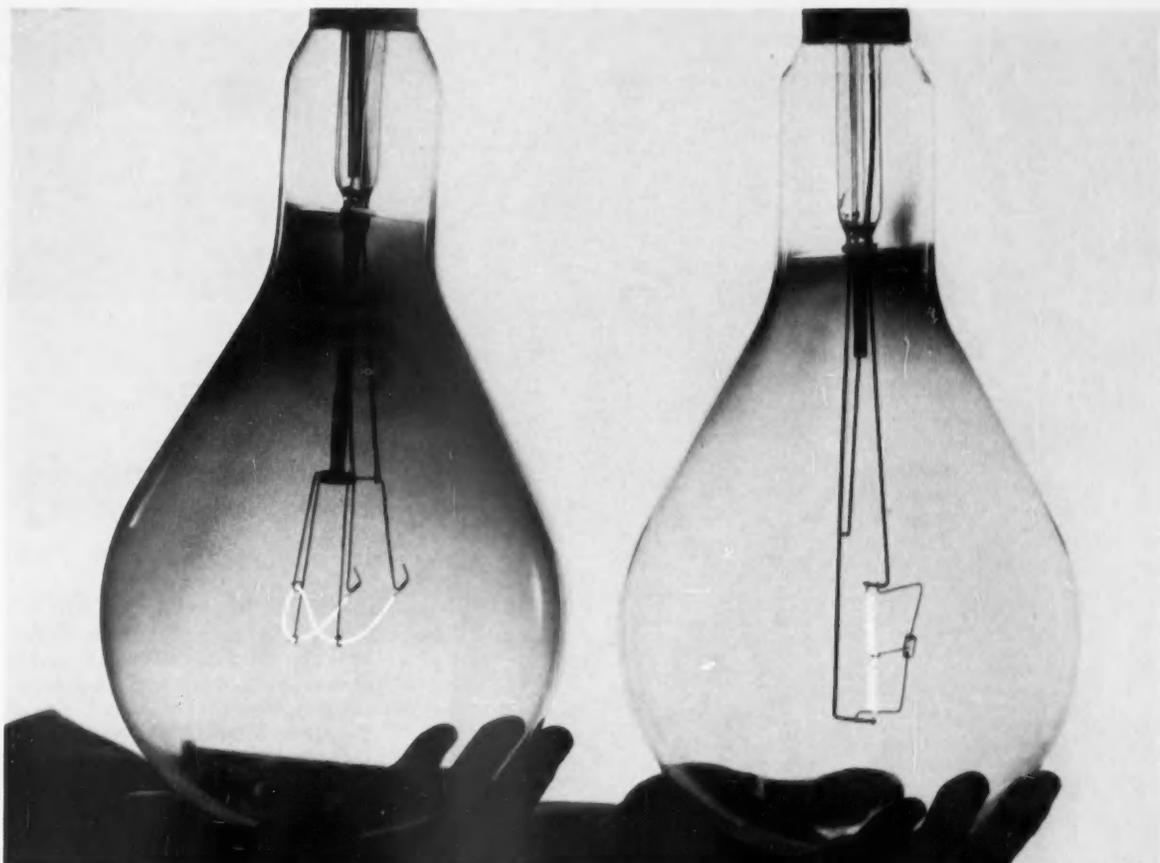
When you specify G-E silicone-rubber insulated cable or any G-E cable you can be sure that the research, knowledge and equipment of the entire General Electric Company have been combined to produce the best possible product. For more information write Section W137-737, Construction Materials Division, General Electric Company, Bridgeport 2, Connecticut.

Progress Is Our Most Important Product

GENERAL  **ELECTRIC**

Announcing: New G-E Bonus Line of lamps, incorporating the most important development in light bulb filaments since 1913!

New G-E discovery uses revolutionary stand-up filament to give you 15% more light from a bulb



Compare standard crosswise filament, left, with new G-E stand-up filament, in bulb on right. Note reduction in bulb blackening after same hours of use.

Promises America a Yearly Light Bonus of Over \$100,000,000

General Electric announces the most important development in light bulb filaments in 42 years—a filament that stands on end. It gives up to 15% more light at no increase in cost to you for current consumed.

The 750 and 1000 watt Bonus Line G-E Lamps are available now, at same list price. Other sizes from 60 to 500 watts are being redesigned to use the new stand-up filament

FOUR YEARS OF RESEARCH

Four years of intensive research were required to solve the technical problems involved in changing from the usual crosswise position to a vertical position.

The light gain achieved by the new stand-up positioning is a minimum of 6%. The new positioning makes it practical for the first time also to use a specially

designed coiled-coil filament in bulbs of 300 watts and over. In these larger bulbs, the two improvements combine to bring the light increase to 15% during the life of the bulb—extra light worth the entire purchase price of the bulb itself!

LIGHT INCREASED, BLACKENING REDUCED

The new stand-up filament increases light output in two ways.

First, the hotter a filament burns the more light it gives, and the vertical position allows the filament to burn

hotter without burning out any sooner.

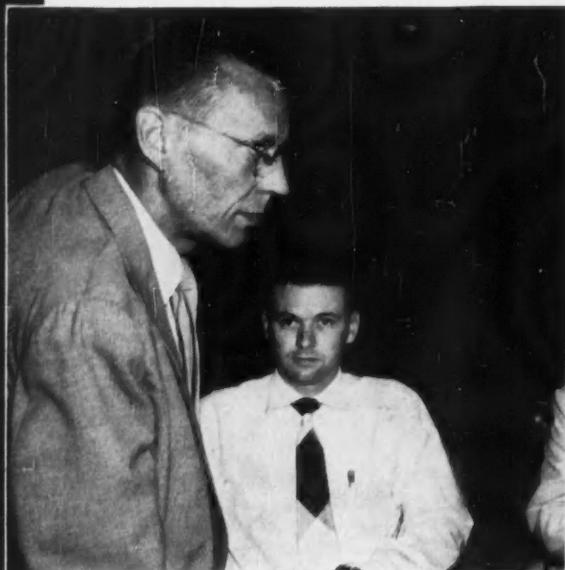
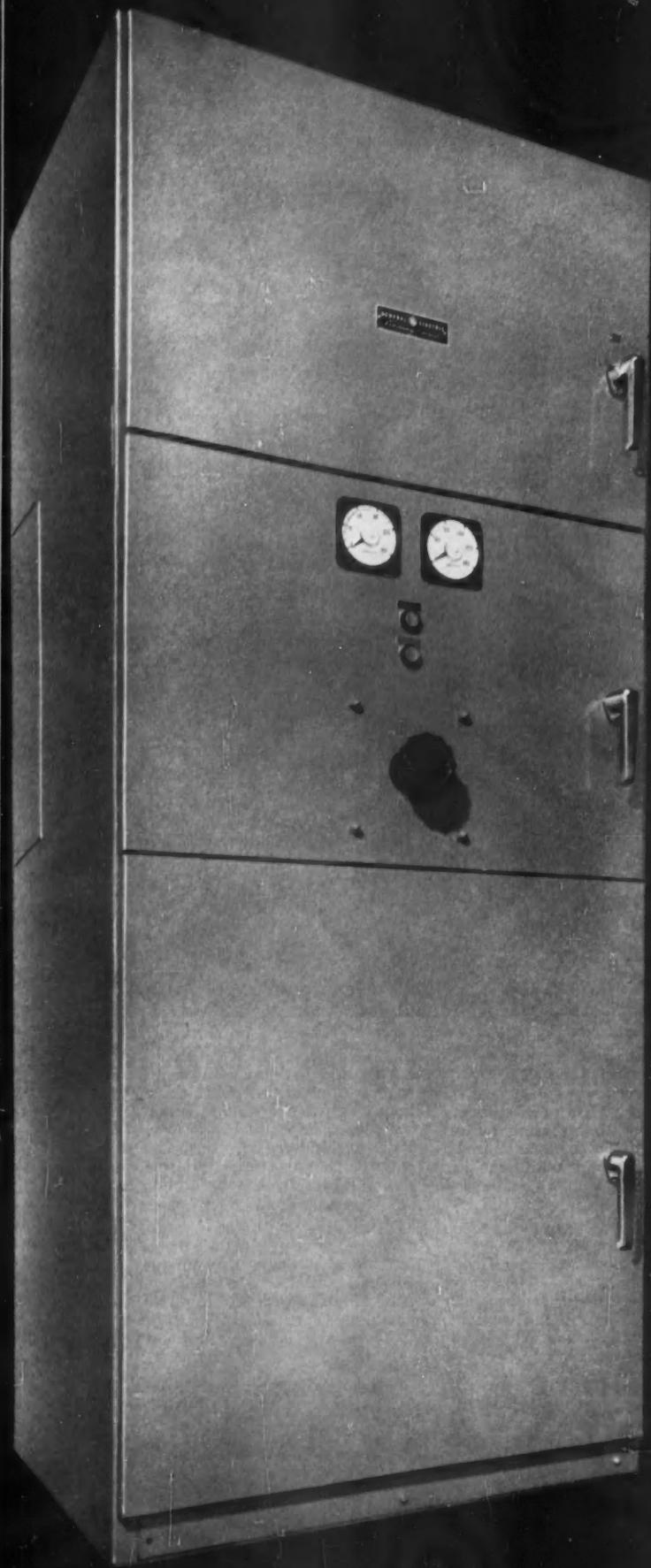
Second, the effect of bulb blackening on light output is cut to a minimum. Blackening is concentrated in the stem of the bulb when it burns base up, or in a small spot at the opposite end when burned base down. Safely out of the way in either case.

\$100,000,000 LIGHT BONUS

G-E incandescent bulbs using the new filament are called the G-E Bonus Line. The value of the light bonus they will ultimately deliver is estimated at over \$100,000,000 a year. For more information write General Electric Large Lamp Department, Nela Park, Cleveland 12, O.

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3 CUSTOMERS STATE . . .

Space, Safety

Placed on the market in July of this year, General Electric's all-new Limitamp Control has received enthusiastic acceptance throughout industry.

1. NEW MOUNTING ARRANGEMENTS. Almost immediately, L. L. Hamig, of Ferris & Hamig, Consulting Engineers, found the exclusive front-connected feature of the new control solved a tough application problem. There is no need for a back aisle with the new equipment, so units may be mounted back-to-back, back-to-wall, or as free standing enclosures yielding great space savings.

2. 50% SMALLER. In another case, H. A. Weigand, of Ingersoll Rand Company specified this new fused starter in a compressor station for the Laclede Gas Company of St. Louis, Missouri. Mr. Weigand stated the new control's 50% floor space saving feature simpli-

◀ **50% smaller than previous models, all-new G-E Limitamp Control offers a gang-operated disconnect switch as standard equipment. See opposite page for space savings comparisons.**

"The all front-connected feature of G.E.'s Limitamp Control gave me the versatile floor arrangement I needed to solve a tough application problem," said Mr. L. L. Hamig (extreme left) of Ferris & Hamig, Consulting Engineers, St. Louis, Mo. Seated are R. E. Watts of Ferris & Hamig and P. L. Kerklan, General Electric Co. Sales Engineer.

"The space savings offered by G.E.'s Limitamp Control helped simplify the installation of a compressor station for the Leclade Gas Co. of St. Louis," according to H. A. Weigand of Ingersoll Rand Company. The compressor station is located in a residential area and conforms to local building codes. This put space requirements at a premium and posed a real installation problem.



Problems Solved by New G-E Limitamp* Control

fied installation where space considerations were a primary factor.

3. ADDED SAFETY. One of the nation's largest automobile manufacturers ordered eight of the starters and within days increased the order to 17. The gang-operated disconnect switch and co-ordination features which afford greater protection of the starter, the controlled equipment, and personnel were exactly what they wanted.

The 30" depth of the new Limitamp Control, which allows the unit to be transported through normal size doorways, has also received industry-wide approval. The unit's 90" height includes bus compartment which is surrounded by steel barriers within the enclosure.

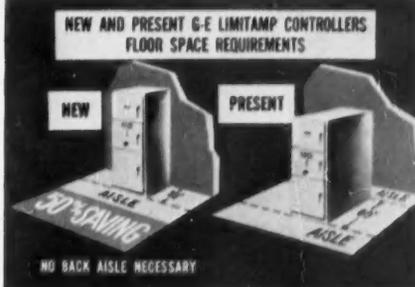
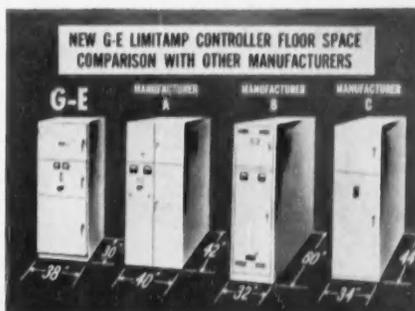
Other features which save time and money on installation and maintenance are the low-voltage panel, hinged to swing out of the

*Trade-mark of General Electric Co.

cabinet, and the contactor which may be easily rolled in or out of the enclosure. This provides ample room for a worker to enter the enclosure while making installation connections.

This all-new Limitamp Control is ideal for high-voltage motors, rated 2300-4800 volts, up to 3000 hp, and may be applied to squirrel-cage, synchronous, wound-rotor, and multi-speed motors on power systems requiring high interrupting capacity for maximum short-circuit protection.

Specify the all-new Limitamp Control through your nearest G-E Apparatus Sales Office. G-E engineers will help apply this new control to your operation. For more information write for Bulletins GEA-6331, GED-2446, to Section 781-14, General Electric Company, Schenectady 5, New York.



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Putting electricity to work around the world

Around the globe, General Electric people are working to make life better with the finest of electrical products and services. G-E experience in research, engineering and manufacturing has enabled and will continue to enable the Company and its world-wide organization to help build the economic strength of many countries, to make living easier for millions of people in hundreds of places. The G-E monogram is accepted everywhere as a symbol of quality and proven performance. G-58-1

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A progress report on semiconductors:

IN THE PAST 12 MONTHS, 8 IMPORTANT STRIDES TOWARD BETTER SEMICONDUCTORS

1955 witnessed a year of great progress for General Electric Semiconductor Products.

Yes, last year *was* a big year for G-E transistors and rectifiers, the biggest yet. During the past 12 months General Electric:

- ★ Developed a new high-temperature rectifier, now incorporated into U. S. Air Force and U. S. Navy specifications,
- ★ Incorporated new techniques in transistor manufacture and design making possible a dependable, economical transistorized pocket radio,
- ★ Produced a new full line of high frequency transistors for computers and switching circuits,
- ★ Reduced prices twice because of an improved controlled processing manufacturing technique which cuts costs, improves product quality,
- ★ Manufactured a new medium power germanium rectifier with an 85° C rating,
- ★ Announced a full year warranty for all G-E Semiconductor Products,
- ★ Added hundreds of new engineers and technicians, thousands of square feet of new facilities to step up semiconductor production,
- ★ Shipped the first quantity of small, highly-efficient silicon rectifiers capable of handling up to 50 amperes at 200 volts and 150° C.

In 1955, a combination of teamwork, skill, and hard work spotlighted General Electric as the company to watch for latest developments in the semiconductor industry.

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But 1955 is history!

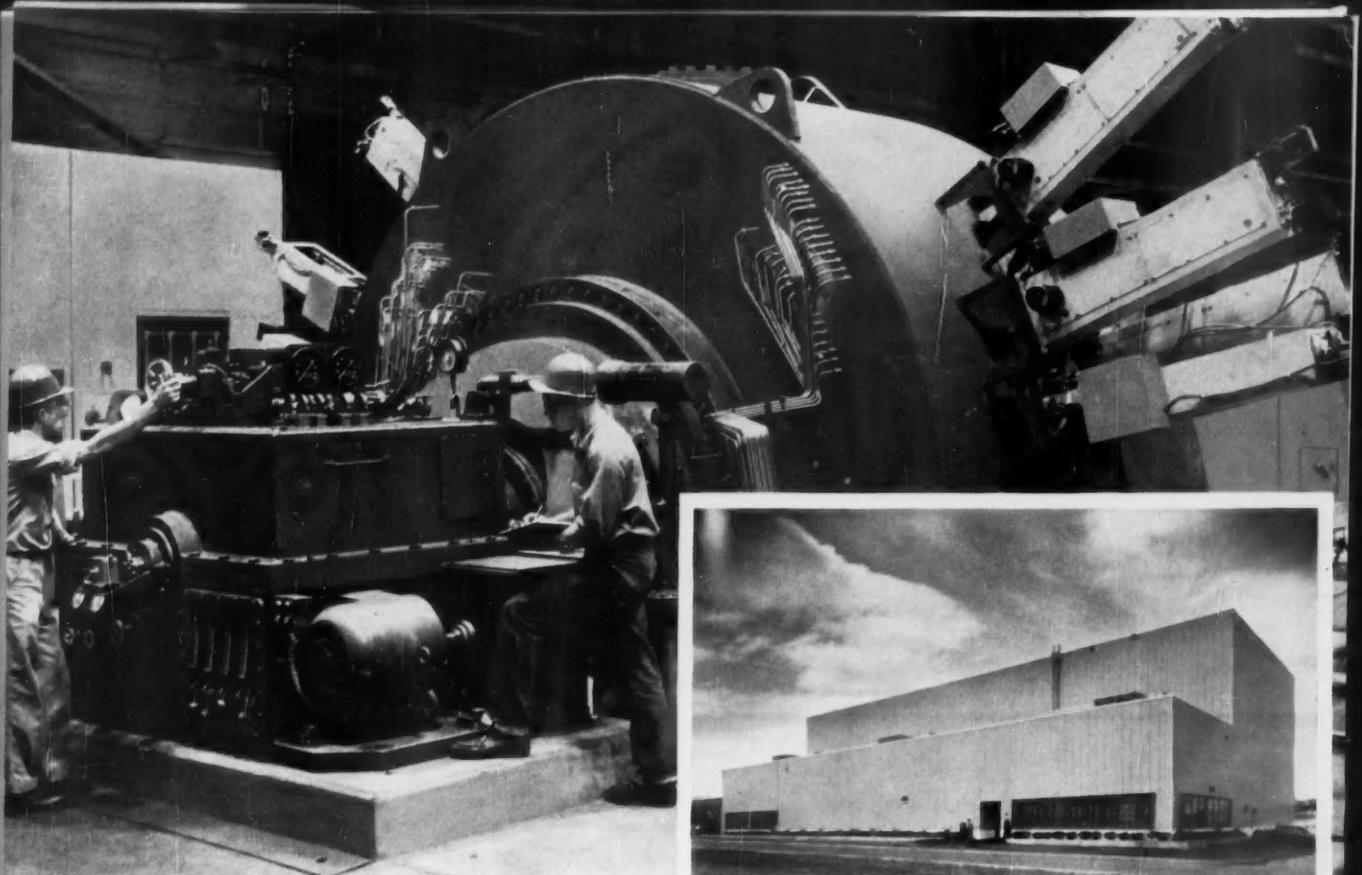
Let's look at tomorrow, the promise it holds for progress in electronic and electrical fields, thanks in part to semiconductors. During the coming year the efforts of G-E Semiconductor Products will be keyed to varied industry needs.

*Here is our Promise
for 1956—*

Look for new products, improved products, at a more economical cost.

Look for General Electric rectifiers and transistors with much higher ratings: Higher frequency ratings for transistors, higher operating temperatures for all G-E Semiconductor Products.

Look to General Electric for the significant advancements in semiconductors. For further information, see your local representative, or, write: *General Electric Company, Semiconductor Products, Section X956, Electronics Park, Syracuse, New York.*



LOW-PRESSURE TEST TURBINE in the new Product Development Laboratory (inset) permits full-scale evaluation of latest concepts in steam path design.

New turbine lab facilities ready to tackle the problems of nuclear power generation

The generation of low-pressure, low-temperature steam by nuclear power reactors re-focuses attention on the low-pressure section of steam turbines and the increased importance of efficient use of the energy in this region. Present G-E low-pressure designs are basically suitable for application in nuclear power plants. Special problems, such as moisture removal to minimize later-stage erosion, need refinement.

The solution to such problems can be evaluated in the Turbine Development Laboratory's new full scale, low-pressure test turbine. The largest 3600-rpm steam parts built by General Electric can be run in this turbine under actual operating conditions.

Other special problems such as corrosion of the turbine parts and contamination by radioactive steam are being tackled in General Electric's other complete laboratory and testing facilities. These and many other G-E programs are keeping turbine development abreast of trends in reactor design.

From America's first commercial generation of electricity by nuclear energy (using a G-E turbine)* to working closely with various study groups, General Electric is helping to make atomic-electric power an economic reality in the shortest possible time. General Electric Company, Schenectady 5, N. Y.

254-33
*At West Milton, N. Y., July 18, 1955

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