

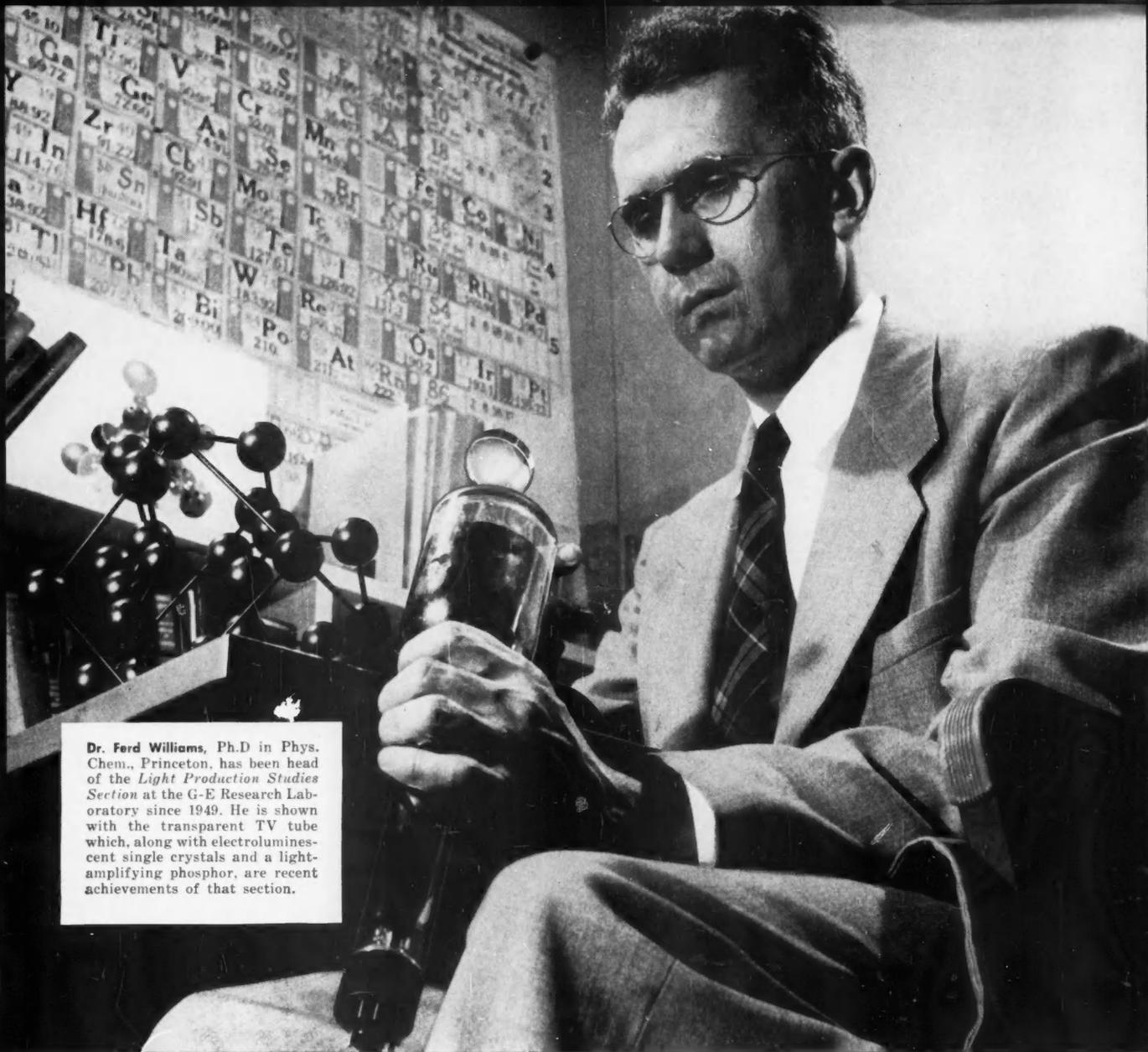
**GENERAL  
ELECTRIC**

# Review



**Research  
and  
Engineering  
Progress  
1954**

**JANUARY  
1955**



**Dr. Ferd Williams, Ph.D in Phys. Chem., Princeton,** has been head of the *Light Production Studies Section* at the G-E Research Laboratory since 1949. He is shown with the transparent TV tube which, along with electroluminescent single crystals and a light-amplifying phosphor, are recent achievements of that section.

## New light on luminescence

**General Electric's Dr. Ferd Williams develops equations to predict accurately the role of new activators in phosphors.**

For years it has been known from experience that the luminescence of solids is governed by small impurities known as *activators*, but theoretical understanding of these phenomena was lacking. Dr. Ferd Williams and his associates in G.E.'s *Light Production Studies Section* have now worked out theoretical calculations for the role of activators in the luminescence of simple phosphors. They have also been able to reproduce the spectra of excitation and emission that are observed experimentally. For the first time it has become possible to make quantitative determinations of the luminescent properties of a new phosphor in advance of laboratory measurements.

Today the most important applications of phosphors are in fluorescent lamps and in the cathode ray tubes used in radar and television. Tomorrow's applications are still in the lap of the future. But the work of Ferd Williams and his associates at the General Electric Research Laboratory gives promise of a better understanding of all luminescent phenomena and the feasibility of new and improved phosphors.

*Progress Is Our Most Important Product*

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**Review**

EVERETT S. LEE • EDITOR

PAUL R. HEINMILLER • MANAGING EDITOR

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**COVER**—GE's \$1½-million Transformer Sound Laboratory, believed to be the largest of its kind in the world, was dedicated in Pittsfield, Mass., during October, 1954. The 58x48-foot room measures 43 feet from track level to ceiling. Each wall consists of 12 inches of concrete, a 2-inch layer of fiber glass, 8-inch concrete blocks, a layer of copper sheathing, dead air space, and more than 12,000 fiber-glass wedges. (For further details about the new laboratory, see page 21.)

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**AFTER YOU GRADUATE...**

## What will you add to jet engine progress?

New, dramatic advances being made at General Electric's aircraft gas turbine operations bring into clear focus the vital role recent college engineering graduates play throughout the company. Typifying such responsibility are R. W. Bradshaw, ME, Lehigh, '48, responsible for design of development engine controls and accessories, and B. C. Hope, EE, UCLA, '49, supervisor of test programs for development of aerodynamic and mechanical components.

Like other electrical, mechanical, metallurgical and chemical engineers,

these young men broadened their background in GE's after-college program of practical engineering assignments in fields and locations of their own choosing. Working with world-renowned engineers, they and other recent college graduates at G.E. show how you can make important contributions in such fields as jet propulsion, electronics, and atomic power early in your engineering career.

For full details on the G-E career suited to your talents and interests, see your college placement director.

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

# LIGHT'S DIAMOND JUBILEE

## AND THE ENGINEER

In the past year we have celebrated the brilliant accomplishment of a young man: Thomas Edison. He produced the first practical incandescent electric lamp at the age of 32.

That was 75 years ago. Since that time 39½-billion electric lamps have been produced, and as many more will be produced in the next 15 years.

What a story for the engineer! I have told it over and over again in the past year. And now I am telling it again, for its fundamentals are the motivation in the life of every engineer.

Edison dreamed of an incandescent lamp—a lamp that didn't exist—and he set about to bring it into being. To do this he had the help of a friend who had faith in him. This help gave Edison equipment and associates with needed skills. And with these he put all of his characteristic intensity and his great technical imagination into the effort of producing a small unit electric light.

Hundreds of experiments took place. Gradually a serviceable lamp filament of carbonized substance and an all-glass hermetically sealed bulb were developed. Lastly the means of obtaining and keeping a vacuum in that bulb were worked out.

Toward the end of October, 1879, Edison carbonized a cotton thread. He placed it, bent in horseshoe form, inside one of his sealed glass bulbs. On the evening of October 19, this crude experimental lamp was connected in circuit. A knot of Edison workers had gathered to see what would happen.

Current was switched on. The lamp glowed with a soft light. Quickly they measured the resistance. It was 275 ohms—overwhelmingly greater than the four or five ohms of previous incandescent lamps. Then they all sat down to watch the slender horseshoe of light, half expecting it to vanish. But hour after hour it continued to glow until the night was spent.

No one had eaten, no one had thought of sleep. The gray of a second dawn found them still at their vigil. That tiny glass bulb with its slender filament contained their hopes of harnessing electricity—that

wild mysterious force—and setting it to work for the benefit of mankind.

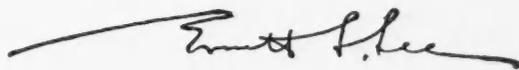
About one o'clock on the second afternoon, October 21, 1879, 40 hours after the lamp first received the current, Edison reached over to the rheostat and gradually increased the voltage until the filament burned out.

The spell was broken. The men leaped up with cries of jubilation. But Edison was quiet in the hour of his tremendous success. As the lamp glowed he envisioned "great cities lighted from central stations," and his mind was alive with plans.

Then comes one of the greatest parts of the story. Edison immediately set about to supply the tremendous demand for his new electric light. He began the commercial manufacture of incandescent lamps in October of 1880, and he later established shops for the manufacture of dynamos, underground conductors, sockets, fuses, switches, meters, fixtures—everything necessary for the complete system—so that everybody could have electric light. On September 4, 1882, only three years after that eventful 40-hour vigil, Edison began the operation of his dream central station for incandescent lighting. It was at 257 Pearl Street, New York City, and it supplied a small number of customers with power for about 400 incandescent lights. Today, there are over 50 million customers of the great electric light and power industry.

In that wonderful story we find all of the fundamentals involved in the broad concept of the engineer: Men with vision to see ahead . . . scientists with ability to bring us new knowledge from nature . . . engineers with skill to form that knowledge into products we all can have and use . . . men to invest capital for equipment for research, development, design, manufacturing, and for selling . . . a public anxious to use the new products . . . a government dedicated to maintain a climate of free competition.

This is the American free-enterprise system. The engineer and the scientist make it go. This is the brilliance of Light's Diamond Jubilee for the engineer.



EDITOR



RESEARCH LABORATORY AT A MOHAWK RIVER BEND NEAR SCHENECTADY IS IN THE MIDST OF A \$13-MILLION EXPANSION PROGRAM.

## Research

During 1954, the Research Laboratory at Schenectady was in the midst of a \$13-million expansion program to increase facilities about 50 percent. A corresponding increase in personnel is also planned, and by 1958 the laboratory staff will number 1560 employees, including 460 professional people. In addition to the new metallurgy and combustion buildings, work now in progress includes a 5-story addition for the main laboratory building and a 2-story addition to an existing wing.

### Chemistry

A new thin-film magnet-wire enamel for the Class B range was developed after a long search for an enamel able to withstand the damaging effects of high temperatures for long periods. Easy to apply with standard enameling equipment, it has superior abrasion and solvent resistance, is flexible, and maintains high dielectric strength after long periods at high temperatures.

Combined pressures and temperatures believed to be the highest ever reached were maintained for significant periods: 1½-million psi at 3600 F for 20 minutes, achieved with a press that has been in operation for several years. A new 1000-ton press is now in use and will open new horizons in the study of super-pressure.

Intensive studies of dielectrics disclosed both an important relationship between the structure of hydrocarbon gases and their sparking potential and

the critical role of oxygen in corona phenomena.

X-ray emission spectrography was shown to be a rapid and convenient method of identifying and determining traces of materials. For example, by means of a technique similar to the common spot test, elements heavier than calcium can easily be determined in microgram amounts.

Ground was broken for the new \$1.8-million Combustion Laboratory and construction neared completion in 1954. Two 800-hp and one 200-hp air compressors will be installed to assist research in this field. The 13,000 square feet of floor space includes test rooms for combustion and a small gas-dynamics laboratory, as well as facilities for turbine-bucket testing. Extensive measures were taken to reduce noise from the building.

Fluidization, a method developed by oil companies during World War II for efficiently bringing gases into contact with solids, is receiving more and more attention from the chemical industry. A unique feature of work in this field by G-E scientists is the use of x-ray absorption techniques to get density profiles of the fluidized solids.

Recent developments in silicone-rubber chemistry permit the covulcanization of silicones with other natural and synthetic rubbers. This process is achieved by incorporating into the silicone gum reactive sites that permit sulfur to be used to join the silicone

with the other rubber. Initial work with butyl rubber yielded a product with improved low-temperature flexibility and excellent corona resistance.

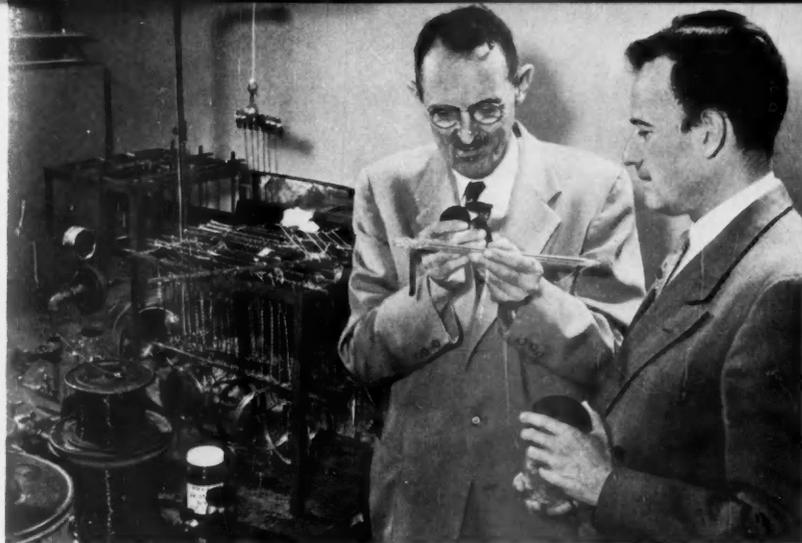
The versatility of silicones was uniquely demonstrated in an application that eliminates the problems of dust, scratches, and fingerprints confronting photographers who want to make enlargements from 35-mm negatives. A silicone liquid used in a special film carrier during enlarging has an index of refraction near that of the film base. By filling the valleys made by scratches on film, it eliminates light scattering during projection and the resultant defects on the print. The liquid also removes fingerprints, and the flushing action of the special carrier permits the filtered liquid to wash off dust particles.

### Electron Physics

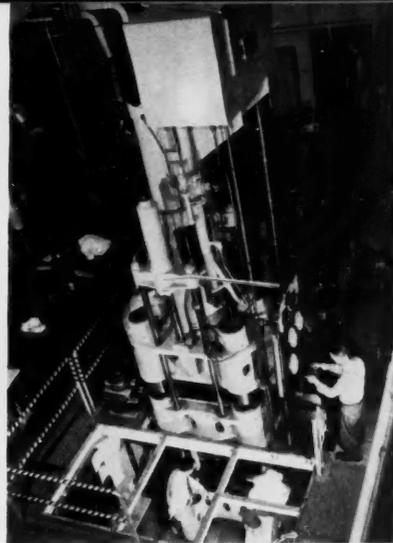
Substantial progress was made in the design of miniature ceramic tubes for microwave frequencies, and work continues toward exploitation of titanium's and zirconium's outstanding gettering properties for final evacuation of vacuum tubes.

The world's only nonferromagnetic synchrotron was in operation almost daily throughout 1954. In actual operation the accelerator achieved energies in excess of 300-million electron volts. Various high-energy nuclear and meson experiments are now being conducted.

Continued studies of secondary emission, ion poisoning, and bombardment



**THIN-FILM MAGNET-WIRE ENAMEL** withstands damaging effects of high temperatures for long periods, has superior abrasion and solvent resistance, and is easy to apply.



**NEW 1000-TON PRESS** at Research Laboratory will open horizons in superpressure study.

effects showed reasons for and means of minimizing the deterioration of TV picture-tube screens.

Work continued on the development of new types of traveling-wave tubes that will allow amplification of signals at higher frequencies and wider bandwidths than is possible with triodes. These tubes employ a slow wave structure, such as a single helix, a double helix, or a loaded waveguide, to slow down microwave signals to the point where they can interact with an accompanying electron stream and thus be amplified.

A new and unusual method of amplifying microwaves is the scalloped beam amplifier. In this tube a microwave signal traveling along an electron beam of periodically varying diameter is amplified without the benefit of an accompanying circuit.

An experimental model was made of a new humidity-sensitive element that passes sufficient current from a 120-volt a-c line to operate available low-cost relays. Also under development was an experimental gas-leak detector sensitive to hydrogen, bottled fuel gas, alcohol vapor, natural gas, and other flammable gases. It will spot a leak as slow as one cubic inch an hour by utilizing an electrical phenomenon occurring in the vicinity of contacts between electrodes and a special type of ceramic used as a core. In the way it is used, the new detector is similar to the previously developed electronic "sniffer." Extremely sensitive to halogen gases, the latter device detects leaks in vacuum systems.

Vacuums equivalent to one billionth of normal atmospheric pressure were



**SILICONE LIQUID** used in special film holder during enlarging fills valleys made by scratches on film (left), eliminating light scattering and the resultant defects on the print.

achieved with a new ionic pump that has no moving parts. It uses electric forces to break up gas atoms and deposit the particles on absorbing surfaces of carbon or titanium.

A reassessment of the field-emission microscope as a research tool made possible important studies of crystal transformations and adsorption phenomena.

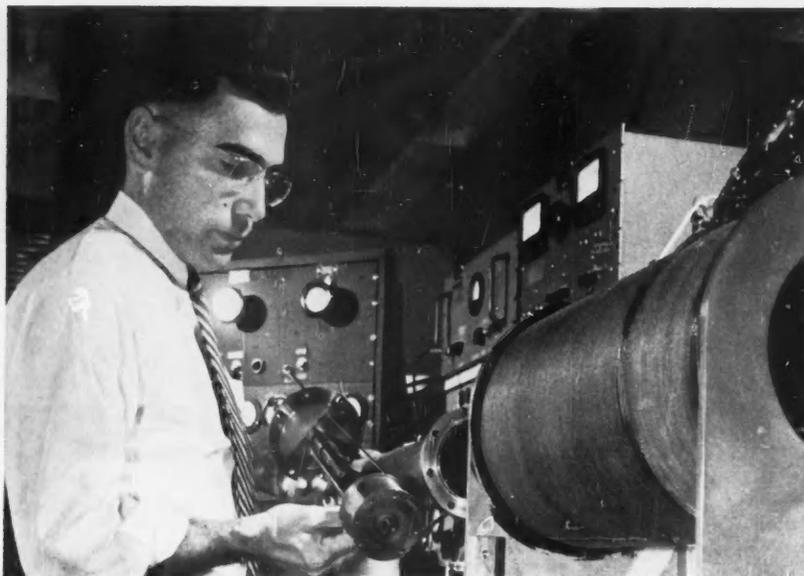
During the year, work done to increase the maximum operating frequencies of junction transistors was followed by a detailed study of transistor parameters in relation to increased frequencies.

Further research was carried out on a method to present color television in the home by projection techniques.

### General Physics

During an extensive semiconductor research program, silicon was processed to a purity and perfection many times better than ever before. Meanwhile, important new effects in semiconductors were found that are analogous to thyatron or gas-discharge action.

Low concentrations (about one part per billion) of dissolved impurity metals were shown to drastically alter the low-temperature properties of germanium crystals. At liquid nitrogen temperatures these crystals show high photosensitivity at long infrared wave lengths. This study is an important step toward understanding local energy levels introduced into germanium by impurities.



**TRAVELING WAVE TUBE**, using a slow wave structure such as single or double helix or loaded waveguide, will allow signal amplification at higher frequencies and wider bandwidths.

Experiments indicated that the presence of certain structural defects, even in small concentrations, can influence germanium's electrical properties. Such defects can be introduced in a controlled manner by plastic deformation or by growing crystals with grain boundaries, thus facilitating a systematic examination of their effects.

The dielectric constants of silicon and germanium were measured directly for the first time. When doped with gold, both materials have extremely high resistivity at liquid-air temperatures. The gold substitutes a new center for the ordinary impurities. Thus direct measurement becomes possible, because conductivity is more easily frozen out on cooling.

As gold diffuses in silicon at temperatures of 1100 C and higher, silicon becomes a dielectric material. A new method for measuring this rapid diffusion was developed, based on the measurement of the surface layer's capacitance. From this capacitance the depth of diffusion is easily calculated and the diffusion coefficient known.

At the request of the U. S. Army's Quartermaster Corps, a study of food preservation by use of cathode rays was extended through a biological research program established in co-operation with Union College, Schenectady.

Theoretical understanding of luminescence is widening one of the most productive areas for research. Recent developments include successful investigation to show the function of manga-

nese as an activator in phosphors; use of radioactive isotopes to identify the activator in zinc sulfide; for the first time, prediction in advance of measurement of a new phosphor's luminescent properties; and new understanding of phosphor resistivity's role in the effectiveness of cathode-ray excitation.

The phenomenon necessary for a solid-state light amplifier was discovered during 1954. Striking increases in luminescent brightness were observed when zinc-sulfide phosphor films were subjected simultaneously to both electric fields and ultraviolet radiation. This enhancement of photoluminescent efficiency increases with field strength. At high fields, the intensity of the emitted visible light is greater than the incident ultraviolet radiation, indicating that true light amplification takes place. Currently being investigated is the similar behavior under x-ray excitation.

In connection with electroluminescent studies, a number of new techniques were devised to activate large single crystals of zinc sulfide. Copper can be diffused into the crystal by alloying it with a drop of indium that has been wetted to the surface of the crystals. The crystals can also be activated by vacuum evaporating copper onto the surface of the crystal and then heating the crystal to allow the copper to diffuse into the lattice. The crystal is then reheated in the presence of chlorine.

Intensive investigation gave new insight into the mechanisms of chemical



**IONIC PUMP** achieves vacuums equivalent to one billionth of normal atmospheric pressure.

reaction and light production in photo-flash lamps.

#### **Metallurgy**

Virtually completed and partially occupied was the new \$3.7-million Metallurgical Laboratory and shop-type structure for the development of metallic and ceramic materials and their processing. More equipment installations will be made this year.

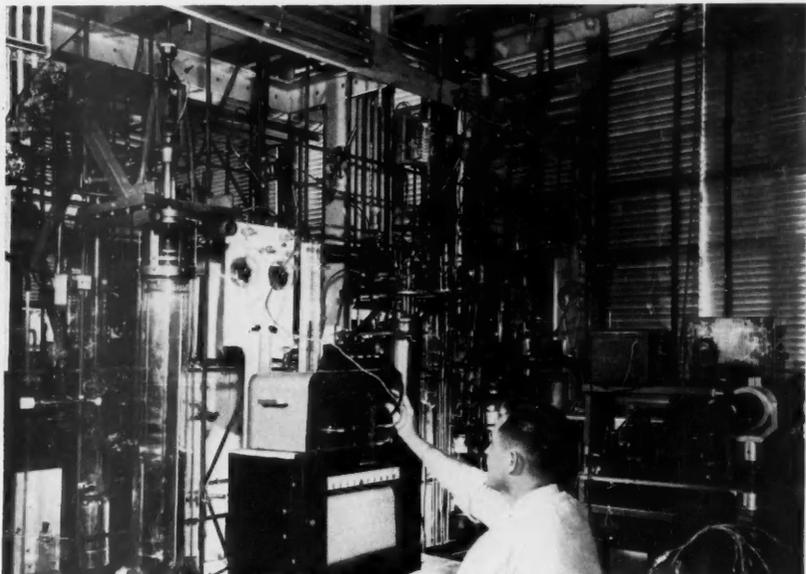
New ceramic compositions have controlled thermal-expansion coefficients, low dielectric losses at high frequencies, and absence of cathode emission poisoning. An important feature of small experimental amplifier tubes now being developed, these ceramics are also used in power resistors and x-ray tubes.

Necessary to understanding many of the reactions that produce high strength in metals is information on the rate and mechanism whereby atoms move about or diffuse in metals. From experiments using radioactive isotopes it was found that in silver alloys atoms move along grain boundaries and through "pipes" in the atomic lattice of metals a million times faster than through the bulk material. Similar behavior is anticipated in alloys other than silver.

Little is known of the fundamental reasons why metals break. An experimental study of the origin, size, shape, and distribution of microscopic cracks in iron was made. Cracks less than a thousandth of an inch wide sometimes appear after the slightest amount of deformation. The tendency of the cracks



**FIELD-EMISSION MICROSCOPE** aids crystal-change and adsorption-phenomena study.



**LOW-TEMPERATURE LABORATORY** contributes to an understanding of how electricity is conducted at room temperature and gives an insight into how to improve conductivity.

to grow in size was related to iron's fracture strength. The relationship accurately describes and predicts the tendency of iron to break under severe service conditions.

Substructure, or the configuration within the grains of metals, is important in determining how metals will deform at elevated temperatures. G-E research metallurgists developed a new method of studying substructure by direct microscopic observation, supplementing the use of x-ray diffraction techniques. This method is expected to give new information on the flow and fracture of metals.

Titanium, a new material of growing commercial importance, is available only in small quantities because of limitations in the methods of melting, alloying, and casting. Studies of the inert-atmosphere arc-melting process resulted in the development of a titanium arc-melting furnace that will significantly aid the production of commercial titanium ingots. A \$14-million arc furnace is now under construction in the laboratory shops for installation in the new metallurgy building.

Pilot-plant developments on superalloy production by means of the vacuum-melting process made possible the entrance of GE's Carboloy Department into a new line of the specialty-metal business. Metals thus produced have improved ductility and fatigue strength because contamination by reaction with the atmosphere is reduced. The new superalloys not only make

possible increased performance and safety in jet and gas-turbine engines but also reduce the amount of critical materials needed.

Further experimentation during 1954 on the growth of perfect iron crystals showed that the strength of these tiny metal whiskers is 100 times greater than that of any known metallic crystals. The growth of nearly perfect crystals of other metals is being studied, and methods of growing larger perfect crystals of iron are under investigation.

Recent encouraging attempts were made to find metal and ceramic coatings to protect molybdenum from oxidation; the goal was to make this strong but easily oxidized high-temperature metal suitable for use in jet engines and gas turbines.

Special equipment was designed and constructed to investigate what happens to materials when they are subjected to extremely high pressures at temperatures near absolute zero. Improved understanding of the superconductivity or zero-resistivity of materials at low temperatures would not only contribute to the understanding of how electricity is conducted at room temperature but also give an insight into how to improve conductivity.

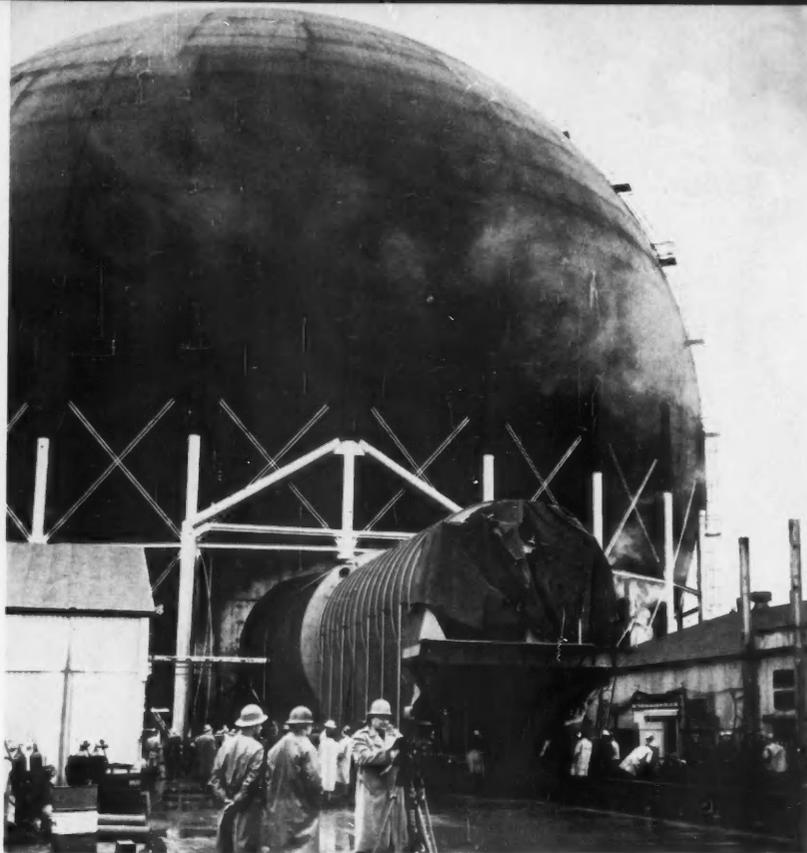
One of the means whereby alloying increases the plastic strength of metals was discovered during 1954. When a metal crystal deforms plastically, one part of the crystal slides over another. In sliding, atoms on one side of the sliding surface are torn away from their

old neighbors on the other side and brought in contact with new neighbors. Because atom configurations of higher energy are produced, large forces are required to cause deformation, resulting in high plastic strength.

Some low-alloy high-temperature steels show reduced ductility in stress-rupture tests conducted at service temperatures for periods longer than a year. The Larson-Miller parameter that permits long-time strength data to be obtained from short-time tests at high temperatures was useful in expanding knowledge of high-temperature strength. But it usually indicates much higher rupture ductility than would be observed in the long-time tests at the lower service temperatures.

Laboratory evaluations of rupture-ductility data for Cr-Mo-V and high-strength 12 percent chromium alloys revealed that ductility varies in a predictable manner in these materials where temperature is raised or lowered. An empirical ductility parameter was derived from these observations.

Two turbine castings (1 Cr- $\frac{2}{3}$  Mo- $\frac{1}{4}$  V), weighing about 5000 pounds each, were quenched in molten salt from the austenitizing temperature. Salt quenching this size casting appears to be feasible from a manufacturing standpoint. Uniform acicular-type microstructures free from primary ferrite were produced in sections up to 12 inches thick. The salt-quenched castings had better impact and yield-strength properties than normalized 1 Cr- $\frac{2}{3}$  Mo- $\frac{1}{4}$  V.



PROTOTYPE ATOMIC POWER PLANT FOR USS SEA WOLF WILL BE TESTED IN THIS SPHERE.

# Nucleonics

One of the most significant statements in the field of nucleonics was made in 1954 when a General Electric official predicted that privately financed atomic power plants will successfully compete with conventional power plants in 5 to 10 years.

Speaking at the Atomic Industrial Forum, in Washington, DC, May 24, Francis K. McCune, General Manager of GE's Atomic Products Division, said:

"First, we at General Electric believe that electric utility companies will be owning and operating a number of atomic power plants within the next 10 years.

"Second, we believe some of these will be full scale and, what is most important, they will generate electricity at competitive costs—possibly within 5, certainly within 10 years."

Reactors best suited for "earliest and most effective competition with conventional fuel plants" were described by McCune as 1) light-water-moderated and cooled boiling reactor; and 2)

graphite-moderated water-cooled reactor.

The first type, he explained, would eliminate the need for a boiler system, because water would be boiled inside the reactor to produce radioactive steam that would power a turbine.

The reason that the boiling reactor was chosen by G-E experts in part, he told Forum members, is its similarity in many ways to conventional steam plants.

This reactor, according to G-E studies, could produce electricity for 6.7 mills per kilowatt-hour, compared with a cost of 6.9 mills for a conventional coal-burning plant. Plants chosen for comparison would each deliver 300,000 net kilowatts of electricity.

He described the graphite-moderated reactor as a direct descendant of the graphite-moderated water-cooled reactors with which we have been producing plutonium at the Atomic Energy Commission (AEC) Hanford site since 1946.

Cost of electricity from the graphite-moderated reactor, the G-E official said, would come to 6.8 mills per kilowatt-hour.

Size of the graphite reactor chosen for the cost estimate was described as quite large, with a net electrical capability of 700,000 kw. The large size is designed to achieve economy of operation.

"The graphite reactor is not necessarily limited to such large sizes," he commented. "It is possible that it might be cooled by boiling water which would make it economic in smaller sizes."

## Hanford Atomic Products Operation

During 1954, General Electric continued to make major atomic-energy contributions in all 3 processes—metal preparations, reactor operations, and chemical separation—of its Hanford Atomic Products Operation in Richland, Wash. Lower unit costs and increased plutonium production resulted from new technical knowledge gained by G-E scientists and engineers at this AEC project.

The \$14-million research facilities of the new AEC Hanford Laboratory area were occupied early in 1954, and studies in radiochemistry, radiometallurgy, pile characteristics, biophysics, and instrument development began immediately.

Last year a major construction program at Hanford was nearly completed, and a production facility was placed in operation, with additional facilities to be completed in 1955. The AEC, responsible for all such programs, believes that this will end the present construction phase at Hanford, now a billion-dollar taxpayers' investment entrusted by the government to General Electric's atomic management.

## Waste Storage and Processing

The most extensive single by-product of the manufacturing process at Hanford is radioactive liquid waste, requiring costly facilities to insure its safe disposal because of its great potential health hazard. Constant review of the waste characteristics and the structural requirements of disposal facilities resulted in considerable cost reductions.

Lowering costs by means of scavenging consists of adding suitable chemicals to the process waste stream from the uranium recovery plant so that a precipitate will be formed. The precipitate removes certain long-lived radioisotopes from the process solution and carries them down into a sludge at the bottom of the tank, leaving a solution

that can be pumped into dry wells for ground disposal. This process is done at a substantially lower cost than previous methods and permits a tenfold reduction in the total volume of required storage-tank space.

Improvement of container design resulted in additional cost reductions. Radioactive liquid waste is stored in underground tanks constructed of conventional reinforced concrete with a liquid-tight steel-plate liner. Improved tank design reduced construction expense without decreasing its ability to fulfill requirements. Tank capacity was made one-third larger by increasing its height, thereby reducing the number of costly dome roofs and amount of excavation and backfill. Eliminating special rolled or pressed shapes also simplified construction.

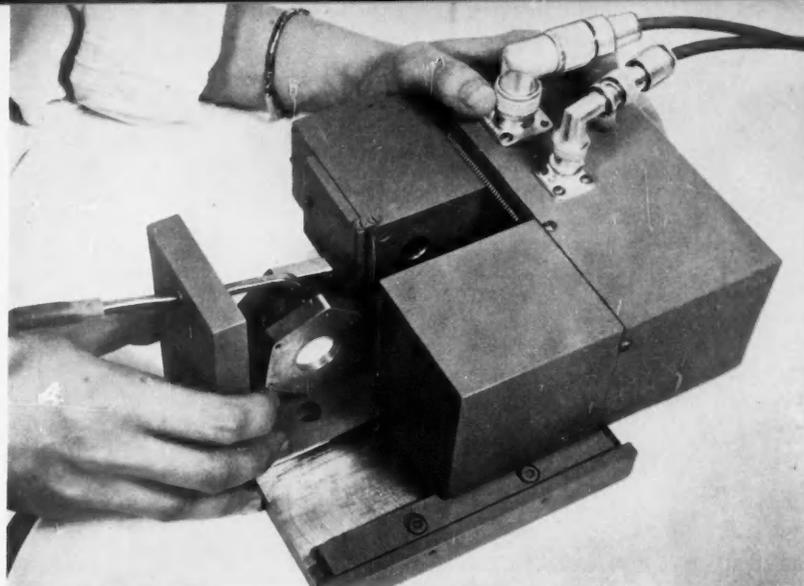
An evaluation of 2 phenomena effected these savings: First, specific gravity of the waste is at its lowest when the tank is first filled and gradually increases during the self-evaporation process; and second, high initial stresses in concrete caused by its shrinkage during curing are dissipated in time by the phenomenon known as plastic flow of concrete. The combination of these phenomena made it unnecessary to allow for the shrinkage stresses in the concrete at the time the tank is filled with the heaviest liquid. A design developed on this basis resulted in a maximum wall thickness of 24 inches, 12 inches less than the thickness previously thought necessary.

On recent tank farms the cost reduction amounted to about 5½ cents per gallon of capacity, resulting in a saving of over \$900,000 on recent construction.

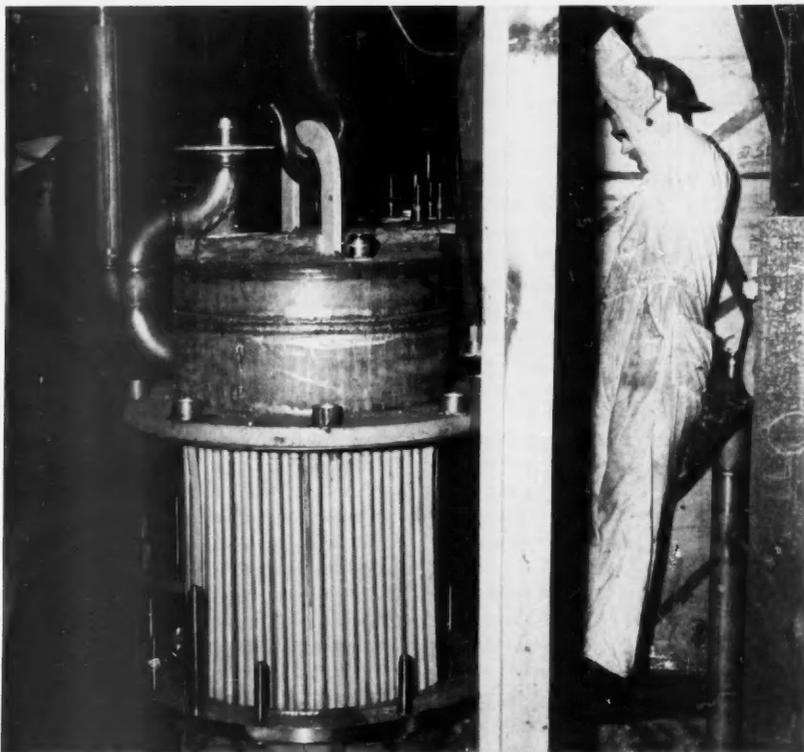
#### Remote Sampling and Analysis

Sampling highly radioactive process streams is one problem in the atomic-energy field that continually troubles scientists and engineers. Laboratory analysis is often necessary because the stream generally contains either a large number of constituents or a small number closely aligned on the spectrum. The problem then becomes one of physical sampling, transportation, and analysis of the radioactive solution.

To accomplish this more conveniently and with less possibility of radiological hazards, a new remote sampler was developed at Hanford and is now an integral part of the process lines. It removes a sample from the process stream by air jet and raises it to a sample



GAMMA-RAY PHOTOMETER IS USED TO DETERMINE HEAVY METALS IN A SAMPLE SOLUTION.



OPERATOR GUIDES CRANE LIFTING TUBE BUNDLE SO TROUBLESOME COIL CAN BE REPLACED.

cup by air lift. A remote pipetter then removes a measured amount and places it in a dilution flask. The solution remaining in the sample cup is recirculated back to the process stream. The device also provides facilities for determining the specific gravity of a sample before it is removed to the laboratory.

G-E scientists at Hanford took the lead in the industrial application of a new microanalysis technique, called

*coulometric titrations*, that permits the analysis of samples as small as 10 microliters, an amount considerably less than a raindrop. Basically, the principle involves running a small quantity of electricity from one electrode to another through the sample solution. The chemical change that occurs at each electrode is proportional to the amount of electricity passing through the solution. Comparison of this amount of



**POSITIVE-ION 2-MILLION-VOLT ACCELERATOR MAKES NEUTRONS FOR CELL-DAMAGE STUDY.**

electricity with known standards permits accurate analysis of the sample.

A gamma-ray photometer, which measures the absorption of gamma radiation, is another aid for determining sample constituents, in this instance heavy metals. Because the ability of an element to stop low-energy gamma rays varies markedly with its atomic number, it is possible to detect the presence of certain metals in a sample by measuring the number of gamma rays that can pass through it. This instrument is also being used to determine heavy metal constituents in alloys.

#### **Tube Bundles**

By redesigning boil-up vessels with heating coils in the form of separate tube bundles rather than as an integral part of the vessel, improvements in separations-process efficiency were made and operating costs reduced.

These vessels hold highly radioactive and corrosive solutions. Previously, heating-coil failure required disposal of the entire vessel. However, it is now possible to replace only the troublesome coil. In addition, 2 tube bundles are used for each vessel so that each can be operated at lower pressure and temperature, thus minimizing corrosion. If a coil fails, the remaining bundle can carry the process load with an increase in pressure, eliminating the need for an immediate shutdown. The cost of one removable tube bundle is about one sixth the cost of the vessel assembly.

#### **Particle Accelerator**

A 2-million-volt Van de Graaff particle accelerator was installed in a specially designed laboratory at Hanford last

year. This positive-ion accelerator is used to produce neutrons of different energies and intensities to aid in the development and calibration of neutron dose meters. The accelerator will also be used for research in radiation biology.

#### **Telemetry**

Telemetry equipment was installed at strategic points in the electric power loop serving Hanford to obtain important plant-operation data. By continuously monitoring electric power consumption, the equipment plays an important part in avoiding unnecessary peak demands and in permitting maximum power utilization within the current peak.

Another telemetry installation will also play an important role in relaying information concerning radiation levels and wind direction and velocity. With much of the development work completed in 1954, plans call for 20 stations located in and near the Hanford project and a main control station containing the transmitter and receiving equipment.

#### **Water Quality Control**

Light-scattering microphotometers are now being used at Hanford to measure water turbidity. When beamed at a water sample at a known angle, the instrument's photocell-amplifier-galvanometer circuit measures the amount of light scattered by the sample. Previous instrumentation had a limited sensitivity but this new device has determined turbidity as low as 0.01 parts per million. Being considered is the possibility of using these instruments instead of chemical analyses currently

made for water quality control. Because fewer chemicals and man-hours are required, the use of microphotometers is expected to result in significant cost reductions in chemically treating the vast amounts of water used to cool Hanford reactors.

#### **Flexibility in Reactor Control**

Techniques developed by G-E engineers during 1954 increased production of plutonium by permitting more continuous operation. In addition to neutron-absorbing control rods to reduce reactor shutdown time, these techniques involve adding, and later removing, special neutron-absorbing materials used in Hanford reactors.

Following the insertion of each supplementary charge of fresh uranium in the reactor process tubes is a complicated and extended period of startup and neutron-flux balancing before the reactor reaches a steady state of operation. Previously this period was made more complicated by additional shutdowns in order to adjust the amount and placement of the special neutron-absorbing material.

The new technique allows the introduction and removal of this material that is hermetically sealed in cans. Now under consideration is the feasibility of adapting the technique for replacing fuel elements during operation.

#### **Tissue Dynamics**

Some observations of basic importance to fundamental biology came from research designed to appraise the biological effects of tritium. It was previously thought that most animal-body constituents were in a constant state of biochemical flux, with tissue components being exchanged rapidly with those in surrounding body fluids. In experiments with animals at Hanford last year, it was found that a large portion of tissues, such as certain collagens, fatty tissues, and to a lesser extent those in the skin and brain, are almost metabolically inert. Also liver, heart, and kidney tissues are more dynamic than others but less dynamic than was formerly supposed.

#### **Autoturbidimeter**

A new method was developed during 1954 for comparing the biological damage caused by the various types of radiations that result from different radioactive elements. With the application of an autoturbidimeter, the new procedure measures the growth rate of

yeast and bacteria colonies by measuring the amount of light they absorb.

### Atomic Submarine—KAPL

Construction of the submarine nuclear-propulsion plant, Project SIR, was completed by the AEC's Knolls Atomic Power Laboratory (KAPL), the nuclear research center operated by General Electric at Schenectady. The submarine hull, a prototype of the propulsion plant section of the USS *Sea Wolf*, was built on an erection slab outside the spherical building by the Electric Boat Division of General Dynamics Corporation. The sphere will house the submarine section and its nuclear-propulsion plant during operation. On March 20, 1954, Spencer, White, and Prentis, Inc. moved the hull into the sphere after Electric Boat had installed the equipment associated with the nuclear power plant.

Nuclear and plant power tests will follow. Operation of this plant will mark the first use of a sodium-cooled intermediate-spectrum nuclear-reactor plant designed for naval propulsion.

Concurrently, construction work on the *Sea Wolf* began at the Electric Boat Division's Groton, Conn., shipyard. KAPL and other departments of General Electric designed and fabricated many of the vessel's nuclear and propulsion plant equipment components.

Studies of a more advanced mobile nuclear power plant for the AEC and the U.S. Navy were also started at KAPL. The objective of the Submarine Advanced Reactor (SAR) program is the design of another high-performance submarine.

### Nondestructive Testing

To assist in the testing of vital reactor components, an improved method of nondestructive testing was developed for application to small cylindrical-shaped parts. The specimen is drawn through a small coil that is part of the tuned circuit of an oscillator operating in the megacycle range. Small changes in the eddy currents induced in the specimen, arising from material irregularities such as cracks and pinholes, cause small changes in coil inductance. This in turn contributes to a frequency change in the oscillator circuit.

Particularly well adapted to production-line testing, the method was applied to seamless tubing, brazed joints, and closed-off tubing containing other material. In certain applications,



AUTOTURBIDIMETER COMPARES BIOLOGICAL DAMAGE CAUSED BY RADIOACTIVE ELEMENTS.

it is superior to ultrasonic, x-ray, or frost-test techniques.

### Machine Calculations

To evaluate nuclear properties of proposed reactor models, the engineer must depend on calculation and experimentation. General regions of interest are determined by calculation. However, because complicated geometrical configurations arise in actual design, the determination of operating characteristics is achieved by experimentation.

Experiments with reactor assemblies are costly and cannot readily cover in rapid succession large varieties of geometrical arrangements. Thus in many instances it is desirable that detailed calculations be devised to replace experiments and to pinpoint fruitful regions for experimental study.

KAPL has taken the lead in establishing an electronic-computer program that can predict the nuclear performance of much more complex models than was previously possible.

### Measurement of Oxygen in Gas

Of paramount importance in liquid-metal heat-transfer technology is the continuous detection and measurement of low concentrations of oxygen in gases. An instrument based on the dew-point principle was designed, built, and tested for such use in the range below 100 parts per million, although it is equally useful in higher ranges. Available instruments cannot be used in these low concentrations. However, the instrument is applicable to the analysis of common gases, such as nitrogen and hydrogen.

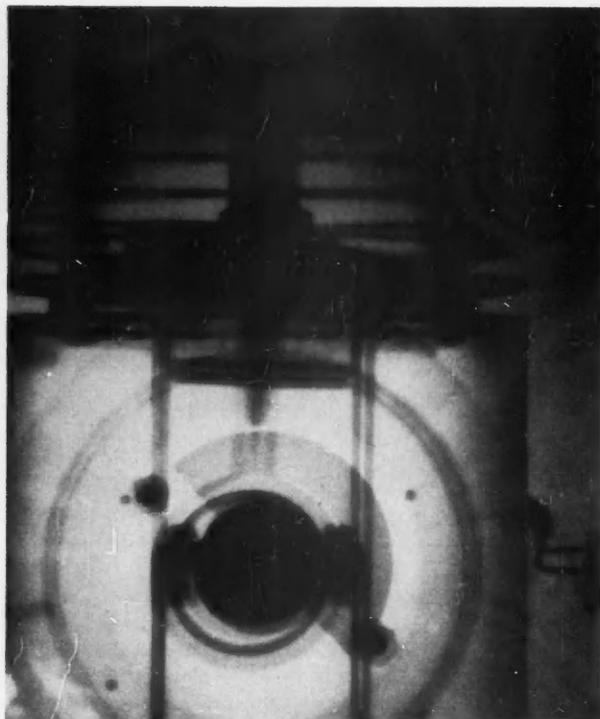
### Semiconductors

Germanium and silicon semiconductors were usefully applied to problems in atomic energy. Observations of the electrical property changes due to nuclear irradiation helped explain how materials are damaged by nuclear particles and rays. Also studied and compared with the power obtained from the photovoltaic effect was the electric power generated by the action of high-energy charged particles on germanium and silicon rectifiers. Because of their damaging effects on the semiconductor, even high intensities of heavy charged particles give low efficiencies of energy conversion. At low intensities where the damage is minor, such rectifiers can be used as flux or intensity monitors for reactor studies as well as health protection.

Theoretical studies show that under idealized conditions conversion efficiency can be as high as 40 percent for infrared radiation on germanium at room temperature and as high as 17 percent for solar radiation on silicon. Efficiency increases with the intensity of the radiation for both light and particle radiation.

### Tritium as a Radiation Source

Tritium, famous as a hydrogen-bomb material, was put to an interesting new use as a highly intense source of beta radiation. Mixed with organic gases, it serves both to initiate a reaction and to act as a tracer in studies of the reaction mechanism. For example, the use of tritium demonstrated that there is no rupture of the carbon-hydrogen bond in the radiation polymerization of acetylene.



**STROBORADIOGRAPH** of a spray compressor operating at 1100 rpm was made with the high-energy x-rays of an industrial betatron.



**CENTERLESS POINTER** of process-instrumentation recorder increases readability, retains high accuracy, and simplifies chart changing.

## Testing and Measuring

Radiographs of internal parts of machines under actual operating conditions were made with newly developed special stroboscopic radiographic equipment. Synchronizing a moving object with the high-energy x-ray pulses from an industrial betatron, the equipment in a series of short exposures produces clear, sharp pictures of a machine's internal working parts.

The first of a new line of general-purpose x-ray gages went into operation in the early part of the year. Used on an aluminum-foil reduction mill, the new gage gives a continuous indication of thickness variations as small as 0.000025 inches. It can also serve as one component of a regulating system to control a product's thickness.

### Process Instruments

New round-chart recording and control-initiating instruments of the electro-mechanical servo type represent major technical advances in process instrumentation. For example, a sustained one-quarter percent accuracy is assured

by a new permanent-magnet standardizing circuit, a static-type converter utilizing germanium, and a unique bridge-balancing unit. The designs are adaptable to either a-c or d-c inputs and for control initiation by either electric or pneumatic means.

### Control-initiating Instruments

A new control-initiating device was designed specifically for attachment to long-scale switchboard instruments. Taking the place of contacts actuated by the instrument pointer, this device is assembled on the front of a standard instrument. It consists of either 1 or 2 set pointers that carry a pair of small coils forming part of an oscillator circuit. Through contactless control, it maintains the 1 percent accuracy and excellent readability of the standard indicating instrument.

### Oscillogram Developer

Rapid, easy development of oscillograms made on photosensitive paper by electromagnetic oscillographs is now

practical. At a rate of 12 fpm the new developer, utilizing prepackaged chemicals, processes oscillograms up to 250 feet long and 12 inches wide.

### Ultrasonics

The amplitude of a pulsed ultrasonic wave's echo transmitted from one side of a dry-shrink fit is now used to measure interface pressure. Amplitude was found to be a function of interface pressure, the roughness of the surfaces in contact, and the object's shape. Relative sensitivities can be maintained by reference to a standard external reflection.

### Gages

Considerable progress was made in the use of resistance-wire strain gages for the measurement of residual stresses, thrust loads on bearings, and vibrations. The techniques for mounting and protecting gages and for recording results were improved so that consistent and accurate data can be made available in a short period of time.



**FILM-THICKNESS GAGE** utilizes new principle to measure coatings on magnetic materials from 0 to 0.060 inch thick.



**CYLINDRICAL-ROUGHNESS SCALES** simplify specification, production, and inspection of the roughness of curved machined surfaces.

Compact wide-range film-thickness gages now utilize a new magnetic-operating principle to measure either metallic or nonmetallic coatings on magnetic-base materials. The gages require no warm-up time, and they are unusually stable and completely self-contained.

Specification, production, and inspection of the roughness of curved machined surfaces is made easier by cylindrical-roughness scales similar to the flat-surface-roughness scales long used in industry. The new pocket-size scales provide a finished sample of turned or ground surfaces such as are required for high-quality economical manufacture.

#### Creep and Rupture

Two improvements for creep and rupture evaluation were developed during the year.

Operating on a differential of  $\pm 0.1$  degree F, an expansion-type thermostat holds the temperature of a test specimen within  $\pm 2$  degrees F even when room temperature fluctuates between  $\pm 20$  degrees F. The second improvement concerns the use of a simple 3-point linkage that allows transfer of the test specimen from a hydraulically operated support to the loading beam. A dial

indicates percentage of total weight applied to the beam.

#### Wattour Meters

The nationally exhibited General Electric Wonder Home of 1954 depicted the increased use of electric energy in American homes of the future. Such an increase will require metering devices capable of measuring the growing electric load.

In anticipation of this growth, the I-55 single-phase wattour meter was developed and is being produced. It has a nominal rating of 15 amp but is capable of accurately metering loads up to 100 amp. Its predecessor had the same nominal rating but a maximum capacity of only 60 amp.

Increasing the maximum allowable load range thermally and accuracy-wise from 60 to 100 amp was accomplished by using larger cross-section conductors in the current circuit and by developing improved load compensators. This was possible without changing the physical size of the wattour meter. Maintaining the same performance characteristics, size and rating, the meter permits utility companies to utilize existing meter mountings, test setups, and equipment. It presents no new problems in handling, testing, and storage.

A probe made of photoconductive cadmium sulfide simplifies field and laboratory testing of wattour meters. It is used with an amplifier controller to count revolutions of the meter disc wherever the general illumination exceeds 30 footcandles.

A new butyl-rubber-insulated current transformer for metering accelerates the trend to use miniature current transformers for 600-volt circuits. This  $4\frac{1}{2}$ -pound unit can be used indoors or out.

#### Photography

Two new products assure optimum results in color photography. A color control meter enables a photographer to correctly control the color of light entering his camera's lens by indicating the proper filter and exposure correction.

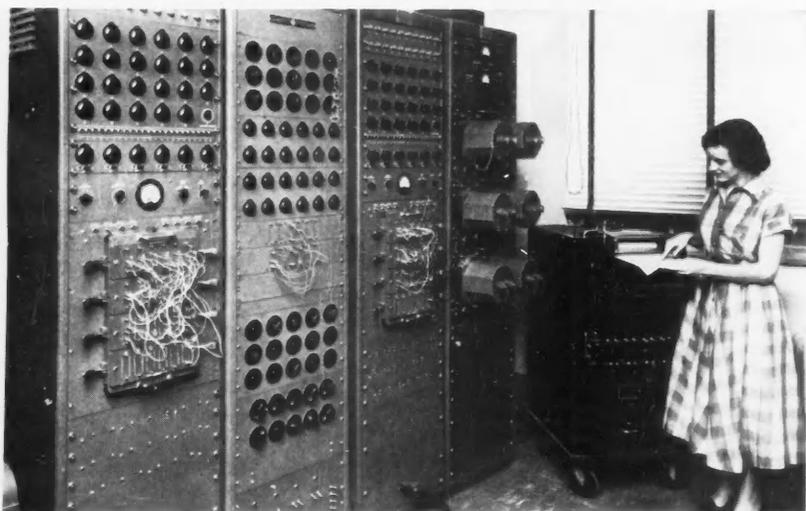
With the other photographic aid, a variable color filter, the photographer needs only one filter instead of the conventional assortment for control of color balance. When this unique product is attached to the lens, the light goes through polarizing and dichroic filters that transmit bluish, neutral, or reddish light, depending on the angle of polarization. Setting for the correct color balance can be read directly from the color control meter or by looking at the scene through the filter.



PORTABLE VIBRATION METER MEASURES UP TO 300-MIL DISPLACEMENTS AT 250 CPS.



HIGH-TEMPERATURE ACCELEROMETER OPERATES IN AMBIENT TEMPERATURES OF  $-50$  TO  $+500$  F.



ELECTRONIC ANALOG-COMPUTER FACILITIES AND TECHNIQUES CONTINUED TO EXPAND IN 1954.

### D-c Telemetering

A d-c telemeter transmitter, replacing 3 different units previously used, greatly simplifies frequency-type telemetering of direct currents. Placed on a single chassis to facilitate rack and panel mounting, it has plug-in-type range-changing and calibrating units.

### Radiation

A scintillation-type alpha hand counter reliably checks alpha-particle-emitting contamination on a worker's hands. The 4-channel device monitors both sides of both hands simultaneously, emitting an electric pulse for each alpha particle detected.

Adapted for spot checks of clothing, laboratory benches, and other surface areas is a similar detector, the lightweight and easily handled alpha poppy. Its efficiency of detecting alpha particles is 40 percent.

### Vibration

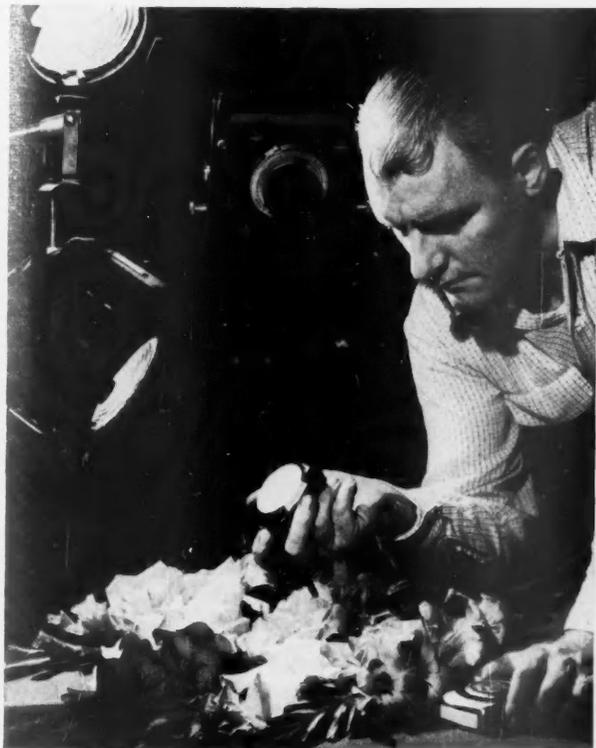
Important applications of a new sturdy high-temperature accelerometer are detection of the vibration levels in aircraft gas-turbine engines and in nuclear power plants. It is capable of operating in an ambient temperature range of  $-50$  to  $+500$  F. Hermetically sealed, the unit can also be used under highly humid conditions. Its useful frequency range is 10 to 600 cycles when loaded by at least 500 megohms.

A new portable vibration meter measures vibration over a frequency range of 10 to 250 cycles. Movement of the instrument does not affect its accuracy. It is designed to measure peak-to-peak displacement from 3 to 300 mils full scale and peak acceleration from 0.03 to 10 G's acceleration full scale.

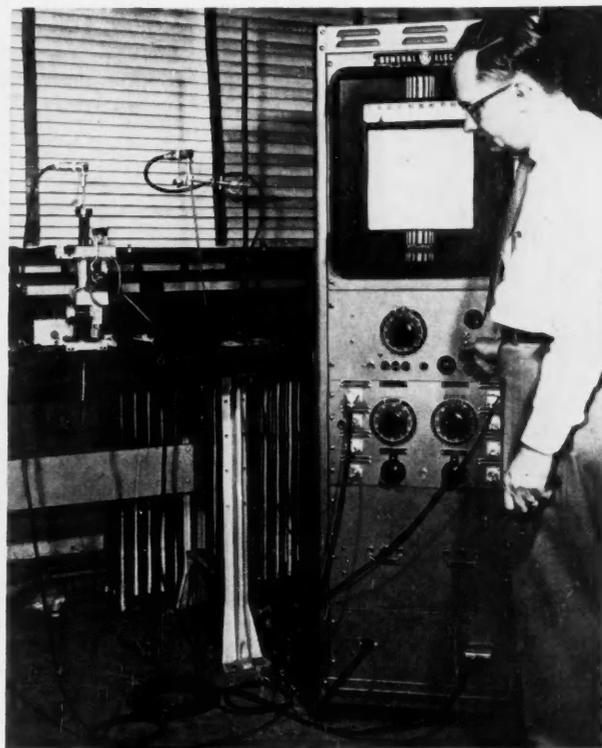
The magnitude of vibration displacement of low-speed multibearing equipment can be detected and recorded with a new vibration recorder. If the monitored displacement exceeds a preset level, the instrument activates an alarm or shuts down the equipment. From 1 to 18 velocity-type vibration detectors can be attached to the monitored equipment.

### Winding Insulation Tester

A 10-kv automatic-winding insulation tester provides a sequence of impulse and 60-cycle high-potential tests for 3-phase stator windings in  $7\frac{1}{2}$ - to 50-hp motor sizes. To assure constant test voltages regardless of stator sizes, circuits providing the test voltages are amplistat controlled. In the event of unusual winding-insulation problems, an



**COLOR CONTROL METER** indicates the correct filter for proper color balance in daylight, tungsten, or photoflood light.



**THERMISTORS** are the sensing elements of the new differential temperature recorder that detects minute temperature differences.

oscilloscope allows a visual diagnosis of the impulse tests. Quality-control instruments give a continuous indication of the rate of rejection.

A new faulty-coil detector locates the exact slot of motor stators in which winding faults occur, such as shorted turns, grounds, or phase-to-phase breakdowns. A pick-up coil mounted on a scanning arm passes over the slots and electronically measures deviations in magnetic fields while the winding is simultaneously undergoing high-voltage impulse tests.

#### Temperature Measurement

Put into operation in 1954, a furnace wound with iridium wire costing about \$700 per ounce reached temperatures of 3400 F in air. With it, data on the thermoelectric characteristics of iridium or iridium-rhodium-alloy thermocouples can be collected at extremely high temperatures and the thermocouples calibrated.

Extremely small temperature differences are automatically recorded with a newly developed differential temperature recorder. Intended primarily for air-turbine tests, this recording instrument employs thermistors as sensing elements.

#### Metals

A new magnetic detector was developed for use with an all-magnetic loop control in steel-mill pickling baths, as well as in other similar applications. Without making physical contact, the detector provides an electric signal that indicates the proximity of large magnetic materials. Steel within 20 inches of the unit can be detected.

Utilizing cyanide and 8-hydroxy quinoline, a new gravimetric method determines the presence of aluminum in a wide variety of iron and nickel alloys. It has distinct advantages in accuracy and economy.

#### Reaction Dynamometer

A reaction dynamometer for measuring torque supplements the electric absorption dynamometer. The device to be tested is mounted on a base suspended on springs; well-known strain-gage techniques measure the displacement proportional to torque. Where the trend is toward higher and higher speeds, the dynamometer promises to simplify facilities for testing motors and generators.

#### Standards

New equipment for standardization checks on electronic voltmeters operates

from 0.00003 to 300 volts and from 50 cycles to 1 megacycle.

#### Computers

During 1954, electronic analog-computer facilities within General Electric were extended to include studies of increasingly complex automatic-control systems involving heat flow and the nonlinear performance of electric machinery.

Digital computers also assisted in solving a wide variety of engineering problems during the year, including guided-missile studies, analysis of radar noise, power-transformer design, bearing-lubrication studies, and operational-research techniques.

The Electronic Thermal Analog Computer (ETAC) can determine rapidly and reliably operating temperatures of electric equipment under a variety of conditions. Once the thermal problem is set up on ETAC in terms of an electrical analogy, the computer is capable of simulating various conditions of loads, duty cycles, and modes of cooling such as radiation, natural, convection, conduction, forced air, and vapor. The ETAC solves in a matter of minutes thermal problems that formerly required days of engineering time.



ENGINEERS PLAN EFFECTIVE SYSTEM PROTECTION WITH AID OF SWING CURVE CALCULATOR.

## Power

Last year on October 21 a significant event in the history of electricity occurred. On that date, as a huge 156,250-kw generator at the Detroit Edison Co. went into operation, the generating capacity of the nation's electric utility industry reached 100-million kilowatts. The episode occurred simultaneously with the 75th anniversary of the exact day Thomas A. Edison tested his first practical electric light. Another interesting aspect of the incident is that at the end of World War II the nation's generating capacity was just 50-million kilowatts. Thus in 9 postwar years the electric utility industry has doubled its total generating capacity.

During 1954 the new swing curve calculator, installed with the a-c network analyzer at Schenectady, cut in half the calculating time required to determine power systems' transient-stability performance following such severe disturbances as lightning strokes. This device enables power-system planning engineers to study more economically and effectively the protection of their systems to insure performance reliability and continuity.

An improved method for solving power-system load-flow problems on an automatic digital computer was developed. Load flow and voltage distribution are determined for a given set of active

and reactive power loads and transformer tap settings by an iterative process that does not require human intervention or judgment.

The first penalty-factor computer was completed in the latter part of 1954 and readied for shipment to one of the country's largest electric utility companies. This analog computer calculates correction, or penalty, factors that take into account the effects of power losses in a system's various transmission lines as they affect the operating efficiency of a whole system. This permits up-to-the-minute control of both station and tie-line loading schedules to maintain the optimum over-all economic adjustment of system operation.

A convenient and rapid means of making both power and system-constant adjustments, the computer solves the complex loss-factor equations to obtain penalty factors in a fraction of a second. Substantial economies in system operating costs should result from the use of this computer.

Small-scale digital computers available in many electric utility companies became extremely valuable tools. Their use for obtaining more economic power-system operation allows new methods of precalculating generation schedules.

Load-frequency control equipment developed for automatic control of gen-

eration in a power system will simultaneously and automatically function to 1) adjust the total output of generators in the area generation to hold constant system frequency when the system is isolated or to hold a desired net power exchange with other interconnected power systems, the equipment sensing any load change within or outside the control area; 2) allocate sudden load changes to those machines and equipment that can best handle rapid changes so that excessive rates of correction are not applied to any generating units in the system; and 3) allocate the total area generation among units and stations on control for maximum economy.

Switching surges, lightning surges, and 60-cycle voltages are generally the 3 types of voltages involved in the design and protection of stations and station-equipment installations. Interest is presently centered in the area of switching-surge voltages because of past emphasis on lightning surges and 60-cycle voltages, and because of the reduction in basic insulation level (BIL) and 60-cycle insulation-voltage-withstand values from fully insulated levels. The transient network analyzer aided the study of the magnitude and wave shape of switching-surge voltages in high-voltage stations (138-330 kv) as they were affected by station configuration of modern and anticipated systems.

In recent years several 14.4/24.9-kv multigrounded wye distribution lines were built to serve sparsely settled areas. These systems have been satisfactory except for some unforeseen developments: excessive lightning-arrester failures, automatic circuit-recloser failures, and reversal of 3-phase motor rotation. Further transient network analyzer studies indicated the possibility of excessive and abnormal voltages due to ferro-resonant conditions after 1 or 2 phases of a 3-phase circuit had been de-energized. Field studies confirmed this, and the remedial measures effective on the analyzer were also effective in the field.

### Turbines and Generators

Progress in the direction of larger and more economical units continued during the year with the shipment and initial operation of several tandem- and cross-compound machines that are larger than any delivered previously. Designs were also completed for substantially higher steam temperatures and pressures than any now in service. And the development and design of direct-cooled gen-

erators to permit reduction in physical size and a further increase in the capacity of single-shaft units proceeded rapidly.

Seven 3600-rpm 200,000-kw tandem-compound units were shipped to TVA's Colbert and Kingston stations. Two of these are already in service. The new 26-inch-long last-stage bucket with 25 percent larger annulus area than any 3600-rpm bucket now operating is being used for the first time in these machines. Four more are on order, and a similar but larger unit is under construction for the Cleveland Electric Illuminating Company. This unit's 260,000-kva generator will be completely direct-cooled: liquid is circulated through the hollow strands of the armature windings, and hydrogen is picked up from the air gap and circulated through the rotor's hollow conductors.

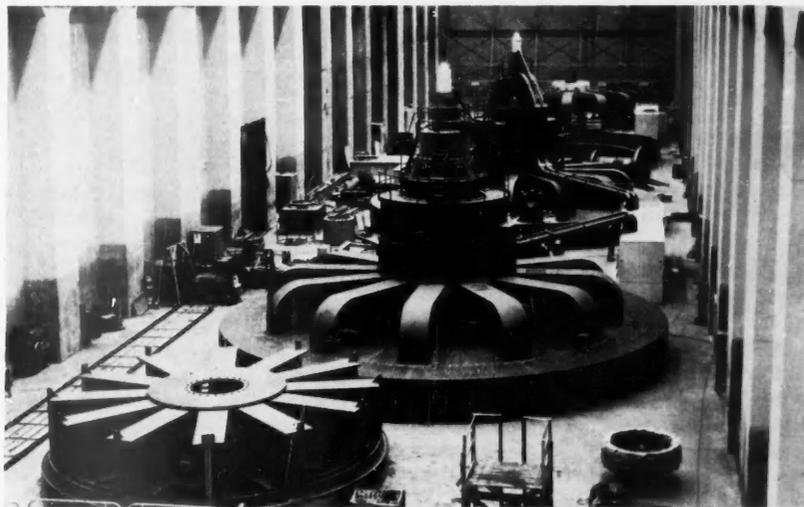
The first of a new type of cross-compound unit went into service during 1954 at the Will County Station of Public Service of Northern Illinois. The 1800-rpm low-pressure double-flow turbine receives steam from the 3600-rpm high-pressure reheat turbine through 36-inch-diameter pipes below floor level. The unit is more compact, lower in cost, and better in appearance than former units having tandem-compound double-flow low-pressure elements. Two similar but larger units, rated 217,000 kw, were shipped. Eight more are under construction; one for the Commonwealth Edison Company will have newly developed 43-inch-long buckets in the last stages and a side outlet exhaust to the condensers. Another still larger cross-compound unit, rated 260,000 kw, is under construction for Detroit Edison.

For installation where the condensing-water temperature does not justify the large annulus area provided by the double-flow low-pressure unit, a single-flow low-pressure type is being offered. With 43-inch-long last-stage buckets, the exhaust annulus area of this machine equals that of a triple-flow 3600-rpm turbine with 26-inch last-stage buckets. The units are suited for 150,000- to 250,000-kw capacities. As compared with the triple-flow tandem machine, the cross-compound single-flow unit is approximately 30 feet shorter in over-all length, equal in price, and about  $\frac{1}{3}$  percent better in economy.

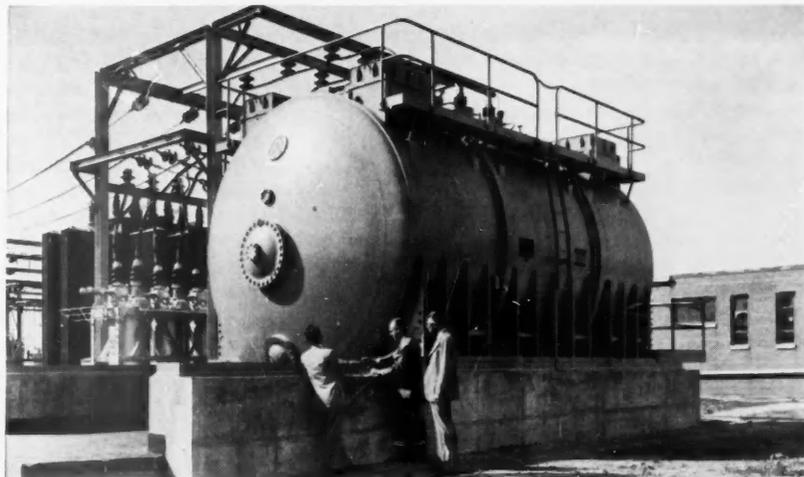
To extend the application of resuperheating to sizes smaller than have been economically attractive with tandem-compound double-flow machines, a new single-flow single-shell turbine was de-



STEAM-TURBINE GENERATORS WILL INCREASE EFFICIENCY OF TOMORROW'S POWER PLANTS.



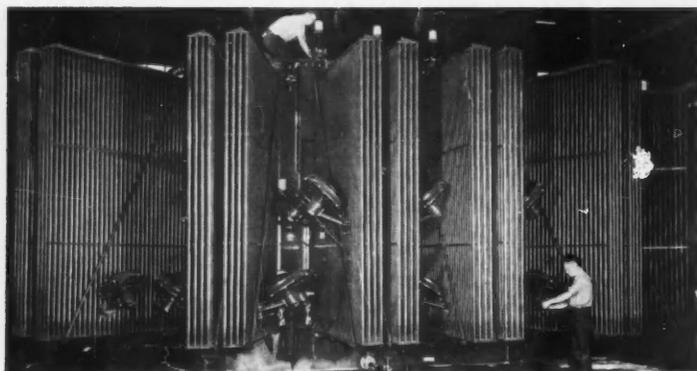
EACH HYDROGENERATOR AT McNARY DAM ADDS ITS 70,000-KW CAPACITY TO POWER POOL.



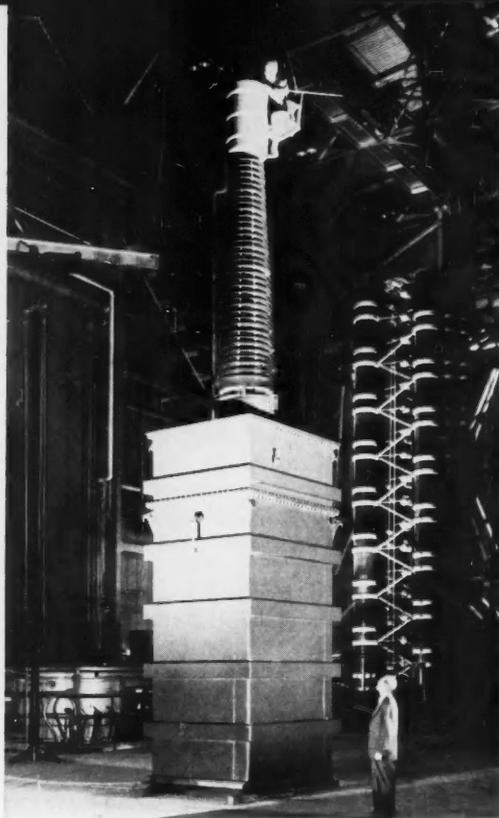
LARGEST 50,000-KVA SYNCHRONOUS CONDENSERS EVER BUILT BY GE EQUAL 75,000-KVA SIZE.



**TEN SIMPLE-CYCLE** 2-shaft gas turbines began operation in a Venezuelan oil-field pressure-maintenance project on a platform in Lake Maracaibo.



**LARGEST SELF-COOLED TRANSFORMER** ever built by GE has top capacity of 140,000 kva with its 46 forced-air cooling fans in operation.



**ROD GAPS** on large potential transformer for Switchgear Laboratory are assembled prior to impulse tests.

veloped for 40,000- to 60,000-kw capacities. An order was received from the Central Louisiana Electric Company for a 50,000-kw unit of this type.

The generator of the supercritical pressure unit for the Philo Station of the American Gas and Electric Company, having initial steam conditions of 4500 psi 1150 F with reheats to 1050 and 1000 F, will be fully direct-cooled. Hydrogen circulates through hollow conductors in both the armature and field. Development and design of this generator was completed during 1954.

A large double-automatic extraction turbine of 225,000-kw capacity was ordered by the Public Service Electric and Gas Company, NJ, for their new Linden Station. This machine, by far the largest of its kind, will be designed for the extraction of 600,000 pounds per hour of steam at 750 psi, 1 million at 150 psi, but with no more than 1¼-million total.

Following construction of a new Product Development Laboratory at Schenectady, the first test began on a group of full-size low-pressure exhaust stages such as those used in GE's largest 3600-rpm turbines.

In addition to the wide variety of turbines, generators, and gears built for

domestic use, a number of export orders were received during the year. Among the more important of those for turbine-generator sets were 4 25,000-kw units for Korea, a 44,000-kw unit for Taiwan, and a 25,000-kw unit for Manila.

A commercially produced steel alloy was adopted for use in high-temperature steam-turbine bolts, buckets, and other components. Laboratory investigations of the microstructure revealed that this steel, as commonly specified, tends to have some free ferrite—believed to be less desirable than a ferrite-free fully martensitic structure. Consequently, the chemical composition ranges were modified to minimize or eliminate the occurrence of ferrite in this alloy.

Appearance of motor-driven exciters for turbine-generator excitation now harmonize with the other apparatus in modern steam-generating stations, and a number of such exciters were furnished to various customers during the year. Each set consists of a d-c generator, an induction motor, and a flywheel. All are mounted on a common base in an enclosure that provides versatile ventilation, accommodating each customer's ventilation requirements.

The advent of highly efficient super-pressure steam-power cycles of 4500

pounds and higher requires novel means for driving the boiler feed pumps. Construction began on 2 4000-hp drives for this purpose. Each of these 3600-rpm induction motors has 2 shaft extensions; one transmits 1400 hp to a constant-speed low-pressure pump that develops 2000 psi. The second shaft extension is coupled through a hydraulic coupling and a step-up gear to an adjustable-speed high-pressure pump that raises the water pressure to 5500 psi at 6500 rpm at the pump.

During the year a number of hydraulic turbine-driven generators having a combined output of 722,524 kva were shipped to various utilities, industries, and governments. The most spectacular installation of hydrogenerator equipment was at the McNary Dam on the Columbia River in Washington, dedicated by President Eisenhower in September. When completed in 1956, as scheduled, the combined output of the 12 G-E hydrogenerators will equal the power used by the homes, businesses, and industries of a city with 5 times the 1953 power consumption of Tacoma, Wash. Two generators were installed in 1953 and 4 in 1954.

Each generator develops 70,000 kw, revolves at 85.7 rpm, is 52 feet in diam-

eter, and weighs 1200 tons. Approximately 40 freight cars are required to transport it from Schenectady to the McNary powerhouse.

Outstanding is the thrust bearing designed to carry a load of more than 4-million pounds—by far the largest load ever carried by any thrust bearing. It represents a 33 percent increase over the previous bearing-load record at Bonneville Dam.

It is estimated that more than 500,000 man-hours of labor are required to build each of the McNary generators.

Early in 1954 the first of 12 G-E amplidyne-generator voltage regulators—the largest ever built—was successfully installed on the first McNary Dam machine. These regulators control the excitation and are designed with twice the rating used on any previous generator voltage-regulator applications.

A 12,500-kw 750-rpm 25-cycle synchronous generator driven by a geared turbine was furnished to a large steel company for plant power generation.

Shipped during 1954 were two of the largest synchronous condensers ever built by General Electric. Although these condensers have a capability rating of only 50,000 kva at ½-pound hydrogen pressure, they are equivalent in physical size to machines rated 75,000 kva. This size was necessary to obtain the low machine reactance required.

Supplied with the condensers were 9 of the largest cast-in-concrete reactors that the Company has built. The condensers and associated buffer reactors are being used by a large electric utility to level the voltage fluctuation caused by 2 25,000-kva electric arc furnaces on the utility's system.

### Gas Turbines

More than 450,000 operating hours have accumulated since General Electric first placed in operation a gas-turbine electric locomotive in 1948. Some 92 gas turbines were installed in locomotives, electric power generation stations, and gas-pipeline pumping stations; in an oil-pressure maintenance project; and in a refinery process.

New designs of both simple- and regenerative-cycle gas turbines permit building into them increased power and efficiency with but a small increase in physical size. Provision is also made for greater reliability and easier maintenance. Important features include a horizontal joint throughout the length of the machine, a reduction in the number of bearings required, and the

use of a mechanical hydraulic control system.

Through tests conducted in the factory and in customers' plants, a specification was developed for Bunker C oil, a residual fuel that can be used in gas turbines with a minimum of oil-ash corrosion. Gas-turbine engineers also developed an oil washing system for treating the oil at the power plant to meet these specifications. Bunker C is a relatively inexpensive oil, making its use as a fuel very desirable.

In co-operation with the manufacturer of heat-exchange equipment, laboratory tests were conducted on an evaporator that makes possible increased output and efficiency of regenerative-cycle gas turbines.

Tests conducted in a steel mill on a single gas-turbine combustor indicate that it is possible and practical to burn blast-furnace gas in a standard-size combustor with little modification. Encouraged by these tests, General Electric has offered for sale gas turbines burning blast-furnace gas for power-generation and mechanical-drive applications.

Last year 10 simple-cycle 2-shaft gas turbines were placed in operation in an oil-field pressure-maintenance project on a platform in Lake Maracaibo, Venezuela. Natural gas is received at the platform with a pressure of approximately 5 psig, compressed to approximately 1900 psig in the driven centrifugal compressors, and then injected back into the field to increase its oil yield.

### Transformers

A new Transformer Sound Laboratory (cover) at Pittsfield, Mass., believed to be the largest of its kind in the world, was dedicated during October, 1954. Designed for the precise measurement of noise levels of power transformers embodying experimental constructions and processes, the anechoic (without echo) chamber of the new facility has the capacity for testing transformers rated 500,000 kva and higher.

Extensive research will be conducted in the anechoic chamber. Complete frequency analyses will be performed on many units, and studies with acoustic transformer models will be employed both to predict the sound level in transformers being designed and to estimate the value of barriers and enclosures as aids to noise-level reduction for transformers now in use.

One of the Sound Laboratory's first contributions is a practical demonstra-

tion of sound cancellation, a technique that can under certain conditions minimize the noise of transformers already in service.

Sound cancellation is basically simple: sound waves from a transformer often have a single command frequency. Sending out another sound beam with identical frequencies but opposite in phase tends to cancel the original waves and causes a cone of silence within a localized zone.

In demonstrations, sound from a loudspeaker mounted on the transformer tank is beamed in the desired direction. Adjustment in the speaker's volume and phase has reduced sound levels as much as 15 decibels at distances of 25 to 75 feet.

At Rome, Ga., General Electric's new medium-transformer plant was officially opened in May, 1954. By the end of the year production was increased materially.

Built to meet the growing demand for standardized transformers, the new plant applies mass-production techniques to the construction of units previously manufactured by the job-shop method. The production cycle was cut as much as 43 percent through the use of conveyORIZED assembly lines and newly developed mechanical processes.

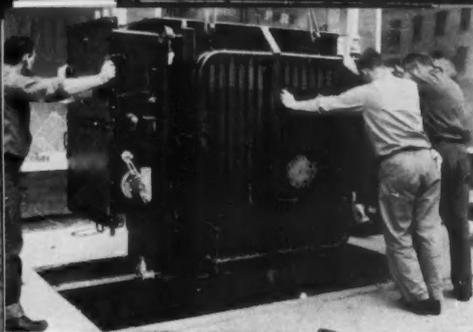
The largest self-cooled transformer ever built by General Electric was delivered to the Raritan River Station of the Jersey Central Power and Light Company during the summer of 1954.

The huge unit weighs 392,000 pounds. To simplify installation, it was shipped upright in its own one-piece tank, stripped only of its radiators, bushings, and other accessories. Rated 84,000 kva, 115 kv, the transformer has a top capacity of 140,000 kva with its 46 forced-air cooling fans in operation.

A new development may revolutionize future transformer construction. A joint project with General Electric and the Consolidated Edison Company of New York, this development involves the first application of a high-dielectric-strength gaseous insulation in high-voltage power transformers.

The new dry-type units, filled with sulfur-hexafluoride gas, foretell the eventual displacement of oil and askarel-filled transformers. Transformers of this type will not only be lighter and safer but also appreciably quieter, because pressurized gas does not transmit sound as well as liquid.

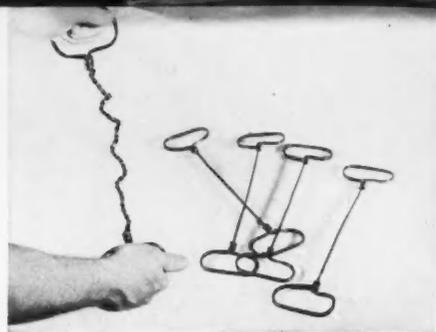
Two transformers utilizing the sulfur-hexafluoride coolant are now on the drawing board. Rated 2000 kva, 69 kv,



**COOLING TUBES** of vault-type network transformers are arranged in new design.



**GAS-INSULATED** 69-kv transformer may revolutionize transformer construction.



**FILM-INSULATED** transformer wire doesn't chip or peel when twisted or hammered.

these units will be field tested by Consolidated Edison. A gas-to-air heat exchanger will cool the gas after it is pumped through the core-and-coil assembly.

The practical application of gas as a high-voltage transformer insulation and coolant may well prove to be the most radical change in transformer design concepts since the introduction of nonaging silicon core steel in 1903.

The practical application of gas as a high-voltage transformer insulation and coolant may well prove to be the most radical change in transformer design concepts since the introduction of nonaging silicon core steel in 1903. Many power transformers in the 330-kv range were under construction during 1954. Sixteen 80,000-kva single-phase units are being built for the Ohio Valley Electric Company's Kyger Creek Station. Four were shipped late in 1954, and the remaining 12 are scheduled to be shipped this year. They will step up the voltage generated at the Kyger Creek Station for transmission to the AEC.

Another group of 8 100,000-kva 330-kv 3-phase transformers, probably the largest in physical size ever to be built by General Electric, are being supplied to step down the voltage at the AEC plant at Portsmouth, Ohio.

The largest and highest voltage-rating potential transformer yet built by General Electric, and possibly the biggest in the world, was designed and manufactured for the Company's Switchgear Development Laboratory in Philadelphia. The transformer will be used in the oscillographic recording of transient voltage associated with high-voltage switching operations. It will also serve as an auxiliary source of power and as a corona-free source for high-voltage testing.

The largest mobile power transformer ever constructed by General Electric was shipped to the Louisville Gas and Electric Company during 1954. The forced-oil-cooled 3-phase 25,000-kva unit is both transformer and autotransformer. It has 4 windings with voltage ratings of 138,000 gr-Y, 69,000 gr-Y, 37,000 gr-Y, and 14,000 volts. Mounted on a 75-ton carryall, the transformer will replace equipment on the line

during emergency periods or during general maintenance.

Electromagnetic models for predicting transient voltages in power transformers were announced by GE in 1952. Of the unity-time-scale type, these first models did the job, but they prepared the data too slowly to be of maximum use for design purposes.

Transformer engineers solved the problem last year by developing a long-time scale model used in conjunction with another new research aid, the slow-speed transient analyzer.

This combination yields all design information with the required accuracy and speed through the addition of a third dimension in voltage-distribution measurement. Now oscillograms taken from the slow-speed analyzer simultaneously show voltage versus space and time. Readings taken directly from these oscillograms yield at a glance such vital information as the amount of insulation necessary on the winding of a transformer at any given point.

An IBM Card Programmed Calculator (CPC) operating for more than a year helps transformer engineers turn out preliminary designs for propositions, requisitions, and standard lines. Detailed designs for the majority of General Electric's conventional power transformers will probably soon be turned out with the CPC.

In one hour it can produce preliminary designs that formerly required 20 to 40 hours of arduous work for an engineer using a slide rule and a desk calculator. Propositions can be given more individual attention by the designer but yet returned faster to the prospective customer. Results of laboratory experiments can be analyzed, developed, and included in designs shortly after data are available.

A new method of coating rectangular wire with film insulation makes possible distribution and power transformers as well as regulators that have increased reliability and reduced weight and size.

A novel method spreads insulation evenly on the edges and flat surfaces of rectangular-shape copper conductors. The conductor is given 5 to 8 separate coats of the film, each of which is baked. Twisting, hammering, or breaking the conductor does not chip or peel the film. Similar insulation has long been successfully used for motor coils and transformer windings of round wire.

Currently, the new wire film is being used on distribution transformers in the 3- to 15-kva range 15,000 volts and below and on 25-kva units below 6000 volts, as well as on power transformers and regulators in similar voltage classes. As soon as new manufacturing facilities are completed, applications will be extended to other ratings.

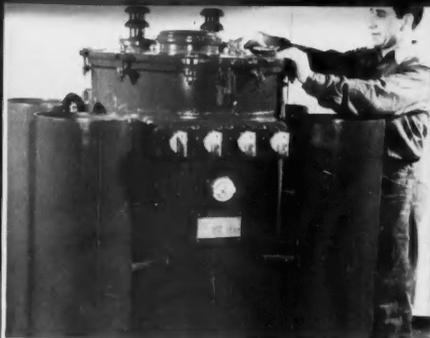
A newly designed cover for pole-type distribution transformers increases transformer life and simplifies maintenance. Its main features are one-piece stainless-steel clamping bands on the tank cover, handhole cover, and bushings, plus a circular rather than an elliptical handhole.

A new finish for subway distribution transformers lasts twice as long as previous subway finishes. It is now applied over the standard finish of single-phase distribution transformers, 167 kva and below, especially designed for use in subway applications where severe corrosive conditions exist.

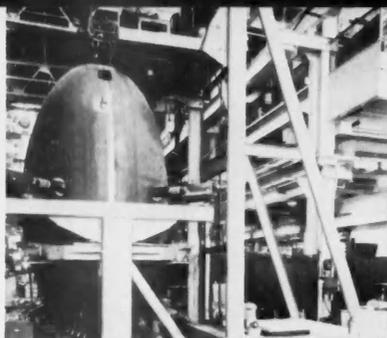
In a new design for vault-type network transformers the cooling tubes are welded together to form radiators. Two or more radiators are then welded to a box-like structure midpoint on each side of the transformer. The box structure stiffens the tank wall, supports the radiators, and serves as a manifold connector between the radiators and tank.

This design leaves free space between the radiators and the outside of the transformer tank, making it easy to reach behind the tubes for cleaning or repainting.

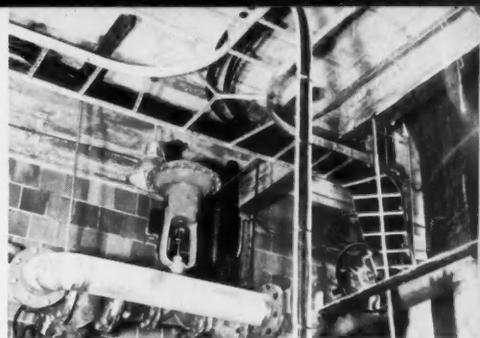
Because of a new bannister-type radiator design, load-center transformers



**CHIMNEY-TYPE RADIATORS** replace numerous tubes in substation-type transformer.



**AUTOMATIC** submerged arc-welding system welds power circuit-breaker tanks.



**PVC JACKET** on interlocked armor cable provides added corrosion resistance.

are now easier to clean and repaint, are more efficiently cooled, and allow more air space between the tank and radiator tubes. Fewer radiator tubes and fewer tube-to-tank connections are necessary, reducing the possibility for insulating fluid leakage.

A new substation-type transformer has a cooling method that utilizes novel chimney-type radiators instead of numerous tubes. This construction allows a reduction in height and weight without any sacrifice in the electrical characteristics of the transformer. For example, weight of a 250-kva transformer was reduced more than 6 percent, and the height 2½ feet, or more than 30 percent. Similar designs are available in substation-type transformers rated 500 kva and smaller, 67,000 volts and less.

Nine huge cast-in-concrete current-limiting reactors utilizing aluminum conductors were shipped last year to the Detroit Edison Company for use in 60-cycle 24,000-volt circuits. Believed to be the largest ever built, each of the single-phase 12,500-kva reactors required more than 11,000 feet of stranded transposed cable. Measuring 6½ feet in diameter and 13 feet in height, each unit weighs more than 15,000 pounds.

In production at the same time was the largest oil-filled reactor ever built by GE. With its 22 radiators completely assembled and filled with oil, the reactor will weigh 135 tons. Designed for service on a 60-cycle 161-kv circuit, the unit is rated 56,000 kva, 15,600 volts, 1200 amp.

Significant advances in understanding how tensile and compressive stresses affect the magnetic properties of transformer-core steels contributed to the reduction of transformer noise and losses. Single silicon-iron crystals prepared in sheet form with predetermined orientations were used in 1954 researches to better understand the structural and magnetic-domain phenomena in silicon steel, which is used primarily in transformers.

### Switchgear

Two 330-kv outdoor substations, the largest ever installed in this country, were designed and built during 1954 to distribute power to AEC's huge plant at Portsmouth, Ohio. Each station has transformers totaling more than 1-million kva, occupies approximately 13 acres, and required about 800 tons of fabricated steel. Total electric equipment in the stations, in addition to the transformers, includes 36 power circuit breakers rated 330 kv, 25,000,000 kva; 115 330-kv air-break switches; 42 330-kv lightning arresters; and more than 20,000 bus, switch, and strain insulator units. The welded aluminum buses have capacities up to 2000 amp. Line towers are 121 feet high, and air-break switches are mounted on steel stands up to 35 feet high.

For protection of the 330-kv transmission system supplying power to the AEC plant at Portsmouth, a new line of electromagnetic carrier-current relays was produced. These relays have an operating speed between 1½ and 1¼ cycles, approximately 25 percent faster than any similar relay.

For welding the heavy steel tanks of the 25-million-kva power circuit breakers being built for the new 330-kv power systems, an automatic submerged arc-welding machine was developed. Weld quality was greatly improved, and welding time was reduced to ⅓ that of manual-welding methods. Utilizing a twin-spotlight photoelectric device to follow the joint seam, the machine automatically positions the welding head and controls the tank turning rolls.

For carrying power between generators, transformers, and switchgear in large generating stations, isolated-phase bus has long been the accepted standard. Such buses have been characterized by extremely heavy supporting structures made necessary by the high stresses developed under short circuit. A new bus development utilizes the principle

that the force on a conductor enclosed in the center of a highly conductive metal sheath is essentially zero. Using aluminum enclosures simplified the bus supports to include only enough insulators to support the conductors. A single insulator is used at each point of support where 4 were previously required.

Irradiated polyethylene was used in metal-clad switchgear as insulation between blowout-coil turns of magnetic power circuit breakers. The product has insulating, thermal, moisture-resistant, and mechanical qualities superior to those of the materials formerly used. It is believed to be the first commercial application of the Company's new product.

A new portable closing device was developed for power circuit breakers in metal-clad switchgear. Liquid carbon-dioxide gas is the source of closing power. This device fulfills a need for a portable mechanism to close a modern power circuit breaker during normal operation of the station by means other than its electric closing mechanism.

The rapid increase in size of steam turbine-generators created the need for much larger air circuit breakers to control their field circuits. Field circuit breakers must interrupt rated short-circuit current at the high induced voltage resulting from the interruption of the highly inductive field circuit when the generator is faulted at or near its terminals. New 4000-amp 375-volt breakers produced during 1954 met these stringent requirements. Ratings have increased from the 1600-amp 250-volt rating of former breakers.

### Capacitors

Early in 1954 the Los Angeles Water and Power Department completed installation of a high-voltage series-capacitor bank at the receiving end of their 260-mile 230-kv Owens Gorge transmission line. This equipment is being tested under various operating



**HIGH-VOLTAGE** d-c cable test unit is mounted in station wagon for field service.

conditions as a prototype for very-high-voltage transmission lines.

Each phase of this 3-phase 60-cycle series capacitor is rated 15,920 volts, 2500 kvar, 157 line amp.

During 1954 the dielectric used in all G-E power capacitors was changed to a new all-temperature dielectric suitable for energizing at temperatures of 115 F (46 C) to -40 C. This advancement enables switching of capacitors in sub-zero temperatures.

Last year a new 20-kvar capacitor in ratings of 460, 480, 575, and 600 volts was introduced. These capacitors, filled with the new all-temperature dielectric, are designed for direct-to-pole mountings and enclosed installations of all sizes.

A new line of capacitors designed for continuous operation in ambient temperatures of -55 to +125 C was announced in 1954. Using tantalum foil electrodes, these capacitors have the superior electrical characteristics associated with similar foil types rated 85 C maximum. Designed in drawn rectangular containers, they incorporate an improved sealing means that utilizes silicone elastomer bushings.

A new glass that blocks the transmission of ultraviolet light is available for manufacturing electric insulators that can be hermetically sealed to apparatus. Possessing high weathering

resistance, these insulators have the needed transparency for visual inspection. This glass led to the use of an improved capacitor dielectric by protecting it from the effects of ultraviolet light.

#### Cable

The constant growth in power demand accentuated the need for solid dielectric cable insulations that will operate satisfactorily at higher-current loadings. Extensive long-time load-cycle testing of cables for use on voltages from 8001 to 15000 volts, plus the evaluation of new developments and improvements in this power cable line, resulted in raising the copper conductor rating to 85 C—an increase of 5 degrees. Thus more power can be transmitted through the cable without increasing the conductor size.

High-temperature 15-kv cables—up to 3500 MCM (1000 circular mils)—with silicone-rubber glass-cloth-tape insulation were made for Consolidated Edison Company of New York for use as generator leads and bus ties. Cables for these connections are generally among the largest conductor sizes made, and in some instances previous types of cable developed excessive cable temperature during the hot summer months under maximum system loads. The new 15-kv ground-neutral cable can operate at 125 C copper temperature, highest ever used on any heavy power cable at this voltage. This installation is the first of its kind.

It is believed that an even higher voltage rating is warranted and perhaps a higher temperature rating. Tests are under way to determine voltage and temperature limits.

Interlocked armor for application to cable can be galvanized steel, bronze, or aluminum; the corrosion characteristics of the atmosphere in which the cable is installed indicates the material to be used.

To give this cable added corrosion resistance, a polyvinylchloride (PVC) jacket was applied over the armor. This new covering makes possible the use of galvanized steel armor that is less expensive than other materials. Cable with the new PVC covering, available in various colors for coding of cable circuits, was used for the first time in 1954 in a paper mill.

Glass cloth of a special weave provides sufficient elongation in finished glass cloth tape so that it can be applied to cable. Primarily because of the pres-

ence of the inert glass cloth, varnished glass cloth insulated cable has a higher temperature rating than the usual varnished-cambric insulated cables.

For the first time in 1954, a 5-kv cable insulated with a varnished-cambric glass cloth was installed in a power circuit where the high ambient temperatures made varnished glass economically attractive.

Improved cable-testing facilities were perfected to safeguard the user of high-voltage solid-dielectric cables against incipient failures due to ionization. Surpassing anything previously used in cable testing, it is capable of detecting internal corona at 50 kv and has sufficient capacity for testing longer cable lengths than normally produced by standard factory equipment.

A portable high-voltage d-c cable test unit mounted in a station wagon was active last year for field service. It helped several contractors, industrial plants, and smaller utilities to perform acceptance and proof tests on cable installations and to evaluate the condition of older installations. The equipment consists of a 100-kv d-c 100-ma full-wave rectified kenetron set and a 20-kv 1-microfarad capacitor discharge set for aiding location of faults.

#### Arresters and Cutouts

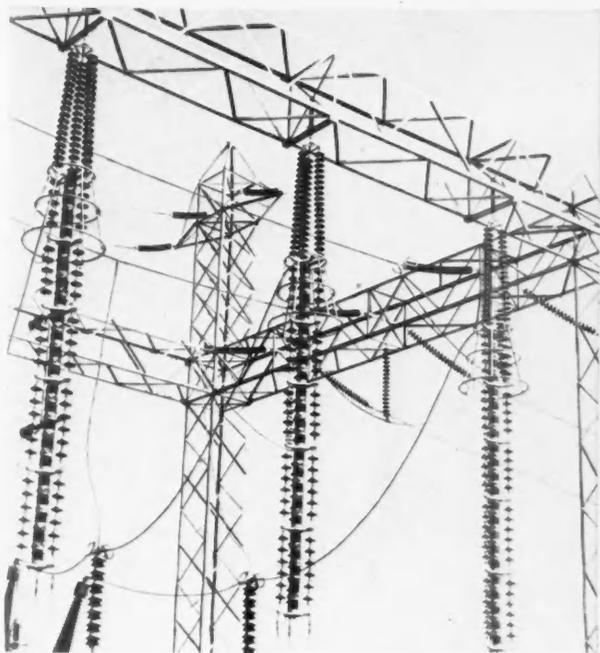
A station-type lightning arrester introduced during 1954 has 20 percent lower IR discharge voltage, 10 percent lower sparkover voltage, and 3 times greater long-duration discharge capacity and endurance than the models it supersedes. Ratings are from 3 to 264 kv.

These new arresters were first installed on a high-voltage power system in Ohio. Notable examples of other service installations are those rated 264 kv line-to-ground. Of suspension construction, they are used on 330-kv solidly grounded-neutral service. This is one of the highest-rated arrester installations ever placed in commercial service.

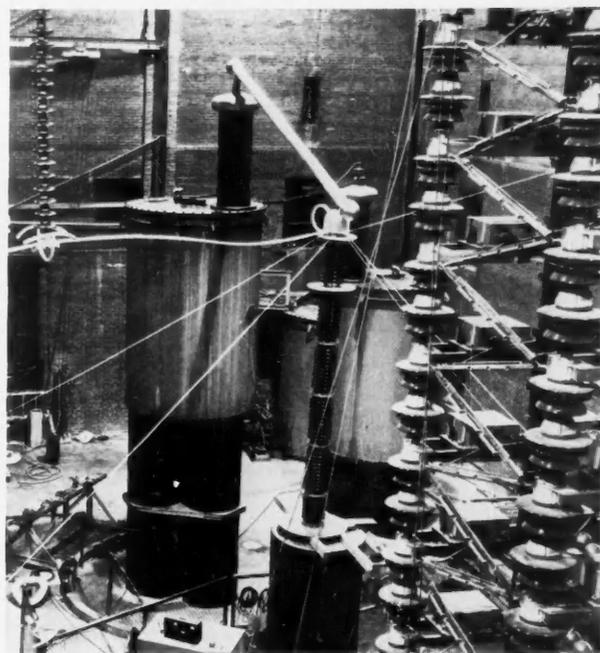
In a new line of enclosed distribution fuse cutouts, all operating functions are available in one basic design. One housing and 4 interchangeable doors in each voltage and current rating provide all the basic operating functions and all NEMA standard interrupting ratings.

#### Insulators

Continued growth of radio and television makes it imperative that high-



**STATION-TYPE** single-pole lightning arresters offering increased efficiency were placed in commercial service.



**CORONA SHIELDS** for 330-kv circuits undergo rigid vibration tests to assure withstanding years of conductor vibration from winds.

voltage power apparatus be free of interference generation in high-frequency bands.

Improvements in glaze composition and glazing techniques now provide all distribution pin-type insulators with conducting glaze areas for control of corona discharges.

Greater use of transmission voltage in the order of 330 to 345 kv spurred the development of several new types of shields that suppress corona from insulator strings, clamps, and fittings. To assure their successfully resisting years of conductor vibration caused by winds, some shields withstood rigid vibration tests of more than 1-million cycles, with a 2-degree angular amplitude of 20-cps vibration frequency.

To assure high-quality and uniform insulators, a new automatic raw-materials processing unit was installed by the Locke Department of General Electric. Proper quantities of raw materials are automatically delivered, weighed, and carried to mixing machines from 2800-ton-capacity storage silos. Equipped with electronic safeguards to avoid errors and capable of handling about ¼-million pounds of raw materials per shift, this unit gives precise control over the highly important initial batching of clays, feldspar, and flint that eventually become high-voltage insulators.

#### Rectifiers

After many years of development, a mechanical rectifier built 3 years ago has since supplied 250-volt d-c power to the Company's switchgear plant in Philadelphia. Based on the success of this long trial run, commercial mechanical-rectifier equipment was built for a large chemical plant. Rated 12,000 amp, 270 volts, it embodies many new features of control and performance. Its high efficiency—more than 96 percent compared with 70 to 90 percent for other types of power converters—provides attractive power consumption savings in continuous industrial processes requiring large amounts of low-voltage d-c power.

A line of miniature selenium cells was improved and expanded during 1954 to include a low-cost general-purpose cell, a hermetically sealed cell, and potted and unpotted assemblies. The design offers extremely high reverse resistance and a life comparable with other industrial rectifiers.

The largest and most precisely regulated static power-conversion unit ever built by General Electric was constructed in 1954. It was part of an 11-unit order totaling 240 kw in 6 cubicles to be used as a power supply for a large computer.

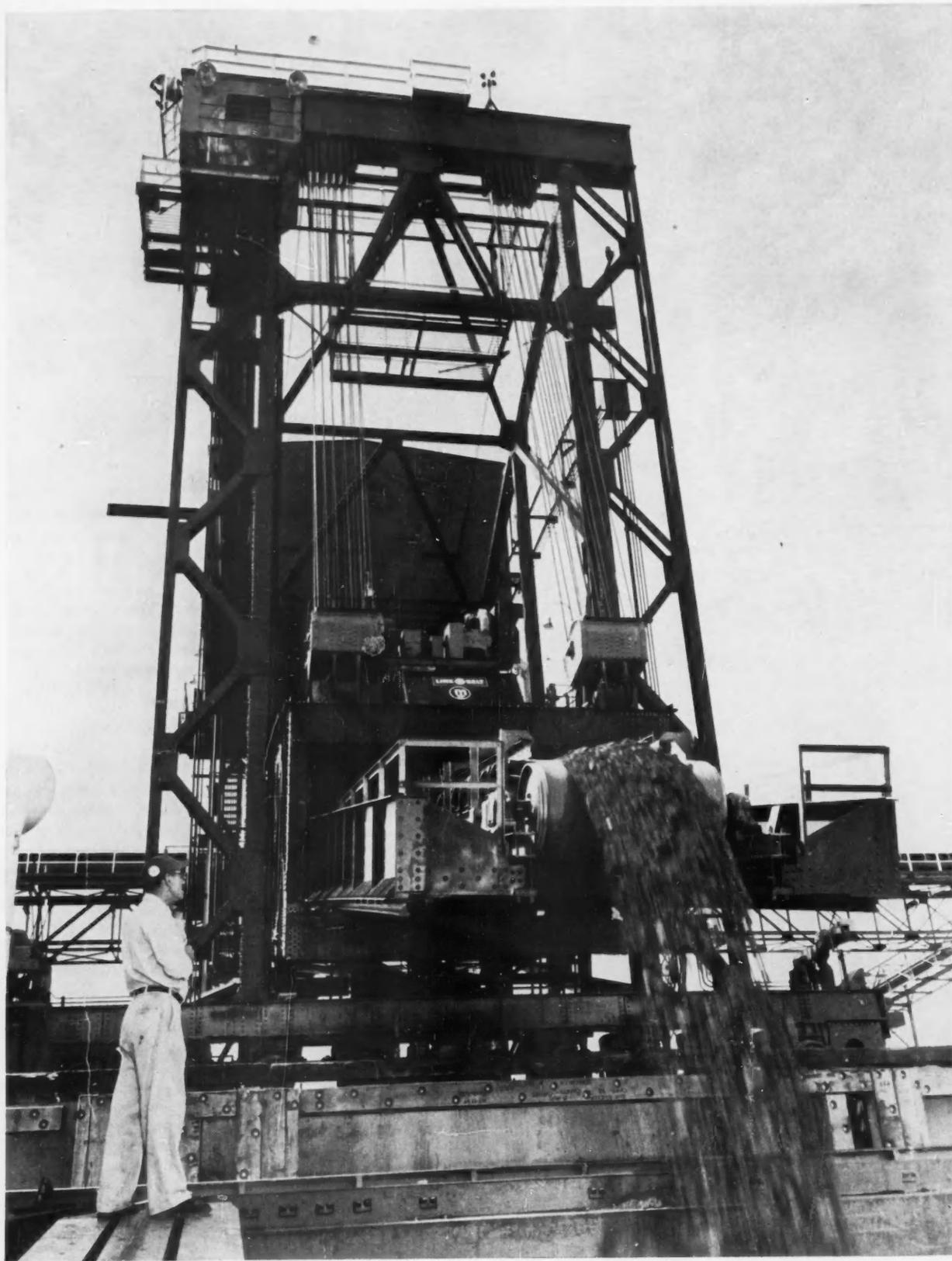
One unit, while not the largest, totaled 45 kw with a regulation of less than

½ of 1 percent on any of these conditions: slow regulation, maximum transient, and ripple. The design does not include tubes or moving parts.

#### Other Developments

A new high-reactance current-limiting feeder busway was developed in ratings from 1000 to 4000 amp. Two 4000-amp busways may be connected in parallel for an 8000-amp rating. Intended primarily for commercial buildings in cities where short-circuit current from network systems is more than 100,000 amp, the busway reduces the high value of short-circuit current to 100,000 amp or less at the switchboard. This permits the use of standard circuit breakers and switchboard equipment. Although the appearance of the new busway is about the same as the standard line of low-impedance busways, the phase busbars are rearranged to produce the high reactance.

A 20 percent reduction in weight and a 25 percent reduction in size were effected in the redesign of the 400-amp plug-in busway. This design improvement was attained by taking advantage of modern scientific knowledge of the heat emissivity of different surface finishes. Although the enclosure of the old 400-amp busway was the same size as the 600, it is now the same as the 225-amp busway.



TWO AMPLIDYNE-CONTROLLED 6000-KW STEAM TURBINE-GENERATORS PROVIDE REGULATED POWER FOR VENEZUELAN ORE-LOADING TOWER.

# Industry

The trend of American industry in 1954 continued toward higher operating speed and more automatic control. Higher speed provides greater output per man-hour, resulting in lower operating cost. But higher speed also calls for an increase in the size of electric drives; in many instances, manual control is ruled out. Thus a greater degree of automation and instrumentation is needed to effectively process and maintain the quality of a product.

Great progress was made during the last few years in automating and instrumenting industry. Still this evolution is far from complete, and equal or greater progress will undoubtedly be required in the years ahead.

## Motors

One of the many features of a new armored-mill motor is its universal-type enclosure. By simply substituting covers over the various frame openings, 5 different systems of ventilation and protection can be obtained. Feet were added to the frame heads for armature support so that the coils and fan will not be damaged when the armature is removed. Connections between motor halves are outside the frame for easier accessibility. Also, an armature spider permits the shaft to be replaced without disturbing the motor's windings.

The motor, rated up to 500 hp at 350 rpm and 230 volts when force ventilated, is already finding use in the electric power-shovel industry. Four such motors were purchased by one manufacturer in 1954 to power the largest shovel ever built. Although designed primarily to keep pace with the electrical needs of the steel industry, the armored motor will also find many applications in oil-well drilling rigs, mine hoists, and ore unloaders.

Small, powerful armored-mill motors also introduced during the year modernized the old theory of approach-table drive in the McLouth steel mill. Instead of only one motor driving an entire set of rollers, a separate motor is used on each cylinder, or roller, on the table. Gear trains and their high maintenance costs are eliminated.

Completed during the year was a development project covering class-H electric insulation for armored motors. Cost

studies are under way to determine the best insulation system.

A new air duct, added to the explosion-proof totally enclosed 50-hp mine motor, results in lower-temperature operation and longer life for the motor. Transferring heat more effectively, the new air duct makes optimum use of the rectangular space available.

In 1954 a number of totally enclosed inert-gas-filled induction motors were supplied to the petroleum industry to be used in hazardous locations in connection with a catalytic-cracking process. A rating of 1250 hp at 400 rpm is typical of this application.

The world's largest power shovel, driven by the new armored-mill motors, receives its d-c power supply from a 37-foot-long motor-generator continuously rated 1930 kw. It is equipped with a self-supporting base for direct mounting on a platform within the house of the shovel.

Twelve 10,000-hp induction-motor gear-flywheel sets supply power for a pumping operation at an AEC installation. The speed of the motors is 595 rpm. Each flywheel, its speed geared up to 1696 rpm, has 114,000 hp-seconds of stored energy to keep the set running for several seconds in the event of power failure.

An advancement in filling-station pumping equipment, a unique motor designed to be submerged in gasoline will supply up to 9 hose pedestals. It is located deep inside the bulk tank, with the pump directly beneath; pressure is maintained through a pushing action instead of the conventional suction method.

The secret of this new submersible motor, rated  $\frac{3}{4}$  hp at 3450 rpm, lies in permitting gasoline to seep in as a bearing lubricant. To protect the stator-core assembly, it is encapsulated under pressure with a special compound.

A quickly reversible single-phase motor is one of several new members of the form-G line of motors. Operating without time delay, the motor is designed for use on door operators, cranes, and machine tools.

Where positive brake action is required, such as on cut-off or index mechanisms, a new compact and dependable fractional-horsepower motor is ideal.

Another development is an explosion-proof motor for general and fan-duty applications in atmospheres that contain gasoline, naphtha, lacquer-solvent vapors, and natural gas. Mounted on a formed-steel base welded to the motor shell, it is available in single- or poly-phase fractional-horsepower ratings.

In the field of induction motors, the year's most important development was a completely new insulation system that increases motor life 50 percent. Designed for induction motors rated 200 to 3000 hp, it represents the first major change in insulating systems over the last half century.

The system combines individual qualities of Mylar and Dacron (polyester resins) and a synthetic hydrocarbon resin. (Mylar and Dacron have 7 times greater physical strength and more than 2 times the dielectric strength of their predecessors, cotton and paper.) This product resists heat-aging better than any other insulating system and has twice as much resistance to chemical contamination.

Another development of 1954 is a package electric system for refrigerating delivery trucks. Basically it consists of standard components: engine-driven alternator, compressor motor, selenium rectifiers, regulator, and evaporator fan motor. Refrigerated trucks using this system will deliver milk and other dairy products, meats, frozen foods, beverages, and flowers.

A parallel advance in the field of air conditioning and refrigeration is the development of new 1/12- to 1/6-hp shaded-pole motors that have the highest efficiency of any built by GE. Improved insulation, cooler all-angle operation, and a long-life sealed-in oil recirculating system are some special features. Their principal applications are in furnace blowers, unit heaters and coolers, window fans, and in room air conditioners.

Under construction for an aircraft company is a vertical-shaft d-c motor that will drive a test stand with which the large rotor blades of helicopters are dynamically balanced. Rated 1500 hp over a speed range of 150 to 300 rpm, the rotor is designed with drip-proof construction and with roller bearings for both thrust and guide. Serving as



LIFE OF INDUCTION MOTORS INCREASED 50 PERCENT WITH NEW SYNTHETIC INSULATION.

power supply for the test motor is a 1250-kw motor-generator set.

To power the turret of a medium military tank, a new set of rotating equipment consists of a 28-volt d-c motor mounted on a common shaft with a traverse and elevation amplidyne generator. Rugged mechanical design includes such special features as a nodular-iron end shield and a mounting ring to withstand severe vibration and shock. Compared with conventional hydraulic equipment, it provides better performance, longer life, greater reliability, and lower maintenance.

A specification for the ideal general-purpose electric-motor grease was determined after 6 years of investigation. Its consistency values were chosen in the grade-2 range so that the grease maintains its structure but is soft enough to lubricate.

The 100-millionth fractional-horsepower motor produced in October set a motor-production record 52 years after GE first manufactured such a motor. By 1965 this total may double, with the Company's building a second 100-million motors in  $\frac{1}{2}$  the time required for the present record.

#### Dynamometers

With the increase in speed requirements of modern automotive engines, gas turbines, and compressors, high-speed testing equipment must also be developed. To keep pace with this trend, a d-c absorption dynamometer rated 300 hp at 2500 to 6000 rpm was placed in service during the year. Also installed was an adjustable-speed induction-motor dynamometer rated 700 hp at 20,000 rpm.

Designed primarily for colleges and mechanical and aerodynamic laboratories, a d-c dynamometer will be used to study fluid flow and energy transfer in such axial-flow machines as turbines and compressors. Consisting of an axial-flow fan direct-connected to a  $7\frac{1}{2}$ -hp d-c cradled dynamometer, the unit is powered by a G-E speed variator. Its axial-flow fan can be operated as a single- or 2-stage machine in various combinations of blades and blade-angles.

#### Control

Produced during the year was the first continuous galvanizing-line control equipment that exclusively utilizes amplistats for regulating circuits. A total

of 22 amplistats are used in 12 regulators, some as preamplifier regulating units, others as power units to supply d-c field excitation. The regulators themselves control voltage, current, speed, and position. All regulators, adjusting rheostats, and instruments required for setting the regulators are concentrated for convenience on a 15-foot section of the 85-foot control panel that houses the equipment.

Another development is a closed-cycle system for controlling elevators. Utilizing an amplidyne exciter, static regulator circuits supply excitation to a d-c generator, which in turn furnishes adjustable voltage to the elevator's d-c motor. Programming control initiates acceleration and retardation as a function of the car's position. For passenger comfort, rates of acceleration change are adjustable right up to the limits of machine characteristics, resulting in the shortest possible over-all trip time.

A new line of d-c operated 2-shoe single-magnet brakes for heavy mill applications meets the rating and dimension standards jointly established by the Association of Iron and Steel Engineers (AISE) and the National Electrical Manufacturers' Association (NEMA). A single adjustment, requiring only a standard wrench, compensates for lining wear of the new brakes.

Versatility and flexibility are provided for the panel designer by a new line of machine-tool transformers that conform to the electrical standards established by NEMA and the Joint Industry Committee (JIC). Small, compact, light, and rugged, the new transformers save panel space and reduce wiring costs. They are available in 16 basic designs and 8 volt-ampere ratings of 50, 75, 150, 300, 500, 750, 1000, and 1500. As an example of their flexibility, 7 combinations of cable leads, terminal boards with solderless connectors, 1, 2, or 4 fuses, and a circuit breaker are available in sizes 300 to 1500 volt-amperes.

Greater flexibility also marks a new line of longer life strongbox industrial solenoids that are 22 percent smaller than previous models of the same rating. The new solenoids are easier to install because they can be mounted in any of 5 different positions, and the strongbox coil includes combination terminal and lead-type connections. Forms are available in force ratings from 1.4 to 40 pounds.

A new general-purpose control center for group assembly of a-c motor starters with short-circuit ratings of 25,000 or

50,000 amp, incorporates most of the desirable features of 5 different control-center designs. One standard 90-inch-high trough accommodates 9 NEMA-size 1-starter units or 6 NEMA-size 2-starter units. It saves up to 50 percent in floor space.

A major control achievement for air-conditioning applications is a new definite-purpose starter that is 50 percent smaller than standard industrial-type starters. The new starter is easily installed and has quick-tripping overload relays for hermetic motors.

New heavy-duty oiltight indicating lights were added to the line of oiltight push buttons, selector switches, and accessory controls during the year. Featuring all-angle visibility, the new 110- to 600-volt lights have glass faceted lenses.

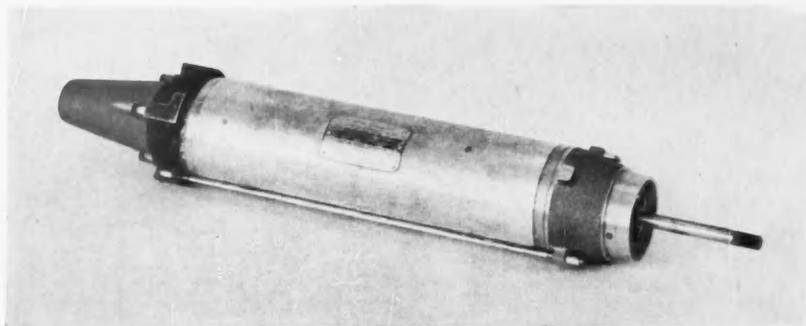
No rectifiers are required in a new pulse-relaxation amplifier, an extremely sensitive magnetic amplifier operating from a pulse power supply. Preliminary tests indicate that it can be controlled by signals of  $10^{-16}$  watts over a temperature range from  $-94$  to  $+284$  F. Several stages can be used to amplify a low-level signal to bring it to the micro-watt level. From there, conventional amplifiers boost the power to higher output levels.

For industrial applications, a standard line of 60-cycle amplifiers is available with d-c outputs of 1, 15, 40, 75, 140, 325, 600, and 930 volt-amperes. Selenium rectifiers are used in the 15-volt-ampere and larger ratings, as are stacked-core reactors that have control winding ratings applicable to a wide variety of industrial control circuits. All units feature the full-wave bridge circuit and operate with d-c signal sources.

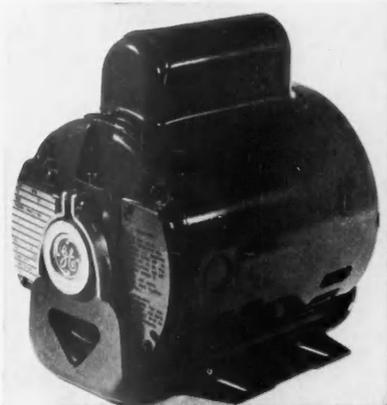
Also developed during the year was a pneumatic limit switch, together with its associated system, that performs the same function on some manufacturing equipment as a microswitch, a relay, and a solenoid-operated valve. The operating life of the switch and its components should far exceed that of the electric devices and should substantially reduce cost.

#### Protective Breakers

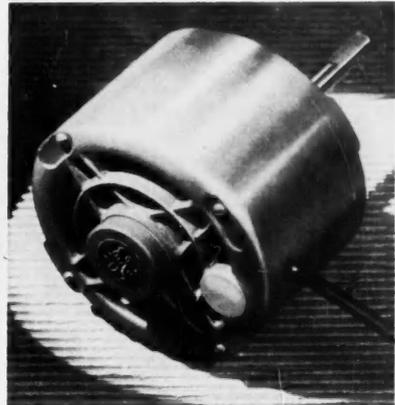
The 600-amp L-frame circuit breaker now has a new universal molded case that is suitable for front connection with single- and twin-cable lugs and for rear connection with studs. Sealed thermal-magnetic trip units rated 125 to 600 amp continue to be used in this breaker. It is also built in a 3-pole wide base for



**SUBMERSED** deep in a gasoline tank, this unique pumping motor supplies up to 9 filling-station hose pedestals. Pressure is maintained through a pushing action.



**QUICKLY REVERSIBLE** capacitor-start motor operates cranes and machine tools.



**SMALL MOTORS** for such appliances as cooling units range in size from 1/12 to 1/6 hp.

both 2- and 3-pole arrangements in all types of industrial enclosures, panel boards, switchboards, and control centers.

A new line of operating mechanisms was introduced for application with the E-, F-, J-, K-, and L-frame circuit breakers. In addition to having a strong die-cast aluminum handle with positive OFF-ON position indication, their 3 padlocks allow locking in either position.

Put into production for the first time this year is a compact 2-pole common-trip plug-in thermal-magnetic circuit breaker in ratings of 15 to 50 amp, 120 or 240 volts a-c. Designed so that an overload on either pole trips both poles simultaneously, the unit can be used as a main breaker in panel boards and load centers or as branch-circuit protection.

A new lead-plated sheet-steel enclosure was designed for industrial circuit breakers and safety switches used in water- and dust-tight applications. Savings in weight up to 75 percent over conventional units permit easier installation and lighter supporting structures. The enclosure accommodates 15- to 225-amp 600-volt a-c circuit breakers,

as well as safety switches rated from 30 to 200 amp, 600 volts a-c.

#### Industrial Heating

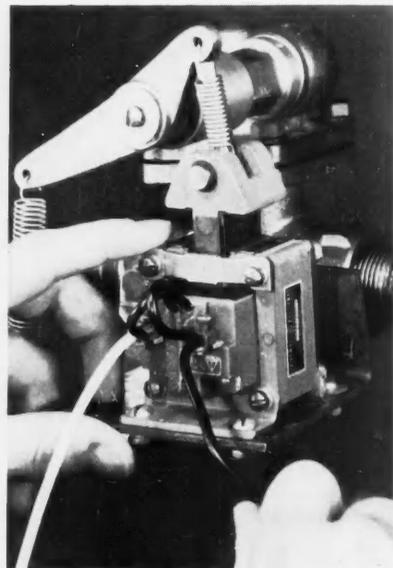
Highlighting the year's developments in industrial heating is a new cold-mold-type inert-atmosphere arc-melting furnace. It melts highly reactive or refractory metals that react with, or become contaminated by, any known refractory or crucible. The new furnace is primarily intended for industrial and academic research laboratories that study the properties of metals and their alloys.

Some of the metals successfully melted in the new furnace are molybdenum, tungsten, tantalum, zirconium, titanium, and their alloys, as well as the more common metals, such as iron and aluminum. Carbides and silicides have also been melted. Ingots produced are either 4 or 6 inches in diameter and up to 16 inches long.

Many special features are incorporated in the furnace to simplify its operation. For example, the completed ingot is quickly and easily removed, because the mold is mounted on a revolving stand that can be swung out



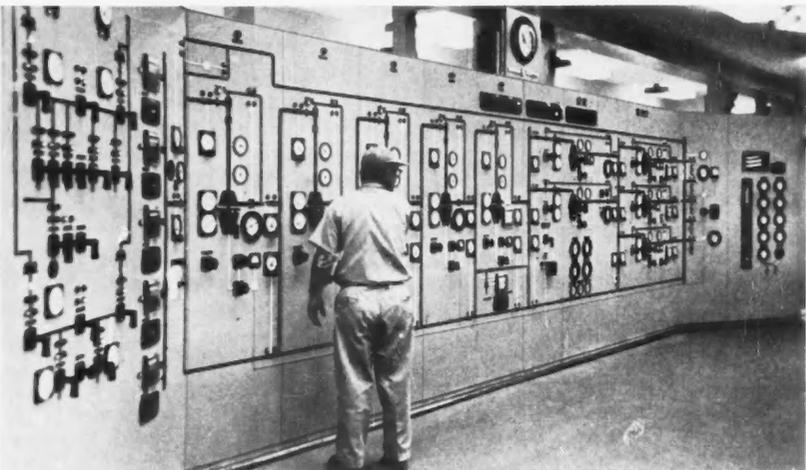
TINY REACTOR (EAR) IN A NEW PULSE-RELAXATION AMPLIFIER REPLACES ELECTRONIC TUBE.



SMALLER SOLENOID IS MORE VERSATILE.



LONG-LIFE A-C TRANSFORMER WELDERS ARE EASILY OPERATED AND HIGHLY DEPENDABLE.



CENTRAL CONTROL PANEL OPERATES A COMPLETE 60,000-HP GAS-TURBINE COMPRESSOR PLANT.

from the rest of the equipment. Air pressure raises the mold into position.

#### Welding Products

Two new rectifier-type d-c welders rated 300 and 400 amp, plus 3 newly designed a-c welders, were introduced last year. Both welders utilize a moving primary coil to achieve completely stepless current control and accurate settings in the low-current range. By taking out 3 screws at the base, the welders' side covers can be removed to expose the interior for inspection and maintenance. An arc-force control operates full time but doesn't cut out when most needed. The control permits welding with shorter arcs than is possible with any other rectifier-type welder. A major design feature of the a-c welder is its operating ease. For example, an automatic hot start gives an extra surge of current for a split second to assure easy and positive starts.

A closely related development is a new powdered-metal electrode that has deposition rates up to 50 percent faster than conventional electrodes. It operates on either a-c or d-c and has minimum spatter and little tendency to undercut.

#### Mining

Gaining recognition in underground mining applications are a-c electric tools, replacing conventional d-c mining machines when feasible. With the use of low a-c voltages underground, the problem of conveniently transforming distribution voltages to usable 480-volt power had to be solved.

With this in mind, dry-type ventilated-mine load centers were designed in ratings of 45 to 500 kva, with a primary voltage of 2400 or 4160 volts and a secondary voltage of 277/480 volts. Because they have a maximum height of 42 inches and a width of approximately 55 inches, the new load centers are readily movable in mine passages or can be lowered endwise down a vertical mine shaft. Accessory equipment of the mine load centers is tailored to specific applications.

Some features of the new mine load centers include breaker protection for the primary and secondary circuits. Ground-fault protection is also provided on the load circuits to insure the safety of personnel and equipment. When desirable, a lighting power supply is included for illumination or for powering small 120-volt equipment. To date, the units are of the open, ventilated, dry type for use in the fresh-air passage.

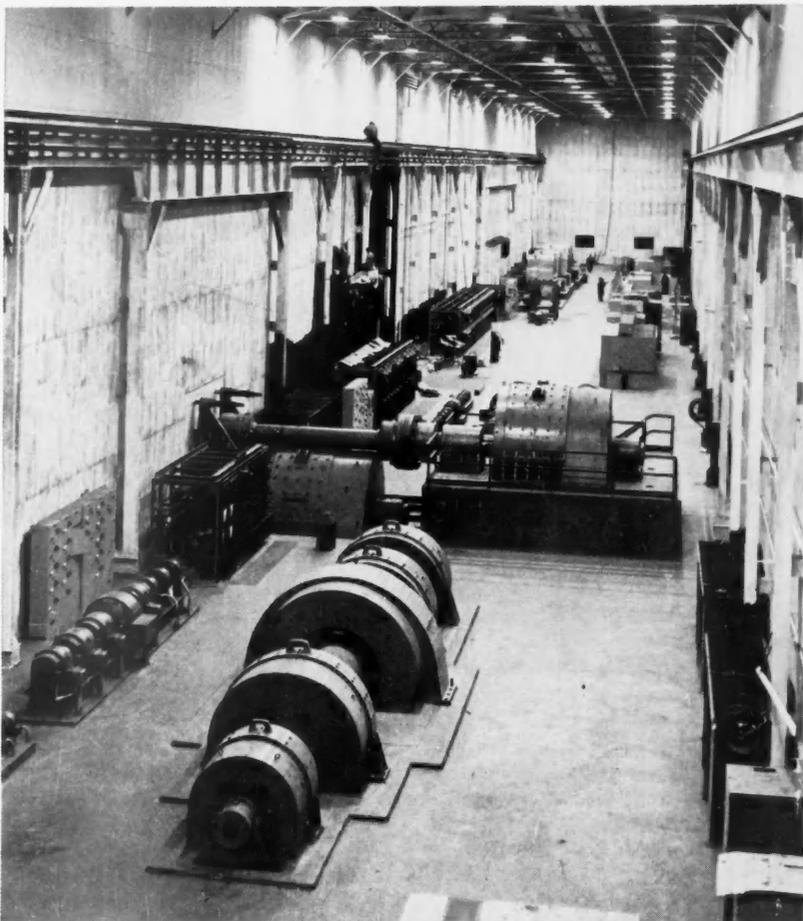
The coal-mining industry is facing severe competition from other fuels, such as oil and natural gas. To remain in the race, it had to apply better, larger, and more efficient machinery.

For example, the world's largest power shovel—capable of taking a 100-ton bite—will be used for open-strip coal mining—a much more economical operation than underground mining. (The shovel is as high as a 12-story building.) Fourteen motors totaling 7500 hp will power the various motions of this mammoth machine. Utilizing amplistat-amplidyne control, adjustable d-c voltage will supply the motors from 2 large motor-generator sets mounted on the shovel.

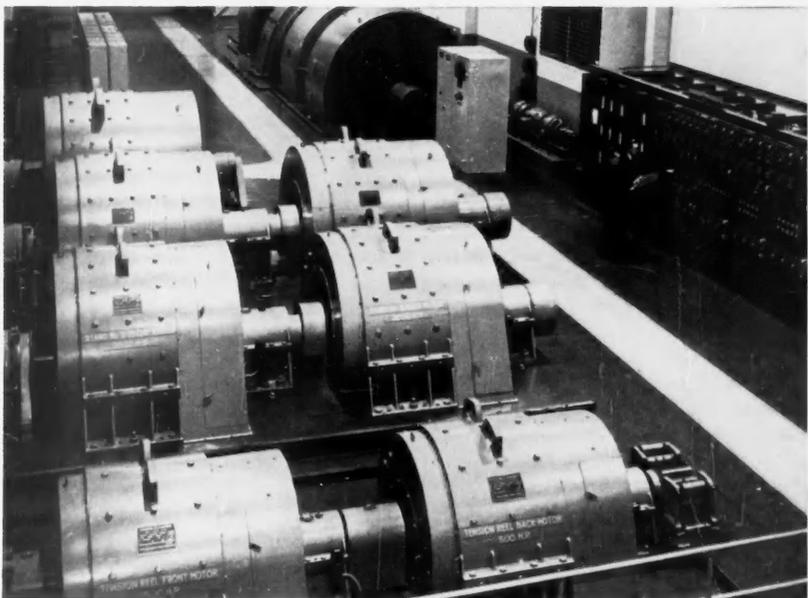
A new underground locomotive went into service in a Pennsylvania mine during 1954. Believed to be the largest in the world, this single-unit 50-ton 600-hp locomotive can pull 1600 tons, the equivalent of 110 loaded mine cars on a level track. Motor power is provided by 4 150-hp motors, 1 to an axle, supplied from the mine's 275-volt d-c power system.

A rapid depletion of high-grade iron ore in the Mesabi Range is turning the steel industry's attention to other geographical sources of raw material. These new projects require large and extensive electrification that takes various forms.

At the Orinoco Mining Company in Venezuela, for example, 2 2500-kw a-c generators are supplying power to power shovels, other mining facilities, and the town. Ninety miles from the mine, at Puerto Ordaz, 2 6000-kw steam-turbine generators supply power to unique ore-



**LARGE HORSEPOWER TWIN-REVERSING MOTORS** in modern strip mills produce sheet steel for the fabrication of automobiles, appliances, metal containers, and the like.



**AMPLISTAT AND AMPLIDYNE** types of control for a new high-speed cold-strip mill were tested and compared with excellent results.



COMPACT A-C GENERATOR ADDS A SIZEABLE SOURCE OF POWER TO VERSATILE TRACTOR.

handling equipment. The latter includes adjustable-voltage conveyor drives with amplidyne control to provide synchronized and adjustable speed for loading ships at a rate up to 6000 tons an hour.

In the northern hemisphere, 6 10,000-hp induction motors are being built for dredging operations required to uncover rich iron-ore deposits at Steep Rock Lake in Canada. The equipment will remove 160-million cubic yards of material—more than that removed by dredges to construct the Panama Canal.

#### Gas and Petroleum Industries

At the end of 1954, 40 gas turbines comprising almost  $\frac{1}{4}$ -million horsepower were pumping gas through America's major gas pipelines. Measured in terms of the gas turbine's reliability and low maintenance, this engineering achievement is remarkable.

Elsewhere, 10 gas turbines went into operation on a platform in Lake Maracaibo, Venezuela. They drive centrifugal compressors, returning gas at high pressure to the oil-bearing sands beneath the lake. This 60,000-hp installation compresses 125-million cubic feet of gas a day from atmospheric pressure to 2000-pounds pressure.

In addition to the gas turbines, the largest G-E process-control panel ever built was furnished for the installation. It brings together in one place control of the gas turbines themselves, gas-flow regulators, various gas measurements, and distribution of about 2000 kva of auxiliary electric power.

In the petroleum industry, the Gulf Oil Company ordered 6 variable-speed steam turbines to drive compressors at one of its oil refineries. Such combina-

tions of a variety of small high-speed steam turbines driving radial-flow compressors fit particularly well into current petrochemical processes.

#### Steel and Other Metals

During 1954, as in preceding years, the total steel tonnage supplied in the form of flat-rolled steel continued to increase. Strip mills, the modern tool for producing sheet steel, roll out this material for the fabrication of automobiles, appliances, metal containers, and the like.

In hot-strip mills the trend during the year was to provide a separate power supply for each of the d-c motors that drive the finishing stands. Thus the heavy interrupting duty on circuit breakers with a common d-c bus is avoided. Also each of the several drives has a greater speed range. Three such mills went into service last year or were under construction. The future will see greater use of rectifiers than motor-generators for the power supplies.

An all-amplistat control for a 5250-hp finishing stand and a 1200-hp reel drive was successfully tried out on a new high-speed cold-strip mill. Both the amplistat and amplidyne types of control were tested and compared on the same mill. These tests, plus computer studies, demonstrated that the best over-all result and simplest arrangement are achieved by utilizing the amplistat as a first-stage amplifier and by maintaining the amplidyne as a power amplifier in the regulating system. Such equipments are now under construction for several cold-strip mills.

Electric drives totaling 28,000 hp are being built for a record-breaking cold-

strip tandem mill that will deliver steel at more than 7000 fpm.

In a new copper-rod mill, copper bars 4 inches square and 54 inches long are automatically delivered from a furnace every 30 seconds. Through a series of rolling-mill stands, they are then reduced to  $\frac{1}{4}$ -inch rods and delivered at 1200 fpm in one of several coilers. From there the rods are removed to a conveyor for cooling and further automatic processing into copper wire. All handling between the roughing and finishing stands is automated.

Another good example of automation is the taper rolling of aluminum sheets used in aircraft manufacture. A fast-acting regulating system synchronizes the movement of the mill screwdowns with the movement of the sheets through the rolls, allowing a sheet's thickness to be gradually tapered as it progresses.

#### Metal-working Industries

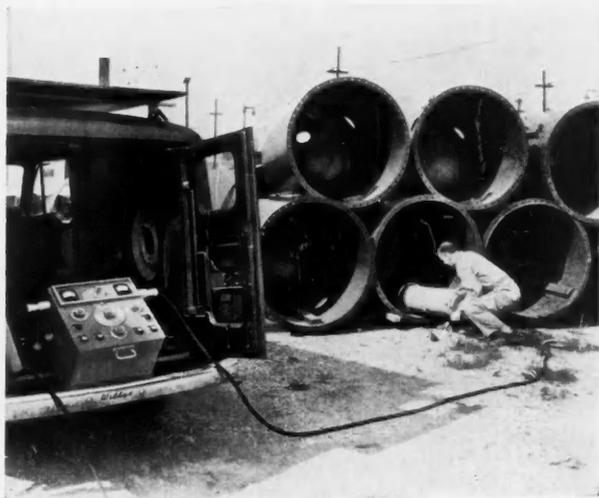
Automatic and continuous production techniques gave rise to a number of new developments in electric drives and systems during 1954.

From information stored on a magnetic tape, a record-playback control system directs the operation of a machine tool. Applied to a skin-milling machine, this system increased the production rate, because it eliminated the time previously needed for numerous template changes and set-ups. First, the initial piece of metal is machined through the use of a tracer control, and this operation is recorded on magnetic tape. Subsequent pieces are then machined merely by making use of the signals on the tape that accurately reproduce the relative motions on the machine. Program cycles up to 1 hour long can be recorded on a single roll of magnetic tape.

Another form of machine control, used on a turret-type punch press, employs information on punched business cards. With this system, the complete sequence of chart motions, together with information needed to select the proper-size punch, are recorded as perforations on punched cards. Then the cards are used in sequence to control each punching operation of the press.

Automatic means were also developed for detecting over-loading on a multiple-die press. A barium-titanate crystal under each die of the press measures the load on that die. If the signal generated during this measurement is excessive, the press is immediately shut down.

The use of large extrusion presses for



LEVEL-CHECKING X-RAY UNIT IS EFFICIENT AT HIGH PRODUCTION SPEEDS; PORTABLE INDUSTRIAL X-RAY UNIT MAKES A 360-DEGREE SWEEP.

continuously forming aluminum shapes resulted in the development of what is probably the world's largest band saw for cutting dies. Electric equipment provides the power to guide steel slabs up to 24 inches thick past the blade of this huge saw. With an amplidyne-controlled electric drive, its operator can smoothly start, stop, and reverse or combine these motions to control the work's direction and rate of feed.

#### Manufacturing Industries

Perhaps the greatest engineering contribution to the manufacturing industry during the past year was in the achievement of better quality control.

One of several special instruments was a turbidimeter that measures the pulp consistency of paper stock flowing through a process pipeline. Already applied effectively in various stages of paper making, it promises success in many future applications.

Another instrument, the moisture monitor, senses the variation in electric capacitance that takes place when the amount of moisture in a sheet of paper changes. It possesses a high degree of mechanical and thermal stability and can traverse a sheet of paper if desired.

A highly interesting application of the magnetic amplifier was made to high-speed hosiery machines. Built to simultaneously knit 30 pairs of full-fashioned stockings, these machines are driven by a 5- or 7½-hp d-c motor. Speed changes rapidly within each knitting cycle in accordance with a prearranged program. Power to the d-c driving motor is supplied from a packaged speed variator, with a magnetic amplifier controlling the voltage.

#### Materials Handling

A novel and interesting development in this field is an automatic parking garage, a promising way to solve the off-street parking problem. By simply pressing a push button indicating on what floor and in which stall a car is to be parked, an operator initiates the vertical and horizontal movement of the garage elevator to a selected stall station.

#### Farming

The International Harvester Company and General Electric made public in 1954 an experimental electric-generating system designed to add a sizeable mobile source of power to the already versatile farm tractor.

The system's mechanical power, a compact 60-cycle a-c synchronous generator, is transmitted from the tractor's engine through gears and a V-belt drive. Controlled by a switch mounted on the dash panel, the generator is conveniently located on the right side of the tractor as a unit attachment. Electric energy is taken from the generator by quickly detachable cables.

Electric power supplied from a tractor can be used to operate specially designed motors on farm machines, such as combines or automatic hay balers pulled by the tractor. It can also be used to operate portable electric tools; provide emergency lighting systems; or become an emergency source of power for appliances, pumps, milking machines, and other electric equipment.

#### Wire and Cable

Silicone-rubber insulation highlighted developments in the field of wire and cable.

Through advanced techniques of compounding and factory processing, one such insulation not only has characteristics similar to those of natural rubber but also has the advantage of extreme heat stability. For certain applications, it is recommended for operation in temperatures up to 200 C. Combined with its moisture-resistant properties, this new silicone-rubber insulation opens up new fields of applications, such as soil-heating cable, appliance wiring, and power and control cables.

A silicone-treated felted-asbestos magnet wire for use as class-H insulation, available in round, square, and rectangular form, was also developed.

#### Industrial X Ray

The level-checking x-ray unit described in the January 1954 REVIEW is now used extensively by canners of popular soft drinks. Although production speed can go as high as 900 cans a minute, the unit ensures a maximum level in every can, spots leaks, and helps maintain the drink's effervescence. The soft-drink industry expects to reach a production level of 13-billion cans a year in the near future.

A new type of portable industrial x-ray unit can produce a 360-degree radiation sweep, enabling radiographers to attain new highs in inspection efficiency and to reduce inspection cost. Placed inside a pipe or pressure vessel, it can be used to take inside-out x-ray views. Because radiation is confined within an enclosed area, this technique offers increased protection to personnel against exposure. It also permits a complete circumferential-weld radiograph with a single exposure.



FIFTEEN MORE GAS-TURBINE ELECTRIC LOCOMOTIVES WERE DELIVERED TO UNION PACIFIC DURING 1954 FOR HIGH-SPEED FREIGHT SERVICE.

## Rail

During 1954, 15 more gas-turbine electric locomotives were delivered to the Union Pacific Railroad, bringing the total in active service to 25. The new units incorporated many improvements and innovations to railroad service including elimination of air filtering by the use of air-cleaning blowers; a new cab design; and the first general application of static excitation control, thereby doing away with rotating d-c exciters.

### Rectifier Locomotives

Shipment began in the last quarter of 1954 on the order of 10 68-foot 174-ton rectifier-type electric locomotives for the New York, New Haven, and Hartford Railroad. These high-speed streamlined passenger locomotives will operate over a 72-mile electrified division between New York and New Haven. Rated 4000 hp continuously and capable of exerting more than twice this power for acceleration, the locomotives will haul an 18-car train between these points in 86 minutes.

Because heavier axle loads are now permitted on the Park Avenue viaduct, the locomotives were the first designed for this service with balanced weight on all 6 driving axles.

They will operate from two power sources: a 600-volt d-c third rail in Grand Central Terminal and an 11,000-volt a-c 25-cycle single-phase overhead trolley on the mainline.

In the d-c zone, the series-type traction motors are supplied directly from the third rail and use resistors for starting. In the a-c zone, a transformer with secondary tap switches reduces the voltage to values that can be impressed on the ignitron rectifiers. With some smoothing, the rectifier output will supply power to the locomotive's traction motors.

D-c motors are also used to drive auxiliaries. During operation in the a-c zone, auxiliary power is supplied from the transformer through a constant-voltage auxiliary ignitron-rectifier system.

### Foreign Locomotives

The year 1954 again saw the application of diesel-electric motive power expand in the world's markets. The shipment of 27 110-ton road locomotives, plus 7 44-ton and 4 25-ton switchers, completed the dieselization of the Uruguay State Railways. Other sizable shipments completed during the year were 30 105-ton locomotives to Argentina; 12 115-ton and 30 70-ton locomotives to Chile; 5 110-ton locomotives to Santa Catarina, Brazil, and 10 76-ton locomotives to Pakistan.

Among those for the most unusual service conditions were 2 83-ton locomotives for the White Pass and Yukon Railroad. Operating between Skagway, Alaska, and Whitehorse, Canada, they climb from sea level to a 2885-foot elevation in 20 miles. Temperatures in this service range from  $-65$  to  $+80$  F. During winter operation the recirculation of radiator air is essential to help maintain required operating temperatures in the engine cab.

### Rail-adhesion Studies

Why are rails slippery at the beginning of rain or in heavy fog or dew? Long a baffling problem, wheel slip reduces operating efficiency and costs railroads thousands of dollars annually. Investigations made in the laboratory and on rails in service disclosed that a thin film of water on a rail acts as a vehicle for spreading a minute amount of journal-box or animal oil over the running band of the rail. This film withstands more than 75,000 psi, which is above normal locomotive-wheel loading. The oil film reduces the rail's coefficient of friction to one third of its normal value. Heavy rain washes the oil film from the rail, and sunshine or lack of moisture causes the oil film to oxidize, restoring adhesion. Work with a major railroad is now in progress to control this source of wheel slip.

### Locomotive Power-plant Study

During 1954, studies were made of highly supercharged diesel engines, compound engines, and turbogas-generator prime movers. Particular attention was focused on engine-cylinder duty, alternative cycles, and alternative machinery configurations.

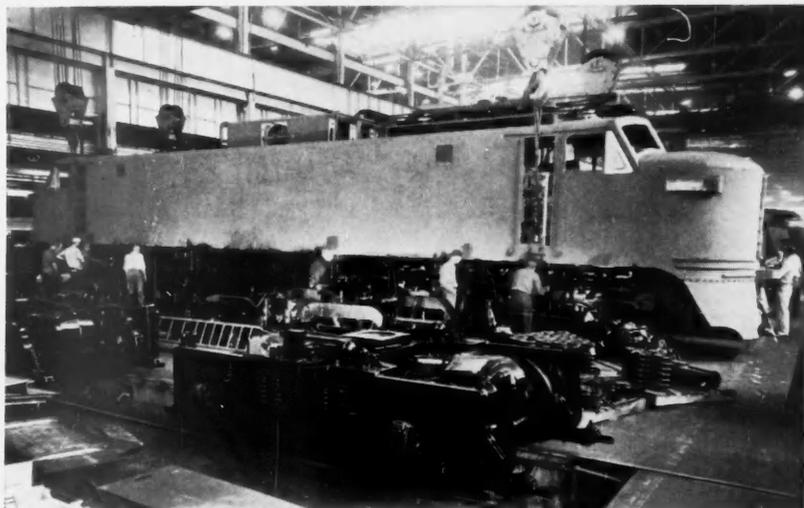
### Locomotive Rebuilding

A major advancement in GE's locomotive rebuilding program was made in 1954 through a \$3-million order to convert 20 Cleveland Union Terminal 3000-volt d-c locomotives for 600-volt d-c high-speed passenger operation between Harmon and Grand Central Terminal on the New York Central. The rebuild work will consist of installing electric propulsion and control equipment plus streamlining and reconditioning mechanical components. The locomotives were originally built by General Electric 22 years ago.

### Industrial Locomotives

The largest mining locomotive for underground service was shipped to the Mathies Coal Co. in 1954. The 600-hp 50-ton unit is 35 feet long and 48 inches high.

Among the many special designs for diesel-electric locomotives were 2 45-ton 23-inch-gage locomotives for the Jones and Laughlin Steel Co. It marked the first time so much weight and equipment was crowded into such a limited space—5 feet 8 inches wide, 8 feet 5 inches high, and 18 feet long. Built to operate in the open-hearth areas, the locomotives are driven by a single trac-



RECTIFIER-TYPE ELECTRIC LOCOMOTIVE WILL HAUL 18-CAR TRAIN ON THE NEW HAVEN.



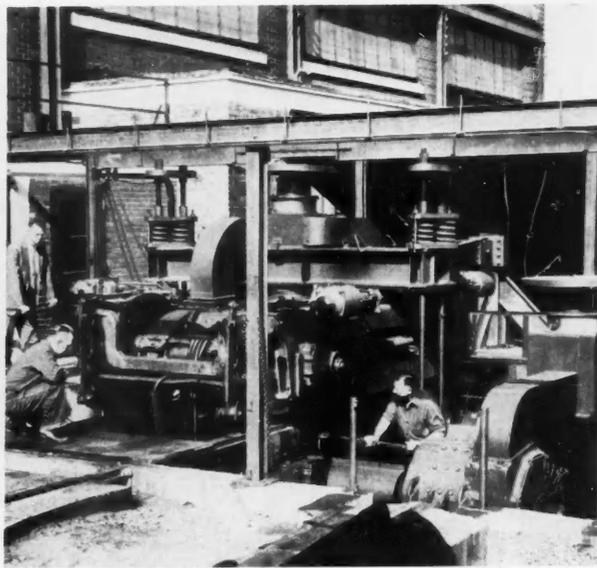
ENGINEERS CHECK WHEEL PRESSURE OF DIESEL-ELECTRIC BOUND FOR SOUTH AMERICA.



DIESEL-ELECTRICS ON WHITE PASS AND YUKON LINE MEET UNUSUAL SERVICE CONDITIONS.



**LARGEST MINING LOCOMOTIVE** for underground service, capable of hauling record tonnages of coal, is 35 feet long and 4 feet high.



**TORTURE CHAMBER** simulates a locomotive run, life-tests traction motors mounted in locomotive truck to prove out new designs.

tion motor geared through a triple-reduction gearing.

Of the many standard and special industrial locomotives shipped throughout the world, the 2 3000-hp units for the Kennecott Copper Co. were the largest.

A 10-ton torque-converter locomotive was also placed in service, and one anthracite coal mine used a shuttle car for the first time.

#### Diesel Trammer

Also among the 1954 advances was a 1½-ton trammer locomotive for 18- to 24-inch-gage track, approved by the Bureau of Mines for nongaseous underground applications. It offers nearly double the power in the same size as previous battery-powered trammers and eliminates the charging time and equipment previously required. Although it furnishes 12 hp, the trammer is so compact that it can fit into a 48x35½x54-inch-high mine cage for lowering to the mine's working level.

The wheels receive power from the diesel engine through a torque converter, clutch, reversing transmission, and right-angle gear box and by chains to both axles to make use of the maximum tractive effort available for its weight.

#### Control for New York Subway Cars

A new all-electric control equipment for subway cars now on order by the New York City Transit Authority employs 2 motor-operated cam-actuated

controllers. One establishes the main circuits; the other commutates resistance during acceleration and braking. Refinements introduced in this control give smoother acceleration and improved dynamic-braking characteristics.

#### Traction-motor Life Test

Facilities for life-testing traction motors mounted in a locomotive truck went into operation during 1954. A sequence timer that automatically controls operation subjects the motors to a 24-hour-a-day duty cycle comparable with a typical locomotive run.

#### Axle-driven Motor-generator Set

Many of the luxuries enjoyed by railroad passengers are made possible through the abundant supply of electric power provided by axle-driven motor-generator sets mounted under each car. During 1954 General Electric introduced a new line of motor-generator equipment with greatly simplified components designed to reduce maintenance costs to a minimum.

The equipment consists of a totally enclosed exciter, a d-c generator, a cooling fan, and an a-c motor, all mounted on a common shaft. The use of an exciter to supply the generator field greatly simplifies the control system. Generator regulation is accomplished by regulating the exciter field with 2 small vibrating-type relays, one for voltage and one for current. A change in car direction does not affect generator polarity, because the exciter output to the gen-

erator field changes as the direction of rotation changes, eliminating the old armature reversing switch. Constant polarity is kept on the exciter field by connecting it to the car battery.

#### Self-cleaning Insulators

Sheathings of a special plastics material prevent crippling damage from severe electric discharges to insulators of traction motors and generators. The discharges vaporize a thin layer of polymer and leave behind a nonconductive, unharmed surface. The plastics-covered brushholder studs withstand repeated flashovers with little damage, require only a small amount of maintenance, and operate with extremely low surface leakage under adverse conditions of moisture and dirt.

#### Signal Transformers

A new line of railway-signal distribution transformers provides efficient and economical operation of railway-signal circuits, unobtainable with transformers designed for general application.

These units are designed to insure low core loss, minimizing the total transformer load on the signal line and, with exceptionally low exciting current, reducing the out-of-phase component of current on the line.

All transformers in this line are designed for continuous duty with a maximum temperature rise of 55 C at full load. Their electrical characteristics are consistently better than the values required by latest AAR specifications.

# Aviation

The one-thousandth Boeing B47 *Stratojet*, presently the world's fastest operational bomber, took to the air October 14, 1954. Each of the plane's 6 General Electric J47-25 jet engines, equipped with new water-injection systems, can develop 6000 pounds of thrust.

Indicative of the times, these new bombers possess 50 percent more power than their prototype, XB-47, which flew for the first time only 7 years ago.

In 1954 a B47 *Stratojet* that refueled in flight flew nonstop from this country to Japan. Last February another of these bombers set an endurance record for this type of plane by completing flights totaling 600 hours—equivalent to more than 10 trips around the world—without a single engine requiring overhaul or replacement.

Other records were established by J47 aircraft during the year. For instance, a new cross-country mark was set when a North American F86-F *Sabrejet*, powered by a G-E J47-27 engine, was flown from Los Angeles to New York in 4 hours and 8 minutes. The same plane established an unofficial record by flying from New York to Washington, DC, in 24 minutes. In June, 12 of the USAF's top jet-fighter units competed in the finals of a target-shooting meet. Both winners and runners-up flew J47-powered North American *Sabrejets*.

Many engineering advances made during the year contributed to the fine performance of the J47-series jet engines. Among these was the development of low-pressure drop nozzles and detergent additives that allow higher flow-rates of the water-and-alcohol mixture injected into an engine's combustion system. Sprayed into the combustion chamber, this mixture increases both the mass flow through the engine and the velocity of jet gases. With the added boost, an aircraft can take off in a shorter runway distance or can easily lift maximum loads. Another improvement was the introduction of a ceramic-coated combustion chamber.

In 1954, General Electric began shipment of its newest and most powerful production engine, the J73, for use in the North American F86-H *Sabrejet*. Although the same size as the famous J47, it has considerably more thrust and lower specific fuel consumption. F86-H



**WATER-INJECTION SYSTEMS** in the J47 jet engines of this Boeing B47 *Stratojet* provide bomber with added boost at take-off from a short runway or under a maximum load.

*Sabrejets* set world speed records for the 100- and 500-km runs at last year's National Aircraft Show in Dayton, Ohio.

Airplane- and engine-evaluation flights were also made last year in the J73-powered Republic F84-J *Thunderstreak*.

The National Advisory Commission for Aeronautics (NACA) credited the 2-stage turbine component of the J73 engine with having the best performance of any jet-engine turbine to date.

New developments in titanium alloys extended their use in jet-engine applications. For example, these alloys made it possible to reduce the J73-engine weight by more than 70 pounds.

## Missiles

Original contributions in the new field of rocket propulsion include a lightweight gas generator, the most efficient ever developed for missiles, and a turbopump, reported to be more

effective than those previously flight tested. Also, the highest specific impulse in rocket flight history was produced by a GE-developed rocket engine.

Although security regulations prevent disclosure of details, General Electric flight tested in 1954 the largest solid-propellant rocket ever built. Security permitted release during the year of the Company's design work on supersonic ramjet missiles and a 3-stage long-range guided missile.

## Flight and Armament Control

A new automatic-pilot flight control is operated without separate control sticks, knobs, or dials. When the pilot grasps the manual control column or touches the rudder controls, the autopilot is automatically disengaged. When he releases the manual controls, the autopilot again takes over. Provisions are made to tie it in with automatic-landing and flight-path controls at airports. This

in any one generating system. On shutdown, generators are automatically disconnected from the bus and ground power.

For 400-cycle 10- to 60-kva aircraft generators, a new 13-pound static voltage regulator was designed. This generator is the lightest, smallest, and best-performing device presently available for aircraft.

A 400-cycle alternator, developed for guided missiles and aircraft, can be driven by d-c motors, jet air drives, or turbines using solid or liquid propellants. The alternator is voltage adjusted at the factory and is designed to meet extreme environmental conditions. This unit is the result of a survey conducted among aircraft and missile manufacturers.

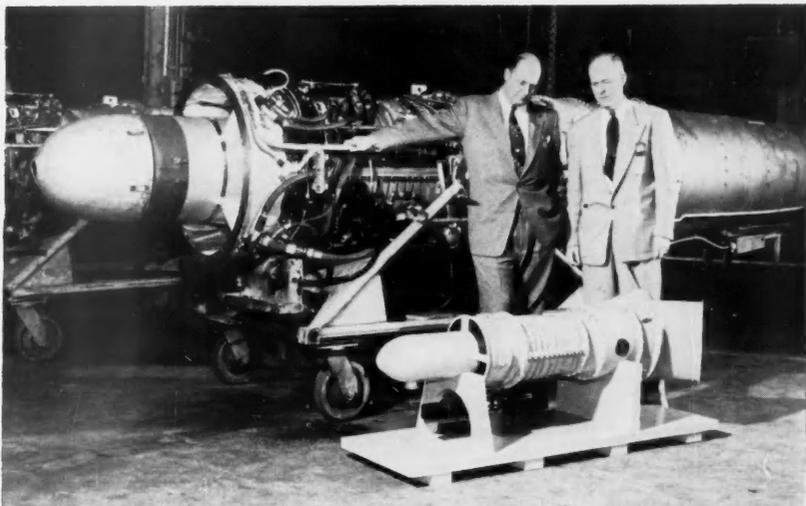
### Electric Systems

A capacitor discharge through a semi-conducting surface forms the basis of a highly efficient miniature ignitor for aircraft gas turbines. The new ignitor greatly surpasses service ignition requirements, having made 13,600 starts in 340 hours with a thermal peak shock of nearly 2000 F at each start. For better ignition, new ignitor geometry avoids thermal quenching and projects the spark into the fuel mixtures.

Meeting the stringent requirements of present and future supersonic flight, a miniature push-pull magnetic amplifier operates at temperatures up to 300 and possibly 400 F. With a d-c input and output, the miniature amplifier can be supplied with power at any frequency from 250 to 3000 cycles; it operates at any voltage between 6 and 18 volts. The amplifier is intended for use in instrumentation or servo applications where frequency and voltage are not closely limited.

Magnetic amplifiers were applied to autopilot systems during the year because of the availability of dry-disc rectifiers. Combined with subminiature electronic circuits for low-power amplification, the magnetic amplifiers effect a 30 percent reduction in size and weight over previous systems of this type.

A newly developed magnetic-amplifier control for jet engines operates without a regulated power supply. By a single movement of the pilot-operated thrust selector, it automatically controls engine speed, accelerations, and top steady-state temperature. One feature of this control is its ability to function over a 4-to-1 voltage and frequency range from power supplied by an engine-mounted alternator.



**GAS TURBINE** for helicopter, shown in front of a J47-17 jet engine, will be easier to cool than other engines of comparable size, use less oil, and require no warm-up time.

Air-borne rectifiers were redesigned in 1954 to reduce their weight and volume and to improve their operating characteristics. Weight in some instances was reduced as much as 50 percent. Air-borne units are now available in the range of 1 to 200 amp, regulated and unregulated.

Subminiature, hermetically sealed transformers with less than 1-cubic-inch volume are used in such applications as gunfire and jet-engine control, as well as radar, navigation, and communication.

Rectangular bases are used to provide better utilization of chassis space. The new units constitute the only complete line of case size for small hermetic transformers currently available on the market.

### Instruments

Random free-drift rates of less than 4 degrees an hour are obtained from a radically improved compass-controlled directional gyro by the use of an unusual concept of gyro motor. Its rotor provides a threefold increase in momentum-to-weight ratio over cylindrical rotors in the same-size conventional gyros. Other improved features include higher servo-controlled synchro-output gyro reset that doesn't affect coupled output, latitude compensation, and hermetic sealing of the gyro.

A new d-c selsyn position transmitter is only one-third the size of its predecessor. Sealed for environmental protection, the new transmitter is designed for the high temperatures of supersonic flight.

### Ball-piston Hydraulic Drives

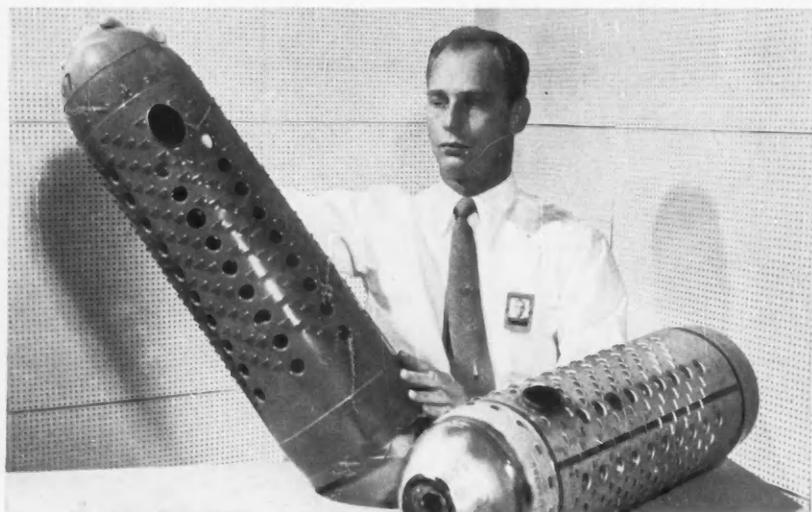
A new line of lightweight constant-speed alternator drives for aircraft is composed of ball-piston hydraulic units. They are unusual radial-piston hydraulic transmissions that use precision-made steel balls instead of conventional cylindrical pistons, connecting rods, and bearings. As engine speed, generator load, and temperatures vary, the drive's self-contained control system automatically adjusts to maintain the constant output speed necessary to drive constant-frequency a-c generators. Drive efficiency averages 80 percent.

A new submerged fuel-booster pump motor, rated 0.65 hp at 7500 rpm, was developed for military aircraft. The motor is unique in that its mounting includes part of the pump fuel-flow manifold.

### Helicopters

Designated the XT58, a small gas turbine is being developed for the Navy's Bureau of Aeronautics primarily to power helicopters. However, with some modifications it can be adapted as a power plant for fixed-wing aircraft.

Preliminary studies of the new helicopter power plant indicate that it will be easier to cool than other engines of comparable size, use less oil, and burn the inexpensive and less flammable fuel generally associated with gas turbines. Requiring no warm-up time, this unit will provide compressed air necessary to drive aircraft accessories and give a smooth, quiet, vibrationless ride. Its low noise level should be a comfort factor for passengers, crew, and bystanders.



**CERAMIC-COATED** combustion liner (left) for jet-engine combustion chamber (right) not only withstands elevated temperatures but also substitutes for strategic materials.



**GAS GENERATOR** for guided missiles has many industrial applications.

important new concept in flight control was incorporated in the FC5's automatic flight-control system.

Now in production is a new gyro-computing gun sight for USAF fighter aircraft to be used in air-to-air combat. The gun sight was reduced 40 percent in weight and size over previous models, with no sacrifice in computing accuracy. Its newly developed computer also permits versatile air-to-ground bombing.

Flight test and work on a closed-loop interceptor system was carried on for the Navy Bureau of Aeronautics in 1954. Completely installed and instrumented in a Douglas F3D *Skyknight*, the system is designed not only to assist a fighter pilot in his thinking but also to act for him in the terminal phases of interception.

#### Testing Equipment

Installation on motor drives for 3 wind tunnels that will be the highest powered in the world was nearly completed in 1954. One drive for the NACA at Moffett Field, Calif., has a maximum rating of 216,000 hp for 1 hour. Another using the auxiliaries of an existing Clymer drive has a continuous 110,000-hp rating and a short-time 132,000-hp rating. The third and most powerful wind-tunnel drive was started and placed in operation at the NACA Laboratory in Cleveland, Ohio. It has a short-time rating of 300,000 hp.

A precision gear and an adjustable-frequency synchronous motor drive, rated 30,000 hp over a speed range of 330 to 12,000 rpm and built for use at Wright Field, will be employed for test-

ing large aircraft propellers and gas-turbine compressors. Among the gear's many unusual features is a built-in mechanism for balancing propellers under test.

New and unusually large is a compressor house developed for wide-range testing of advanced-design compressors, combustors, turbines, and other jet-engine components. Five centrifugal compressors operate in various series and parallel combinations—from single to triple stage—to cover the complete range of pressure and vacuum requirements for test cells. No special cooling is needed.

#### Research

In 1954 the development of a reverse-thrust system for jet engines was considered as a solution to the problem of faster landing speeds. At the request of the USAF, a scale model of a thrust spoiler that will eventually evolve into a thrust reverser was built and put under test. It is designed for application to the B47 *Stratojet* bomber.

As part of the work of extending the speed of developmental supersonic aircraft, studies of cabin-cooling refrigeration cycles were initiated. Air cycles, vapor cycles, and combinations of both are being evaluated. The work will contribute to the development of a new line of cabin-cooling equipments.

Processes and equipment were developed for electrolytically removing work-hardened surfaces and polishing the high-temperature-alloy buckets and blades used in jet engines. This process permits certain high-temperature alloys to be

used where the removal of work-hardened surfaces is essential.

#### Aircraft Generators

The use of paralleled a-c generating systems continued to grow during 1954.

A complete generator protective system was delivered for installation and test in a new USAF light bomber. It contains positively selective overvoltage protection, open-phase protection, under-frequency protection, and generator controls.

Another new development was the completion of an automatic aircraft-generator control and protective system. Automatically paralleling the aircraft's 2 400-cycle alternators, this system eliminates the need for human supervision. It is protected by various means to prevent the generators from paralleling when they are not operating correctly.

Similar developments for 2 airplanes are a-c systems that require no attention from the pilot. When the pilot starts the engines, the generators come up to speed, the ground power-source is disconnected from the bus, the generator circuit breakers are closed, and the generators are paralleled with little or no transient dip.

Additionally, the system's magnetic-amplifier voltage regulators divide reactive load within 10 percent of the average load on all machines. This is done without human supervision for all ambient operating conditions during the 5000 flight hours between overhauls. During flight, the systems are protected from most malfunctions that can occur

## JOB PERFORMANCE RATINGS

Men ranked in top quarter by supervisors

Men ranked in second quarter by supervisors

Men ranked in third quarter by supervisors

Men ranked in last quarter by supervisors

## INTERVIEW RATINGS (PERCENT)

Low Average and High



# Selection and Counseling

To assist our engineers in determining the field of engineering they may best be suited for and to make accurate predictions of job success in engineering work, various methods of testing and counseling were used. GE initiated a study using the research approach to learn the

effectiveness of a trained interviewer; provided a counseling service for a group of engineers; and investigated the validity of certain psychological tests often used to predict personnel performance.

In the study to predict success in engineering, 164 engineers voluntarily

participated. Each took an experimental battery of psychological tests plus an intensive personal interview. The combined results of tests and the evaluation made by the trained interviewer were compared with the on-the-job performance rating made by the engineer's supervisor. The prediction of job success from the over-all ratings of the interviewer proved highly related to the supervisor's rating of actual performance.

Considered alone, the psychological tests proved useful in identifying the low-rated man in job performance but were not very accurate in identifying the high-rated man. Interviews revealed the type of information generally obtained by attitude or opinion surveys.

As a service, professional counseling provided to one group of engineers proved useful in helping the engineer determine his field of maximum productivity. Through a series of aptitude tests and a counseling interview, a professional counselor advised a large number of engineers. Ninety percent indicated that they benefited from this program which emphasized the individual's development and the need to recognize his capabilities early in his career. Made clear to those counseled were the areas of strength and weakness in their engineering growth.

# Accounting

By consolidating data from more than 131 plants in 101 cities and 26 states, the G-E accounting organization's headquarters prepare financial statements and reports for management, the board of directors, and share owners. Reports include monthly statements that compare actual operating results with budgets and with the results of prior periods for each department, quarterly statements, cash-requirement forecasts, press releases, and financial data. Additionally, various reports are prepared for the Securities and Exchange Commission, trade journals, and many governmental agencies.

Prior to complete decentralization of GE's operating departments, data were mailed into the group's headquarters at Schenectady. With the growth of the Company, this consolidation of data became a monumental task. Results for a given month could not be made available until later and later in the following

month, thus detracting from the usefulness of many reports.

A rapid means of transmitting and consolidating financial data from all locations was put into operation in 1954. The leased telegraph and telephone network of the Company was utilized, a coded teletype arrangement made, and receivers installed for direct receipt of financial data in accounting headquarters. Under this system, teletype messages are transmitted during off-peak hours to Accounting Operations Department all over the country. Each message coming into the main switching center that is destined for accounting use bears a special code. The coded-tape information is then converted to punched cards. Next, data are consolidated and statements printed completely by machine.

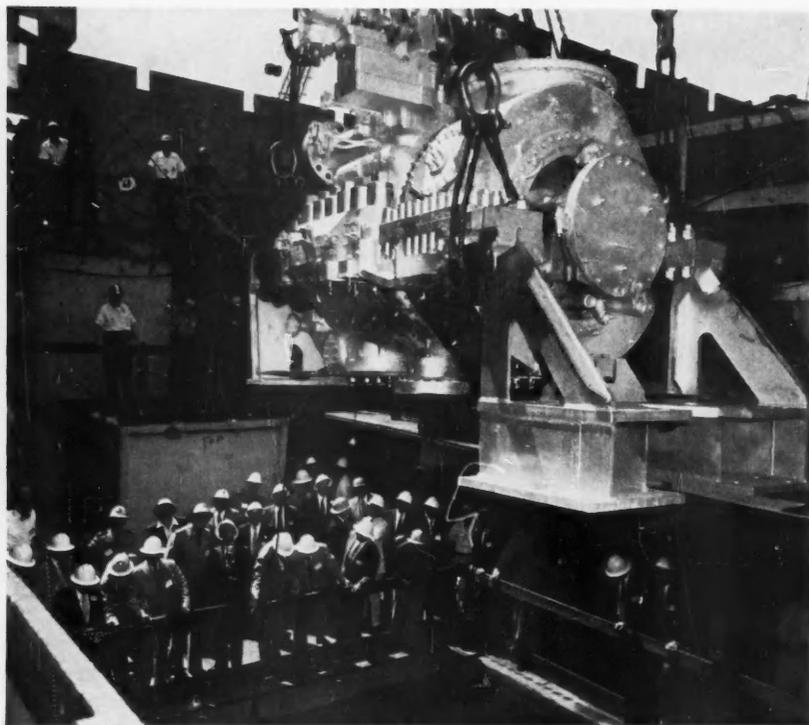
The day after telegraphic receipt of data, a finished report is on its way to the Company's executive offices in New York City. Reduced manual drudgery



**MECHANIZED ACCOUNTING** consolidates financial data from all over the country.

allows accountants to concentrate on analyzing and interpreting these reports. Latest operating results are available 2 days after department books are closed.

The most significant benefit of mechanized accounting is that management now has up-to-the-minute results of far-flung operations. Plans can be promptly formulated and corrective action taken.



NAVY'S USS SARATOGA RECEIVES ITS HIGH- AND INTERMEDIATE-PRESSURE TURBINE.

## Marine

In 1954 the U.S. Navy ordered propulsion steam-turbine gear units for its 2 latest aircraft carriers. Duplicates of the prototype turbines and gears installed in the Navy's USS *Saratoga*, they will be the most powerful ship-propulsion units ever built.

Steam-propulsion turbines were also under way for 8 new Navy destroyers, 3 of which will be equipped with reduction gears. Representing the latest designs, the propulsion turbines will have a 2-casing 3-element arrangement with the high- and intermediate-pressure elements built into one casing. The low-pressure element will be built into the other casing.

Electric ship-propulsion equipment also played its part during the year. Propulsion d-c generators totaling 4190 kw and d-c motors totaling 3690 hp were furnished to propel Navy auxiliary vessels.

A number of hydraulic torque appliers were developed and built for the U.S. Navy and for a manufacturer of ship-propulsion reduction gears. Used at General Electric, these devices test large ship-propulsion reduction gears at de-

sired torques and speeds. The torque produced by a torque applier can be accurately measured under any set of test conditions with the aid of an electronic torque meter.

The first proposed application of an American gas turbine for propulsion of a merchant vessel was made in 1954. To repower a Liberty ship, the U.S. Maritime Administration purchased a regenerative-cycle 2-shaft gas turbine from GE. Maximum rated 6500 hp, the turbine is designed to burn specification Bunker C fuel oil.

### Control Equipment

For Navy applications a compact size-0 manual motor starter meets high shock requirements. It can be used for machine tools and similar applications aboard ship. Thermal-overload relay trips with interchangeable heater units up to 15 amp is one feature of the new starter. Another is a sliding glass-melomine barrier that protects the operating mechanism from dust, grit, and similar matter.

Developed to save space and weight, new magnetic starters and thermal-over-

load relays for a-c 400-cycle shipboard service meet all Navy requirements generally expected of conventional 60-cycle equipment.

New control equipment was designed and built for a 50-foot coastal minesweeper developed by the Navy. A gas-turbine-driven generator supplies power for the mine sweeping operation. Belted to it are an auxiliary generator for ship's service and constant-voltage supply plus an amplidyne generator for regulation. All components comprising the control equipment are housed in 2 spray-tight cases.

The first G-E application of static exciters to large Navy vessels was made in 1954. Three static exciters and voltage regulators were built for the USS *Saratoga's* 400-cycle 600-kw turbine-driven generators. Eliminating the need for a 12,000-rpm rotating d-c exciter with a commutator, the static exciter is more reliable and requires less maintenance. So successful is the new design that duplicate equipment was ordered for the *Saratoga's* sister ship.

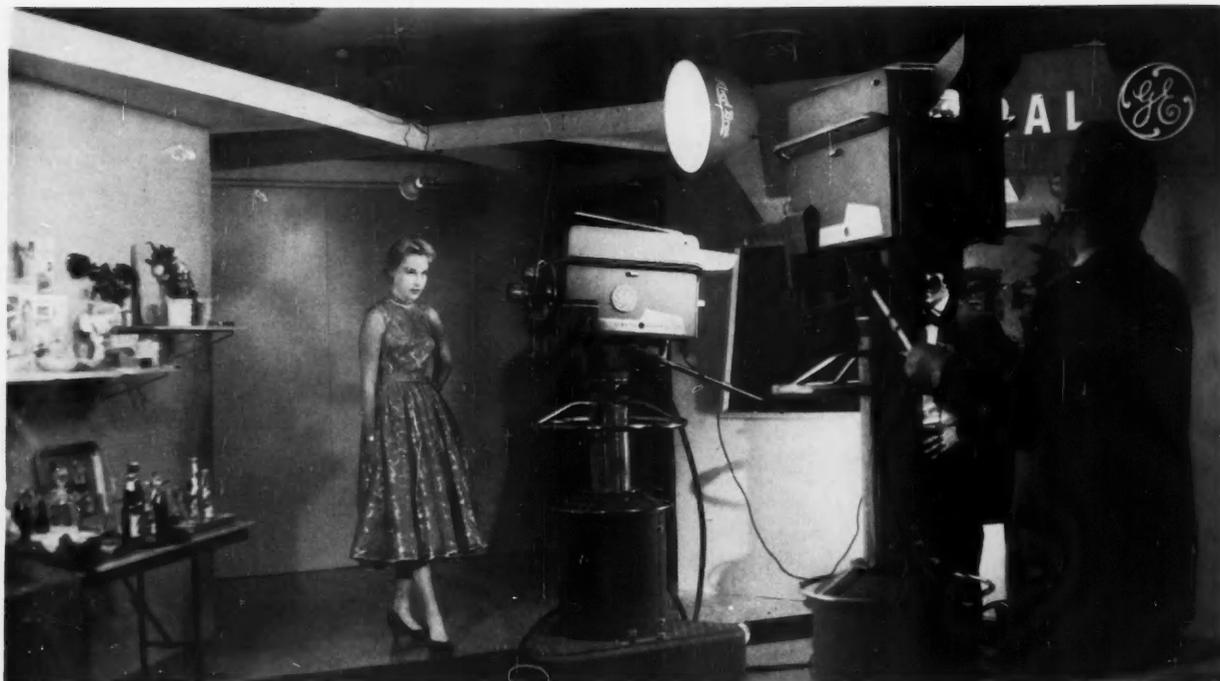
A 50-amp-frame single-pole 125-volt circuit breaker that will be in production soon meets U.S. Navy specifications for the atomic submarine and other shipboard applications. It is the only 50-amp plug-in single-pole breaker in industry that measures up to the Navy's high shock requirements of 2000 foot-pounds. Small size and a noncombustible glass case particularly suit the new unit to naval shipboard lighting-panel usage.

### Mark 31 Gun Sight

Highly satisfactory tests were made aboard ship of the Mark 31 gun sight, controlling 5-inch antiaircraft guns on targets. The Mark 31 continuously and accurately computes the lead angle and superelevation relationship between the line of sight determined by the gunner and the servo-driven gun. As a result of the tests, quantity production of the gun sight for small naval ships is contemplated. The United States, British, and Canadian navies are all interested in the equipment.

### Foreign Shipping

In 1954 a total of 12 turbines and reduction gears for ship propulsion were shipped or under construction for Japan, Canada, Norway, and Italy. These units varied in rating from 12,500 to 19,250 hp. Such orders reflect the preference that foreign companies have for the advanced design of American steam turbines, generators, and gears.



FIELD-SEQUENTIAL COLOR-TV CAMERA USED WITH A CHROMACODER IS LIGHT AND EASILY HANDLED AND TRANSMITS A COMPATIBLE SIGNAL.

## Electronics

Color television made its commercial debut in 1954. On December 17, 1953, the Federal Communications Commission (FCC) approved the petition of the National Television System Committee (NTSC), adopting its proposed signal specifications as the standard for commercial television broadcasting in the United States. Thus in the latter part of January, 1954, compatible color-TV broadcasting began officially. Thousands of engineering man-hours went into formulating NTSC's signal specifications; it was a vast co-operative effort by highly skilled engineers and scientists throughout the electronics industry.

### Television Broadcasting

There is insufficient experience to determine which of the present methods of color-TV pickup is superior for broadcasting either film or live shows. But color-TV equipment introduced by General Electric during the year exhibited distinct advantages in cost and performance.

One example is the sequential color-TV camera that has many advantages over other camera designs. Signals from

a field-sequential camera, however, are not compatible; that is, they cannot be viewed on existing black-and-white receivers.

Through close co-operation with the Columbia Broadcasting System (CBS) Laboratories, GE was able to produce in 1954 a translator called a *chromacoder* that converts color-TV signals from a field-sequential camera into the compatible signals approved by the FCC. The chromacoder transmits pictures that are in every respect the equal of those produced by other live camera pickups. Sequential color-TV cameras are as light and maneuverable as conventional black-and-white TV cameras. Additionally, the chromacoder system is simpler to operate than other systems. Much less expensive in operating-tube cost, it is also far less in first cost when more than two camera channels are used. Equally important, it offers for the first time truly remote pickup color-TV equipment.

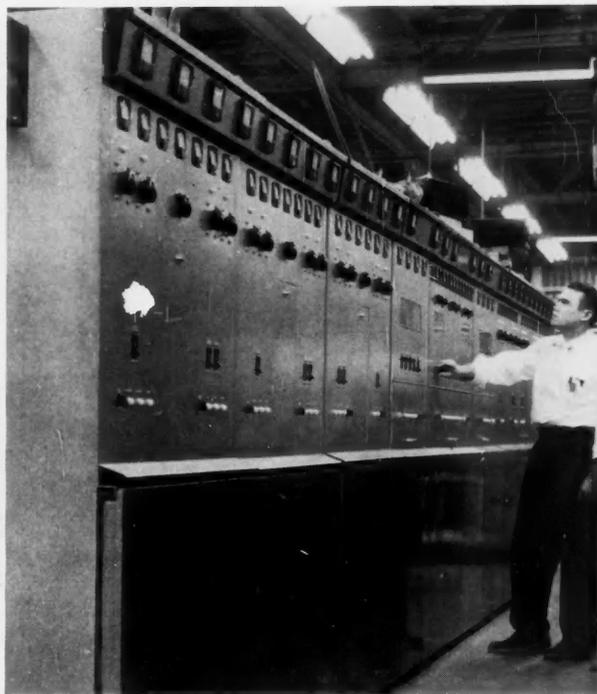
In co-operation with the Eastman Kodak Company, a unique continuous motion (CM) projector for the field-sequential system was also completed and put into production. Combined

with an all-new film scanner, the projector produces color-TV signals far superior to other film-pickup systems in resolution, color fidelity, signal-to-noise ratio, ease of adjustment, and cost of operation.

A new film camera for TV studio use was also put on the market. Its vidicon-type camera tube permits better-quality pictures than the iconoscope, with less demand on the operator.

A new automatic level-control program amplifier is the latest approach to the old problem of satisfactory audio-level control of broadcast applications. Designed as a compact plug-in unit interchangeable with standard G-E program amplifiers, it can be readily adapted to any console or audio system. Small size, scope of application, and low price make it the only product of its type presently available to the broadcasting industry.

In April of 1952 the FCC announced the maximum ratings for TV service to extend coverage and improve reception: 100-kw effective radiated power (ERP) for low-channel very high frequency (VHF), 316 kw for high-channel VHF, and 1000 kw for ultrahigh-frequency



HIGH-POWER TRANSMITTERS: FIELD SEQUENTIAL SYSTEM (LEFT) TRANSMITS COLOR SIGNALS; 45-KW UHF EQUIPMENT, BLACK AND WHITE.

(UHF) transmissions. General Electric is continually developing and producing new equipment and techniques to realize their benefits.

In some instances the logical step to higher power output was to utilize proved equipment with high operational reliability. Thus the 1000-kw ERP maximum is reached in the new G-E amplifier by duplexing the outputs of 4 12-kw UHF transmitters to produce 45 kw of visual power. The 1000-kw ERP is then accomplished by using an antenna with a gain of 25 and a transmission line with an efficiency of 0.89 or better. To produce 23 kw of aural power, 2 additional 12-kw units are employed. (The 12-kw UHF transmitter utilizes the klystron tube.)

On low-channel VHF the G-E 35-kw transmitter reached the 100-kw ERP maximum with a 4-bay antenna. For high-channel VHF, however, a 50-kw transmitter was needed to achieve the 316-kw ERP maximum with an 8-bay antenna. To realize this gain in a single amplifier stage, a new ceramic-coated tetrode was developed. Using 4 of these tubes, the 50-kw amplifier can be excited from any suitable 5-kw source.

A linearity corrective amplifier that meets the new and stringent requirements placed on TV transmitters by color TV permits close adjustment of the transfer characteristic at both black

and white regions. Envelope-delay corrective circuits provide compensating predistortions for the transmitter and receiver characteristics.

Exclusively used for UHF monochrome TV, notch duplexers need correction for passing color signals. One solution to this problem found during the year, considered on a system basis, was a combination of duplexer returning and modulator peaking. An alternative is an all-pass phase-correcting filter as a separate addition.

A complete line of low-pass r-f filters permit transmitters to meet the FCC ruling that radiations outside the normal channel must be at least 60 decibels below the visual carrier. The filters are coaxial and connected in series with the transmitter's aural and visual r-f output lines.

New antennas and accessories were introduced in 1954 to handle the outputs of high-power amplifiers. Antenna ratings, for example, were increased by using styroflex lines for intrabay harnessing on bat-wing antennas. For helical antennas a new high-power feed adapter of 60-kw capacity was designed to match antenna capacity. To allow smoother performance and simpler field adjustment of the 50-kw amplifier, a new constant-impedance vestigial side-band filter was also made available during the year.

A notable achievement in special TV antennas is the installation of a 40-foot 2-section channel-10 helical antenna for WVET-WHEC in Rochester, NY. This, incidentally, is the first helical antenna for VHF. Additionally, it supports above it a 90-foot 6-bay channel-5 bat-wing antenna for Rochester's station WHAM.

In the field of closed-circuit television, a prototype Eidophor large-screen projection TV equipment went into operation at 20th Century Fox Laboratories in New York City. The new equipment is a great improvement over the earlier Eidophor model. Some of its features are the brightest light source presently available, suitability for illuminating a 30x40-foot screen in full color, greatly improved simplicity and reliability of electronic operation with a reduction of about 50 percent in power consumption, and increased life expectancy.

Sequential-type closed-circuit TV equipment is now produced by General Electric. During the year GE acquired the camera chain and projector designs from CBS.

Originally designed for hospital use, this equipment is being adapted for many applications in industrial and educational fields. In these areas, color TV has distinct advantage over black and white.



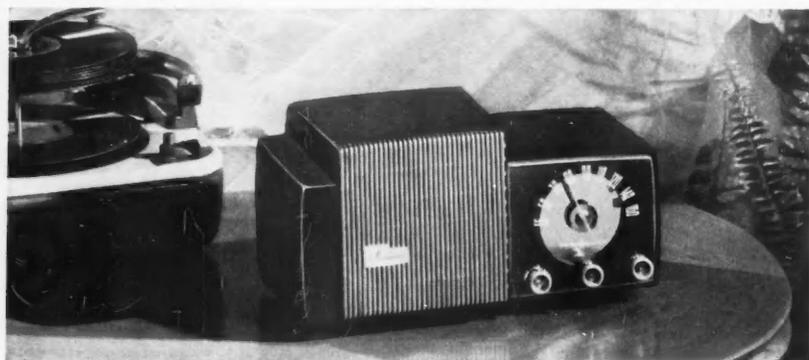
**CERAMIC-COATED TETRODE** is used with a 50-kw amplifier for high-channel VHF.



**TV CONSOLE** with low-placed screen is adapted to modern furniture, relaxed viewing.



**TRANSISTORIZED** battery-powered radio receiver may soon be feasible to mass-produce.



**NEW RADIO RECEIVERS OFFER GREATLY IMPROVED AUDIO FIDELITY AND TONAL RANGE.**



**MICROWAVE LABORATORY WAS STARTED ON THE CAMPUS AT STANFORD UNIVERSITY.**

### TV Reception

Early in 1954 GE introduced its first commercial color-TV receivers. They utilized 40 electronic tubes, including a 15-inch picture tube, and consumed 425 watts of power at 117 volts a-c. The viewer's controls include those normally used for black-and-white TV plus 2 color controls. Although production of these receivers was limited, much valuable engineering, manufacturing, and field experience were gained. Toward the year's end, plans were formulated

for the introduction of larger screen sets.

A low-noise UHF-TV tuner was developed that tunes continuously over the 460-900 megacycle band. In tests the tuner had noise figures of about 7 decibels, voltage gains of 4 to 7, image rejection of about 25 decibels, and bandwidths of 7 to 12 megacycles over the 460-900 megacycle band. Although such a tuner isn't economically feasible at present, its development is important from a long-range viewpoint because it

shows what can be built using a superior tube.

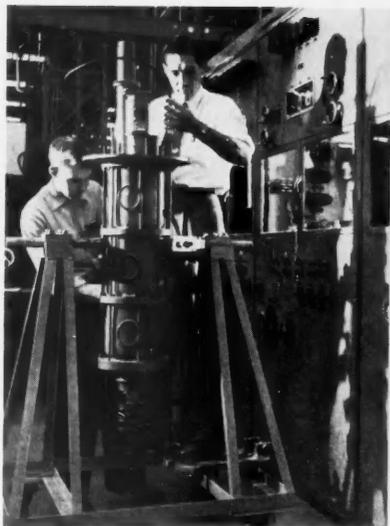
Another development is a new VHF-UHF television station monitor. It covers UHF channels up to 890 megacycles, maintaining an accuracy of  $\pm 500$  cycles for periods of 30 days. This performance represents a considerable advance in frequency monitoring.

A new trend in TV-receiver design began this year with the introduction of GE's unique console receiver. The picture tube is only a few inches from the floor—the best viewing position for a person relaxing in a modern, low, easy chair. Mounted above the picture tube are the receiver chassis and manual controls. This unit has 2 speakers for improved tone. Because it is a full 7 inches lower than conventional 21-inch consoles and because the picture tube doesn't project from the rear, this receiver can be placed flush with the wall under some picture windows.

### Radio Receivers

During the year improved audio fidelity was the trend in plastics table-model radio receivers. Good fidelity was formerly limited by the small size of cabinet and speaker. Improved audio circuits enabled G-E engineers to produce better base and high-frequency response with minimum distortion. Additionally, the tonal range of the speaker was greatly improved by mounting the loud speaker on the front of the cabinet rather than on the rear, as is the conventional practice.

The performance of a new transis-



**KLYSTRON TUBE** for UHF telecasting has 12-kw output, a power gain of about 200.



**RECEIVING TUBES** filled with clear plastics are sliced for microscopic examination.



**HIGH-POWER** transistor amplifier sends 20 watts into speaker with negligible distortion.

torized radio receiver of the future compares favorably with that of a standard 5-tube line-operated radio receiver. Battery powered, it employs 7 transistors and operates on standard 15-volt flashlight cells. The ultramodern receiver with its large high-output speaker requires no electric cord, thus serving the dual function of table and portable radio. Continual decreasing of transistor cost may soon make this set a reality in the market place.

Standard 4-inch loudspeakers for table and portable radios were redesigned during the year. A new magnetic structure eliminates the expensive operation of fabricating and welding metal parts and substantially reduces the speaker's size and weight.

#### Hi Fi

The introduction of a moderately priced 12-inch loudspeaker made available smooth high-fidelity sound reproduction in the range from 40 to 15,000 cycles with an absence of peaks. Incorporated in its design is a cone-type high-frequency speaker, or tweeter, that reproduces a sound range from 1800 to 15,000 cycles through a listening angle of more than 100 degrees. There is no interaction between the tweeter and low-frequency speaker, or woofer.

New tone arms were designed for professional and home use in top-quality phonograph equipment. Rigid structural design and 4 precision ball bearings eliminated spurious responses and minimized record wear. The new tone arms provide smooth response

without resonance to below 20 cycles when used with G-E cartridges.

#### Transmitting Tubes

Six additional 12-kw klystron tubes for UHF telecasting were introduced during the year. Designed for use as r-f amplifiers, they cover the entire UHF band—470 to 890 megacycles. Each type provides 12 kw of power output at synchronizing peak level.

In the spring of 1954, GE took the first step in establishing production of image orthicons and vidicons for television cameras. Commercial production is scheduled for 1955.

A new metal-and-ceramic lighthouse transmitting tube for VHF and UHF television was developed. Its construction allows operating temperatures up to 200 C and resists shock of 400 G's. Some features of the new tube are an oxide-coated indirectly heated cathode, an anode capable of dissipating 100 watts with forced-air cooling, parallel-plane construction, disc seals, and silver-plated external metal parts.

Three new reference cavities with only  $\pm 0.4$ -megacycle maximum frequency drift were introduced at the national IRE convention in March, 1954. Designed for service as frequency-determining references in microwave systems, the cavities are of the fixed-frequency vacuum-sealed transmission type. They can be adapted to existing equipment without changing electrical specifications.

A new tube designed primarily for air-borne radar gun sights operates re-

liably without pressurization at altitudes of 60,000 feet. A 3-cm pulse magnetron, the tube is a forced-air-cooled fixed-frequency pulsed oscillator. It has a peak power output of 9 kw and operates at frequencies between 9345 and 9405 megacycles.

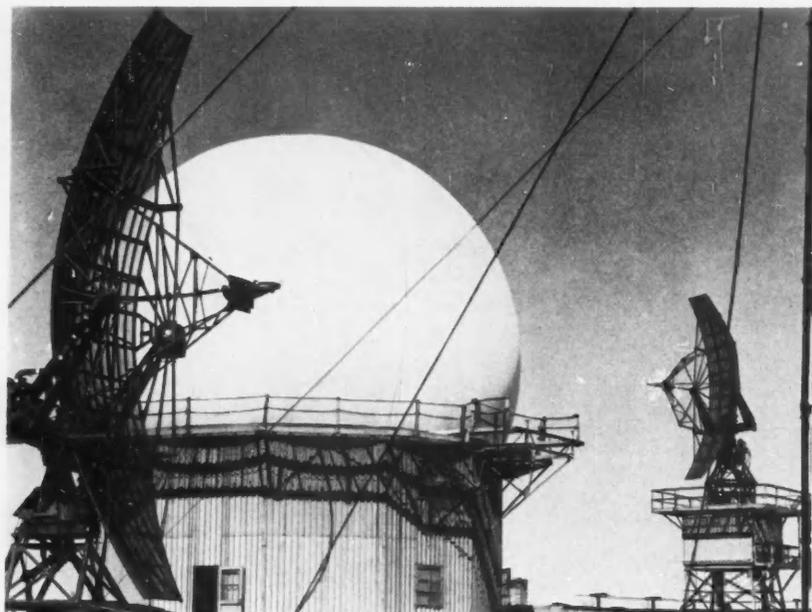
#### Receiving Tubes

Aluminized TV picture tubes have attained industry-wide acceptance because of performance advantages. Their application and adaptability to new receiver designs, as well as to the replacement market, were extended in 1954 by the addition of new black-and-white tubes of this type. (Aluminizing the picture-tube screen gives greater initial brightness, higher brightness during life, and better picture contrast.)

Another improvement on TV picture tubes made during the year was a reduction in size. This was accomplished by increasing the deflection angle on 21-inch tubes from 70 to 90 degrees. Electrostatic focusing guns for these and 17-inch picture tubes were also improved.

Satisfactory progress was made in all aspects of color-TV picture tubes. Processes were developed for mass-producing color-TV tubes and their special electron guns requiring extremely small electron beams and high current densities.

The interiors of glass vacuum tubes for radio and TV receivers can be microscopically examined with a technique innovated during 1954. Briefly, the tube is immersed in clear, liquid plastics



**POWERFUL RADAR HEIGHT FINDER** can be mobile unit (left), housed in radome (center) in Arctic climates, or fixed unit (right) for installation in temperate areas.

and its submerged glass tip cracked off. The vacuum inside the tube sucks in the liquid plastics. After hardening, the tube's glass envelope is broken away and its plastics-encased parts are sliced into 1/4-inch-thick sections for study.

Four new color-TV receiving tubes were put into production: high-voltage rectifier, high-output full-wave rectifier, sheet-beam synchronous detector, and high-voltage pentode.

Development on the 33rd of a series of high-reliability tubes was completed during the year. In effect this means that aircraft and mobile radio equipment can now be designed using highly reliable tubes in every socket. (Existing air-borne or mobile radio receivers can utilize these tubes in 90 percent of their sockets.)

A new line of service-designed TV receiving tubes solved an industry-wide problem that has plagued service-dealer operations since 1946. The tubes were designed to function under the varying operating conditions in different makes and models of TV receivers. They lessen service-dealer callbacks for early tube failures and reduce abnormal dealer inventories of a given type.

Seventeen of a new complete line of television receiving tubes were introduced in 1954. Designed for series-string circuits, the tubes' main feature is a uniform heater warm-up time of 10½ seconds. All utilize 600-ma filaments.

A new miniature twin-triode tube was developed for amplifier or counter service in digital computers. With it, electronic computers can be designed that are faster than many now in use. Previously a tube developed for TV receiver service was used in this application.

#### Microwave

Beginning operation in an ultra-modern building on the Stanford University light industrial tract at Palo Alto, Calif., is GE's new Microwave Laboratory. The laboratory will carry out applied research and advance development of microwave tubes and basic tube techniques, exploring their application to commercial and military systems. Small quantities of new tubes will also be fabricated. Providing opportunities for training qualified G-E employees, the microwave laboratory will help establish and maintain an aggressive long-term program for the development, manufacture, and use of beam-type tubes.

New 2000-megacycle microwave equipment provides easy operation, unexcelled performance, high long-term stability, and low operating costs. Its multiplexing equipment operates on the time-division principle with a novel method of synchronization known as quadriphase. This system gives rise to smaller units with fewer tubes and operating controls, plus higher long-

term stability than previous multiplex designs.

A 2000-megacycle transmitter was developed for the Signal Corps during the year. Amplitude modulated, its output to the antenna system is 30 watts. Multichannel point-to-point communication is achieved by subdividing the subcarrier bandwidth into 4000-cycle telephone channels.

#### Mobile Equipment

Mobile 20-watt and fixed-station 30-watt radio equipments for 450-megacycle operation were produced in 1954. Sensitivity of their receivers is less than 1 microvolt for 20 decibel quieting. High Q-cavity resonators in the receiver inputs and transmitter outputs protect the equipments from and prevent interference with UHF-TV transmission.

#### Carrier Current

In the field of carrier current, use of lightweight materials in a fabricated construction achieved a 50 to 64 percent weight reduction in line traps, with equal or improved over-all performance.

The design of a plug-in transistor voice unit for use with carrier pilot relay equipment was completed. This, incidentally, is the first application of transistors to G-E power-line carrier equipment.

#### Radar

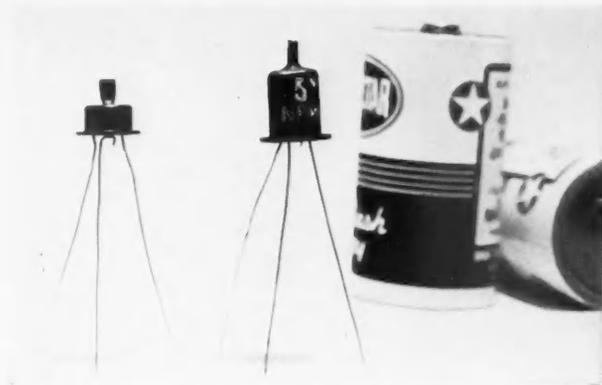
Developed for the USAF was a new and powerful radar height finder that detects high-flying aircraft at altitudes 3 times higher than previous units of its type. Used with search radar, it gives information on distance, altitude, and flight direction of the aircraft. The new radar's radio energy is concentrated into a narrow beam like that of a searchlight. So powerful is this energy that it can light fluorescent lamps 100 feet away.

Many of the new units, both mobile and fixed, are used in the radar fence that guards North America. Other units are being supplied to countries that receive aid from the United States under the Mutual Defense Assistance Pact.

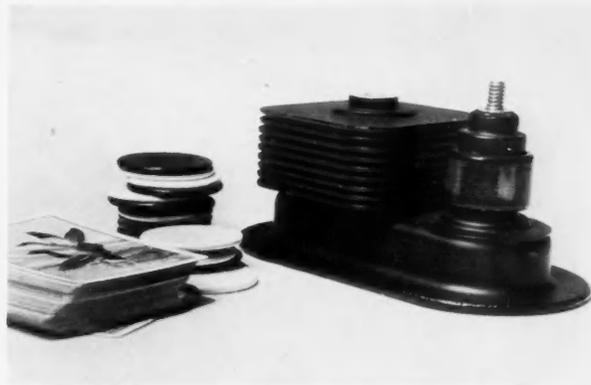
#### Semiconductors

Lower losses and higher efficiency were achieved in silicon rectifiers of the 100-ma to 1-amp range through the development of a new single-crystal alloy-junction process. These rectifiers operate above the temperature of molten solder.

Developmental high-power transistors were incorporated in a public-address



**LOW POWER NEEDS** of audio- and radio-frequency transistors permit flashlight batteries to power entire circuits for months.



**MINIATURE** germanium power rectifiers range in operation to 400-amp output and have efficiencies approaching 100 percent.

system that delivers a record-breaking output of more than 20 watts into a loudspeaker. The total harmonic distortion is less than 4 percent.

Switching characteristics of double-base diodes were extended to higher temperatures in fabricating the first developmental silicon double-base diodes. At the same time, a more controllable electric pulsing process speeded development of new gold-bonded diodes.

In 1954, germanium transistors and power rectifiers were produced in quantities for the first time. Except in the hearing-aid industry, few of these devices were utilized in mass-produced equipment. Most manufacturers evaluated them for possible mass production in 1955.

There are 2 general types of transistors: the p-n-p fused-junction audio-frequency amplifier with a 40-decibel gain that produces 75-mw output; and the n-p-n rate-grown triode, an r-f oscillator and amplifier with a 24-decibel gain at 455 kc and a 12-decibel gain at 2000 kc. Both these transistors are hermetically sealed and meet military specifications. The p-n-p transistor dissipates 150 mw at 25 C ambient and 30 mw at 85 C. At 25 C the n-p-n transistor dissipates 50 mw and at 85 C, 10 mw.

Also introduced were 3 new rectifiers that cover the range of a few milliamps to hundreds of amperes. These miniature rectifiers not only have efficiencies approaching 100 percent but also increased reliability. Their low forward resistance drop, plus their ruggedness and small size, points to two unusual applications—a self-excited alternator and a commutatorless d-c generator.

A 1½-inch square fin was added to a small 100-ma junction rectifier, resulting in a current-rating increase of 500 ma for a single cell. Stacked and

multiphase arrangements of bridge and multiphase circuits deliver up to 5 amp.

Output and stacking arrangements of the medium-current rectifier were designed for industrial use. Unfinned single units are rated 1 amp at 65 C and 200-volt peak inverse voltage; stacked rectifiers deliver up to 30 amp.

High-current rectifiers utilizing a germanium wafer 1 cm square have outputs of 35 amp at 200-volt peak inverse, with 2000 cubic feet a minute of 55 C cooling air. In bridge and stacked arrangements, they will produce currents in excess of 100 amp.

#### Automation

Developed in 1954 was a 5-tube radio-receiver chassis whose parts can be automatically positioned with special equipment. This unit's performance is equal and in some respects superior to its metal-chassis counterpart. Printed circuits and special components appreciably reduced its cost and size. (Approximately 98 percent of the soldered connections are made simultaneously by a dip-soldering process.)

Under contract with the U.S. Army Signal Corps, GE is progressing rapidly on the construction of an automatic component assembly system at its Advanced Electronic Center, Cornell University, Ithaca, NY. The system will automatically assemble electronic components to a printed-circuit board, producing a major subassembly in a piece of electronic equipment, such as a communication receiver or a radar equipment.

For use in high-accuracy positioning systems an electronic digital servo was developed. It can find and remain at positions identified by numerical input orders received from electric storage devices that use punched cards or tape,

switches or registers. The electronic system can be attached to any mechanical device capable of producing position-marking pulses.

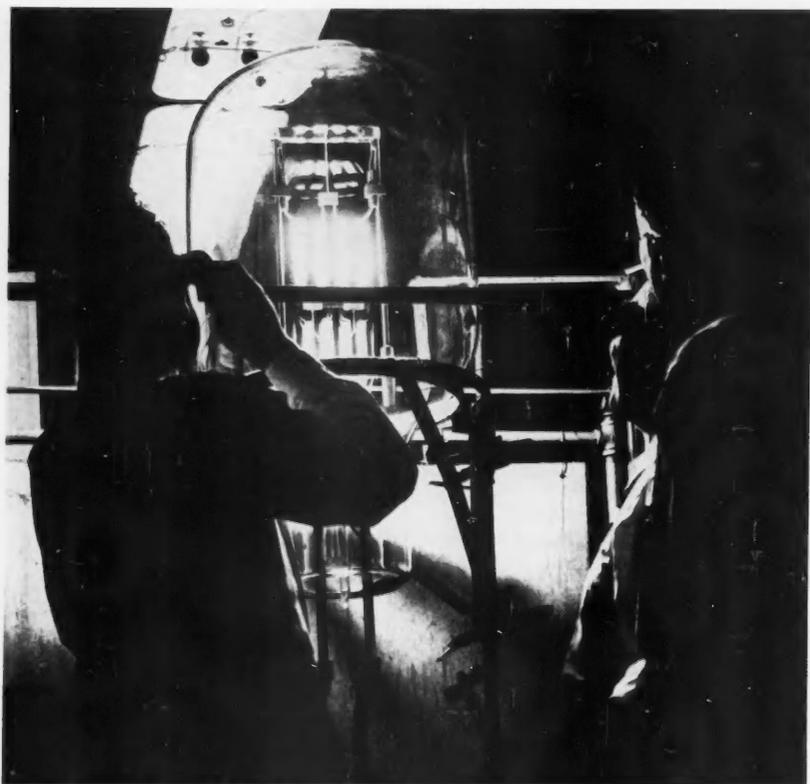
Trouble-free operation of electronic subassemblies is ensured by an automatic tester that allows an operator to run a complete go-no-go component test in 90 seconds. The device can be used for tests of resistance, impedance, continuity, leakage, and a-c or d-c voltages.

Newly developed military electronic equipment in the Lockheed *Constellation* forms a combat intelligence center in flight. With it, a commander can analyze a tactical situation rapidly and accurately and can co-ordinate the activities of air, sea, and land forces. This flying instrument center, composed mostly of G-E electronic equipment, includes powerful air-borne search radar, as well as other types of radar, radios, and electronic equipment.

#### Magnetics

New saturable cores made of grain-oriented nickel-iron alloys have almost perfectly rectangular hysteresis loops. One direct result of this development is a magnetically regulated d-c power supply that is much smaller and lighter than its vacuum-tube counterpart. Other devices built and tested are a magnetic filament-temperature controller, a magnetic radio modulator, and a magnetic-amplifier drive for a radar antenna.

In conjunction with the U.S. Air Force, a dynamic hysteresigraph was developed during the year. It records the dynamic hysteresis loops of magnetic materials at frequencies about 10,000 times higher than that possible with previous instruments of its kind. The instrument has already yielded information about unknown phenomena of magnetic materials and ceramics.



WORLD'S LARGEST LAMP, RATED 75,000 WATTS, HELPED CELEBRATE LIGHT'S DIAMOND JUBILEE.

## Lighting

October 21, 1954, marked the 75th anniversary of Thomas A. Edison's epoch-making invention of the world's first practical electric light. On that day, the year-long salute to Edison—Light's Diamond Jubilee—reached its climax throughout America, concluding the first 75 years of our modern age of light. An even brighter future is predicted.

As one of the keynote features of General Electric's observance of Light's Diamond Jubilee, the Company produced the world's largest and most impressive artificial light source—a 75,000-watt incandescent lamp.

Also, significant lamp developments made during the anniversary year serve a wide range of uses. Air transportation, photography, street lighting, and luminous display are among the many fields benefiting from particular lamp improvements.

### Facilities

Late in 1954 ground was broken for a \$2-million laboratory at Nela Park, Cleveland, and for a \$1,692,000 facility

in the nearby suburb of Euclid. The buildings will house research operations, offices, and pilot-plant operations. A program calling for the rapid expansion of technical staffs intensified the need for new laboratories. For example, it is expected that the number of research scientists will be increased by about 70 percent in the next 4 years. The entire technical staff will probably increase about 40 percent by 1959.

### Infrared Lamp

Development of a revolutionary type of infrared lamp for scores of heating, drying, baking, cooking, and other uses was announced in 1954. Producing more than 4 times the energy concentration delivered by the popular 250-watt infrared bulb, the slender quartz lamp, slightly larger in diameter than a cigarette, can withstand high temperatures and the shock of violent temperature changes. Even when heated to cherry red, the lamp can be doused in water or touched with a piece of ice without cracking. Two 500- and 1000-watt sizes

were introduced for use on circuits rated 125 and 230 volts respectively.

### Tiny Flashbulb

A tiny flashbulb helped to revolutionize the nation's photography habits during 1954. In many cases, cameras and flash equipment were designed around the new bulb, described as "the world's smallest, least expensive, and most convenient and reliable flashbulb." Rated at approximately 4000 lumen-seconds, it provides sufficient light for good black-and-white pictures at distances up to 15 feet when used with existing reflectors, fast film, and box cameras. Newly designed reflectors for the bulbs are only 3 or 4 inches in diameter. Cameras with built-in reflectors are predicted.

### High-output Fluorescent Lamp

Development of a high-output fluorescent lamp that produces 35 percent more light than any previous fluorescent light source was announced during 1954. First of the new line is an 8-foot-long 1½-inch-diameter standard cool-white lamp. Rated 100 watts, it has a total light output of 6800 lumens, almost 3 times that produced by the popular 40-watt size. Of the rapid-start type, the lamp's rated life is 7500 hours. Its new base incorporates 2 recessed contacts in a single element and allows the lamp to be inserted easily and safely in push-pull lampholders that were also developed by General Electric.

### Sealed-beam Headlight

Designed to increase visibility in clear weather, a new, brighter sealed-beam auto head lamp is also more effective in rain, fog, and dust.

The new lamp's high beam gives 25 percent more light and allows drivers to see objects farther ahead than do present beams. The low beam produces about 23 percent more light and directs twice as much light far ahead, down the right side of the road. Thus drivers can see pedestrians as much as 80 feet farther ahead than before. Also, the low beam greatly reduces the spill light above the beam. Thus less is reflected back into the driver's eyes from fog or dust particles in the line of vision. New filaments are 7 percent more efficient and operate at 50 and 40 watts instead of 45 and 35.

This lamp is regarded as the most important automotive development in headlighting since the all-glass sealed-beam head lamp was introduced in 1939.



**NEW BULB** rated at about 4000 lumen-seconds is world's smallest flashbulb.

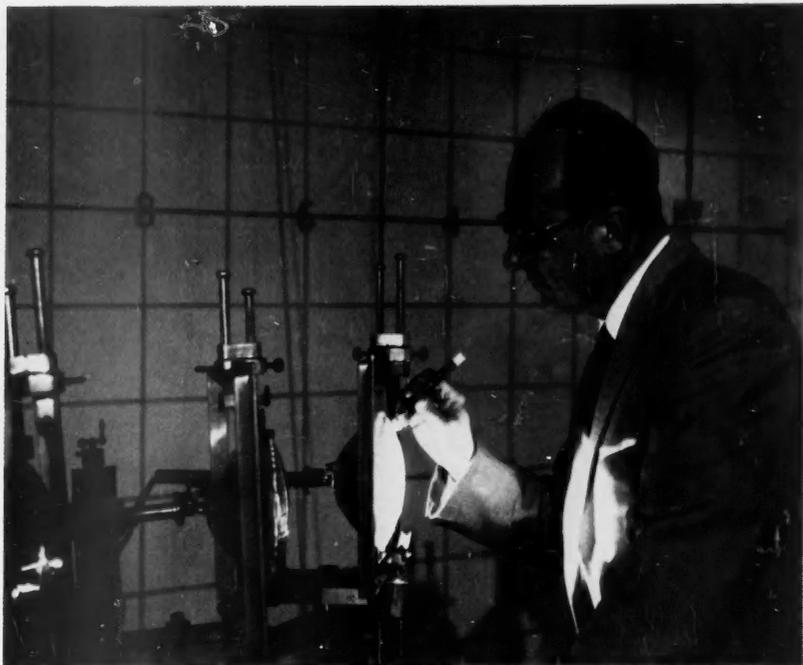
#### Mercury Lamp

Light output of the 400-watt color-improved reflector mercury lamp was boosted from 12,300 to 18,000 lumens, or 46 percent, during the year. This increase was made possible by using as the reflector the fluorescent phosphor on the lamp's inner surface and by eliminating the metallic coating. For the first time, light from both inside and outside the phosphor is fully utilized. In all other types of fluorescent lamps much of the light from the inside of the phosphor is lost through cross reflection and absorption.

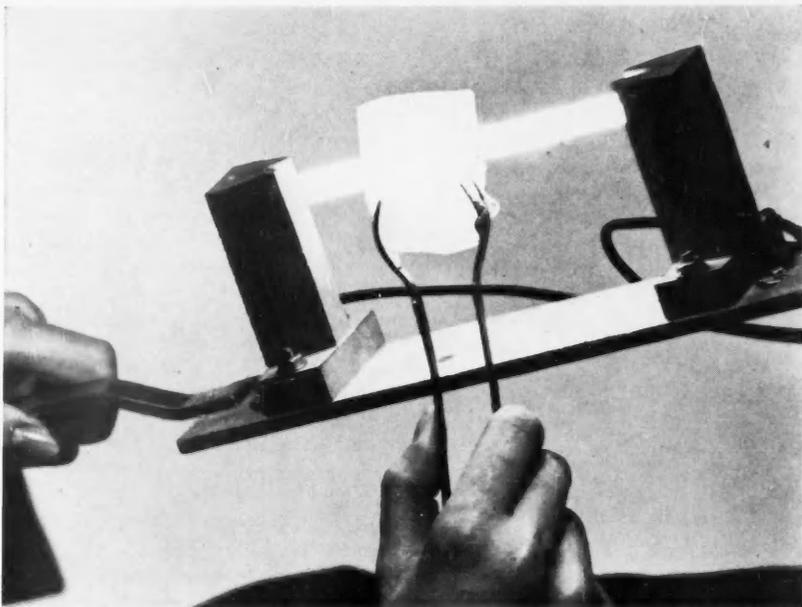
#### High-frequency Lighting System

The nation's most modern and efficient general lighting system was installed during the year in Union College's new Alumni Memorial Field House, Schenectady. The lighting system that operates at 400 rather than 60 cycles uses a rotating-type frequency converter. Each fluorescent lamp produces about one fourth more light than at 60 cycles. The 400-cycle ballasts are much simpler, more efficient, and 80 percent lighter than conventional ballasts.

A unique feature of the installation is a new GE-designed fixture that is 8 feet square and is less than half the weight per lamp of comparable fixtures in conventional installations. Each of the 35 fixtures contains 14 8-foot slim-line fluorescent lamps. Because each lamp produces more than 6000 lumens, the total output of the entire installation is about 3-million lumens. Although somewhat similar systems have been developed by GE for plant growth and airplane and bus lighting, the Union



**SEALED-BEAM AUTO HEAD LAMP** increases low- and high-beam light 23 and 25 percent respectively, allowing drivers to see about 80 feet farther ahead than with present beams.



**RUGGED INFRARED LAMP** refuses to be cooled off even by an ice cube. The slender quartz lamp produces more than 4 times the energy concentration of the 250-watt bulb.

College project is the first of its size to be lighted by means of 400-cycle power.

#### Predicting Life of Fluorescent Lamps

It is now possible to predict the life of a particular fluorescent lamp. Formerly this could be found out only by burning it until it blinked out after an average period of 7500 hours. Other

things being equal, the life of a fluorescent lamp is proportional to the quantity of emission coating held by the lamp's cathode. To determine the amount of coating, the lamp under test is compared in an electronic circuit with a lamp having an uncoated cathode. When current is applied, the coated cathode's temperature is slower to increase. This



ELM ROAD AT GE'S NELA PARK, CLEVELAND, IS ILLUMINATED BY FLUORESCENT LIGHTING, FIRST SYSTEM OF ITS TYPE IN NORTHERN OHIO.



TWO DIFFERENT LIGHT DISTRIBUTIONS ARE AVAILABLE BY MERELY CHANGING SNAP-IN REFLECTORS IN MERCURY STREET-LIGHTING DEVELOPMENT.

difference in resistance to heating is roughly proportional to the weight of the emission coating and can be read on a meter. The technique is useful as a laboratory device in detecting short-life lamps.

#### Airplane Landing Lamp

An improved airplane landing lamp, rated 600 watts, provides a longer and more uniform service life, a more stable beam pattern, lower maintenance costs,

and greater safety assurance. Its new construction containing no filament supports eliminates lamp failure due to the filament being worn away by the support under normal airplane vibrations.

#### Fluorescent Lamp Dimming

A new and simplified method increases the flexibility of fluorescent lamps by regulating their brightness. The dimmer, which controls the light output of up to

20 40-watt rapid-start fluorescent lamps at one time, supplements a more complex electronic control device introduced by GE in 1952 for controlling a larger number of lamps. This dimmer utilizes a rapid-start ballast with one end of the secondary winding brought out and connected to a movable tap of a variable reactor. This is connected to the side of the primary winding to which the secondary is normally connected.

### Airport Lighting

Designed for specific U.S. Air Force requirements was a 37½-kw regulator with output regulation immune to variations in primary voltage and frequency. Used for runway lighting, the unit consists essentially of a static resonant regulator supervised by an induction-type regulator.

Designed for direct burial in the ground, molded-rubber series transformers were supplied to the Air Force for operating series-connected runway lighting.

### Street Lighting

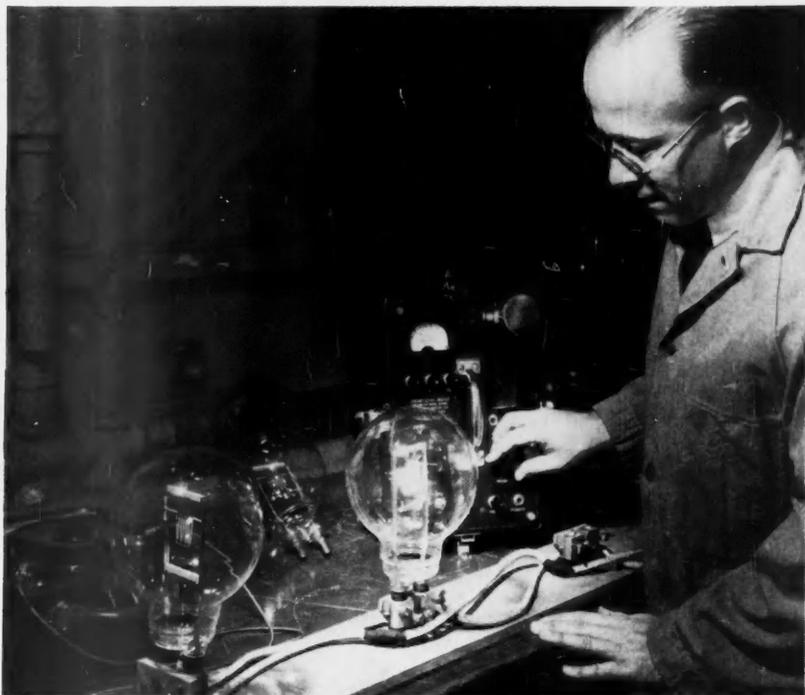
Unveiled at General Electric's Nela Park in Cleveland was northern Ohio's first installation of fluorescent street lighting, which is also understood to be the first fluorescent system for park roadways in the entire United States. It features 35 6-foot-long fluorescent luminaires, as well as 14 incandescent types and 8 mercury-lamp units, all General Electric designs. The fluorescent luminaires, each housing 4 new 100-watt rapid-start fluorescent lamps, deliver more uniformly 4 times the illumination produced by the previous system.

The latest development in mercury street lighting presents the ultimate in flexibility. Two different light distributions are available: one for narrow- and one for medium-width streets. This is accomplished by merely changing snap-in reflectors. The same glassware is used with both reflectors, thus reducing glassware replacement problems for users. The unit will also accommodate 5 different types of mercury lamps, 3 of which vary in size from 11,000 to 20,000 lumens, the other 2 being used for color control. Besides conventional mogul multiple sockets, this unit also offers an entirely new socket for ballastless operation of mercury lamps.

Because of its simplicity and directness of control, photoelectric control is a popular method of energizing street-lighting circuits. It recognizes the light level at its location and turns the street-lighting circuit on or off in accordance with predetermined light levels. Because a preference has been shown for a meter-socket mounting of control devices, the line of photoelectric controls now includes a new meter-base type that is jack-mounted in a standard I-50 watt-hour meter base. The unit uses a printed circuit and dip-soldering techniques.

### Portable Lamps

A new convenience in portable lamps is a ring that completely encircles the



**NOISE-FREE INCANDESCENT LAMP BULBS** for use in TV and motion picture studios should noticeably improve the audio portion of programs on home receivers and theater movies.

lampholder, thus eliminating fumbling for the button, knob, or chain used on conventional lampholders. Depressing any part of the ring's circumference turns the light on or off.

Another new lighting fixture that requires no tools or electric connections can be attached to table radios by a simple snap-on clip. Although its use with radios is its most popular application, the flexible clip also attaches easily to planters, small aquariums, bookends, wall plaques, shelves, and many other kinds of bases.

### Other Developments

Noise-free incandescent lamp bulbs were developed during 1954 for use in TV studios and motion-picture studios. Because high-wattage lamps previously used emitted a humming noise that could be picked up by sensitive microphones, the new lamps should noticeably improve the audio portion of TV programs on home receivers and theater movies.

Engineers devised methods of constructing the large lamps so that the noise was reduced to a point where it could not be detected by sensitive instruments even in a quiet studio.

Introduced as a companion to the 200-watt spotlight, a 200-watt PAR-46 floodlamp can be used in window dis-

plays, yard lighting, building floodlighting, and outdoor area lighting.

Reduction in the size and improvement in the performance of the 200-watt incandescent light bulb took place during the year. The new lamp is the same size as the 150-watt lamp before it underwent a similar shrinking process 3 years ago.

In the field of yuletide lighting, a new 7½-watt Christmas lamp is available in a variety of colors, has a smooth over-all brilliance at 10 percent fewer watts, and burns at a cooler temperature than other Christmas lamps.

During 1954, all 3 sizes of General Electric circline fluorescent lamps were introduced in Deluxe Cool and Deluxe Warm white colors.

A new line of indoor-outdoor luminous-tube transformers for lighting neon signs are 30 percent lighter, 35 percent smaller, and about 75 percent quieter than the corresponding old ratings.

A line of transformers was introduced for operation of 400- to 5000-watt photochemical lamps, whose primary application is in photoreproduction machines.

A new starter gives longer average life to regular 40-watt fluorescent lamps. Its glow switch, entirely different from previous types, prevents the voltage surges that cause instant starting and thus shorten lamp life.

# Medical

A million-dollar industrial clinic was dedicated during 1954 at General Electric's main plant in Schenectady.

Regarded as one of the finest industrial medical facilities in the East, the new 2½-story brick and concrete building houses an industrial hygiene laboratory, serves as an emergency facility for ill or injured employees, and expedites preplacement and other types of physical examinations.

## Clinic Activities

Considered to be one of the most complete and modern industrial hygiene laboratories in any American plant, the clinic's second floor houses the new headquarters of GE's industrial hygiene laboratory, now 4 years old. Chemical engineers in the laboratory conduct a continuous investigation of working conditions, solvents, acids, dusts, airborne contaminants, humidity, noise, illumination, and conditions involved in welding and other processes. Functioning as a Company-wide activity, the new laboratory also investigates preventative measures for occupational illnesses.

Some features of the clinic include separate areas for skin diseases and other infections; sections for ear, nose, and throat ailments; fully equipped operating rooms for emergencies; x-ray facilities; a clinical laboratory for bacterial and chemical tests; a section for cardiogram studies; a dispensary area; and rooms for physical therapy and medical analysis.

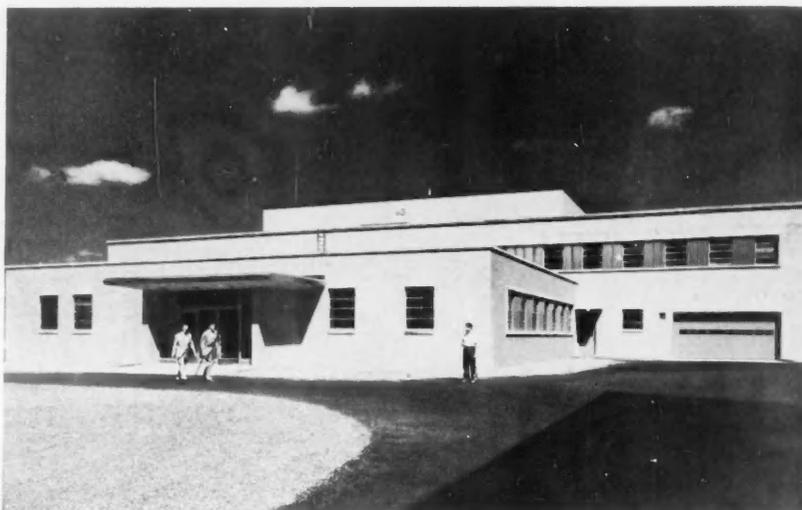
Although equipped to handle almost any emergency, it is not a bed hospital. Patients severely injured or seriously ill are given emergency treatment and then rushed to hospitals outside the plant.

The offices of Workmen's Compensation and Safety are also located in the new clinic for increased efficiency.

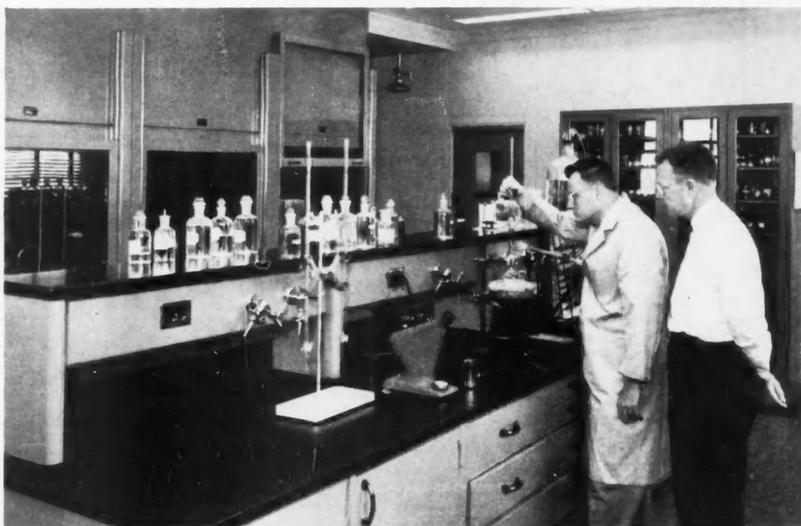
## Cassette-changer Phototimer

Adaptation of precision phototiming to x-ray-film cassette changers was an important accomplishment announced in 1954. Phototiming is the use of an electric eye to precisely maintain a constant film density, regardless of variations in patients' chest thickness or density.

The new device equips G-E cassette changers with a high-speed phototiming



MILLION-DOLLAR INDUSTRIAL CLINIC CONDUCTS MANY BENEFICIAL EMPLOYEE SERVICES.



CLINIC'S INDUSTRIAL HYGIENE LABORATORY CONTRIBUTES TO BETTER WORKING CONDITIONS.

detector that consistently duplicates the desired film density. In addition, it provides a mechanism that will automatically and adequately shield the inactive film regardless of the type of view selected.

Usually used for chest radiography, a cassette changer enables the operator to make stereoscopic pairs of radiographs.

As far as control of technique factors is concerned, the human chest is one of the most critical areas for radiography. Using 60-cycle current and 1/20 of a second as the normal exposure time, a variation of 1 pulse of radiation will greatly affect the film density.

To meet the requirements of density control in chest radiography, the timing device should be of high speed (1/30

second) and the associated controls such that the desired film density be consistently duplicated at the selected speed.

In the finished product the detector package is mounted in the changer's rotating frame. Depending on their position, 4 motor-driven shutters either absorb the radiation or permit it to reach one or more of the fluorescent screen assemblies.

By a system of electric interlocks, all stereoscopic operation is automatic. After the first exposure, the actuating of the stereoscopic switch causes the rotary frame to exchange the position of the two cassettes. At the same time, each pair of shutters moves into the relationship previously held by the other pair.



NEW DESIGN ENABLES ROOM AIR CONDITIONERS TO BE INSTALLED FLUSH WITH INSIDE WALL. FRONT SNAP PANEL HIDES TWO CONTROL KNOBS.

## Air Conditioning

A fourfold increase took place in 1954 in the sizes and types of home cooling equipment designed to go with the present gas- and oil-fired furnace line. For the first time, air-cooled units were offered for cooling the entire home without the use of water. Previously, the only units were water-cooled, used with upflow furnaces in houses with basements.

Four sizes of air-cooled units for basementless, basement, attic, or crawl-space house construction were introduced in each of 3 arrangements: downflow, upflow, and horizontal. The water-cooled line of equipment was also extended to suit all 3 types of installation requirements.

Because of the increasing popularity of basementless and split-level houses, GE's gas- and oil-fired heating lines were greatly expanded to meet such requirements. At the same time, the features necessary for integration with home cooling equipment in year-round air-conditioning systems were retained. For instance, 2 sizes of oil-fired downflow furnaces and horizontal furnaces and 5 sizes of gas-fired downflow furnaces and horizontal furnaces were placed in production.

### Room Air Conditioners

New room air conditioners in  $\frac{3}{4}$ - and 1-hp sizes not only cool, dehumidify,

ventilate, exhaust, and filter as do standard units but also heat over the full range of outside temperatures. The reverse-cycle (heat pump) principle is utilized to take advantage of its high efficiency and economical operating cost when outside temperatures are above 42 F. When they go below 42 F and the outside coil frosts up unless defrosting equipment is used, the compressor mechanism automatically stops, and a high-capacity electric heating element takes over.

Other units of  $\frac{1}{2}$ ,  $\frac{3}{4}$ , 1, and  $1\frac{1}{2}$  hp can be so installed that the unit either projects into the room any distance up to 13 inches or is flush with the room's inside wall.

Higher power factors and more efficient fan motors result in lower operating costs, lower running currents, and less trouble with household wiring. For instance, the new  $\frac{1}{2}$ -hp unit draws only  $7\frac{1}{2}$  amp, so it can be installed on existing 15-amp multiple-outlet circuits.

### Capacitors for Air Conditioners

Placed in manufacture during 1954, dual-section capacitors for room air conditioners do the same job of improving power factor as 2 individual capacitors of the same voltage ratings. These two-in-one units can be applied wherever electric circuits in air condi-

tioners are designed for 2 running capacitors and a method of switching. Less expensive than 2 individual capacitors, they also occupy less space, weigh less, and require less handling in assembly.

### Oil Burner Ignition Transformers

Redesigning of the domestic oil-burner-ignition transformer line emphasized standardization of parts to permit automation of assembly operations. In addition, a new line of replacement units allows jobbers and distributors to reduce their inventories.

### Power Packs for Air Filters

New power packs for industrial and commercial electrostatic air filters, designed in conjunction with air-filter manufacturers, were produced for the first time in 1954. Designed for 115-volt 60-cycle circuits, the units are available in 6500/13,000-volt d-c outputs of 0.002, 0.0075, and 0.020 amp (ionizer current). They not only represent a substantial reduction in size and weight over previous designs but also mount with minimum projection from the mounting surface. Further, they protect personnel against shock during installation and operation. Electrostatic air filters are used in laboratories, hospitals, and in air-conditioning systems of many commercial institutions.



**INSTALLATION OF HEATING CABLE** embedded in the steps of the Pennsylvania Railroad's Suburban Station in Philadelphia keeps stairways free from ice and snow.

## ... For Building Construction

An important 1954 development in the heating-wire field was a new wire rated 90 C that can be used for both plaster and dry-wall construction. Nylon coating over the thermoplastic insulation provides superior abrasion resistance.

The use of electric heating wire for homes is becoming increasingly popular, because the system requires no boiler or furnace; no storage space for fuel; and no chimney, radiators, or ducts. Temperatures can be tailored to suit individual requirements by separate

room or zone thermostats and can be kept within a 4-degree differential between floor and ceiling.

### Heating Cable

During the year many new applications were made for heating cable, including keeping bridge approaches, bridges, stairways, and other danger spots free from ice and snow. One such installation was made in the steps of the Pennsylvania Railroad's Suburban Station in Philadelphia.

### Circuit-breaker Load Centers

A new line of circuit-breaker load centers for the modern residential market was put into production. They are available in 2, 4, 8, 12, 16, and 20 circuits, single phase, 3 wire, 120/240 volts a-c as well as 12 and 20 circuits, 3 phase, 4 wire, 120/208 volts a-c. For use on service entrances, both lug and circuit-breaker mains can be obtained with 50-, 70-, and 100-amp ratings and with 50-amp circuit breakers. Plug-in breakers for the branches include 15, 20, 30, 40, and 50 amp, single- and double-pole construction. A distinctive 16-circuit unit with split-bus construction permits 8 single-pole lighting circuits and 3 double-pole appliance circuits, as well as other circuit combinations.

### New Fused Service-entrance Unit

A new 4-circuit fuse-puller unit for service-entrance and load-center use is smaller, lighter, and more conveniently arranged than earlier designs. It uses less wall space, has locked-in line-load connection and easily removable fuses, provides positive clamp connections and silvered current-carrying parts, and runs 10 C cooler, with less power loss than older units.

### Mercury Switch with Lighted Handle

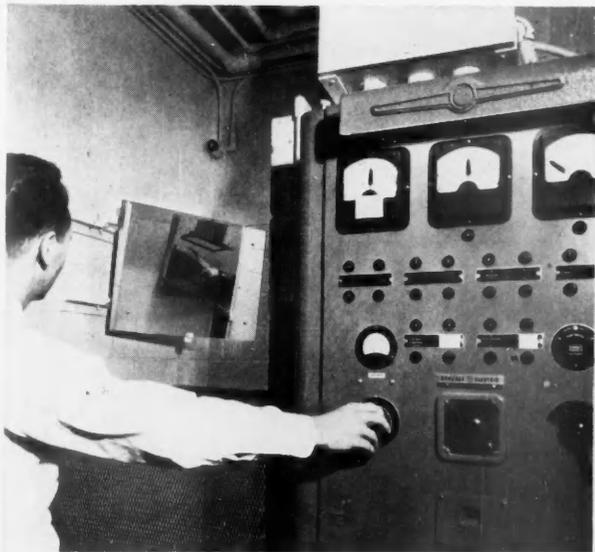
A new switch with neon-lighted handle was added to General Electric's line of mercury switches. A small neon glow lamp, with limiting resistor placed directly in the switch's plastics handle, makes it ideal for bathrooms, bedrooms, long hallways, entrance ways, and children's rooms, as well as hotel, motel, and hospital rooms.

### Surface Devices

An important wiring development was a new line of surface devices with pressure-lock terminals. They include an outlet, lampholder, and switch—all more compact than the old line. To wire these devices, 2-conductor cable is stripped and inserted in the pressure-lock opening. Wood screws are provided with each device for fastening them to the desired surfaces.

### Other Developments

Other redesigned and new items include a line of drier outlets, both surface and flush types; a line of grounding outlets and caps to meet 1953 National Electrical Code (NEC) requirements; redesigned surface and flush range outlets.



**MIRROR** permits observation of electron-bombardment progress as polyethylene film is irradiated behind barricades in pilot plant.



**GAMMA RADIATION** checked with scintillation counter indicates the abrasiveness of a plastics molding compound on metal-mold parts.

## Chemical and Metallurgical

After years of scientific and engineering research, GE introduced in 1954 an irradiated type of polyethylene that doesn't readily flow until temperatures exceed 350 F. It is free of stress cracking when in contact with any of a wide variety of solvents.

Because the unirradiated product's good electrical properties are retained, it is expected that the application of polyethylene as an insulation can now be extended to the higher temperature range. Its first commercial application was to metal-clad circuit breakers. Presently a pilot plant is producing limited quantities of irradiated-polyethylene tape insulation.

### Phenolics

A test using radioactive tracer techniques determines the abrasiveness of a plastics molding compound on metal-mold parts. A part molded from the compound being studied is placed inside a large bell-shaped cast-iron chamber to shield it from the surrounding atmosphere. Then its gamma radiation is checked with a scintillation counter. Counts, normally run for one minute, indicate the amount of radioactive metal particles in the molded part and thus the compound's abrasiveness.

In the field of foundry products, two new grades of phenolic-resins were intro-

duced for the shell-molding process. One, a powdered resin, serves as a bonding agent for gluing together shell-molding halves, eliminating costly mechanical fasteners. The other, an intermediate-grade shell resin, was developed for shell-molding jobs that do not require unusually high rigidity and slow cure. One large automotive manufacturing company is now producing all crankshafts, camshafts, and valves by this process.

In an unusual application developed by a G-E customer, powdered phenolic resins serve as a binder for continuous cotton batting used in automotive upholstery and padding. Applied in powder form to the batting machine, the phenolic resin is melted and cured on the cotton, imparting strength and resiliency to the finished batt.

Another powdered resin was developed as a binder for asbestos fibers in automotive brake bands and brake blocks. Contributing mechanical strength to the brake band, the phenolic resin also imparts the friction characteristics needed for today's rugged automotive braking conditions.

### Polyesters

Introduced to the low-pressure laminate field was an important electrical grade polyester resin. Used with glass

mat, it produces high-strength laminates with excellent electrical characteristics. This fire-retardant resin is especially adaptable to applications where exposure to an electric arc or other source of flame is encountered.

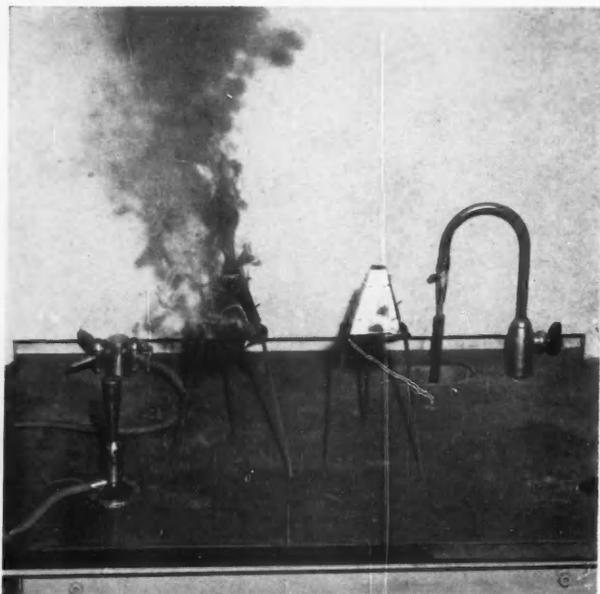
In 1954, an entire line of polyester low-pressure laminating resins were made available in light-stable grades. Although highly resistant to color change caused by ultraviolet light, they retain the desirable properties of their parent resins. The rapidly growing volume of polyester-glass corrugated sheeting for architectural and lighting applications spurred on this development.

The property of nonair inhibition was successfully built into wet lay-up polyester resins during the year. Hard tack-free cures can be obtained with the resins without resorting to surface cover-up.

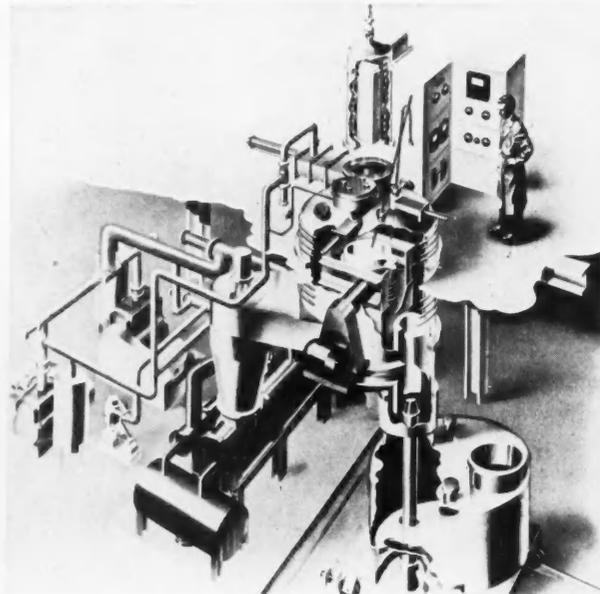
### Insulating Varnishes

Physical and electrical properties of insulating varnishes and wire enamels can now be determined without using substrates. Varnish or enamel applied to polytetrafluoroethylene is stripped off in sheet form after curing, then tested for dielectric strength, power factor, and chemical resistance.

Also developed were two new insulating varnishes approved for manufac-



**TEEPEE TEST** compares conventional polyester-glass laminate with the new fire-retardant product having good electrical properties.



**VACUUM-MELTING FURNACE** scheduled for installation early this year is capable of handling 1000 pounds of high-temperature alloys.

turers' and the U.S. Navy's use. They differ in viscosity to meet customer requirements. Economy and general utility are combined with their special features.

In place of conventional varnishes, one manufacturer uses permafil to insulate TV power transformers. The resulting products are lower in cost and more durable.

Permafil is also used in the manufacture of specialty products for electric motors. Because a product needs only one dip instead of two, the cost is lower than with conventional varnishes. Further, it has improved bonding properties and resistance to voltage surges.

#### Chemically Resistant Resins

A new series of chemically resistant low-cost resins that can be produced in flexible form should find applications in the fields of phenolic coating resins and flexible, chemically resistant finishes.

After two years of continuous exposure in a synthesized industrial condensate, a new resin superior to other finishes tested was introduced as a primer for air-conditioning products.

#### Laminates

In 1954, considerable experience was gained in the production of 5½-inch-diameter tubes of silicone-glass laminate. Used as a coil form in a frequency-changing device aboard ship, they have dielectric-loss properties and heat resistance similar to silicone-glass-laminate sheet stock.

Undergoing development is a new series of paper-base laminates of improved appearance that will supply the entire line of NEMA paper-base grades. These laminates will have much better fabricating quality and electrical stability than the old grades. Closely related in the choice of intermediate materials, they offer the advantages of better standardization.

Realistic reproductions of Broche Fantasia and Florient Rose marbles in natural colors are obtained by using papers printed in close color registry. Modern furniture manufacture will provide the largest outlet for these new decorative marble laminates. Successful architectural applications include paneling the interior of a bank.

A glass-cloth laminate bonded with epoxy resin has unusually high mechanical strength, superior bonding strength, and good dielectric properties. Under conditions of high humidity, its insulation resistance is extremely high. Most of the material produced to date is used in military electronic equipment.

A complete new family of silicone-rubber glass-cloth insulating tapes combines the toughness and heat resistance of silicone rubber with the various types and thicknesses of glass cloth. The new line includes fully cured tapes on straight-weave and bias cloth, as well as semicured tapes on two different cloths.

Possessing high dielectric strength and heat resistance, a new series of extremely flexible mica mat tapes con-

taining no volatile material is expected to find application as an insulating material for high-voltage armature coils.

New low-cost heater plates made of mica mat are strong, have good punchability, and do not smoke at electric-toaster temperatures. Such toaster heating plates sell for about 20 percent less than the former flake-mica plate.

Improvements in mica mat equipment and processing made possible the production of a uniform sheet 0.001 inch thick. Availability of mica mat in this thickness will undoubtedly open the way for many new applications.

#### Silicones

A new silicone fluid that has the lubricating ability of organic fluids was extensively evaluated during 1954. One of its advantages is high-temperature stability. Although present specification fluids are limited to 600 F, this product appears to be usable at temperatures in the order of 750 F.

Revealed during the year was much new information about the formulation of silicone water repellents for textiles. At the same time, a new silicone water repellent was introduced to the textile industry.

In conjunction with the Abbott Laboratories of Chicago, GE made radio-active silicones available for medical and industrial use. Designed exclusively for laboratory and clinical work, the new fluids are readily measurable in minute amounts and are expected to offer a

clearer insight into silicone behavior in the human body.

In another development, a new silicone resin was specifically designed as a vehicle in formulating heat- and weather-resistant protective coatings. It combines outstanding heat resistance with an unusual balance of flexibility, hardness, and curing speed. Additionally, colored formulations have an exceptionally good gloss retention at temperatures as high as 500 F.

An entirely new and versatile family of silicone fluids resists high temperatures and shear breakdown in automotive vibration dampers and substantially increases the water repellency of protective skin creams. They pour more freely at temperature extremes than any other fluid in existence today. Further, they remain stable even when exposed to 300 F for thousands of hours.

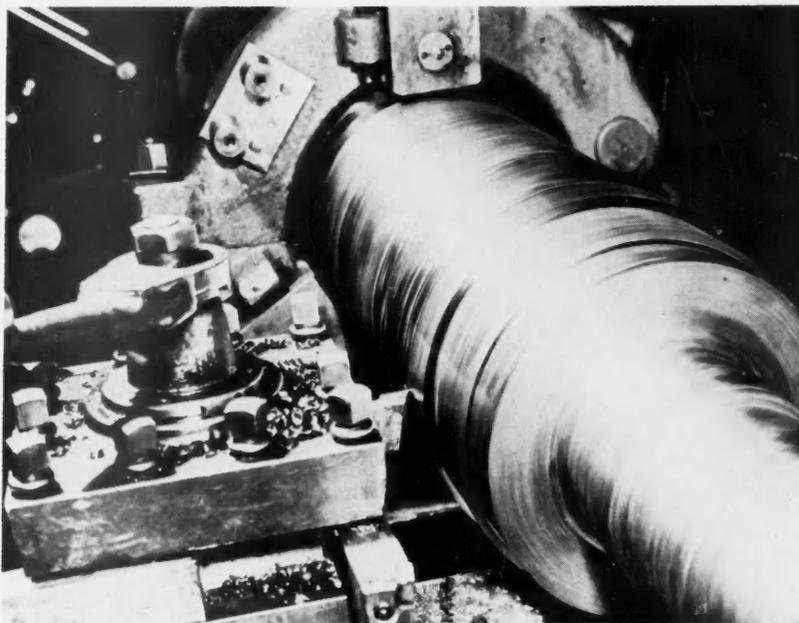
Some other characteristics of these fluids are unusual chemical and physical inertness and superior release qualities. They are expected to find applications as fluid couplings, torsional vibration dampers, shock absorbers, and bases for medicinal ingredients.

#### High-temperature Alloys

The commercial production of vacuum-melted high-temperature alloys for jet-engine aircraft, atomic-energy installations, and other special needs posed many challenges during 1954. Design of and preliminary preparation for installing vacuum-melting pilot-plant facilities were the year's biggest projects. Vacuum furnaces capable of handling 100 to 1000 pounds of high-temperature alloys will be set up by April, 1955. (Present facilities include a 400-pound vacuum furnace.)

To fully utilize all of this unusual equipment, the development of alloy systems for operations in excess of 1600 F is being pushed. These alloys will probably be made of a nickel or cobalt-chromium base, hardened with molybdenum, tungsten, carbon, titanium, and aluminum.

The vacuum-melting technique not only increases the high-temperature strength of certain alloys but also improves the yield. That is, the ratio of the finished product's weight to the ingot's weight is increased. From a practical standpoint, this technique is a controllable method of facilitating the melting of highly reactive metals on a large scale. For example, vacuum melting opens the way for the use of such reactive elements as titanium, zirco-



**WEAR-RESISTANT** medium-duty carbide cutter with unusual grain structure removes approximately 30 percent more metal from motor shafts than previous cemented carbide.

nium, and aluminum in alloys in higher percentage than possible with conventional melting methods.

#### Carbides

In 1954, carbides made another important advance with the development of a new medium-duty highly wear-resistant grade for light roughing and general finishing of steel. It provides up to 30 percent better performance than existing grades of carbides for this work. Having an unusual grain structure, this new extremely tough carbide can withstand cutting temperatures as high as 1800 F.

The application of carbides to multi-spindle automatic screw machines was investigated during the year. Studies indicate that with carbides, automatic-machine users can expect a 50 to 100 percent greater return on their capital investment because of production increases on the machines.

#### Magnetic Materials

A new recording hysteresiograph makes a complete and accurate record of a magnet's entire hysteresis loop. All parts of the major or minor loops can be explored at will with this device. The magnet's performance can then be recorded for future use.

Contributing to manufacturing, a high-speed high-sensitivity magnetizer and energy tester automatically records

production-line magnet energy. First of its kind, the tester is able to handle radio-speaker magnets at the rate of one a second.

Facilities were increased for determining the effect of rolling processes on magnetic steel, primarily to investigate the effects of temperatures, reductions, and previous steel history as measured by the texture of the rolled steel. Through scheduling and evaluating such variables, better quality steels for use in magnetic circuits can now be formulated.

#### Other Developments

A new process allows aluminum to be joined to ceramic bodies. As a result, lightweight aluminum can be used more extensively in place of conventional metals for electrical headers and in other applications requiring insulated hermetic seals.

Through the introduction of another process, parts made by powder metallurgy can now be satisfactorily electroplated. This development will broaden the application of these metallurgical materials.

New copper-base alloys have ultimate strengths between 185,000 and 200,000 psi and are highly resistant to stress corrosion. The new alloys, modifications of copper-nickel-silicons, will offer longer life for highly stressed metal parts in corrosive atmospheres.



ELECTRIC KITCHEN CENTER, SINGLE UNIT OF 4 MAJOR APPLIANCES UNDER ONE COUNTER, LOWERS OVER-ALL COST AND INSTALLATION FEES.

## Appliances

A development in kitchen appliance design was the Electric Kitchen Center, a single kitchen service with built-in combination washer-dryer, sink with food disposer, automatic dishwasher, and electric range complete with storage drawer. Mounted under an 8½-foot-long stainless-steel counter, the entire center can be installed as a single unit in any type of kitchen.

This combination unit cuts down on over-all cost and installation fees. Individual appliances can be pulled out separately for servicing. Future models of appliance components in the center will be designed so that they can replace any of the appliances in the present center, if desired.

A one-control faucet is mounted in the beveled backsplash panel behind the sink. On both sides of the sink are plug-in appliance panels with 4 receptacles in each, including one controlled by a timer. A high-wattage griddle plugs in beside the surface cooking units, and a pull-out cutting board is located at the left of the sink.

### Appliance Park

The last of 5 production buildings was completed at Appliance Park, Louisville,

Ky., and limited output of household refrigerators was begun. The most modern assembly-line production of automatic washers, clothes dryers, ranges, food disposers, and dishwashers was already under way in the other 4 buildings.

The 4-year construction program that began in 1951 on the 1000-acre tract was about 80 percent complete by the end of 1954. It is a major part of the Company's 10-year postwar expansion program, during which General Electric will spend an average of \$190 a minute, totaling more than \$1 billion by the end of 1955.

By midyear, employment is expected to reach 7200; final employment figures should be about 10,000.

Each building incorporates the latest in automation of production-line techniques. Building 2, which can more than house Yankee Stadium, is now in full production of electric ranges. Some 9 miles of conveyors carry the ranges through various stages of manufacture, from sheet steel to the completed packaged product. In the fabrication of range bodies a flat sheet of steel is stamped by a giant press and welded into a range body in about 2 minutes, using 50 feet of floor space. The entire Park will use

some 800 tons of sheet steel daily when in full operation.

### Refrigerators

A wall-type refrigerator, a new concept in the industry, was introduced in 1954. Its 10-cubic-foot storage space includes 8 feet for fresh food, 2 for frozen. The unit's shallowness not only makes it easy to get food in and out but also keeps the counter work space below it accessible for convenient loading and unloading. Magnetic closures are built into each door. The refrigerator is hung on the wall, much like a picture. No special attaching or reinforcing devices are needed.

Because of the success of the revolving refrigerator shelves introduced in 1953, they were incorporated in all floor models except the smallest. Other standard equipment include corner lighting, yellow or blue interiors, adjustable door shelf, juice-can dispenser, and bottle rack.

An entirely new type of combination refrigerator has a 4-cubic-foot freezer at the bottom of the cabinet with a 9-cubic-foot fresh-food compartment above it. The freezer door is opened by a convenient foot pedal. The fresh-food



**NEW 10-CUBIC-FOOT REFRIGERATOR** hangs on the wall like a picture, requires no special attaching or reinforcing devices. Its shallowness makes food easily accessible.

compartment is within easy view and reach.

#### Washer-dryer

A washer-dryer combination provides fully automatic washing and drying with one setting of the controls.

Up to 8 pounds of clothes can be loaded into the drum through a front door. A flexible cycle control provides wash times up to 15 minutes, with hot or warm water, followed by 3 rinses. After a final centrifugal extraction, the clothes are tumble-dried in heat from a 4000-watt unit. A film of cold water flowing down the inside of the tub wall condenses the water vapor that results from the drying process. This condensing water also carries lint to the drain, thereby eliminating the need for a lint trap.

The length of the drying cycle is controlled by a thermostat system that senses the approach of dryness, reduces the heater input during the latter stages, and finally shuts off power automatically when correct dryness is attained. By means of the dry-control dial on the backsplash, the thermostats can be set for any of several types of fabrics.

The 2 speeds, tumble and spin extraction, are obtained with a 2-speed gear transmission. An unbalance switch guards against excessive vibration during extraction, returning the machine to tumble speed briefly for redistributing the clothes around the drum.

#### Automatic Washer

General Electric's new automatic washer uses a recirculating water system

and filter to continuously remove sand, silt, and lint from the wash and rinse waters, thus minimizing redeposition of such foreign materials on the clothes.

During activation, clarified water is pumped into the wash basket from a settling basin in the outer tub, displacing silt and lint-laden water that overflow into the tub. Meanwhile, the larger soil particles migrate to the orifice in the bottom of the basket and empty into the tub. The settled soil remains in the tub until the water is spun from the basket when it is carried away with the waste water.

Lint is removed from the recirculated water by a filter that is dropped on top of the activator after the basket is loaded with clothes. The lint agglomerates into balls that are easy to gather and discard.

A vital part of the recirculation system is a new 2-way pump containing a simple water-operated valve that automatically diverts the flow to the basket during activation and to the drain during extraction.

#### Coffee Maker

A new automatic coffee maker can brew from 2 to 9 cups at a time of any desired strength from MILD—STRONG. A special setting allows the user to reheat the coffee without percolating it. The coffee maker operates like this: Assume you are making 9 cups at the STRONG setting. As soon as the coffee maker is plugged in, the 400-watt heating-pumping unit and the 400-watt booster unit come on. With both units in parallel, the temperature of the water rises quickly and pumping action begins.



**FREEZER'S** new location permits easier access to refrigerator shelves.



**ONE SETTING** of the controls provides fully automatic washing and drying.

At approximately 150 F the booster unit cuts off, and the pumping unit continues its action. Operating alone, it heats and pumps water until the temperature reaches about 195 F and then goes off because the coffee has been brewed. A signal light indicates that the coffee is ready, and the 50-watt stays-hot unit keeps the coffee at serving temperature.

#### Steam Travel Iron

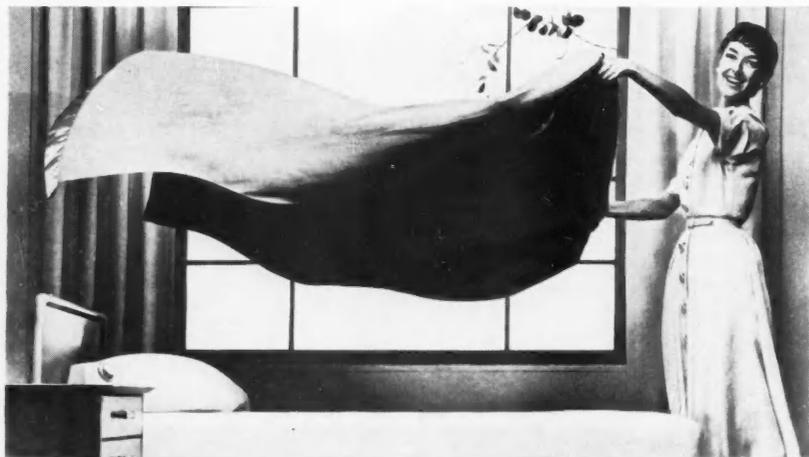
Vacationers and travelers are enjoying an extra luxury—a steam travel iron operating on a-c or d-c that weighs only



**ELECTRIC AUTOMOBILE CLOCK** has a sweep-second hand for the first time.



**AUTOMATIC COFFEE MAKER** will reheat coffee without percolating it.



**ALL-COTTON AUTOMATIC BEDCOVERING** is lightweight and suitable for use throughout the year. Trim contoured corners give perfect fit plus plenty of foot room.

27 ounces when filled with water. Employing a detachable bulb as a water container, the new iron supplies steam for 17 minutes of continuous ironing. Without the bulb, the model is a fully automatic dry iron. Its handle folds down, permitting both iron and bulb to fit in a cloth carrying case. The new iron is also popular as a lightweight steam iron for hurry-up jobs on children's clothes where small areas need attention.

#### Clocks

A new ceramic wall clock designed by industrial designer Russel Wright to suit any room in the modern American home is made of semivitreous china in a choice of 4 colors.

During 1954 the Telechron Department of General Electric introduced the

calendar clock that shows the day of the week and the date of the month through windows in the dial. This is accomplished by using 2 concentric discs intermittently driven by a sector gear added to the alarm-clock movement.

Another application of this movement is in the calendar clock radio. As in the calendar clock, the day indicator changes automatically after midnight.

A new alarm clock with "top shut off" alarm lever rather than the conventional "back shut off" is more convenient to operate.

An automobile clock development utilizes the basic principles of a new type d-c torque motor supplying power to a movement, with the timing regulated by means of a specially designed governor. It is believed that these are

the first auto clocks with a sweep-second hand.

#### Timers

New and greater flexibility for the appearance designer is obtained with a Telechron "knob-in-line" radio timer now in production. The set knobs may be located in one line at the bottom, on either side, or at the top of the timer and adjusted in distance from the center stack to suit the size of a clock face.

A modification of this calendar timer feature used on a clock radio has a muting switch that allows the user to go to sleep to the sound of soft music. As a result of an automatic switching operation, he can be awakened by the radio playing at normal volume. Another modification of the Telechron timer is built into an electric blanket control to shut off the blanket in the morning. It also provides a convenience outlet which can time a radio or any other appliance.

A new Telechron timer for room air conditioners went into production in 1954. A skip feature can be added to permit week-end, holiday, and overnight idle periods at the user's choice, with normal operation resumed early in the morning, as required.

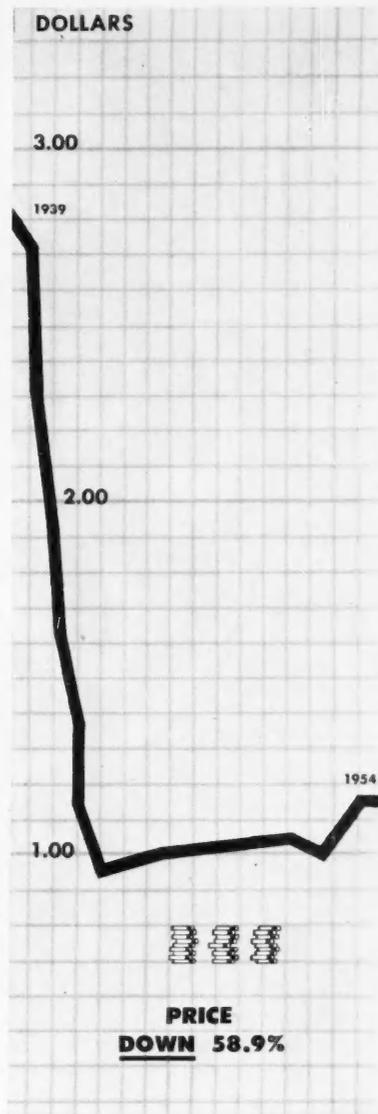
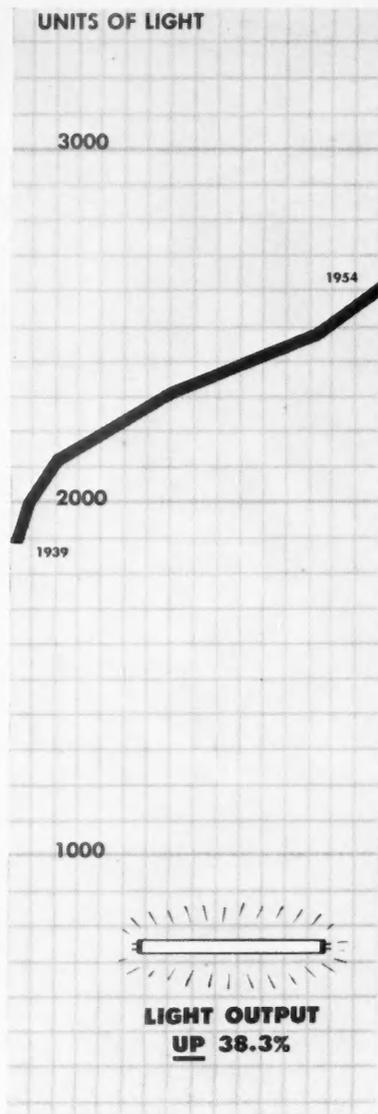
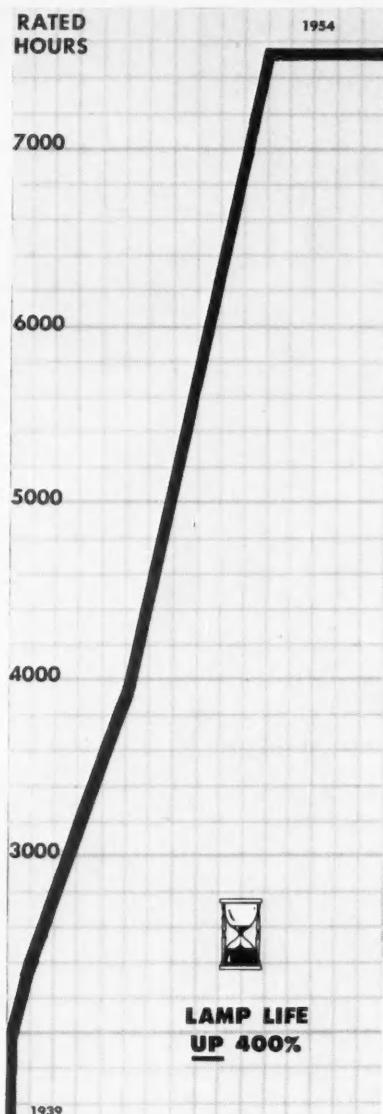
#### Automatic Bedcover

A new all-cotton automatic bedcovering is lightweight and suitable for use throughout the year. Available in 2 pastel colors, it is washable and mothproof. The blanket takes well to traveling, consuming little more room than a pair of pajamas.

#### Other Developments

An extension cord, featuring a slim, crushproof service block, retains the 3 outlets of the cube-type service block but is half the size and much stronger than the traditional design. Current-carrying parts lend structural support to the virtually solid housing.

A new contact for cordset attachment plugs improves contact and reduces destructive overheating even in worn outlet receptacles. This is accomplished by a unique combination of bowed-out spring sections on both sides of the contact, plus a slight but precisely formed thickening at the tip end of the contact. The bowed sections grip at the receptacle slot, while the anchor loop at the tip of the contact provides not only improved electric connection but also greater mechanical holding force to reduce the annoyance of accidental disconnecting. Ω



**16 times more value for  
your fluorescent lamp  
dollar than in 1939**

Today you don't have to pay more than \$1.15 for the finest fluorescent lamp made: General Electric. Sixteen years ago it would have cost you \$2.80 or \$1.65 more. And while price has been going down, we've been pushing quality up. General Electric has upped light output 38%, increased lamp life 400%.

In terms of what you really judge lamps by, a General Electric 40-watt fluorescent lamp that lists at \$1.15 today is a 16-times bigger value than it was in 1939.

For further information, contact your G-E lamp supplier or write to Lamp Division, General Electric, Department 166-GE-1, Cleveland 12, Ohio.



*Progress Is Our Most Important Product*  
**GENERAL  ELECTRIC**



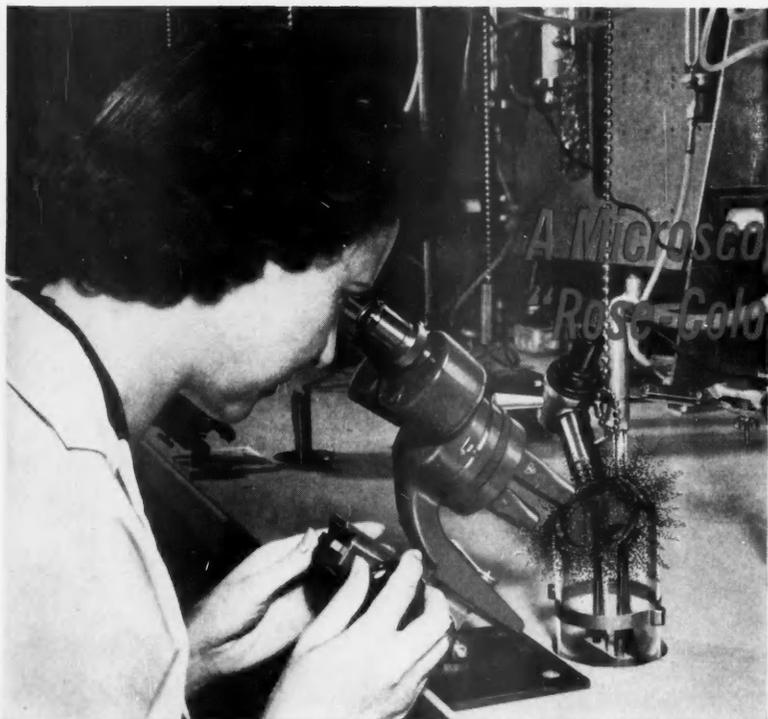
## Putting electricity to work around the world

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.

C-55-1

INTERNATIONAL  
GENERAL  ELECTRIC  
COMPANY

A DIVISION OF GENERAL ELECTRIC COMPANY, U.S.A.



A Microscope With  
"Rose-Colored Glasses"



## Germanium Products

TRANSISTORS • DIODES • RECTIFIERS

**T**HE eyes of the operator pictured above only see tiny transistor elements about to be assembled. Our eyes see much more and we see it without benefit of a 40-power microscope. This year, the same germanium transistor will be formed from mass production techniques and made available at low unit cost. Hand tooling becomes a thing of the past.

But, in addition to this widely publicized G-E "rate-grown" transistor, there are other germanium products of immediate concern to circuit design engineers. Stacked rectifiers were recently announced. These units are of the smallest size yet developed. They reduce comparable rectifier size and weight by as much as 75%. For your application the G-E stacked rectifier can be arranged from 1 to 12 fins with a total of 143 power combinations.

Diodes, too, share this spotlight on semi-

conductor product advancement. Last year, hermetically sealed units were perfected to master the damaging influences of moisture or gas contamination. Their stability and pulse recovery characteristics ideally answer requirements of magnetic and computer customers. Production now moves forward rapidly.

General Electric is at a point today where only development of new or improved equipment incorporating germanium products is a limiting factor. G-E germanium is ready to assist the engineer at work on business office electronics, automation of manufacturing processes, miniature radios, irons, etc. So, whatever your current electronic design problem is, act now to obtain up-to-date information on all G-E germanium products. *Germanium Products, Section X955, General Electric Co., Electronics Park, Syracuse, N. Y.*

*Progress Is Our Most Important Product*

• • • • **GENERAL**  **ELECTRIC** • • • •



## 1-HOUR TRANSFORMER DESIGN?

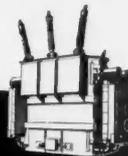
The answer is yes! General Electric's new Card-Programmed Calculator—an IBM mechanical brain—can work out in 60 minutes transformer design problems that formerly took 20 to 40 hours "by hand."

Already, certain designs for customer quotations are being delivered in record time. Eventually, engineers will use the Card-Programmed-Calculator to help design most G-E power transformers. G-E designers are using the hours saved for basic engineering and development work. CPC is just one of the tools G.E. uses to give you faster delivery of improved power transformers. General Electric Company, Schenectady 5, New York.

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**Power  
Transformer  
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