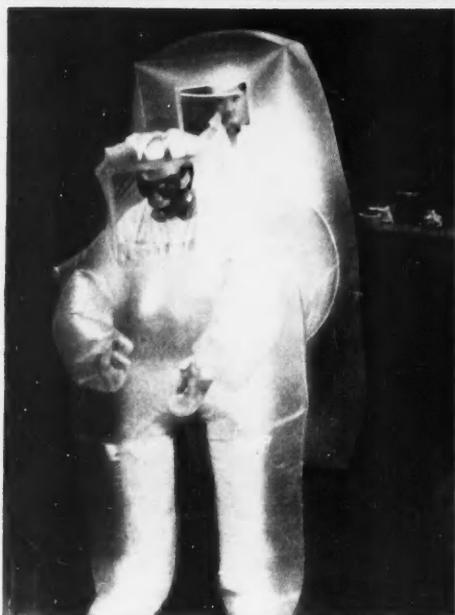
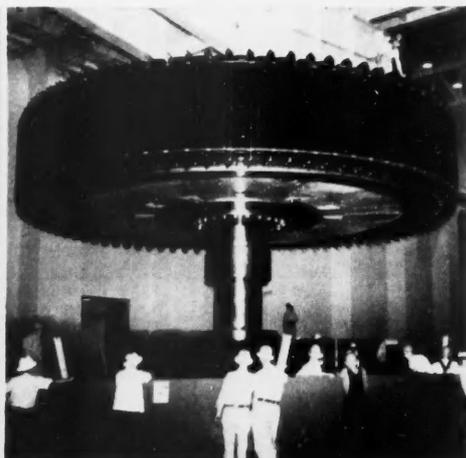
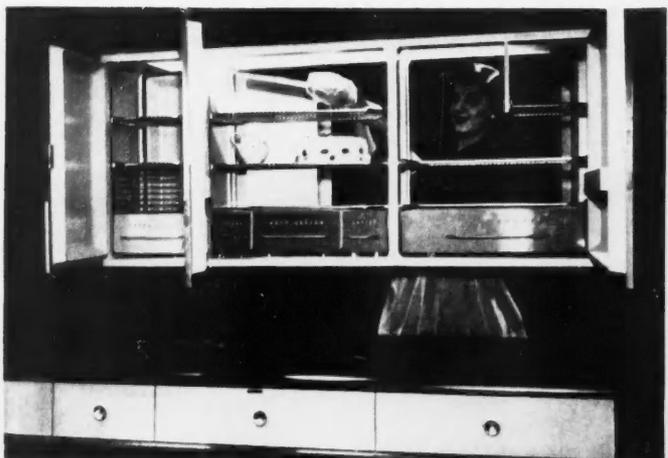


GENERAL  
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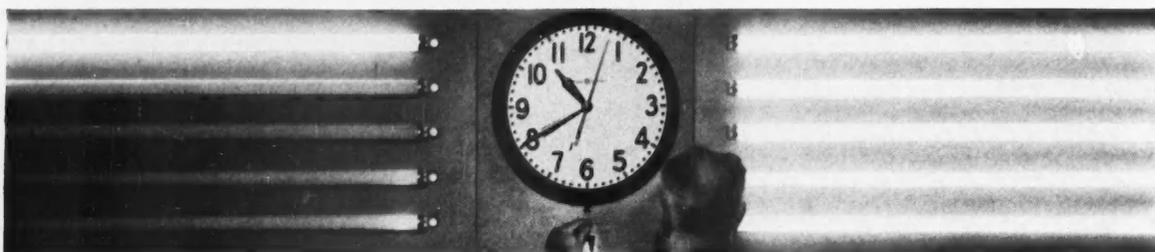
# Review



RESEARCH AND ENGINEERING PROGRESS - 1953

JANUARY 1954

YOU EXPECT THE BEST VALUE FROM G-E FLUORESCENT LAMPS



**New G-E "Rapid Start"  
lamps light up twice  
as fast as others**



This series of pictures shows how General Electric can save you the annoyance of waiting for light.

All the lamps were started as the second hand on the clock reached zero. Within two seconds, the G-E Rapid Start lamps—right of the clock—were fully lighted. It was nearly six seconds before all the regular lamps, left, lit up.

G-E Rapid Start lamps eliminate the starter, cause of up to half of regular lighting maintenance troubles. They have extra long life, too. Reason: a triple-coil cathode that holds more starting chemical.

General Electric Rapid Starts are another example of why you can expect the best value from G-E fluorescent lamps. For free folder, "Facts About Rapid Start", write: General Electric, Dept 166-GER-1, Nela Park, Cleveland O.

*You can put your confidence in—*

**GENERAL  ELECTRIC**

**GENERAL  
ELECTRIC**

*Review*

EVERETT S. LEE • EDITOR

PAUL R. HEINMILLER • MANAGING EDITOR

**RESEARCH AND ENGINEERING PROGRESS • 1953**

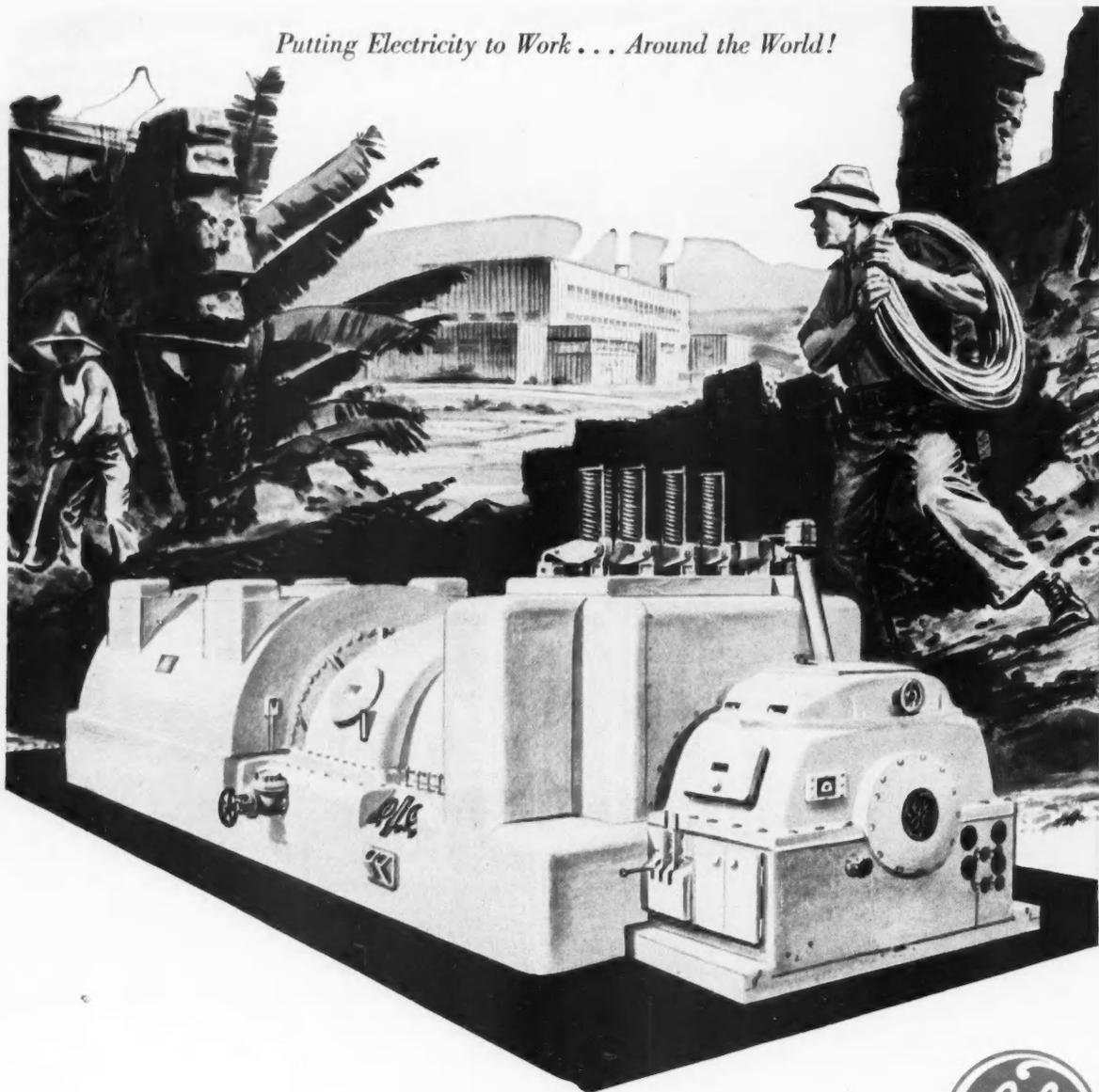
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**THE COVER**—Tomorrow's refrigerator-freezer in a developmental stage has ½-inch panels of a new insulation (pages 10, 57) . . . Rotor weighing about 588 tons is lowered into the stator of a 73,700-kva hydraulic turbine-driven generator. Three such generators, the largest electric machines in physical size ever built, were shipped to McNary Dam (page 23) . . .

Plastics "bubble" allows operator to enter radioactive hoods safely and conveniently. Air pressure inflates and forces the plastics tunnel and figure into the hood (page 13) . . . B-47 *Stratojet* bomber powered by six G-E J47 turbojet engines is being refueled in mid-air. The J47 series of turbojets is used on such planes as the *Sabrejet* and the *Fury* (page 39).

THE GENERAL ELECTRIC REVIEW IS ISSUED IN JANUARY, MARCH, MAY, JULY, SEPTEMBER, AND NOVEMBER, BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NY, AND IS PRINTED IN THE U.S.A. BY THE MAQUA COMPANY. IT IS DISTRIBUTED TO SCIENTISTS AND ENGINEERS THROUGHOUT INDUSTRIAL, CONSULTING, EDUCATIONAL, PROFESSIONAL SOCIETY, AND GOVERNMENT GROUPS, BOTH DOMESTIC AND FOREIGN. . . . THE GENERAL ELECTRIC REVIEW IS COPYRIGHTED 1954 BY THE GENERAL ELECTRIC COMPANY, AND PERMISSION FOR REPRODUCTION IN ANY FORM MUST BE OBTAINED IN WRITING FROM THE PUBLISHER. . . . THE CONTENTS OF THE GENERAL ELECTRIC REVIEW ARE ANALYZED AND INDEXED BY THE INDUSTRIAL ARTS INDEX, THE ENGINEERING INDEX, AND SCIENCE ABSTRACTS. . . . SIX WEEKS' ADVANCE NOTICE, AND OLD ADDRESS AS WELL AS NEW, ARE NECESSARY FOR CHANGE OF ADDRESS. . . . ADDRESS ALL COMMUNICATIONS TO: EDITOR, GENERAL ELECTRIC REVIEW, SCHENECTADY 5, NEW YORK.

Putting Electricity to Work . . . Around the World!



**FORGED FROM THE RUINS...** *a new Manila!*



The occupation was over. Manila was free.

The task of rebuilding would take the strength of a giant. Electricity would be needed for many jobs.

But the Manila Electric Company had lost a large part of its facilities; service had to be restored to pre-war levels...and beyond. Meralco officials saw that Manila could become a larger, more industrialized city.

Equipment was specified... ordered from G. E.'s U. S. headquarters. When these generators, switchgear, and other units arrived, they were installed

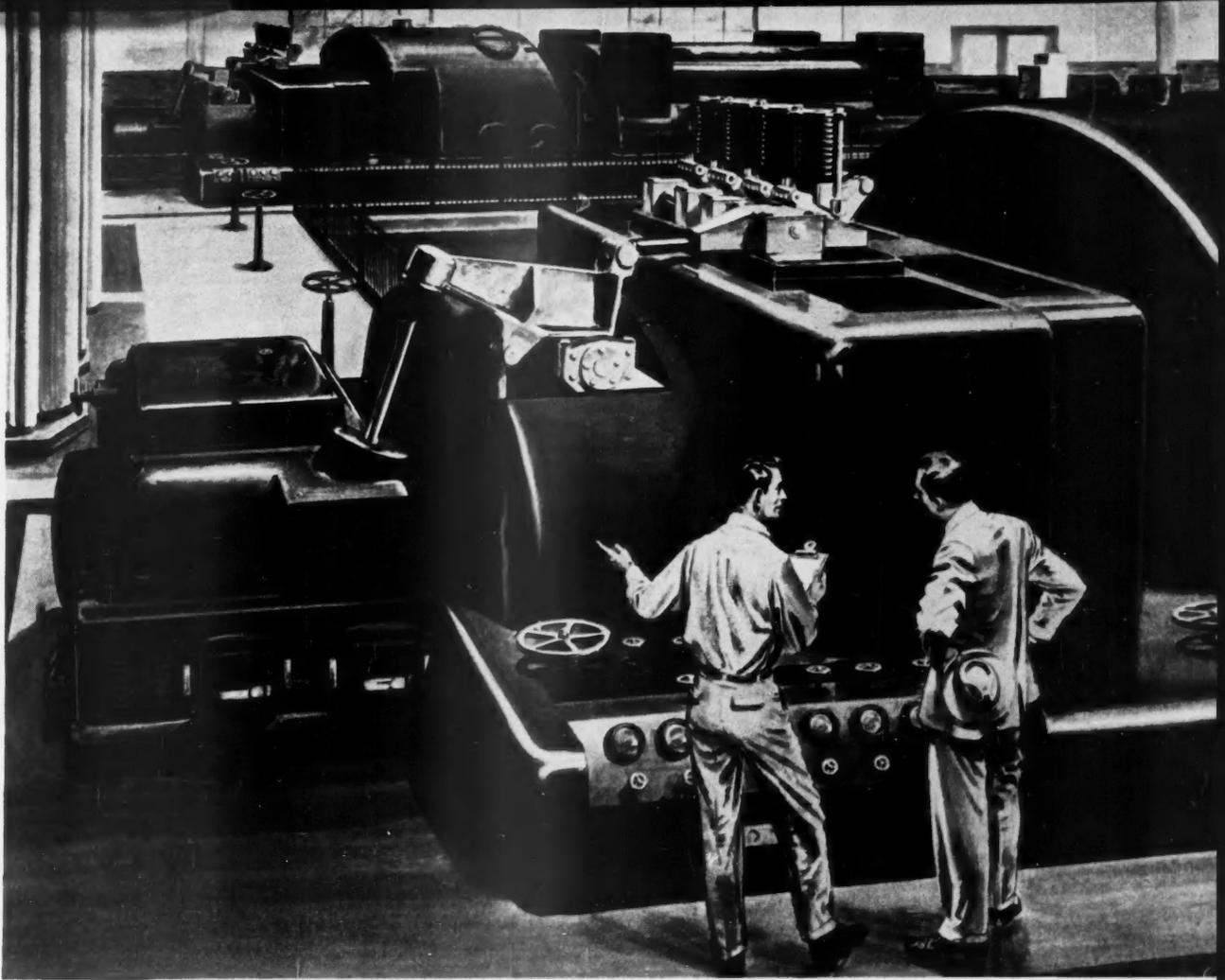
with the help of the G-E field organization, became vital components of the Rockwell Power Station—most modern steam power plant in the Philippines.

Thus G-E equipment and expert engineering coordination were put to work in the Philippines. You can take advantage of this same service wherever you may be.

1A-33-32E

**INTERNATIONAL  
GENERAL  ELECTRIC  
COMPANY**

A DIVISION OF GENERAL ELECTRIC COMPANY, U.S.A.



Two 100,000 kw G-E reheat turbines at the Lee Steam plant of the Duke Power Company near Greenville, S. C.

## G-E tandem-compound, double-flow design spurs trend to reheat turbines

**Design advantages yield new highs in station efficiencies; cut down cost of installation and maintenance**

The modern reheat turbine of the tandem-compound, double-flow design has been hailed as one of the most significant of recent G-E contributions to turbine progress.

Making possible the increased efficiency of reheat in size ranges from 50,000 to 150,000 kw, the design has won acceptance throughout the electric utility industry.

The first such unit was installed at the Dunkirk Station of the Niagara-Mohawk Power Corporation. The remarkable record of this turbine, and the widespread adoption of the design for machines in many other installations throughout the country has been an important factor in today's overwhelming trend to the reheat cycle.

A typically successful performance has been turned in by the two 100,000 kw units at the Lee Steam plant of the Duke Power Company pictured above.

The combination of high efficiency with low installation cost and pronounced savings in maintenance expense, shows why this type of reheat turbine will continue to grow in popularity throughout an increasingly cost-conscious industry. General Electric Company, Schenectady 5, N. Y.

254-16

*Progress is our most important product*

**GENERAL  ELECTRIC**



## FROM CAMPUS — TO CAREER IS A BIG STEP

When the graduate leaves the college campus to begin his career he is taking an extremely important step. For he is leaving the area of directed-development in college and entering the area of self-development in industry.

Closing the gap between his campus experiences and the realities of earning a living is not easy. The complicated maze of modern industrial society has made this transition a tough task. While the craftsmen of former years grew up with the business, the college graduate of today steps into a strange organization at a relatively high level. He has had no opportunity to understand, through a long period, the methods and operations of the concern.

During his first few years, he is finding his place in the organization—learning its policies and objectives, and at the same time shaping his professional career. He needs all the assistance and guidance he can get.

Here at General Electric, hundreds of young men have found that intensive efforts are made to "bridge the gap"

between college and industry—and to help young professional people realize their goals. Through extensive training programs, classroom study programs, leadership programs, and guidance in professional development, carefully selected young men are prepared for positions of responsibility and leadership in their individual fields.

Providing college graduates with the opportunity to know the Company and find the right job in it . . . giving them high-level, flexible orientation and training . . . offering continued opportunity for professional growth are most important tasks at General Electric. Nothing is more important—for our young professional people are our biggest asset.

*If you are interested in building a career with General Electric, see your college placement director for the date of the next visit of the G-E representative on your campus. Meanwhile, for further information on opportunities with General Electric write to College Editor, Dept. 2-123, General Electric Company, Schenectady 5, New York.*

GENERAL  ELECTRIC

# THE ENGINEER AND THE ELECTRICAL INDUSTRY

The prophecy made years ago by Dr. Steinmetz that the electrical age—and the electrical industry—was in its infancy, can still be made today. In 1935 the electrical manufacturing industry supplied only 1.7 percent of the gross national product. Today it supplies 4 percent. There are those who forecast that as early as 1961 the products of electrical manufacturing will represent an estimated 5½ to 6 percent of the gross national product.

The forecasters have been busy, too, drawing dotted lines to show the probable kilowatt-hour output of electric power in the years ahead. A once daring prediction of one-trillion kilowatt-hours for the year 1970 is now moved ahead to 1965, and the really long-range prophets are talking among themselves about an annual output of five-trillion kilowatt-hours by the year 2000.

These figures are all figures of promise for the engineers—not just for the electrical engineers, but for engineers in all fields. For in the midst of the great electrical industry today stand the scientist and the engineer. In the construction of the electric power plants, and the dams, and the structures, we need the civil engineer. In the vast machinery of production and transportation driven and controlled by electricity, and in the production of electric power, we find the mechanical engineer. In using the materials from the mines of the earth for the building of electric machinery, we have the mining and metallurgical engineer. In applying the materials and the processes of industry, it is the chemical engineer.

And in the widespread array of electric and electronic products for the electric power of industry and transportation and the farm, for lighting and communications everywhere, for service and entertainment in the home, and for the services of commerce and government, there stands the electrical engineer. He has advanced his engineering to provide electric power and light and service for every use and entertainment of mankind. This has been characterized as more revolutionary for the well-being of the people of the world than any other material thing in recorded history. It is largely the basis for the productivity of our country.

And co-ordinated with the efforts of the electrical engineer in this undertaking are the efforts of the mechan-

ical engineer, the chemical engineer, the civil engineer, the chemist, the physicist, and the metallurgist.

From the great research laboratories of industry scientists have brought forth new knowledge and new materials that engineers have formed into products for the people to have and to use. And from our engineering schools have come young engineers to take their places with those who have come before. The basis of electrical advance has been scientific from the very beginning.

The electrical industry is an industry of vision and of great names. Benjamin Franklin revealed the electricity of the feeble current to be the same as that of the lightning discharge of great destructive force from the clouds above. Morse brought forth the telegraph; Bell, the telephone. Edison, who many believe to be the greatest inventor the world has ever known, brought electricity to man in the form of the incandescent lamp to establish vast opportunities for a new-found power. Elihu Thomson and his associates built on a firm foundation in their vision of the service to man which they beheld in the early days of the electrical world. Marconi revealed the radio. All these were men of vision to accomplishment, as have been those who have followed in their train to bring the electrical industry to where it is today.

By virtue of its position, the electrical industry must be prepared to grow more than twice as fast as the remainder of the economy. Based on the best estimates of the growth of the economy as a whole, it is probable that in the next 10 years as much electrical generating equipment will be built, sold, and installed as has been built and installed in the industry's past 75-year history.

What a prospect for the engineer! Such growth means the solution of new and more complex technical problems, together with the advancement of managing ability to solve the many human problems that come with the expanded units of production. In both of these realms the call for solutions is intense. In ever-expanding avenues the opportunity for the new is more extensive than ever.

With vision to perceive, with courage to advance, and with ability to achieve, the challenge to and opportunity for the engineer and the scientist in the electrical industry today were never greater.



EDITOR



FUTURE ADDITIONS TO RESEARCH LABORATORY WILL BE USED FOR FUNDAMENTAL WORK IN THE FIELDS OF COMBUSTION AND METALLURGY.

## Research

Plans for two new research facilities, one for the development of metallurgical and ceramic materials and the other for fundamental work in the field of combustion, were announced during 1953. Both buildings will be a part of the Company's multimillion-dollar Research Laboratory at Schenectady.

Radical advances in metals and related products will be hastened by the new metallurgical facility that was started late in 1953 and is scheduled for completion by the spring of 1955. It will provide extensive laboratory space and equipment where materials and processes originating in the laboratory's metallurgical research program can be evaluated on a pilot-plant scale. This pilot-plant stage forms an essential step between research and application.

### High-temperature Alloy

A new high-temperature alloy was evaluated and produced on a pilot-plant scale during 1953. It possesses the same strength as the most widely used alloy for such high-temperature applications as the turbine buckets in turbojet engines. But its higher operating temperatures—70 F higher than the present 1500 F—will mean significantly improved performance. The alloy is vacuum cast because this offers added control of composition plus freedom from slag and oxide impurities in comparison with conventional melting processes.

### Piezoelectric Materials

A ceramic material under development is a lead niobate compound displaying a high degree of piezoelectrical properties over a broad temperature range. Piezoelectric materials, or ferroelectrics, are materials that directly convert electrical energy into mechanical energy, and vice versa. Such crystals have numerous applications, for example, in dielectric amplifiers and as transducer elements.

### Alloy Design

In the field of alloy design a broad exploration of high-temperature alloys was completed and from this, relationships were developed for predicting the properties of combinations of metals in alloy form. The data and the empirical relationships developed from the data constitute the most comprehensive contribution to the field of alloy design yet made. From this information numerous materials have already been designed; several are now in use or will shortly be applied to General Electric products.

Further information necessary as design criteria for alloys is data on the properties of the intermetallic compounds and second phases occurring in metals and alloys. These compounds and phases occur as particles of varying size and shape that greatly change the mechanical, magnetic, and electrical properties of the alloy. The deformation

properties of these particles are measured by means of a hot-hardness tester; the resistance of the specimen to penetration by a special high-temperature indenter is measured at temperatures as high as 1500 C.

Information on the properties of such compounds is also applicable to the formulation of a new class of materials sometimes called *cermets*, in which a compound or compounds form the major constituent bonded by a small amount of metal.

### Metals of the Future

Through experimentation in the field of refractory materials such as molybdenum, titanium, zirconium, and chromium—the so-called metals of the future—a new zirconium alloy was developed during 1953. The alloy contains a small amount of aluminum and has excellent oxidation and corrosion resistance (better than stainless steel at temperatures as high as 500 C). Commercial use of materials similar to this alloy is anticipated in the near future.

One of the problems in using refractory metals is their brittleness at low temperatures. A greater understanding of the brittleness of these materials as related to the solubility of oxygen in the refractory metals was obtained. This may also lead to an improvement in ductility.

Several years ago Cond-Al, a creep-resistant high-conductivity aluminum

alloy, was developed. Recent research has led to the development of Super Cond-Al, a new alloy of still higher creep strength with equivalent conductivity and a much simpler processing sequence.

Work on magnetic sheet materials such as oriented steels used in transformers and motors continued during 1953 and should lead to an improvement in the processing of these materials, as well as to a better control of the manufacturing sequence. Other magnetic materials such as those used for high-frequency application were studied and new alloys evaluated.

### Crystal Growth

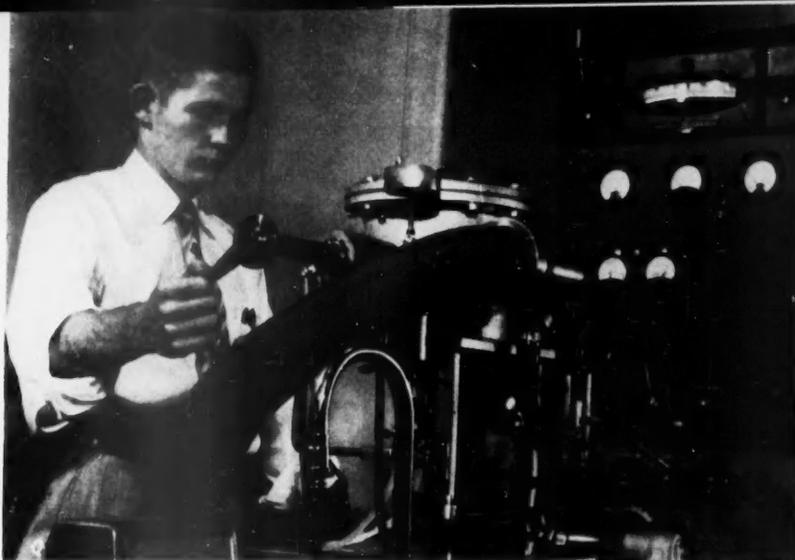
The need for additional information about the behavior of materials is, in part, responsible for studies during 1953 of the growth of perfect crystals and their properties. Perfect crystals are free from imperfections on an atomic scale, imperfections that ordinarily result from accidents during their growth or during deformation of the crystal. Highly corrosion-resistant, they have interesting electrical and magnetic properties, and are many times stronger than materials with defective crystal structure. The defects in imperfect crystals were studied because of the important role they play in determining how crystals deform and fracture, the magnitude of their electrical conductivity, the rate of self-diffusion, and other properties.

One of the deformation processes of metals studied was the deformation of zinc in compression. This deformation mechanism, called *kinking*, has been interpreted in terms of the motion of a particular type of crystal imperfection called a dislocation. The impact of this concept on the science of metals is only beginning to be felt. Further study of their behavior and properties is certain to be significant.

### Combustion

Construction work will begin this spring on the new \$1.6-million facility for fundamental work in the field of combustion. Two air compressors of 800 bhp each, designed to operate efficiently over a range of pressures up to 500 psig, will supply most of the air. One 200-bhp standard 125-psig machine will be used for tests that do not require large amounts of air.

Special features include extensive sound treatment inside the structure and on all intake and exhaust systems.



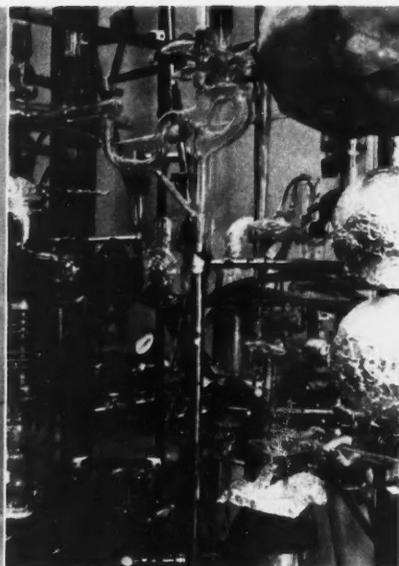
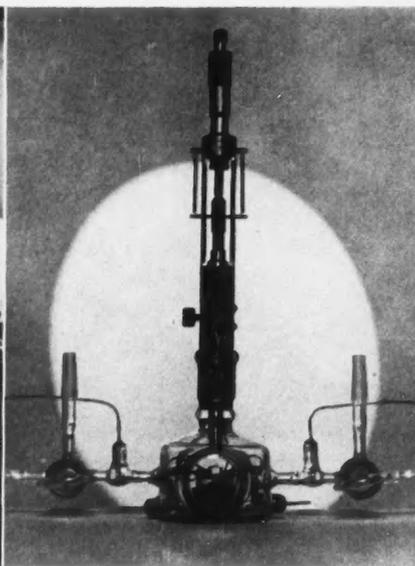
HOT-HARDNESS TESTER MEASURES RESISTANCE OF METALS TO HIGH TEMPERATURES.



NEW INSULATION IS AT LEAST 10 TIMES AS EFFECTIVE AS CONVENTIONAL MATERIALS.



ELECTRIC BREAKDOWN OF MATTER IS STUDIED WITH THE AID OF THIS APPARATUS.



**RESIN-FILLER BINDING FORCES** are studied by investigating adsorption of gases by solids (*left*); fine wires under delicate forces are used in electrical-contact studies (*center*); and vacuum-fusion technique determines traces of oxygen, hydrogen, and nitrogen.

Part of the program on combustion will involve detailed studies of the mechanism of flame stabilization, carbon formation, radiation properties of flames, and the principles of scaling. Research facilities for fatigue testing of turbine buckets under controlled conditions approximating those of turbine operation will also be provided.

#### New Insulation

A new flat-panel type of thermal insulation that has at least 10 times the insulating power of the best conventional materials was developed during 1953. The new insulation consists of a specially compacted pad of glass fiber enclosed in a thin metal envelope, hermetically sealed, and evacuated to a pressure less than 100 microns of mercury. At ordinary temperatures a  $\frac{3}{8}$ -inch-thick panel of the insulation can replace a  $3\frac{1}{2}$ -inch-thick pad of conventional glass-fiber or rock-wool insulation.

Since the evacuated panels are very stiff and mechanically strong, they can contribute to the mechanical strength of a structure. And field and laboratory tests indicate that there is no difficulty in holding the required vacuum for 30 years or more if the panels are sealed and outgassed properly during their manufacture.

Vacuum-type thermal insulations are not new—look at the wide use of thermos bottles and Stanley flasks. But the novel feature of this new insulation is its ability, when in the form of flat

panels, to support the crushing load of the atmospheric pressure without suffering a decrease in its excellent insulating characteristic. In previous vacuum insulations, the walls have had to be strong enough to support the load of atmospheric pressure.

#### Dielectric Breakdown

A program to study the phenomenon of electric breakdown of matter to help determine the electrical behavior of insulation was well under way in 1953. Although all three forms of matter are under investigation, the greatest effort continues to be concentrated on liquids.

Among the properties of liquids important in determining the electric strength (the voltage at which breakdown occurs) are composition, temperature, density, and structure. For example, it was found that a branched-chain paraffin hydrocarbon has a lower electric strength than the corresponding straight-chain hydrocarbon. The electric strengths of straight-chain hydrocarbons are correlated in a very simple way with their densities, a circumstance that was anticipated because a greater resistance to the flow of electrons is to be expected in a denser material. The effect of temperature on the electric strengths of these aliphatic hydrocarbons was accounted for in its entirety by the change in density that a change in temperature causes.

The experiments were carried out using single rectangular pulses of volt-

age varied from  $\frac{1}{4}$  to 50 microseconds. Short pulses were used to avoid heating the liquids by the prolonged application of electric stresses. In this way electric strengths as high as 5-million volts per inch were measured for liquid paraffin hydrocarbons.

By varying the pulse length, electric strengths of these liquids increased rapidly as the pulse was shortened below one microsecond, approximately the time required for the normal breakdown process.

In studying liquids it was observed that the nature of the cathode influenced the measured values of the electric strength; this was traced to cold emission of electrons from the cathode under the influence of the large electric fields present.

#### Electrical-contact Studies

To explore the electrical properties of surfaces, fine wires under extremely delicate forces were used, with areas of real contact estimated to be as little as  $10^{-8}$  square centimeters. These methods revealed unexpected insulating films on electrical contacts, including some derived from ordinary fingerprints. By the use of the new techniques thin films caused by chemical action or by contamination due to polishing or to handling can be easily detected.

#### Adsorption Studies

The adsorption of gases by solids was investigated to learn more about the resin-filler binding forces in various



OIL WHIP IN HIGH-SPEED JOURNAL BEARINGS IS STUDIED ON THIS TEST STAND.

solid materials such as filled silicone rubber and mica mat. Measurements on the heptane ferric oxide system were made as a first step in this study. These measurements proved that complexities previously found in this system did not exist, and that the theoretical equations governing such systems were actually valid down to pressures where only 40 percent of the solid surface was covered with a single layer of molecules. This significant discovery should simplify future investigations of the adsorption of gases by solids.

#### Vacuum-fusion Analysis

Because metallurgists are increasingly concerned with the effect of parts-per-million amounts of oxygen and other gases on the properties of metals, a vacuum-fusion technique has been adopted for determining traces of oxygen, hydrogen, and nitrogen. It is currently the only acceptable method for determining oxygen in metals.

Approximately one gram of the metal to be analyzed is fused in empty space in a graphite crucible. The evolved gases are pumped into a calibrated volume and analyzed by fractional freezing.

Metals successfully analyzed include iron, chromium, titanium, zirconium, cobalt, niobium, and many alloys of these and other metals.

#### Electron Diffraction Studies

A new temperature chamber designed for electron diffraction studies at high temperature was developed during 1953. It can accommodate both transmission and reflection samples, and is capable of being adjusted to temperatures ranging from ambient to 1000 C. The chamber, a complete plug-in unit, is adapted to the manipulator of the diffraction instrument to permit alignment of the sample with the electron beam.

Samples may easily be changed without removal of the chamber from the manipulator. A thermocouple is included for measuring the temperature of the sample.

Since the properties of substances are greatly different at temperatures above ambient, this high-temperature chamber will open greater opportunities for research in the diffraction field. Many new and better products can be discovered through the study of thin films and surfaces, such as selenium rectifiers, germanium diodes and transistors, oils and waxes, alloys, and ceramics.

#### X-ray Pole-figure Data

In the study of silicon-iron structure a system was devised whereby it is possible to reduce complicated data in the quantitative analysis of pole figures

to give the intensity, degree, and type of preferred crystal orientation. The simplified system, expressible in numbers, will be invaluable in the field of crystal texture evaluation, where present techniques are just beginning to bring forth good quantitative pole-figure data.

#### Oil Whip in Journal Bearings

Past experience with high-speed machinery and extensive studies of lightly loaded high-speed bearings established the existence of a new kind of vibration—oil whip—that could not be eliminated by the old methods of balancing or running the machine at other than resonant speeds.

This oil-whip vibration generates forces in the oil film itself at speeds above twice the first resonant critical of the rotor.

Recent studies were aimed at determining the characteristic pattern of oil whip and the effect of various operating conditions and bearing designs. Oil viscosity, loading, and speed have a decided effect on whip. New antiwhip bearings were designed that either reduce or completely eliminate this oil-whip vibration.

With a better understanding of the phenomenon, engineers are in a much better position to anticipate and to cope with the problem in design work in new high-speed turbines and accessories, guided missiles, superchargers, and motors operating at high speeds.

#### Schlieren Technique

The Schlieren technique, used for making visible supersonic or subsonic gas flow in jet or wind-tunnel studies, also proved useful during the past year in studying the behavior of transparent liquids. The Schlieren apparatus shows that the application of voltage causes an oil flow between two electrodes and as the potential difference between the electrodes is increased, the oil begins to flow turbulently through the gap. The nature of this behavior is important in studying the dielectric strength of the liquid and the technique of measuring it.

Of considerable interest is the similar turbulence produced when one of the electrodes is heated and voltage is applied between the electrodes. In this case, the turbulence substantially increases the amount of heat transferred from the heated electrode to the liquid because of the disruption of the ordinary heat-flow pattern.



Last plate is welded atop the world's largest sphere to house test facilities for a submarine atomic power plant

# Nucleonics

General Electric engineers and scientists at the Atomic Energy Commission's Hanford plutonium manufacturing plant in the southeastern part of Washington state made important contributions during 1953 to the Company's prime objective in this operation—increased production of the vital nuclear fuel at lower unit cost.

The past year saw important gains toward this objective in all phases of plutonium manufacturing. More production was obtained from reactors in existence at the beginning of 1953 with still more predicted for reactor facilities now under construction.

Increased productive capacity brought with it the necessity for matching increases in activity throughout other phases of the Hanford operation. Such activities as metal preparation, chemical processing, storage of radioactive wastes, and processing of recovered uranium into uranium oxide were stepped up by improving and enlarging old facilities and incorporating improved designs in new ones.

Approximately \$30 million has been spent on research and development at Hanford since September, 1946, when the Company assumed the role of prime contractor to the Atomic Energy Commission. The research and development effort to date has been carried on principally in support of the production plant to improve process yields, reduce costs, and increase output. According to the AEC this extensive research program has saved hundreds of millions of dollars.

Although tremendous strides have been made, appreciable development work in the fields of plutonium production and atomic energy remains to be done. To assist in accomplishing this effort, a new \$14-million laboratory area was completed at Hanford and occupied by the General Electric Company during the year.

## Uranium Recovery

The plant for recovery of uranium from the underground radioactive waste tanks utilizes an existing separations building that was converted to this use. A large stockpile of waste containing uranium has been accumulating in underground tanks since the original Hanford chemical batch-processing operation began in 1945.

## Chemical Separations

A continuous process plant for chemical separation of plutonium and uranium from waste products was completed in 1952. And a new improved \$40-million separations plant is currently under construction at Hanford.

## Self-concentrator Utilizes Heat

An industrial application of thermal atomic energy was developed and placed in use at Hanford in 1953. Highly radioactive wastes produced during the creation of plutonium are stored in underground tanks. To minimize storage space the solvent is boiled off; previously this was accomplished by applying steam heat to waste solutions. Now, a self-concentrator makes use of the heat generated spontaneously by the vigorous radioactive decay of the waste elements themselves.

## Ground Disposal of Atomic Wastes

Extensive geological and hydrological work, combined with laboratory and field operations, has determined that the ion exchange capacity of natural Hanford soils is such that ground disposal of process wastes of moderate radioactivity may be continued and expanded with high assurance of safety.

## Protective Plastics Suit

G-E personnel can enter large highly radioactive hoods safely and conveniently, totally enclosed within a virtual plastics "bubble."

Using a sealing method perfected at Hanford, operators join together suitable thermoplastic sheet material, creating a translucent plastics skin molded roughly to the shape of the human figure. A large opening left in its back is sealed to a plastics tunnel attached to an entrance port on the hoods. Air pressure forces the tunnel and plastics figure into the hood and inflates them. An operator can then step through the port and tunnel into the "plastics man" and work, safe from plutonium contamination.

## Atomic Heat to Warm Buildings

Reactor facilities now being constructed at Hanford were designed by General Electric personnel in co-operation with the C. T. Main Company to use the heat from pile coolant water in an industrial-scale heating system. This

heating system will serve a new reactor building and buildings adjacent to it—the largest practical use of atomic by-product heat in the country.

## New Hanford Laboratories

A laboratory area conceived by General Electric scientists and engineers and costing about \$14 million was completed during 1953. The laboratories are designed for work with radiation and radioactive materials in the fields of chemistry, metallurgy, physics, engineering, and biophysics. Approximately 600 people are assigned to this area.

The radiochemistry building is the largest unit and contains approximately 50 laboratories ranging from general-purpose units through highly specialized instrument rooms for emission or mass spectrographs. This building provides facilities for laboratory-scale process research as well as for process improvement, trouble shooting, and analytical development.

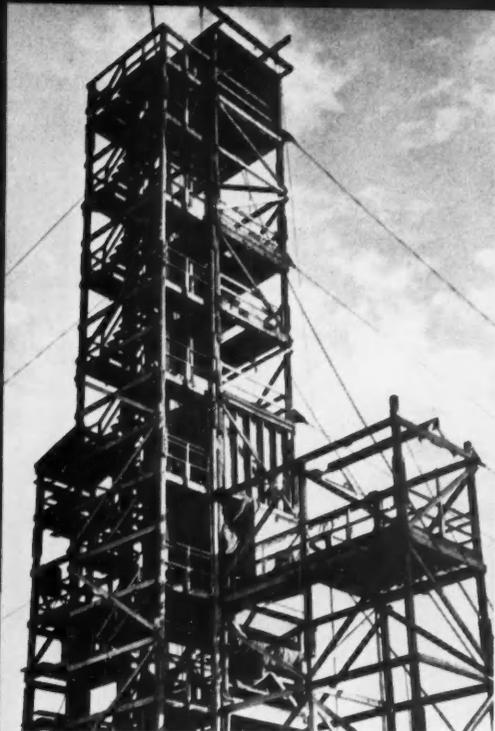
From the radiometallurgy laboratory will come more complete and accurate knowledge of irradiated metals—especially the fuel slugs from Hanford reactors. Attention will also be directed to problems in fuel structure, metal preparation, canning, and deterioration of the fuel element. The new structure contains three multicurie cells for study of materials with intermediate radioactivity and a fourth multicurie cell for study of highly radioactive substances.

The pile research and development building houses large laboratories for investigation in the fields of physics and metallurgy. Urgent problems of pile operation and construction will be solved in these facilities.

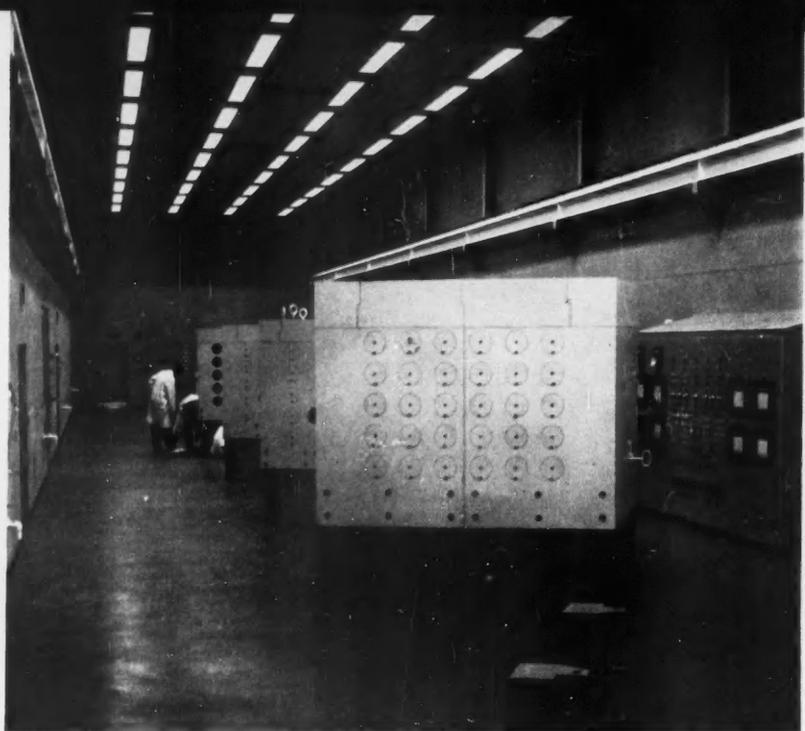
The biophysics building provides facilities for the development of personnel protection methods and also for the measurement of environmental hazards arising from Hanford operations.

The mechanical development building houses the technical shops for the precision fabrication of intricate laboratory apparatus as designed by the Hanford scientists and engineers. In addition, mock-up space is provided for test assemblies of large devices.

The library and files building makes available to the employees 25,000 books and 250,000 technical documents in addition to numerous technical periodicals and journals.



**TOWER** where neutron-absorbing rods are tested to be used for nuclear reaction control.



**RADIOMETALLURGY LABORATORY** contains three multicurie cells for study of materials with intermediate radioactivity plus a fourth cell for highly radioactive substances.

#### **New Aquatic Biology Laboratory**

Construction was recently completed on a new laboratory at Hanford to house personnel who study Columbia River life. The new facilities are available to study effects of Hanford effluents on aquatic life including salmon and other fish of considerable value. Such studies demonstrate that Hanford has no significant adverse effect on the aquatic life of the river. Answers can also be obtained to biological problems concerning hazards of water-borne radioactivity and the toxicity levels of certain process materials.

#### **Radioactive Effect on Plants**

Experiments at Hanford to determine the effect on plants of radioactive products in the soil culminated in 1953.

Plants are grown in the chambers in nutrient solution cultures containing various radioactive contaminants. In fission-product isotope studies it was observed that most plants absorb strontium in about the same concentration as it is present in the soil. The isotopes of cesium are absorbed in quantities about one-tenth less than the amount present. Isotopes of such elements as yttrium, ruthenium, and cerium are absorbed only in very small quantities.

#### **Biological Hazards of Plutonium**

More information about the control of biological hazards that can be caused

by plutonium was obtained in 1953 from three studies at Hanford.

Experiments involving more than 500 individual feedings of very dilute plutonium solutions to each of 200 rats resulted in a new and more accurate value for the extent of absorption of plutonium from the intestinal tract. The value obtained is lower by a factor of 40 than the 0.1 percent absorption previously assumed in calculations of maximum permissible concentrations.

Studies were made of the therapeutic effectiveness of various agents in removing plutonium deposited in these rats. Some agents effect significant excretion of plutonium when administered shortly following plutonium injection, but are not significantly effective when administered 30 days after plutonium injection.

A comprehensive study of the absorption of plutonium through the skin of rats, and of the effectiveness of a variety of agents in removing plutonium from the skin, was instituted. Preliminary results indicate that significant absorption occurs only when the plutonium is present in solutions capable of destroying the outer layer of skin. The most effective decontaminating agents are also those that remove the top layer of skin. Whether such agents may increase the subsequent absorption of plutonium not removed is one phase of this study that requires further attention.

#### **Double-crystal X-ray Spectrometer**

To facilitate investigation of the crystallographic characteristics of pile-irradiated materials, there was need at Hanford for an x-ray diffraction unit capable of being used to study highly radioactive irradiated materials that emit intense beta and gamma radiations. The exact type and degree of irradiation damage to high activity materials was largely a matter of theoretical conjecture.

An x-ray diffraction unit developed at Hanford utilizes a double-diffraction technique. A monochromating crystal is placed in the diffracted beam of x-rays between the radioactive sample and the detector. When the crystal is set at the correct Bragg angle for diffraction of the characteristic x-rays, it acts as a discriminator, rejecting beta and gamma radiations emitted by the radioactive samples that would otherwise saturate the detector, but transmitting the x-rays. Shielding material is placed along the path of the x-ray beam between the sample and the detector to absorb beta and gamma rays emitted by the sample and scattered by the crystal.

The preliminary tests showed that the instrument was capable of yielding excellent diffraction patterns from highly radioactive specimens.

#### **Metallograph**

A shielded remote microscope called a metallograph is another development



**STUDIES DEMONSTRATE** that Hanford effluents have no significant effect on aquatic life (top); experiments determine the effect on plants of radioactive substances in soil (lower left); rats are fed dilute plutonium solutions to develop modified exposure limits.

at Hanford that is proving a powerful tool for investigating the properties of radioactive metals. The metal to be examined is enclosed within a cell that interposes 10 inches of steel or equivalent between the operator and the sample. Light from an arc lamp is funneled into the cell through a solid lead glass "light pipe" nearly as dense as the steel walls. The image is brought out to the eyepiece and camera through a similar glass pipe. The lead glass screens out dangerous radiation even though the source is as strong as several hundred curies.

#### Counter Deterioration Measured

A method of measuring the gradual deterioration in the counting properties of Geiger-Mueller radiation counters was developed at Hanford. The deterioration is thought to result from damage to the gas and electrodes in the counter during the strong electric discharges that produce the counts. Studies at Hanford show that characteristics of counters changed in a simple manner with the amount of usage of the electronic tube in the counter.

The most easily measured characteristic, however, is the logarithm of the ratio of the height of the voltage pulses from the counter for two different counting rates. This quantity increases in proportion to the use the counter receives. The measurement can be made

while the counter is still in service and, if necessary, the counter can be replaced in advance of failure.

#### Atomic Submarine—KAPL

The spherical building that will house a submarine hull and its atomic power plant was completed during 1953. Thus the stage is set for the testing of a submarine nuclear-propulsion plant by the Knolls Atomic Power Laboratory (KAPL)—nuclear research center of the Atomic Energy Commission operated by General Electric at Schenectady.

Located at West Milton, NY, 18 miles northwest of Schenectady, the 20-story sphere constructed by the Chicago Bridge & Iron Company has a volume of more than 5-million cubic feet. Five miles of radiographed weld hold together its one-inch-thick preformed steel plates—total weight, 3850 tons—and make the structure airtight.

The fractional submarine, minus bow and stern, will be complete in detail and corresponds to the engine-room and maneuvering-room compartments of a seagoing submarine. The test hull is being constructed and fitted by the Electric Boat Division of the General Dynamics Corporation in whose Groton, Conn., shipyards the keel of the *Sea Wolf* was laid last September.

Constructed alongside the 225-foot sphere, the test hull will be skidded through an opening cut in the wall of

the sphere. Once the hull and other test facilities are inside and the opening is sealed, access to the sphere will be through air locks.

The nuclear power plant being built by KAPL is part of the submarine intermediate reactor (SIR) project.

"Intermediate" describes the neutron energy range at which the reactor will operate. SIR will be fueled with enriched uranium; the heat produced by fission will be removed by a liquid-metal coolant (sodium) that will convert water to steam to drive the propulsion turbine.

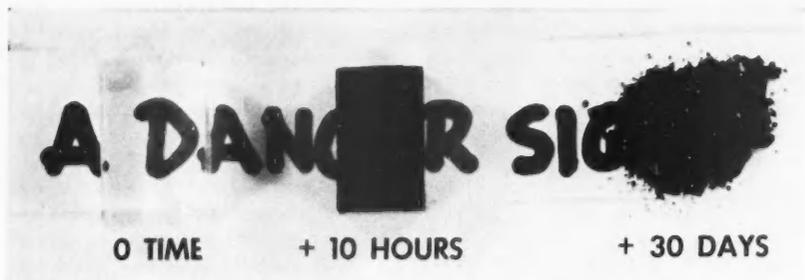
Studies of even more advanced nuclear reactors and power plants are making continual progress. The aim is to significantly increase the speed and endurance of an atomic-powered submarine.

#### Neutron Source

The thermal test reactor at KAPL was modified during the year to provide high neutron-flux levels and thereby broaden its usefulness as a research tool. Originally designed for precise radioactivity measurements and as a standard neutron source, the reactor has been modified to include water cooling for 10-kw operation; in addition it now provides neutron flux that can be used to produce experimental quantities of radio isotopes. This reactor can also be used for neutron beam experiments.



GIANT MANIPULATOR ASSEMBLES OR DISASSEMBLES MACHINERY IN RADIOACTIVE AREAS.



EXPERIMENT SHOWS DAMAGE TO LITHIUM FLUORIDE RESULTING FROM RADIATION EXPOSURE.

#### Solvent Extraction

A new type of equipment developed at KAPL is designed to overcome the limitations of apparatus now used in solvent extraction processes. Called the pump-mix mixer settler, it uses a unique stirrer and baffle arrangement to mix and separate two immiscible liquids. Permitting continuous operation, the equipment is compact, easily maintained, and highly efficient. By using multiple stages, it is possible to achieve difficult separations of radioactive prod-

ucts. A U.S. patent covering this development has been made available for licensing to industry by the Atomic Energy Commission.

#### Radiation Damage

Serious changes in solids can be produced by long exposure to radiation of 10-trillion neutrons per second per square inch of material. For example, KAPL scientists found that lithium fluoride of optical quality becomes opaque after 10 hours in a reactor; after

30-day's exposure it crumbles completely. They also found that neutron radiation will disintegrate plastics, harden metals, change the characteristics of semiconductors, and break down electric insulators.

Besides evaluating various materials under neutron flux conditions, KAPL scientists are trying to understand the fundamental nature of radiation damage. Their research involves both theoretical and experimental studies of damage to different classes of crystalline solids. It should result in a better understanding of radiation damage while revealing more about the general behavior of solids.

#### Reactor Simulator

Because hand calculating methods are impractical for analyzing the operation of a nuclear power plant, KAPL engineers developed a reactor simulator employed in conjunction with other analog computing equipment. This simulator represents the time behavior of the nuclear plant's power systems—including the reactor itself, piping, heat exchanger, and control components.

The response of the plant to various signals and disturbances can be studied in a fraction of the time required by hand-calculating methods. Hence, the actual control-component prototypes can be tied in and the over-all performance of the power system evaluated.

#### Biggest Manipulator

A 15-ton remote-controlled overhead manipulator developed for GE's Aircraft Nuclear Propulsion Department will make possible the assembly or disassembly of large machinery in radioactive areas.

Believed to be the largest of its kind in the world, the device will pick up heavy parts, position them, and fasten them in place. In addition, it can drill and tap holes; use power wrenches, hammers, or riveters; and handle a sheet-metal saw. While its grip lacks the flexibility of human fingers, the manipulator can telescope its "forearm" and revolve its "wrist." In other ways, however, it possesses the same degree of motion as the human hand and arm.

Resembling a gun turret, the manipulator will operate from a crane bridge 34 feet high; its vertical maneuverability will range from floor level to a height of 25 feet. The heart of the control mechanism is a system of eight amplidyne's that provide automatic control.

# Testing and Measuring

In 1953 a card-programmed calculator solved for General Electric many divergent problems in design and application engineering. Typical of the solutions was a digital scheme that determined the mechanical torque developed after a short circuit occurred on the generator of a three-unit set. In another instance calculations were carried out to analyze the operation of a mechanical rectifier during such transients as sudden overloads and supply voltage dips.

A problem in obtaining the natural frequencies of transformer windings was also solved with the help of the card-programmed calculator. This solution aided in predicting performance of power transformers undergoing severe electrical disturbances.

## Analog Dynamic Tester

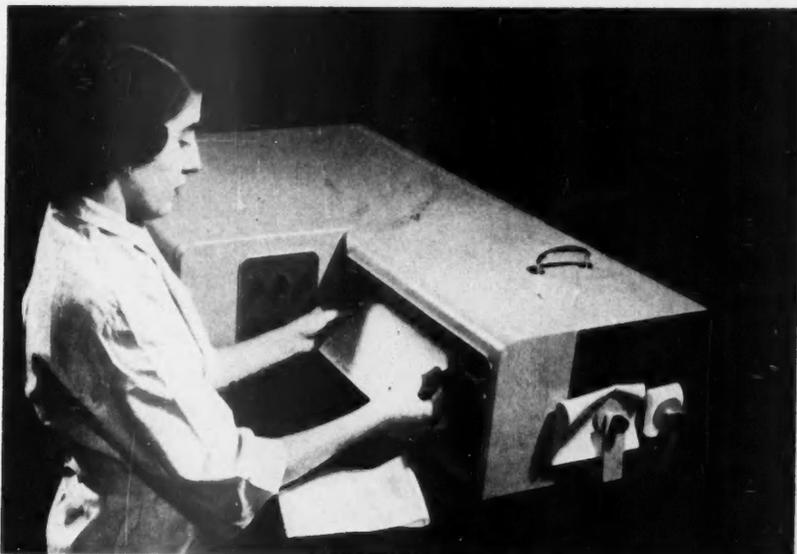
An analog dynamic tester for making acceptance tests of analog computers purchased by the Armed Forces was constructed in 1953. Although designed specifically for checking a gun-aiming computational system, its basic features may be applied to a wide field of applications.

In its present form the analog dynamic computer supplies three input functions to a computing system along with correct values of the six answers the system should compute. The computed answers are in the form of angular rotations, and the tester checks these angles to within plus or minus two minutes.

Test results recorded automatically show in magnitude, direction, and form the deviation of the computing-system answers from the theoretically correct answers. The tester is suitable for both shop and field operation.

## Radioactive Measurements

Gear wear is being measured by a highly effective technique—the use of radioactive gears. With this method minute traces of wear are detected down



NEW SPECTROPHOTOMETER RECORDS COLORS INDISTINGUISHABLE TO THE HUMAN EYE.



ELECTROMETER READS RADIATION DOSAGE OF POCKET-TYPE IONIZATION CHAMBER.

to about one five-hundredth of conventional measurements. In effect, two hours of radioactive wear measurement will furnish the same information as 1000 hours of previous measuring techniques.

Radioactivity found still another use in detecting the amount of air in an air-oil emulsion. Here, absorption of gamma rays from a Cobalt-60 source is a measure of the air in emulsion.

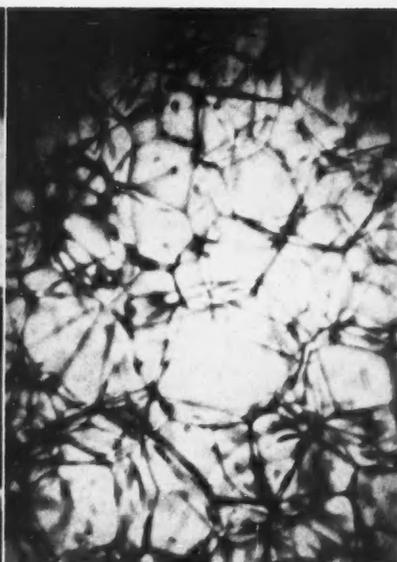
## Spectrophotometer

Developed during the year was a new recording spectrophotometer with advantages over its predecessor in speed of recording, compactness, and versatility. This instrument, capable of

measuring color differences indistinguishable to the human eye, is of particular value to textile manufacturers, dye makers, and printer's ink manufacturers.

## Mass Spectrometer

A new ion resonance mass spectrometer identifies constituent gases of an unknown gas mixture and measures the relative amounts of each. Based on the principle of resonance of ionized particles in a magnetic field, the device separates ions according to their mass-to-charge ratio. One of its most important uses will be as a continuous gas analyzer in the various process-manufacturing industries.



**X-RAY MICROSCOPE** (left) photographs details of specimens normally opaque to light. X-ray micrograph shows grain structure of an aluminum-tin alloy magnified 100 times.

**SYSTEM SURVEYS** up to 8.7 kv are now practical with butyl-molded hook-on transformer.

### Radiation Dosage

An accurate rapid means was made available for reading pocket ionization chambers, or "pencils," that record radiation dosage. This pocket-chamber electrometer measures voltage decrease on the pencil—essentially a small charged capacitor—as it is discharged. The voltage is in turn converted to a direct indication of exposure in milliroentgens.

### X-rays

Developed for chemical, metallurgical, biological, and medical fields, an x-ray microscope photographs details within specimens normally opaque to light. Magnifications equivalent to that of the conventional light microscope are available. A point source of x-rays is produced by focusing an electron beam to a very small spot on a tungsten window. A specimen placed near the source of x-rays produces an enlarged shadow on a photographic plate several centimeters distant.

### Ultrasonics

One of the main limitations of ultrasonic testing was removed with development of an automatic recording instrument. This method of testing was formerly totally dependent on a human operator's accuracy in recording each indication appearing on the cathode-ray tube. Now a finished chart gives a complete picture of test results, indicating any flaws present in the speci-

men. The new recording system permits a much higher scanning speed and thus increases reliability of the test.

Another development in ultrasonics is the use of surface waves to detect flaws in ceramics that exist on or near the surface. The high sensitivity of the ultrasonic tester easily detects tight and extremely shallow cracks. This factor plus the small size of the search unit and the mode of wave propagation offers a new approach to the non-destructive testing of ceramic and glass objects.

### Surge Voltage

Because corona discharge generally precedes insulation breakdown, the ability to detect corona is highly important. Two new instruments make this possible under 60-cycle and surge conditions: First, a surge corona detector detects corona pulses under transient conditions at a minimum of 10 millivolts. Second, an insulation analyzer with a 3000-volt output has a corona-peak voltmeter and dielectric-loss millimeter built in, with minimum readings of 100 microvolts and 5 microamperes, respectively.

A portable instrument that records surges under operating conditions was developed for use in any circuit subject to surges of short duration. Operated from standard 60-cycle power, the instrument records peak amplitudes of surges up to 5000 volts that may be as short as one microsecond to crest.

Smaller utilities and industrial plants can make high-voltage proof tests and locate faults in electric cable by renting a mobile test set complete with operator from GE's Wire and Cable Department. Having a 20-kv pulse generator for fault location, it is capable of putting out 100 kv d-c at 100 milliamperes (rectified full wave) for high-voltage d-c testing.

### Hook-on Voltmeters

Butyl molding was applied to hook-on transformers in 1953. Developed for outdoor-system surveys when used with inkless-type recording voltmeters, they are equipped for secondary grounding and open-circuit protection. The waterproof locking-type transformer can be hooked around either insulated or bare conductors up to 8.7 kv without interruption of service.

Another hook-on voltmeter introduced during the year was a low-cost pocket-size model. Seven current and voltage ranges are built into the instrument. To eliminate the possibility of reading the wrong scale, a range-changing mechanism makes visible only the one selected.

### Resistance Temperature Detector

Tungsten wire was used in a highly improved resistance temperature detector. It provides flexibility and standardization in a single design for measurements of  $-180$  to  $300$  C. Stability and long life of the instrument are

assured by welding the tungsten to lead wires and sealing it in a helium atmosphere.

#### Process Timers

To facilitate time-programming and timing of industrial processes, a line of compact process timers in single- and double-circuit form was introduced. Ten different time cycles from 60 seconds to 30 hours are achieved with identical parts except for motors and dials. Three or more associated circuits are controlled by interconnecting two or more timers.

#### Turbidimeter

A new recording turbidimeter is used to accurately and continuously record the turbidity, or murkiness, of liquids. Designed for use in municipal water-treatment plants, pollution-control agencies, or industrial waste liquids, the device measures turbidity as a function of light scattering. It can be installed directly in a process stream to record completeness and efficiency of the process.

#### Condensation Nuclei Meter

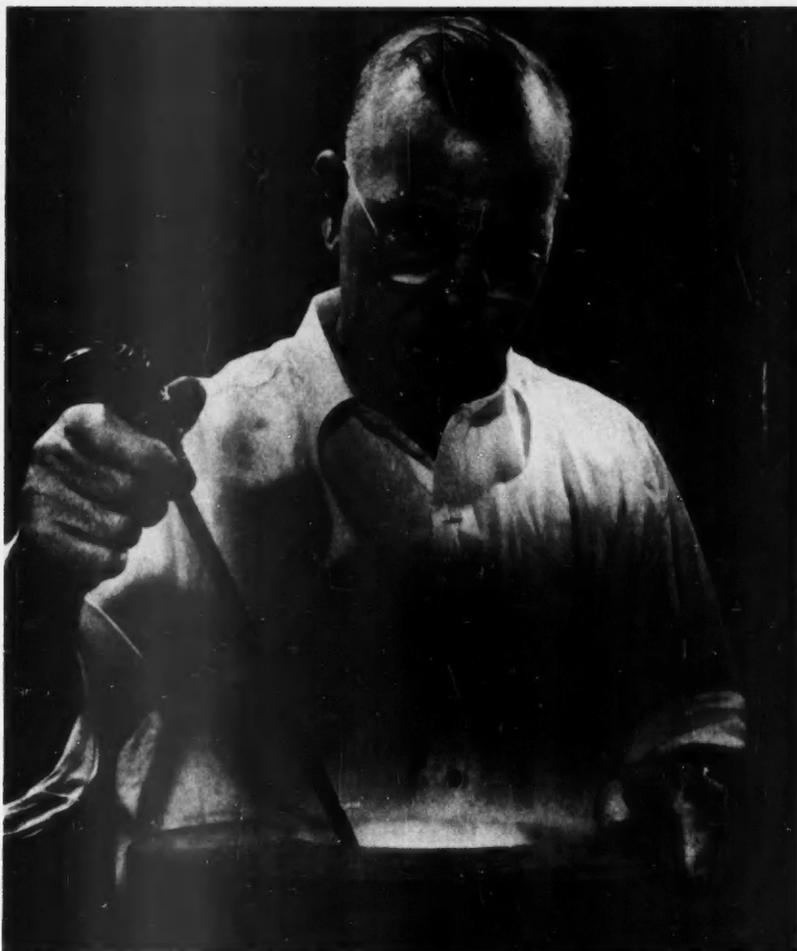
A new battery-operated condensation nuclei meter measures submicroscopic particles in the air. In urban surroundings most of these particles are products of combustion but are much smaller than smoke particles. A cloud is formed on the particles by a sudden expansion of air in the meter, and the decrease in light transmitted is a measure of condensation nuclei. An average smoke-free city has about 50,000 particles per cubic centimeter; in rural areas a value of 5000 is typical while 500 is common far out over the ocean.

#### Vacuum Ultraviolet Spectrometer

Researchers can more rapidly probe the mysteries of solid-state physics with the vacuum ultraviolet spectrometer developed during 1953. All equipment for the device is included in a single package, thus allowing rapid sample changing and transmission spectra recording.

#### Anodized Aluminum

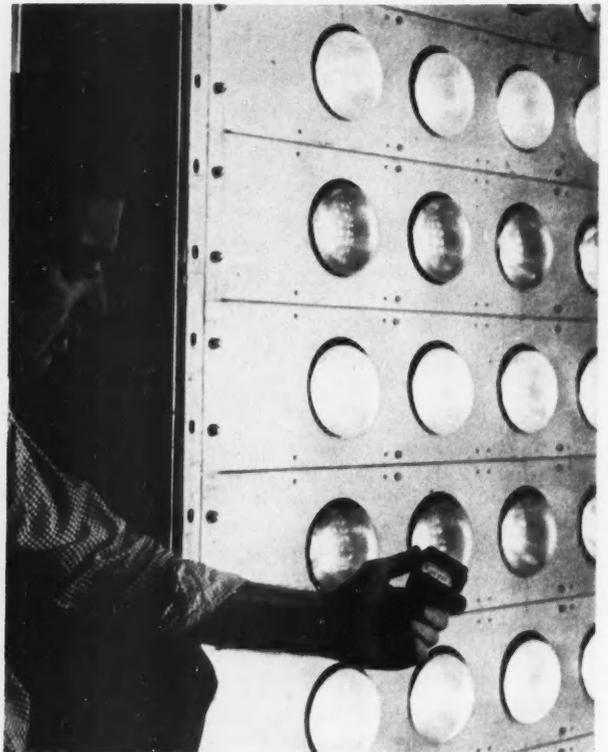
To determine the 60-cycle breakdown voltage of anodized coatings on aluminum, a special voltage-breakdown tester was devised. It operates on the principle that the breakdown voltage of an anodized coating is proportional to the thickness and type of film on the sample under test.



**TUNGSTEN WIRE** resistance-type temperature detector provides flexibility and standardization in a single design and gives an unusually wide range of temperature measurements.



**WATTHOUR METERS** with nominal 50-amp rating are capable of continuous operation up to 200 amp. Temperature rise under this load is 20 C lower than that of former meters.



IMPROVED ROUGHNESS SPECIMENS (LEFT) CONTROL QUALITY OF MACHINED SURFACES. INFRARED METER MEASURES HEAT OF DRYING LAMPS.



VACUUM GAGES ARE HIGHLY SENSITIVE AT LOW VACUUM PRESSURES (LEFT). PANEL INSTRUMENT WITHSTANDS 2000 FOOT-POUND SHOCKS.

### Fatigue Arrester

Equipment was designed to shut down a pneumatic fatigue machine when the sample's natural frequency changes 0.1 percent. The machine is stopped at varying degrees of specimen fatigue so that causes of failure can be investigated. A frequency meter indicates deviation from the specimen's natural frequency to an accuracy of 0.005 cps.

### Creep Tester

Creep-testing equipment placed in operation during the year determines the properties of high-temperature alloys with greater precision. Tests of creep and rupture can be run at temperatures up to 1800 F and loads to 10,000 pounds, with radiation losses from the furnace (350 watts at 1500 F) minimized by efficient insulation. Creep tests are made in both tension and compression. Employing an improved form of anticipating circuit, a heat control holds the specimen's temperature within plus or minus two degrees.

### Outdoor Butyl Current Transformers

Another development was the first butyl-molded current transformer for outdoor 5-kv service. Along with a corrosion-resistant structure, it has versatile mounting features that permit top-, side-, or bottom-connected installations.

### Watt-hour Meters

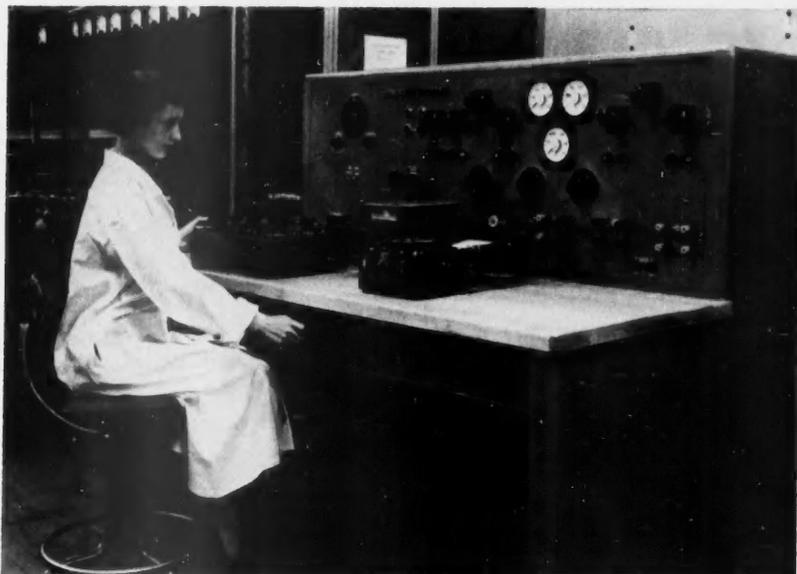
Newest of the watt-hour meters with magnetically suspended rotors (Type I-50) is one with a nominal 50-amp rating capable of continuous operation up to 200 amp. At this load its temperature rise is 20 C lower than that of the superseded design at 150-amp load. The small size and co-ordinated insulation of the basic I-50 are retained in the new meter by using a unique stator design.

### Differential Voltage Indicator

A differential voltage indicator makes possible measurement of differences in d-c voltages or in any other quantities convertible to d-c voltages. Differences of 1 millivolt to 30 volts in inputs of 1 to 400 volts can be measured up to a 300-to-1 ratio.

### Surface Roughness

Valued throughout industry are surface-roughness specimens that are used to specify, control, and check the quality of machined surfaces. Now more accurate and lighter specimens are made by a process of electroforming nickel on



CONSOLE STANDARDIZES INSTRUMENTS SUCH AS WATTMETERS AND VOLTMETERS.

master sheets. Increased accuracy results from closer control of the master surfaces, and 50 percent lighter weight is obtained by eliminating lead backing.

### Infrared Meter

Rapid evaluation of infrared processing such as paint-baking and other drying-lamp applications was made possible by the introduction of a high-range infrared meter. Radiant energies up to 10 watts per square inch are read directly in the 3000 to 35,000 angstrom range. Of pocket-size, the instrument is completely self-contained.

### Leak Detector

Leak detectors that sense halogen gas are now 30 percent lighter. A new balancing circuit for automatically compensating background air contamination and a loud-speaker—in addition to the indicating instruments—are contained in the 17-pound control unit. One model incorporates an instrument and flashing light in the pistol-like "sniffer."

### Vacuum Gage

A simple low-cost gage was developed during the year for direct continuous reading of vacuum pressures from 1 to 20,000 microns. The gage components are designed for 1000 microns at mid-scale, providing high sensitivity at low vacuums. This gage makes these unusual features available to laboratories and industry.

### D-c Instruments

Portable d-c ammeters and voltmeters in both  $\frac{1}{4}$  and  $\frac{1}{2}$  percent ASA accuracy

classes were introduced with many improvements over the familiar mahogany case design. Because of spring-mounted jewels, break-resistant molded windows, and rugged plastics cases, the new instruments, weighing 50 percent less than the older type, can withstand rougher treatment.

### Shock-resistant Instruments

Sealed and rugged panel instruments built for the Signal Corps are capable of withstanding 2000 foot-pound shocks. Their heavy flat glass windows are sealed by a titanium-hydride process. Included in their design are sponge-rubber-mounted jewels, beryllium-copper control springs, and silicone-rubber terminal seals.

### Portable Galvanometer

Improved high-sensitivity portable galvanometers were introduced in 1953 for measuring low values of current and voltage in laboratories and factories. Versatility is provided by a translucent scale tilted at 15 degrees. The instrument's moving elements can be easily changed for different measurement scales.

### Instrument Standardizing

An instrument standardization console was developed to meet the frequent need for standardizing ammeters, voltmeters, and wattmeters. Instruments are standardized directly without having to resort to previously standardized instruments.

# Power

In the field of power, studies were made to evaluate recovery voltage-rate requirements of electric power systems as they may exist in 1960. These were initiated in view of current interest in air-blast circuit breakers that depend for their interrupting capacity on the rate-of-rise of a system's recovery voltage. Although such investigations have been carried on extensively in Europe, they are recent in America because of the predominant interest for the past 10 years in oil circuit breakers.

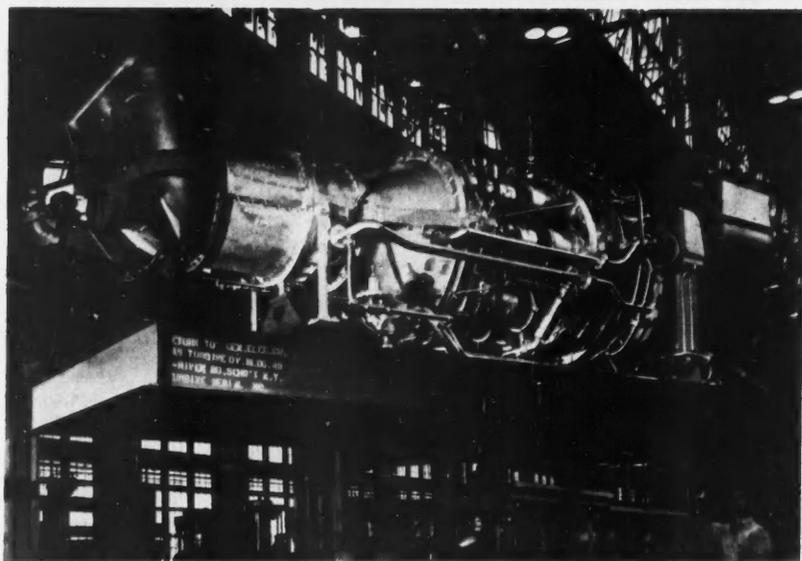
Also studied were abnormal voltages sometimes experienced on distribution systems having shunt capacitors when one or two phase conductors are opened. Prior to this study investigations did not simultaneously include the effects upon abnormal voltages of both the system load and the transformer's magnetizing characteristic. But this was accomplished by simulating in miniature a grounded wye, or four-wire, distribution system, with floating-wye, or delta-connected, capacitor banks for kilovar supply.

A survey in 1953 showed that series capacitors were being applied to increase over-all power-system economy. And to evaluate the best location, economy-wise, for series capacitors in a transmission system, four methods of installation were investigated. The conclusion reached was that based on a firm power-supply transmission, the most economical and practical location for series capacitors is in the intermediate switching stations.

Incremental transmission losses are another important factor in the economical operation of a power system. During the year their analysis was greatly simplified by development of transmission-loss formulae expressing system losses in terms of plant and interconnection loadings. Based on these formulae, a penalty-factor computer is undergoing construction for a large utility. When completed, its use will permit a higher degree of operating economy, for the computer will determine instantaneously the correction factors to be applied to each station in scheduling power plant loadings.

## Turbines and Generators

Highlighting power progress in the past year was shipment of the first



**DIRECT-COOLED** generator field (top)—another step toward larger 3600-rpm generators—was installed in a hydrogen-cooled turbine-generator rated 125,000 kva. Simple-cycle gas turbine (bottom), one of 10 two-shaft units, begins journey to oil fields in Venezuela.

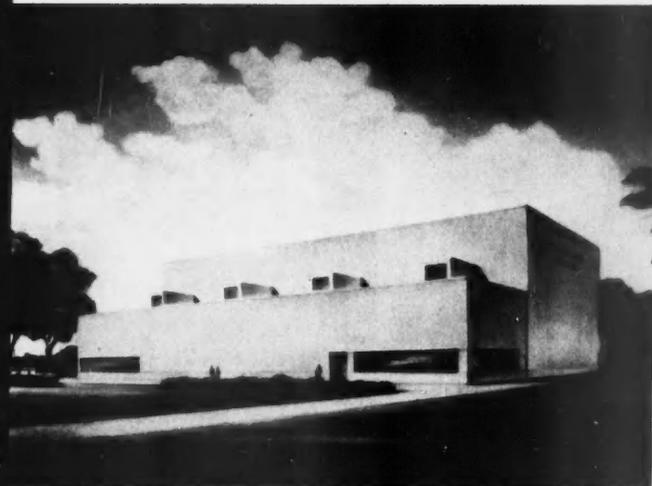
turbine-generator field with direct-cooled conductors. It was applied to the conventionally cooled 125,000-kva armature of a generator operated by a large eastern utility. By means of an airgap pick-up design, the field is directly cooled as gas is scooped from the airgap and forced into hollow copper conductors. Hence temperature drop through the conductors' insulation is avoided.

The field was built to evaluate design and to gain experience in manufacturing techniques. Tests in the factory prior to shipment indicated that at 30 psig hydrogen pressure the field's capability could be increased to double that of

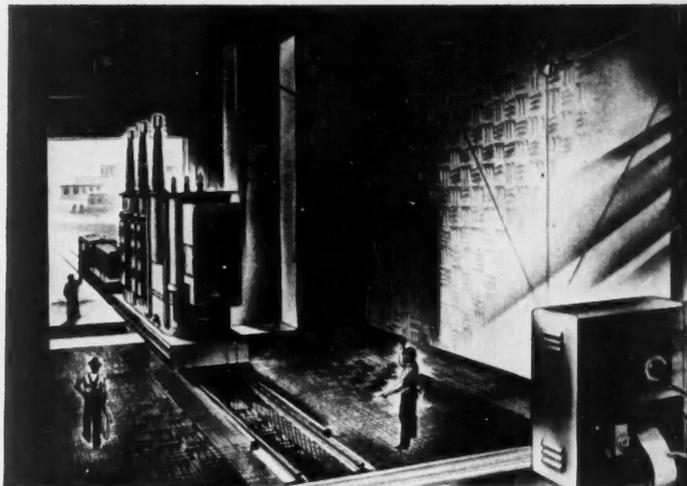
fields with conventional ventilation at the same gas pressure.

The development of direct-cooled fields is considered a necessary and important step toward meeting customer requirements for extremely large 3600-rpm generators.

Three 3600-rpm turbine-generators, largest of their kind in the world, began service in 1953. Rated 216,000 kva at 30 psig hydrogen pressure, all are performing satisfactorily at the Joppa Station of Electric Energy, Inc. The generators are of double-frame construction with the outer frame divided into three sections. Their cores are made



**TURBINE LABORATORY** under construction at Schenectady will direct attention to more efficient use of steam for generating power.



**TRANSFORMER NOISE** will be studied in a modern sound-test laboratory—largest of its kind—located at Pittsfield, Mass.

of oriented-grain silicon strip and their field windings of Cond-Al, a new high-strength high-conductivity aluminum alloy. An additional 19 machines of similar rating are on order.

The largest 1800-rpm turbine-generator now operating went into service for the Consolidated Edison Company of New York during the latter part of 1952. It is rated 225,000 kva at 15 psig hydrogen pressure with a 245,000-kva capability at 30 psig hydrogen.

During 1953 a number of hydraulic turbine-driven generators having a combined output of 860,000 kva were shipped to various utilities, industries, and governments. They included three huge 73,700-kva generators—the largest electric machines in physical size ever built—for Columbia River's McNary Dam.

Also built or on order are five geared steam turbine-generators of the salient-pole type. Operating at 25 cps and ranging from 7500 to 25,000 kva in size, they will serve as power supply generators for various industrial customers.

The American Gas and Electric Company has ordered a 120,000-kw turbine-generator of highly advanced design for its Philo Station. Operating well above the critical pressure of steam, 3206 psia, the new plant will be the most efficient generating unit ever built. Its unprecedented steam pressure—4500 psig—is almost double the highest pressure currently used for power generation; its steam temperature of 1150 F is 50 degrees above the highest temperature.

The steam through the turbine of this unique plant will be heated twice, and its generator will incorporate the newest

developments in ventilation. Such a project represents a progressive spirit on the part of the power industry to seek improved methods of generating electric energy at lower cost.

Construction of a product-development laboratory began in August, with a completion date planned for the end of 1954. The new facilities will make it possible to explore new areas in the development of power-generation equipment. Research will be carried on in both the high- and low-pressure sections of turbines and in the design of turbine buckets. Also, certain types of generators will be tested under no-load conditions.

An electronic computer is now solving turbine-design problems that would take months to calculate if handled by ordinary means. Programming is under way to use it for determining heat balances of turbine-generator installations when preparing propositions. Other calculations will be made when programs are completely designed.

#### Gas Turbines

Last year the first oil-refinery application of a combustion gas turbine driving a centrifugal compressor was made. The single-shaft unit consists of a 5700-hp simple-cycle gas turbine driving a 16-stage centrifugal compressor. Process gas entering the compressor at 15 psia is discharged at 285 psia. A waste-heat boiler recovers exhaust heat from the gas turbine for generating process steam. Used to start the unit is a 500-hp steam turbine.

Installation of 10 simple-cycle two-shaft gas turbines was started in 1953 at

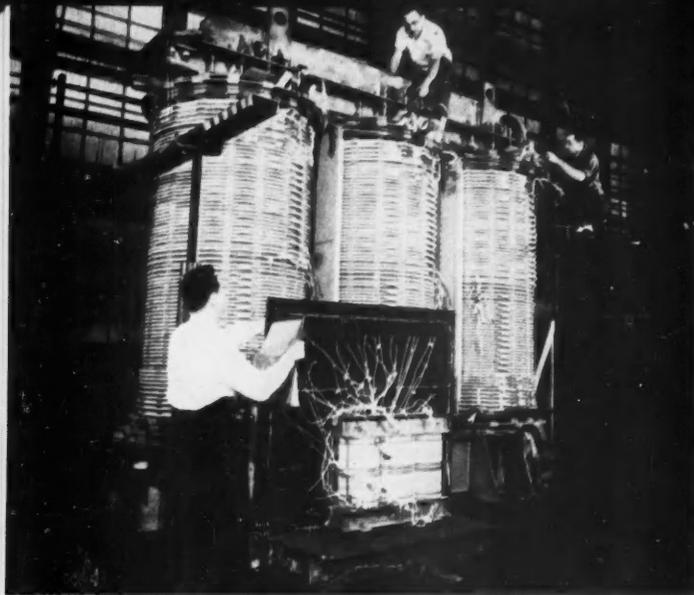
Lake Maracaibo, Venezuela. Placed on a large platform in the middle of the lake, the turbines will drive centrifugal compressors for repressurizing oil fields below. As oil from the fields is pumped to a lakeside refinery, the attendant natural gas will be piped to the turbine-compressor platform at 5 psig. There the gas will be compressed in seven stages to 1925 psig and pumped back into the earth.

Gas turbines of the two-shaft type were selected for this application because of the high-speed load range. All are designed with explosion-proof electric accessories.

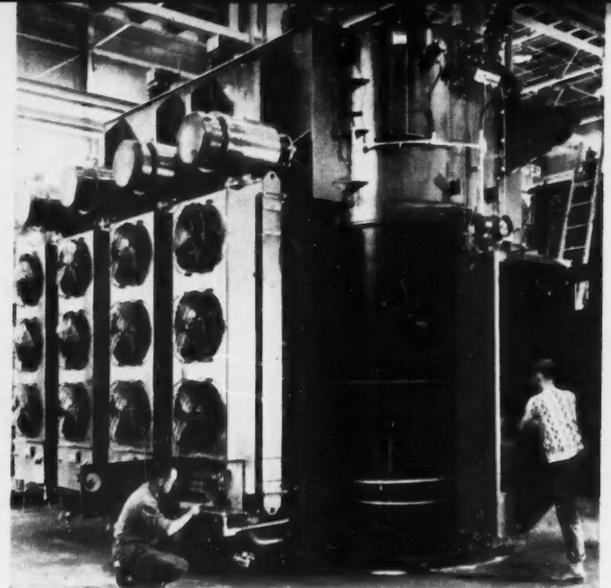
#### Transformers

A major contribution to large power transformers was the development during the past year of the electromagnetic model. With this new tool engineers can, in the design stage, quickly obtain knowledge of transient voltages in any power transformer. Developed over a period of several years, the electromagnetic model combines the best features of the geometric and equivalent-circuit models it supersedes. In all cases its accuracy is more than adequate for design purposes. A model of a 300,000-kva 161-kv transformer has already been built and tested and the design of this unit is now under way.

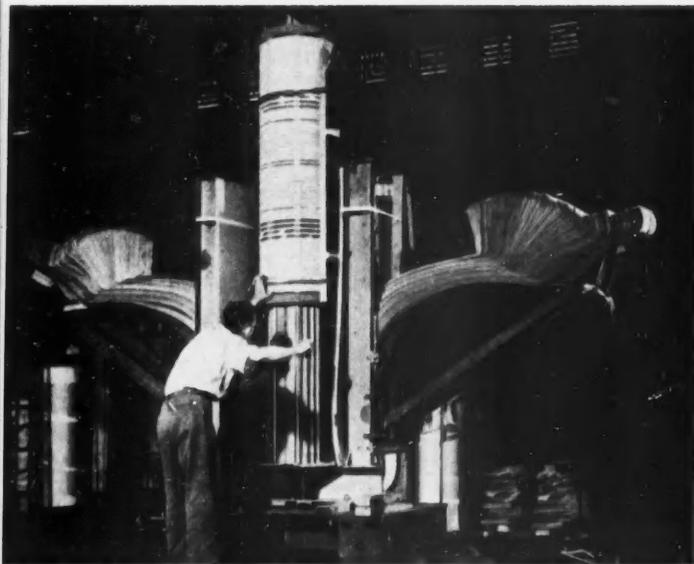
In 1953 construction was begun on a million-dollar sound-test laboratory. The largest of its kind in the world, the new laboratory will be used for studying noise in power transformers. Although most of the factors contributing to such noise have already been determined, adequate facilities were



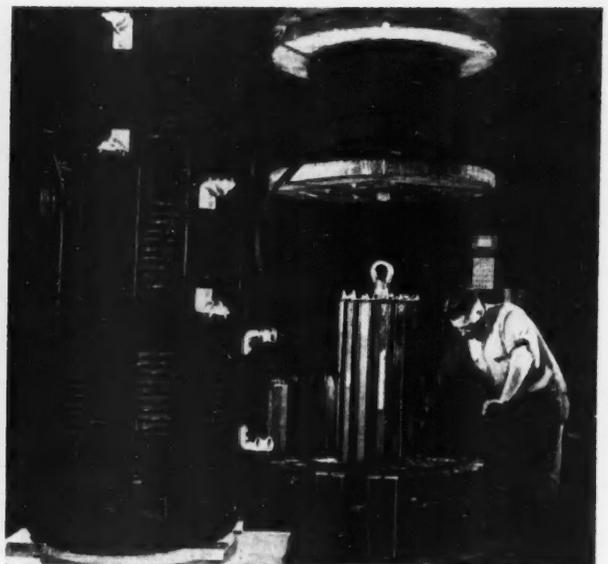
**ELECTROMAGNETIC MODEL** of a 33,333-kva power transformer is only 1/6 the size and 1/216 the weight of its bigger brother.



**HIGHEST-RATED POWER TRANSFORMER**, 175,000 kva, steps up voltage from 17,500 to 115,000 volts. It is forced-oil, air-cooled.



**ASSEMBLY OF WINDINGS** on wound-core power transformer, extended to all single-phase units rated up to 5000 kva, utilizes corisil.



**CURRENT-LIMITING REACTOR** with aluminum conductor markets for 10 percent less than similar reactor with copper conductor.

never before available for sound testing large transformers and for evaluating progress in reducing the transmission of noise.

Two 175,000-kva power transformers, the highest rating yet built by General Electric, were shipped during the year. They are of the forced-oil air-cooled type employing seven oil-to-air heat exchangers. Installed in two new stations, the transformers step up generator voltages from 17,500 to 115,000 volts. They were shipped upright and completely assembled except for bushings and unit coolers.

The use of wound-core power-transformer construction was extended to include all single-phase units rated 5000 kva and below. Thus, full advantage of the directional properties of corisil—a highly oriented cold-rolled silicon steel first used in distribution transformers—can be realized.

A new type of bridge network for the measurement of impedance and impedance loss in power transformers was a major development of 1953. Application of this network has reduced errors involved in low-power-factor loss measurements by as much as 10 to 1 over

conventional instruments. In addition, it has replaced conventional watt-meters used for obtaining accurate loss data on all induction voltage regulators.

A new member of the load-ratio-control family went into standard production during the year. Developed especially for the medium kilovolt-ampere transformer field, it has a double-break-type contactor incorporated with a tap selector into a unit assembly on one panel.

New terminals to which either aluminum or copper conductors can be connected are now supplied on all pole-



**BUSHING CONNECTOR HOLDS ALUMINUM WIRE UNDER 200-POUND PULL.**



**CREPE-PAPER INSULATION** for cable in liquid-filled transformers won't break when sharp bends are made in the cable, and will not contaminate oil.



**VOLTAGE REGULATOR** designed for urban lines provides 10 percent higher and lower range of regulation in 32 steps.

type distribution transformers. Unique spring devices prevent connections from loosening because of temperature changes or, in the case of aluminum, cold flow.

Experimental distribution transformers using aluminum instead of copper windings are being produced in a number of ratings. Over-all weight, dimensions, and electrical characteristics of these aluminum-wound units are practically identical to copper-wound transformers. While many of the new units are being tested on customers' lines, there are no plans to shift to the use of aluminum at this time.

In accordance with the new EEI-NEMA standards, network transformers from 300 to 1000 kva are now built with brazed-on wiping sleeves. This modification eliminates leaks caused by gasket failures.

A new suspension-type transformer was introduced for use with small script and block-letter neon signs. Smaller than any on the market, the new unit has an attractive gray finish. Its high-voltage leads come out through a porcelain insert in one side of a ballast-type case.

The rapid expansion of television has forced public utility companies to make doubly sure that electric apparatus on their lines is free of radio noise. Such a situation requires that tests be made of new apparatus and frequent checks made of old. To this end a 100,000-volt 50-kva testing transformer was designed with an extremely low internal radio noise level. It makes an ideal power supply for NEMA-approved test equipment.

The impulse breakdown mechanism of transformer oil in a nonuniform field was investigated during 1953. And high-speed photographs revealed a remarkable similarity between the propagation of a negative streamer in oil and a stroke of natural lightning to open terrain. The over-all velocity of oil streamer propagation was found to be one-tenth inch per microsecond at critical breakdown—one-fiftieth that of a lightning-stroke leader.

A strong flexible crepe-paper insulation having excellent dielectric properties was developed to insulate cable in liquid-filled transformers. Creped in two directions, it won't break when sharp bends are made in the cable,

nor will it contaminate the insulating liquid.

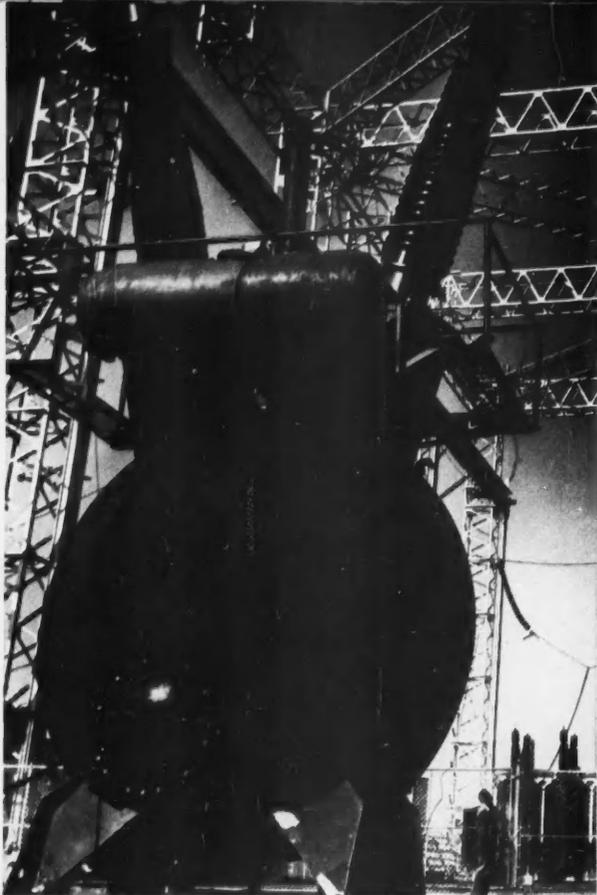
#### **Arresters and Cutouts**

A new-type lightning arrester is now provided on all EEI-NEMA 7200- and 7620-volt unit-type distribution transformers. Applicable anywhere on the system regardless of short-circuit currents, the new 9-kv arrester for 7200-volt transformers weighs only 10 pounds and is only 14¼ inches long. The 10-kv arrester for 7260-volt transformers weighs 11 pounds and is 15½ inches long.

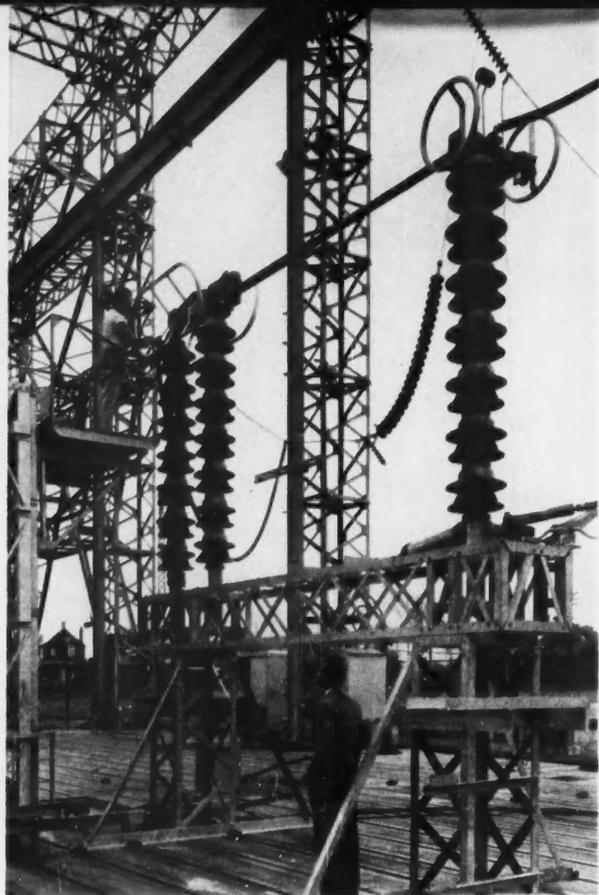
Large numbers of station-type lightning arresters are in use on superhigh-voltage power systems. Both suspension and base-mounting types have been furnished for power projects involving 330-kv transmission—the highest commercial transmission voltage now operating in the United States.

Ratings of station-type arresters and protective capacitors were extended during the year. They will now provide lightning protection for large a-c rotating machinery rated up to 24 kv.

Improved and simplified, new 7.8-kv and 15-kv 100-amp open-dropout cut-



**ONE POLE** of a high-speed steel-clad impulse circuit breaker, rated 25,000,000 kva, was built for three-phase 330-kv service.



**AIR SWITCH** designed to co-ordinate with circuit breakers (left) is rated 330 kv, 1600 amp and has an over-all length of 22 feet.

outs were introduced during the year. Their hollow-tube insulators are made of wet-process porcelain with compression-clamped fittings for maximum mechanical strength. The cutouts are of birdproof construction, and are shielded against dirt deposits and sleet. Interchangeable fuseholders in both ranges provide for 2000-amp interrupting capacity.

A new line of universal cable-type fuse links gives users all the benefits of standardization. Some features of the new EEI-NEMA links are low melting temperatures, continuous current-carrying capabilities, and long auxiliary tubes. They are electrically and mechanically interchangeable with other makes of EEI-NEMA standard fuse links.

#### Regulators

The need for larger single-phase pole-type step regulators for use on urban lines was satisfied with the introduction of a 200-amp 2500-volt single-phase regulator. This new design conforms to the same rigid standard of ASA Class 1 Accuracy as existing regulators of lower ratings. It provides a 10 percent higher

and lower range of regulation in 32 five-eighths percent steps.

An all-electric control for voltage regulators, used to control high-intensity runway- and approach-lighting systems, automatically selects any one of five predetermined brilliances. The average brilliance change takes about two seconds, without interruption to the system's power supply. Also, maximum voltage on individual lamps is limited so that excessive burnouts won't occur in short periods of time.

#### Reactors

Cast-in-concrete current-limiting aluminum-wound reactors that meet all requirements of the ASA standards recently went into production. Because of savings in cable cost, they are being marketed for 10 percent less than equivalent copper-wound reactors.

#### Switchgear

During 1953 a number of large complex "brain centers"—specifically engineered duplex switchboards—were built for one of America's major atomic-energy projects. These switchboards will control and protect electric equipment

fed from the project's incoming, distribution, and auxiliary power supplies.

High-speed steel-clad impulse breakers with high capacity and reduced oil volume went into production during the past year. Their voltage ratings run from 138 to 330 kv. At 138, 161, and 230 kv, the new breakers have short-circuit interrupting ratings of 10,000,000 kva; their operating time from fault inception to clearance is three cycles. For 330-kv service—the highest transmission voltage currently used in the United States—the breakers have a short-circuit interrupting rating of 25,000,000 kva. This establishes a world's record in the high-voltage circuit-breaker field.

Another development is a new operating mechanism for station-type air-blast circuit breakers. Of single-cylinder design, the mechanism's speed is controlled by a full-stroke direct-connected double-acting oil dashpot. Maximum air pressure is maintained in the driving cylinder throughout its operating cycle, and speed is controlled by the dashpot's resistance to motion. The mechanism is a great advancement in the station-type cubicle field.

When high-capacity circuit breakers operate at or near their full rating, transient forces occur at high speed because of rapid acceleration and deceleration of moving parts and high pressures generated during arc interruption. To measure these forces, new high-speed-travel and pressure-measuring equipment was developed.

Contributing to the design of high-voltage oil circuit breakers—138 kv and up—is a technique used in conjunction with the electrolytic analyzer. From scale-model circuit breakers set up in the electrolyte, three-dimensional magnitude and distribution of electric stresses are determined at high voltages.

The highest voltage switch ever furnished in regular production is a new outdoor air switch rated 330 kv, 1600 amp. Having an over-all length of 22 feet, its height with the blade open is approximately 25 feet. Designed to coordinate with 25,000,000-kva power breakers, a total of 131 switches are in the process of manufacture and shipment.

Single- and three-pole automatic circuit reclosers were redesigned to function more efficiently in distribution systems. Current ratings in two frame sizes now range from 25 to 140 amp, while operating characteristics of the new reclosers permit their interchangeability with other makes. A tank seal was provided to eliminate moisture contamination of the insulating oil. Along with other improvements, the use of inhibited oil provides longer life and decreased operating maintenance.

The metal-enclosed isolated-phase bus was extended in rating to 8000 amp at 14.4 kv—the highest rating in industry. Able to conduct power from generators rated 200,000 kva, the bus utilizes aluminum in place of copper conductors. Also, a new method for silver plating aluminum conductors was developed during 1953, and isolated-phase bus equipment design was made available in even higher ratings.

A new insulation that won't sustain combustion increases the safety and dependability of metal-clad switchgear. During 1953 it replaced all sheet-insulating material.

#### Protective Relaying

The first installation of all-electronic directional-comparison carrier-relaying equipment was completed last year. All measuring and comparing functions of this equipment are performed by elec-



**ELECTRICAL FAULT TESTER** reduces manufacturing losses by providing improved control of the quality of capacitor paper during production. It is also a valuable laboratory tool.

tronic means, utilizing industrial tubes, germanium diodes, and electrolytic capacitors. Operating times of less than one cycle were obtained. This departure from conventional electromagnetic relaying makes possible extremely high-speed operation, and thereby improves system stability and service continuity.

#### Capacitors

Subminiature capacitors were developed in 1953 for application in high-quality electronic equipment and communication circuits. Ratings cover a range from 0.001 to 1.0 microfarads, 100 through 600 volts d-c. The capacitors have silicone-rubber bushings that provide exceptional resistance to physical and thermal shocks.

Another development was a micro-miniature line of electrolytic capacitors for use in hearing aids and other small electronic devices. This new line satisfies the need for extremely small low-voltage capacitors with relatively high capacitance ratings.

A new paint with improved resistance to salt spray, humidity, and chemical fumes is being applied to all power-capacitor units and housings. This super-melaglyp paint withstood salt-spray tests for 1400 hours—twice as long as its predecessor.

Since 1948 the average size of distribution transformers has increased steadily. To provide a low-cost solution to the problem of secondary power-factor improvement, a 5-kvar 240-volt secondary capacitor was introduced last year. It sells at a cost-per-kvar lower than the 3-kvar capacitor.

Improvements in dielectric materials during the past few years made it possible to build a 15-kvar 230-volt secondary capacitor in a case only slightly larger than that used previously for a 7½-kvar capacitor.

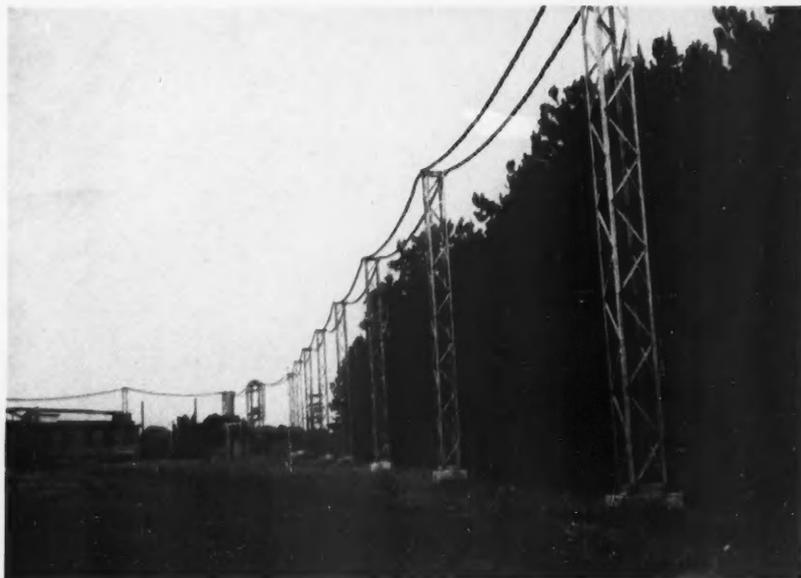
Completely redesigned in 1953 was the line of factory-assembled automatically switched open-rack-assembly capacitors for pole mounting. These can now be furnished without switches, with two types of oil switches, or with additional units in place of switches. Available are a wide variety of voltage and kvar combinations.

Building-block equipment introduced during the year consists of capacitor units, buswork, and fuses, all housed in a steel framework, factory-assembled, and shipped as a package. With these building blocks, ranging from 250 to 600 kvar and from 2400 to 7960 volts, any voltage and kvar rating can be constructed by assembling the blocks in proper series and parallel arrangements.

Improved control of the quality of capacitor paper was made possible by development of an electrical fault tester. It provides a more discriminating evaluation of faults in capacitor paper during production than was formerly possible, thus reducing manufacturing losses. In addition to its importance as a production tool, the tester is of great value in the laboratory.

#### Cable

Facilities are undergoing expansion for the production of aerial cable that will simplify tapping for future load conditions.



**PREASSEMBLED AERIAL CABLE**, insulated with varnished cambric, was installed at the Highland Cotton Mills, High Point, NC. Parallel feeders carry power to five load centers.



**POWER TAKE-OFF PLUG** is utilized in a plug-in-type busway distribution system.

When voltage and conductor size are beyond the practical limit of rubber insulation, aerial cable is now thermoplastic jacketed and insulated with varnished cambric.

The corrosion problem of preassembled aerial cable in installations such as chemical plants and paper and lumber mills was solved during the year. The cable is now furnished with the messenger and binder protected by thermoplastic or neoprene jackets.

Underground feeder cable is now available in one-, two-, or three-conductor constructions and in sizes No. 14 to 4 Awg inclusive. It is primarily intended for farm use where service-entrance conductors are brought to a pole located in the barnyard.

An improved thermoplastic insulated wire for electric machine tools is rated for operation at 90 C. The wire carries a type TW rating at 60 C and has high

resistance to water, solvents, acids, and alkalis.

Another thermoplastic appliance wire was made available for use where ability to withstand high operating temperatures is the prime requisite. It is rated for safe operation at 105 C.

#### Rectifiers

A new 13,000-volt d-c 25-ma power pack was introduced for users of electrostatic air-filter equipment. Employing selenium rectifiers, the device has the advantages of reliability and long life. Also, circuit improvements over conventional packs provide it with a more favorable volt-ampere characteristic.

After three years of laboratory and field tests germanium power-rectifiers are being successfully used in applications ranging from electric-truck battery chargers to large industrial power-conversion units. Largest of the germanium power-rectifier installations to date is rated 160 kw and delivers 1350 amp at 120 volts d-c. Germanium's high efficiency in the power field—98 to 99 percent—promises to bring about major changes in conversion from a-c to d-c.

The development of miniature rectifiers has opened new fields of application. They are especially useful when current of only a few milliamps is needed over an extremely wide range of voltage. For example, being made for the military are tiny assemblies that have an output of only a few volts and microamperes. At the other extreme, a linear accelerator used for nuclear research

employs miniature rectifiers with an output of 500,000 volts at several milliamps.

#### Insulators

During 1953 a fog-type suspension insulator was developed for use in areas where atmospheric contamination is a serious factor in performance. The new insulator has a smooth outer surface, free from corrugations that can act as dirt traps and can be easily short-circuited by dripping water.

A 7½-inch-diameter suspension insulator was made more rugged and shock resistant than before. Its shell was made deeper for more effective protected leakage distance, and its inner corrugations were opened for easier cleaning in dirty atmospheres. Clear open space between the inner corrugation and pin simplifies connection under hot-line working conditions.

Several years ago it was found that compression-glazed surfaces give insulators higher mechanical strength and much greater shock resistance. But it has now been demonstrated that to obtain maximum electrical performance, glaze thickness must be held within a few thousandths of an inch. And so means were developed to accurately control the glaze thickness on suspension-type insulators.

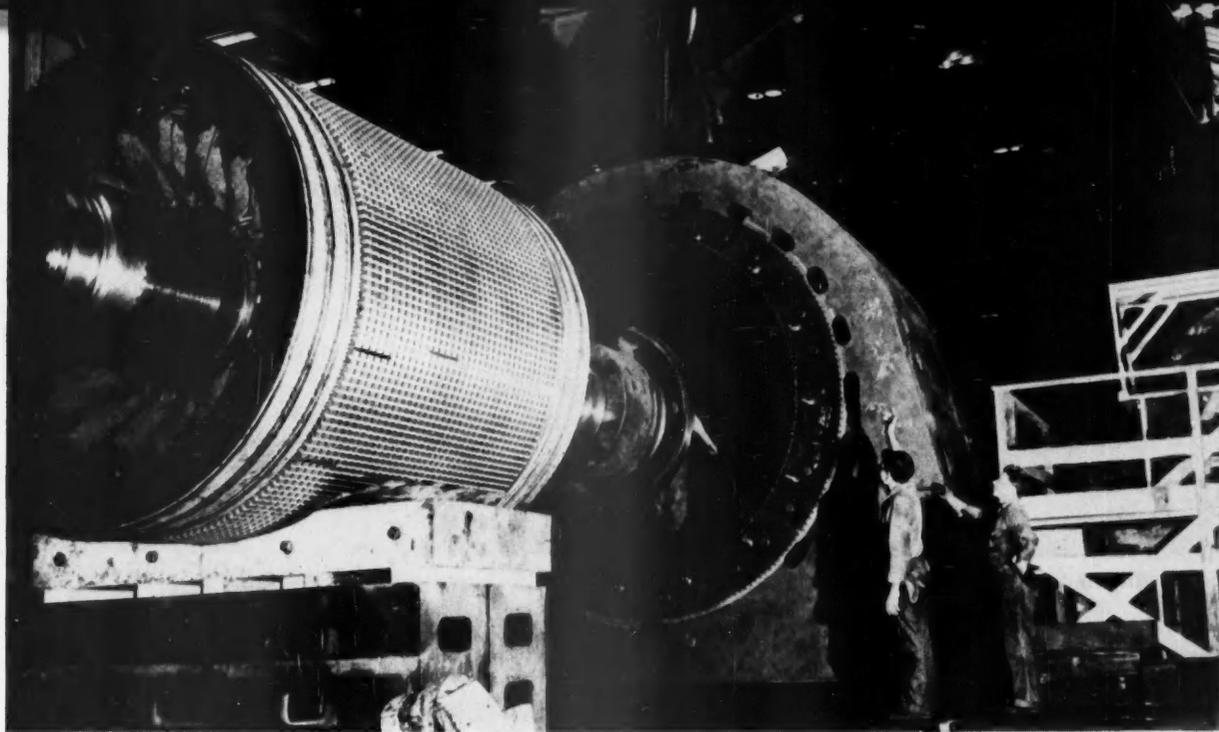
#### Other Developments

The International Business Machines Corporation will install the plug-in type of busway distribution system throughout its new research center at Poughkeepsie, NY. Thermal magnetic circuit-breaker protection for all convenience outlets in monitor boxes is a distinctive feature of this equipment.

A newly designed device for distribution systems now combines ground detection and neutralizing functions.

Also designed for these systems was an improved power take-off plug. It incorporates a switching mechanism, provision for current-limiting, high interrupting-capacity fuses, and other important features. Horsepower-rated, it is suitable for conventional, time-delay, and current-limiting fuses.

An unusually compact two-pole common-trip thermal-magnetic circuit breaker is now available in ratings of 10 to 50 amp, 120/240 volts, a-c. Designed so that an overload on either pole trips both poles simultaneously, it may be used as a main breaker in panel boards and load centers, or as branch circuit protection.



ROTOR FOR 45,000-HP INDUCTION MOTOR BEING ASSEMBLED FOR NACA'S SUPERSONIC WIND TUNNEL AT MOFFETT FIELD, CALIF.

## Industry

American industry continued to expand and modernize during the past year, with electricity playing a prominent role. Although the percent of power privately generated by industry relative to that purchased from utilities has dropped steadily, its actual generating-plant capability has risen from 12,750,000 kw in 1946 to over 15,000,000 kw in 1953.

Today the average American production worker is using electricity at the rate of 16,000 kw-hrs per year. And in the years since 1946 his productivity has risen some 20 percent. At the same time the electric "content" of the average industrial product has increased 24 percent.

The phenomenal rise in industry's use of electric power required in turn the application of sound engineering principles of power distribution. Modern distribution systems should now include such features as: 1) neutral grounding at all voltage levels, 2) combination 480/277-volt systems for small load-center distribution, 3) greater selectivity of feeder protection, and 4) adequate interrupting capacity of circuit breakers.

Throughout industry there is an ever-widening use of continuous processes—manufacturing techniques that

have been stimulated by adjustable-speed drives and automatic controls for regulating to close tolerances such process variables as speed, load, and tension. Meanwhile, electric equipment responsible for the success of these processes grows more complex. And it is more important than ever that an analytical approach be employed to evaluate equipment before it is actually built. Already, application and design engineers are making extensive use of analog computers, differential analyzers, and other mechanical aids.

### Motors

Four induction motors, rated 45,000 hp at 685 rpm and 6900 volts, were furnished the National Advisory Committee for Aeronautics (NACA) Ames Laboratory wind tunnel at Moffett Field, Calif. They will be connected in tandem to produce a total of 180,000 hp to power a giant compressor that will drive air through the wind tunnel at supersonic speeds; the compressor rotor was also built by General Electric.

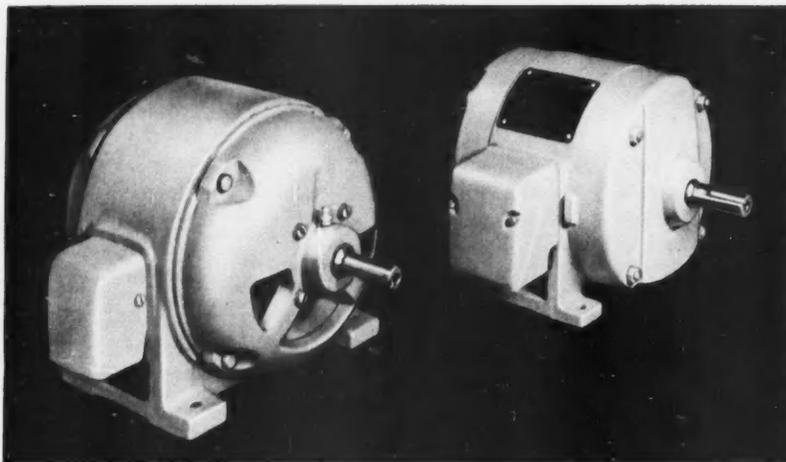
Also under construction for the NACA are three other wind-tunnel drives, the largest and most powerful induction motors ever built by GE. One drive, intermittently rated at

216,000 hp, has four wound-rotor motors connected in tandem. Another, continuously rated at 110,000 hp, has three motors on the same shaft. The third and largest wind-tunnel drive is rated 300,000 hp for intermittent service and 250,000 hp for continuous service.

A 1000-hp d-c motor went into operation on the *Hydro-Quebec*, a 280-foot dredge vessel. Totally enclosed, it drives a cutterhead that digs heavy boulders and sticky marine clay from the bottom of the Beauharnois Canal on the St. Lawrence River, near Valley Field, Quebec, Canada. Ruggedly constructed to withstand the extreme operating vibration, the specially built motor is force-ventilated by a 7½-hp integrally mounted blower motor.

Large synchronous motors ranging up to 6000 hp were delivered to the steel industry in 1953 for main-drive mill applications. In addition, large synchronous and induction motors were furnished to both the steel and mining industries as drive motors for motor-generator sets.

Eight 4500-hp 240-rpm 4000-volt synchronous motors, totally enclosed and self-ventilated, are being manufactured for the pulp-grinder drive of a large paper mill. It is one of the largest single



**OLD AND NEW**—new polyphase motor (right) is reduced 40 percent in size, offers better protection, higher efficiency, and quieter operation than the model it supersedes.

orders ever received for this type of application.

A new line of polyphase induction motors, in sizes from 1 to 30 horsepower, was introduced in 1953. The motors are built in the new standard NEMA dimensions. They were completely redesigned to offer better protection, higher efficiency, and quieter operation.

New insulation materials and better methods of heat transfer have made it possible to reduce the physical size of the motors an average of 40 percent and their weight per horsepower about 22 percent. A new bearing design, together with the latest developments in grease, greatly reduces maintenance.

In addition, the new motors offer higher efficiency than those of earlier design. Available now in 1-, 1½-, and 2-hp sizes (1800 rpm), they are of horizontal dripproof and totally enclosed fan-cooled construction. Larger sizes will become available at regular intervals. Motors planned for 1954 production include vertical, single-phase, wound-rotor, explosion-proof, and face-and flange-mounted models.

A 15 to 20 percent reduction in overall size was accomplished on the redesigned line of totally enclosed unit-cooled d-c motors. They are available in constant- and adjustable-speed ratings from 15 to 200 hp. Advanced ventilation and new heat-transfer techniques are responsible for their more efficient design.

Vertical squirrel-cage motors rated 1500 hp at 600 rpm are now pumping water from the Columbia River at the Atomic Energy Commission's GE-operated Hanford Atomic Products Opera-

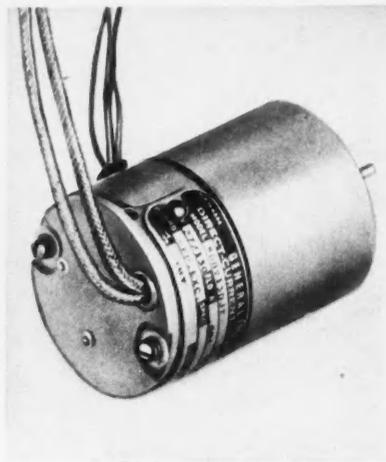
tion in Richland, Wash. Designed to start and operate at temperatures of -20 F, the motors are totally enclosed, with air-water heat exchangers employed for cooling.

Undergoing construction for the same operation are horizontal wound-rotor induction motors rated 10,000 hp and 600 rpm. Each motor, along with a precision gear and flywheel, is part of a system that drives a centrifugal pump; each is coupled to the other by a flexible shaft coupling, the largest weighing nearly 6000 pounds. The gear unit, also built by GE, increases the speed of the set from 595 rpm at the motor to 1696 rpm at the 30,000-pound flywheel. Purpose of the flywheel is to keep the set running for several seconds in the event of power failure.

Expansion of the petroleum industry's catalyst-cracking process has increased the demand for totally enclosed inert-gas-filled motors. They were designed for use in hazardous gas locations where larger horsepower sizes are required than are provided by the totally enclosed fan-cooled explosion-proof type of motor.

A new two-speed high-slip open motor was designed to drive sugar centrifuges. Vertically mounted, it has a squirrel-cage rotor with an extended end ring. Along with constant-torque output, the new motor has many mechanical advantages, notably, its adaptability for pipe ventilation.

Five all-new fractional-horsepower motors were introduced in 1953. Manufactured in over 100 different models—many designed for mounting in a variety of positions—they are reduced in weight and size up to 50 percent.



**TINIEST MOTOR**, 0.002 hp and the size of an ink bottle, contains 1½ miles of wire.

For example, the oil-burner motor, while delivering full-rated power, requires less space than its predecessor. Another, the jet-pump motor, was designed for vertical or horizontal use and includes a through-ventilation system plus a large grease reservoir. Lawn-mower motors are afforded excellent protection by a new insulation. General-purpose utility motors now have a broader field of application because of their reduced size and weight.

The smallest d-c motor built by General Electric was radically redesigned in 1953. The size of an ink bottle and rated 0.002 hp, it is used in the fire-control computers of military aircraft. The tiny motor has a 3-mil air gap and contains about 1½ miles of wire.

An electronic computer now determines in a matter of minutes the temperature rise of aircraft motors supplying time-varying loads. Various duty cycles and cooling systems are simulated on the electronic thermal analog computer with simple plug-in connections, plus resistance and capacitance settings. In this way engineers obtain the best size and weight designs in a relatively short time.

#### Protective Breakers

The F-frame plastics-cased air circuit breaker in 15- to 100-amp ratings was modified to more closely co-ordinate with the starting characteristics of modern motors. It now provides a longer time delay at moderate overloads. Formerly including ratings of 15 to 50 amp maximum at 250 volts a-c and 125/150 d-c, the E-frame plastics-cased breaker of one-, two-, and three-poles was redesigned to include current ratings

to 100 amp. The new design provides thermal-magnetic tripping operation.

Plastics-cased breakers, incidentally, are now produced for such specialized applications as reverse-current protection for aircraft generating systems, plug-in-type mounting, and protection for high-frequency circuits in the textile and woodworking industries.

#### Electromagnetic Pump

Bearing directly on the use of nuclear energy for power generation, an electromagnetic pump is being constructed. It will be used to pump conducting fluids—mainly liquid metals—from atomic reactors to heat exchangers. In operation the conducting fluid passes between two sets of windings and undergoes forces similar to those exerted on the rotor of an induction motor.

#### Dynamometers

During the year automotive and other industries purchased a large number of dynamometers to test and appraise engines, transmissions, and other component parts. The trend is definitely toward the use of d-c adjustable-voltage dynamometers.

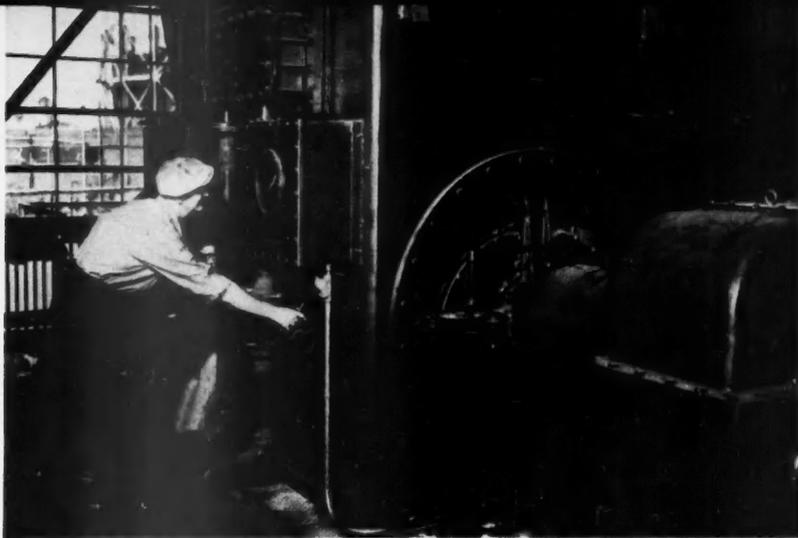
One piece of equipment for testing heavy-duty truck axles duplicates in the laboratory grueling field tests over rugged terrain. The input shaft of the mechanism under test is driven by a 450-hp d-c motor, while the output shafts drive d-c generators, all connected in a loop circuit.

#### Control

Production was started during 1953 on a two-stage electrohydraulic control valve. The valve may be applied directly as a remote-position controller for more accurate positioning of heavy loads, or it may be applied as a component in more complex electrohydraulic control systems. Manufacturing techniques now employed produce a more uniform product at lower cost.

The same two-stage electrohydraulic valve was successfully used as the basic component in a velocity-type control for hydraulic-powered winches. Four such winch controls are combined in a ship-board installation for refueling at sea.

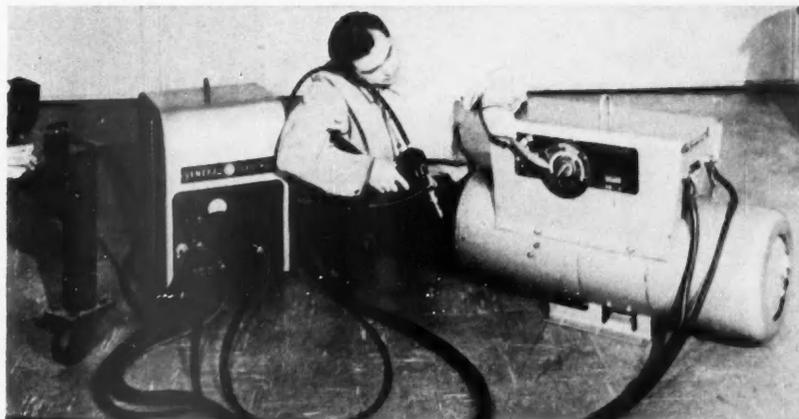
A new line of standard amplistats can often be used in place of vacuum-tube amplifiers or amplidyne in a number of industrial and military applications. These would include such applications as field excitation for variable- or controlled-speed d-c drives, voltage regulators, power-rectifier controllers, and



INERT-GAS-FILLED INDUCTION MOTOR IS USED IN CATALYST-CRACKING PROCESS.



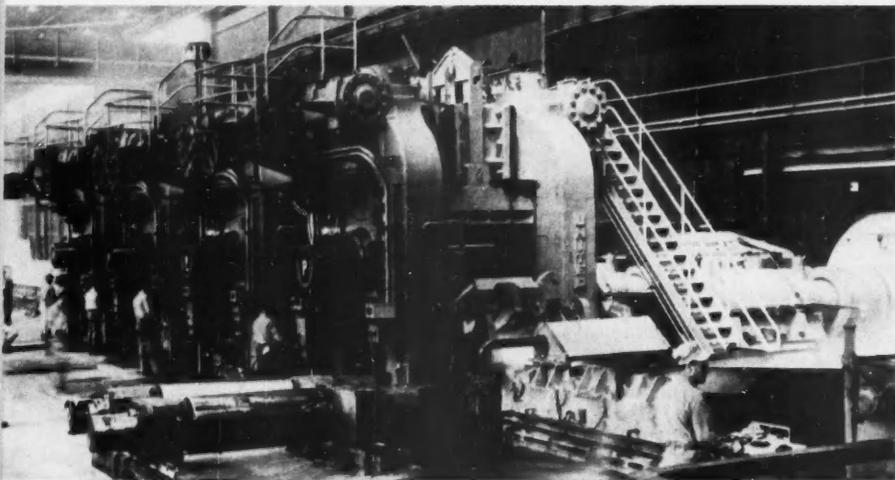
CONTROL CABLE WITH SILICONE INSULATION UNDERGOES A 24-HOUR TEST AT 1400 F.



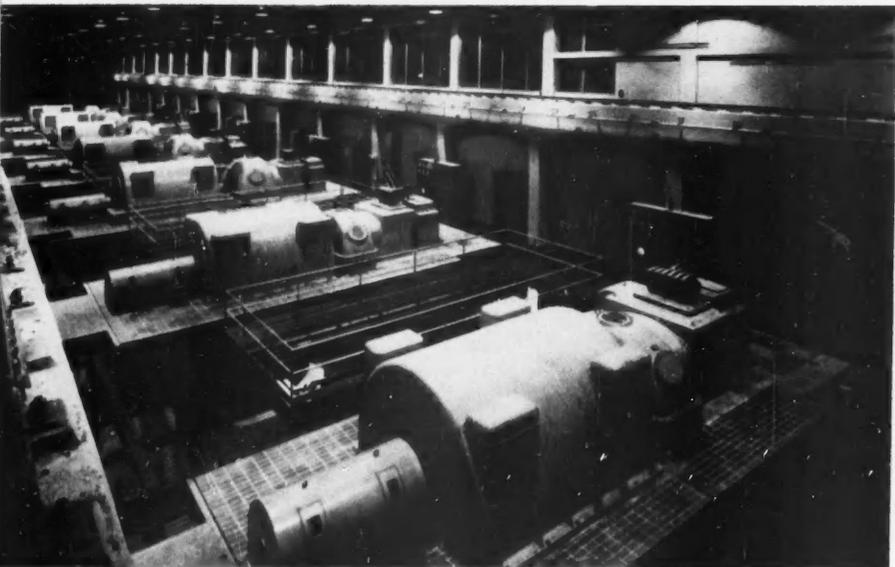
NEW WELDER JOINS STAINLESS STEEL AND OTHER METALS WITHOUT USE OF FLUX.



ORE UNLOADER USES SEVERAL REMOTELY CONTROLLED ADJUSTABLE-VOLTAGE D-C DRIVES.



FINISHING-STAND MOTORS IN STEEL MILL ARE POWERED BY SEPARATE RECTIFIERS.



TURBINE-GENERATORS SUPPLY RECTIFIED D-C POWER TO SOUTHERN ALUMINUM PLANT.

servomechanisms. With 9 basic models for 60-cycle use and several 400-cycle models for aircraft use, the new amplifiers' ratings range from 0.05- to 930-va output.

Single- and two-dimensional tracing heads that control tool movement in one or two directions are available for machine tools. By combining the tracing heads into a single unit, depth control of a cut is obtained with a concentric stylus. The maximum dimensional deviation of a cut is 0.001 inch with a tool travel of 10 inches per minute.

Introduced during the year was a new packaged liquid rheostat. Assembled into a common framework are the rheostat tank, motorized electrode drive, control panel, electrolyte pump, and heat exchanger.

A new type of holding brake if accidentally set while the equipment is in operation will burn itself free. Rated 2000 pound-feet, the brake has a single screw adjustment for restoring it to its proper holding torque after a burn-free cycle.

A new silicone-rubber-insulated control cable will maintain circuit integrity even in the event of a severe fire. Recently developed, it is used for vital circuits located in and around power stations, boiler rooms, and high-temperature processing operations. Protected and identified by colored glass braids, individual conductors of the cable are enclosed by asbestos braid or armor, depending on the application. The new cable has a copper temperature rating of 257 F (125 C) and an insulation that is as moisture-resistant as the best grades of rubber.

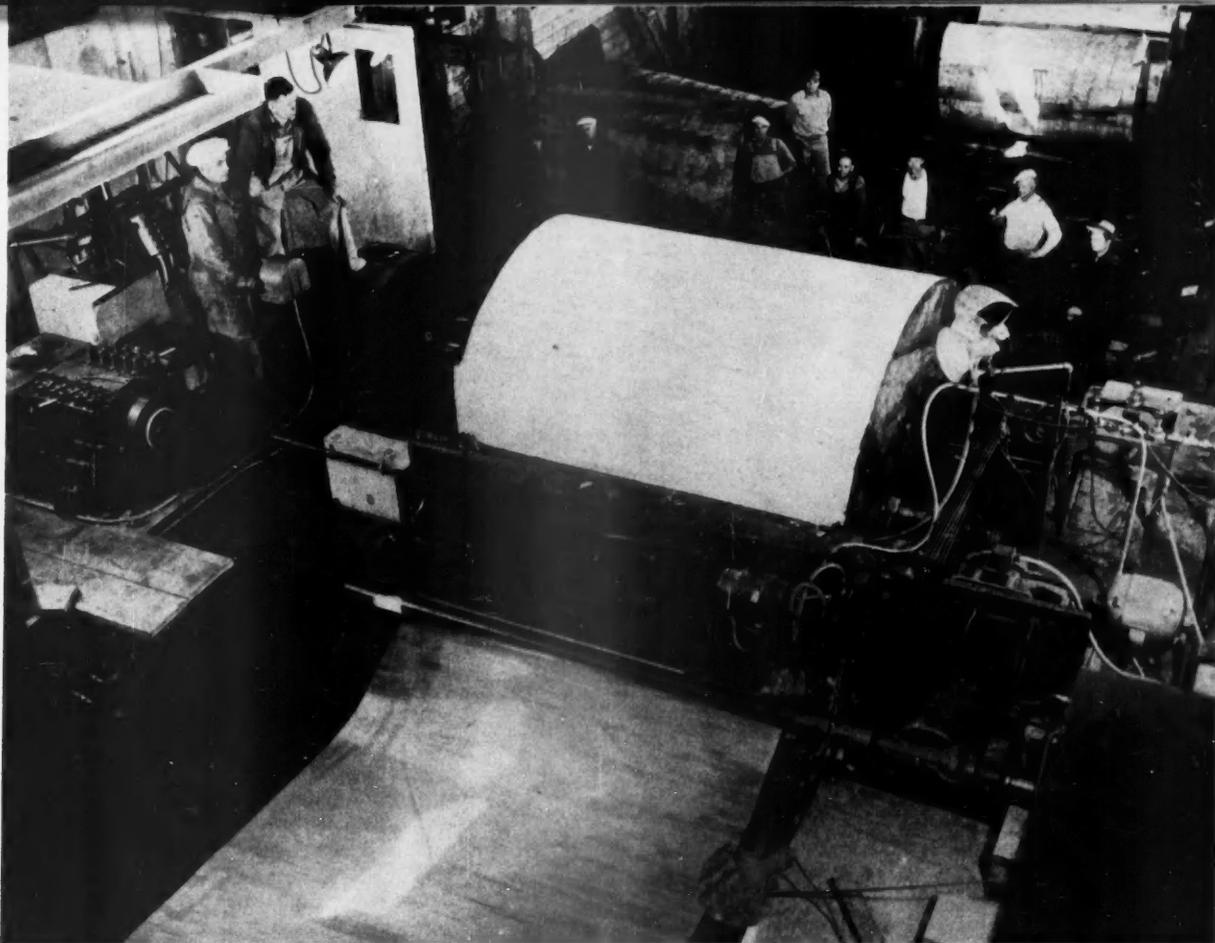
#### Switches

A motor-starting switch widely used in the textile industry was improved to make it completely lint- and dust-tight.

Also put into production was a new line of standard-duty industrial switches rated 30 to 200 amp at 250 and 600 volts, with 2, 3, and 4 poles. The new switches meet NEMA Type A specifications, with an interlocked side-operated handle design for industrial or commercial applications.

A saving of 60 to 75 percent in weight of industrial safety switches for water- and dust-tight applications was realized during 1953. It was accomplished through the use of a lead-plated sheet-steel enclosure in place of cast iron.

Developed for an electric-range manufacturer was a two-pole a-c switch,



VENEER LATHE, POWERED BY A 100-HP ADJUSTABLE-VOLTAGE DRIVE, PEELS A CONTINUOUS 0.1-INCH SHEET FROM DOUGLAS FIR LOG.

small and rugged, that disconnects power when the range backplash is turned down. The manufacturer's requirements were that the switch be small, inexpensive, and capable of sustaining more than 6000 cycles at rated load—even though its actual operating frequency would be only a few cycles.

Other range switches developed during the year are intended primarily for the control of surface units and ovens. Some features of the new switches are a minimum of riveted joints between current-carrying members, fine silver contacts, and small size.

In the room-air-conditioning industry there was wide acceptance of a new line of push-button switches for manual control. An operating condition can now be selected without going through intermediate positions—an impossibility with the previously used rotary switches.

#### Heating

Completely redesigned during the year was a 50-kw induction heater. Featuring sturdy design, accessibility, and the utmost simplicity of circuits,

it occupies 60 percent less floor space than its predecessor. Along with a continuously variable output from zero to 100 percent of its rated capacity, there is a significant increase in its reserve and peak power. The heater meets Joint Industry Conference Standards and the radiation restrictions of the Federal Communications Commission.

One gas producer was modified to provide a protective atmosphere for the continuous bright heat treatment of low-carbon steel.

#### Welding

A radically new welder with a rising volt-ampere characteristic joins aluminum, stainless steel, and other metals without the use of a flux. In operation a consumable electrode—a wire as small as 0.030 inch in diameter—is pulled through a hand gun at speeds up to 750 inches per minute. The new process utilizes an electrode current density 3 to 10 times that used for conventional arc welding and has a deposition rate up to 30 times greater. Automatically regulating itself to the correct electrode

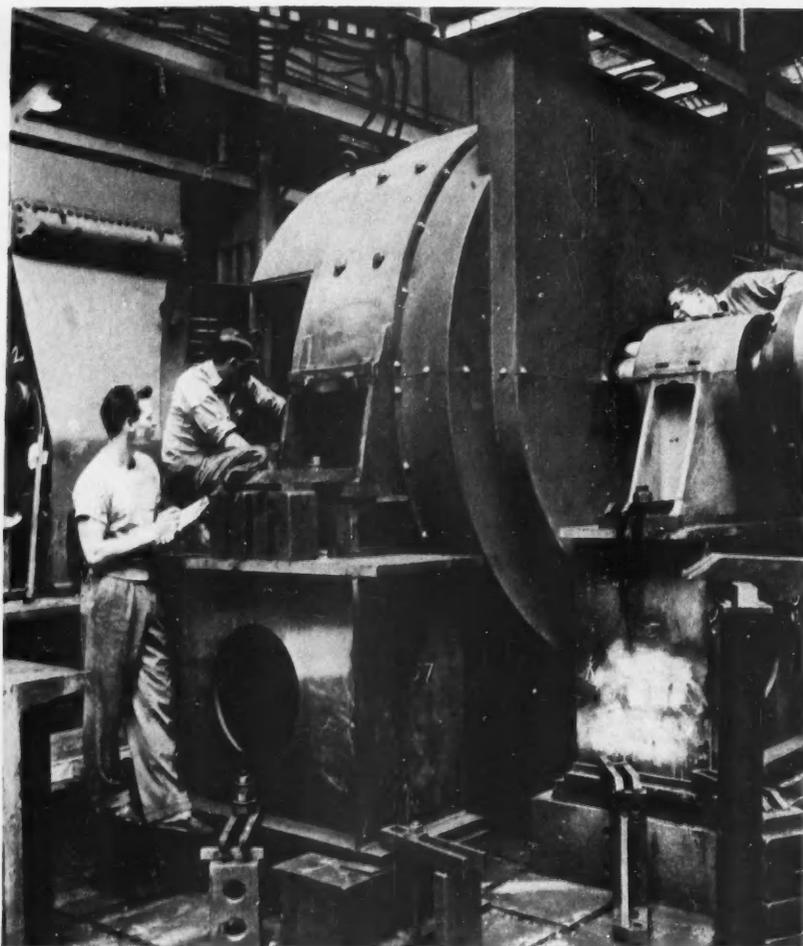
current, the welder requires a less skilled operator.

Developed during the year was a special-type electrode for welding stainless-steel turbine components operating at temperatures of 1100 F. When used in conjunction with high-temperature heat treatment, the electrode greatly minimizes the embrittlement of welds under service conditions. Its composition is such that the ferrite content of deposited weld is metal controlled within 1 to 4 percent; the silicon-carbon is limited to a 5-to-1 ratio. Hence, cracking is avoided even if the ferrite is lost through base-metal dilution.

Shielded semiautomatic inert-gas-metal arc welding was substituted for manual methods on aft-frames and inlet-guide vanes of aircraft gas-turbines. A 40 percent reduction in labor cost was realized, while welding time was reduced by a factor of five to six.

#### Mining

A load-center substation was constructed with permanent skids so that it can be towed from place to place



**FIRST MOTOR** used as direct drive for a Yankee main dryer in the paper industry is rated 500 hp at 90 rpm and is force-ventilated. The rotor is mounted on the dryer shaft.

within a mine. Receiving input power at 4160 volts, it delivers 480-volt three-phase power for operation of mining machinery, and 240/120 single-phase power for lighting circuits.

Two 6000-hp mine hoists, the world's largest, will be installed in an Arizona copper mine. Each will be equipped with two 3000-hp d-c motors, supported by a flywheel motor-generator set to smooth out peak loads on the power system.

Track-laying shuttle cars built by GE are finding good acceptance in the coal-mining industry. Having a high degree of maneuverability, they are particularly suited to mines with soft ground.

A highly complete belt-conveyor system was engineered for loading Venezuelan iron ore into boats. Several adjustable-voltage d-c drives remotely controlled from a centralized point are employed on the system for greater operational flexibility.

#### Steel and Other Metals

A reversing blooming mill of a large steel manufacturer was electrified in 1953. Only 7½ days were needed to dismantle the old steam engine, rebuild the foundation, install electric motors, and resume the regular work schedule. An amplistat-amplidyne control gives the mill an unusually fast reversal and acceleration, yet affords complete protection to the electric equipment.

What is believed to be the fastest rolling mill in the world—a 7000-fpm cold-strip mill—produced marketable steel on its first day of operation. This was brought about by thorough pre-operational analysis of its electric equipment, aided by an electronic analog computer. Adjustments were made before the mill was put into service.

Use of rectifiers for supplying power to main-roll drives is now firmly established. Several hot-strip mills have been put into successful service with

rectifiers supplying all the power for their finishing stands and for starting up the mills as well. Another hot-strip mill will have its 5000-hp and 3500-hp finishing-stand motors powered by separate rectifiers of the pumpless type. Rectifiers are also used on several other types of mill drives.

An improved width gage was developed to measure "on the fly" the width of hot steel strip. It is a non-contacting device consisting of two phototube scanners mounted some 13 feet above the edges of the hot metal. Potential savings with this device are high. For example, with a mill rolling two-million tons of steel strip per year, holding the width of strip one-eighth inch closer would be equivalent to converting 8000 tons of steel from scrap into marketable product.

Built for blast-furnace skip hoists handling a charge of 37,500 pounds at 600 fpm were two amplidyne-type controllers. A programming control furnished with each skip hoist automatically regulates the number of trips, the material handled by the skip, and the distribution of material in the furnace.

The continuing demand for aluminum has stimulated the growth of a new industry in the Gulf area. With water-power sites no longer readily available, aluminum producers have taken advantage of the abundant natural gas in Texas and Louisiana for the generation of electricity. Lignite coal in Texas is also being utilized. Over one-million kilowatts of generating equipment has been installed, about half of it in the form of gas-engine-driven d-c generators. The other half consists of steam turbine-generators with ignitron rectifiers converting the power from a-c to d-c.

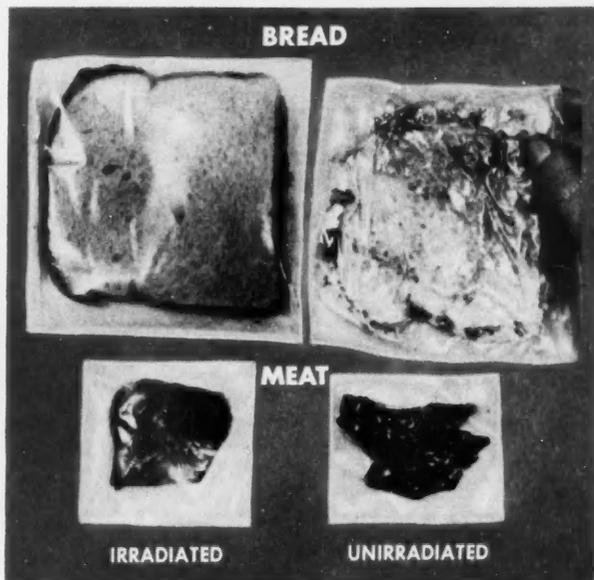
Last year the trend toward automation was quite pronounced in the metal-working industries. Accordingly, a large number of automatic contour-follower equipment was built. For machining such parts as wheels for gas and steam turbines, an electronic speed variator (packaged d-c adjustable-voltage drive) successfully solved the problem of automatically maintaining a constant cutting speed.

#### Manufacturing Industries

In the paper and lumber industries the electronic-amplidyne speed control continues to be the standard. Over 1000 such regulators have been built and put into service since the war.



**LIQUID-LEVEL CHECKER** used in canning industry inspects 900 containers per minute and detects levels to one thirty-second inch.



**PLASTICS-ENVELOPED** food samples are fresh several weeks after exposure to cathode rays (*left*); unsterilized samples are decayed.

Although refinements are added to the speed control from time to time, it is basically the same regulator combining better than 0.1 percent accuracy with stability and low maintenance cost. Now, differential speed instruments measure the relative speeds, or draw, between sections of a paper machine with the same accuracy. And electromagnetic tensiometers that measure and control paper tension were accepted as essential equipment by many mills.

Electric-driven log-carriage drives are also increasing in number. The trend is to combine lumber and paper mills and to convert lumber waste into saleable products rather than to use it for fuel.

The first motor ever to be applied as a direct drive for a Yankee main dryer in the paper industry was shipped during the past year. Rated 500 hp at 90 rpm, the d-c motor has a number of unusual features. One is the arrangement of the rotor for mounting on the dryer shaft that also serves as the outlet tube for the steam that heats the drying surface. The motor is force-ventilated because of the high ambient temperature surrounding it, and because of the hot steam passing through the rotor shaft in the heart of the motor.

The remarkable success of d-c electronic drive for printing presses continued throughout 1953. Each press and folder is driven by a separate d-c motor, with power supplied from an adjustable-voltage ignitron rectifier. Seven plants

purchased equipment of this type during the year, bringing the total number of installations to 39.

#### Materials Handling

Adjustable-voltage d-c drives for such heavy materials-handling machinery as ore bridges, coal towers, and Hulett unloaders gained in popularity during the year. Providing lower maintenance cost and kilowatt peaks on power lines, these d-c drives consume 30 to 50 percent less power per ton of materials handled with constant potential electric equipment.

A novel automatic charging system for blast furnaces establishes the order in which ore, coke, or limestone are fed into the skip bucket. When the operator presets several push buttons, the material is automatically screened, weighed, delivered to the bucket, and hoisted to the top of the furnace. A revolving furnace top assures proper distribution of the charge.

#### X-ray

Proof that x-ray diffraction offers an ideal tool for analyzing protein structure was provided during the year by a project whose principal objective is to determine the positions of atoms within protein crystals. Like the atom, the protein molecule has locked within it answers to many scientific riddles—most important, the nature of living tissue.

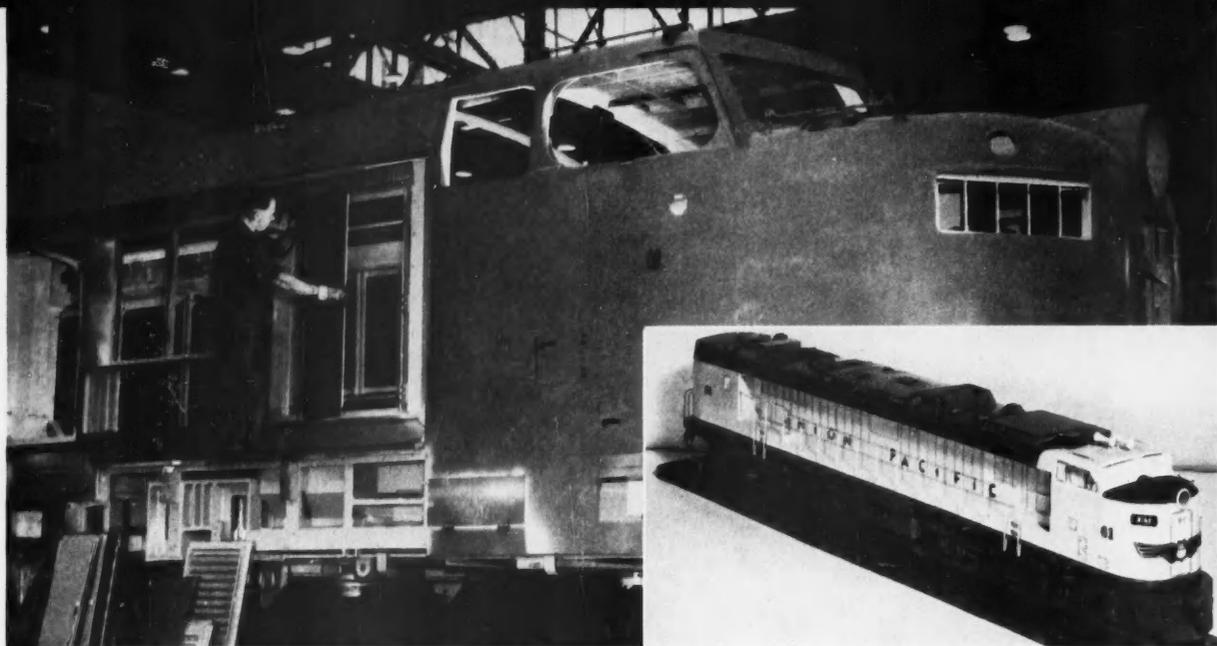
Financed by the Dean Langmuir Foundation, the Rockefeller Founda-

tion, the Damon Runyon Fund, and aided by the International Business Machines Company, this program is taking place at the Polytechnic Institute of Brooklyn.

At its newly opened Cathode-Ray Sterilization Laboratory in Milwaukee, the General Electric Company demonstrated that food and drugs exposed to cathode rays (beams of electrons) can be sterilized to resist spoilage.

Last May nearly 100 American scientists gathered at the laboratory to hear the latest findings in this new field of research. They were shown samples of plastics-enveloped bread and meat that were still fresh several weeks after exposure to cathode rays. In contrast, identical samples of bread and meat not sterilized and kept in duplicate plastics envelopes were moldy and decayed. Since the electron beam has a varying effect on different foods, the problem now is to find the ideal technique for processing each food individually.

The basis of a high-speed liquid-level checker in the canning industry is a crystal of cadmium sulfide about the size of a matchhead that detects signals from a 100,000-volt x-ray tube. Operating at high speed, the x-ray unit can inspect better than 900 containers per minute, detecting liquid levels within an accuracy of one thirty-second of an inch. The unit is being adapted to the inspection of canned or packaged products such as milk, juices, waxes, chemicals, cereals, flour, and insecticides.



RECESSED CAB DESIGN ON NEW GAS-TURBINE ELECTRIC LOCOMOTIVES. FIFTEEN UNITS FOR UNION PACIFIC WILL LOOK LIKE MODEL (INSET).

## Rail

Extensive tests and studies were conducted during 1953 in the development of the rectifier-type locomotive and its effect on railroad power and communication circuits.

The unique nature of power conversion by single-phase mercury-arc rectifiers required development of calculating methods quite different from those previously used to determine the performance characteristics and design of electric traction equipment.

Construction is also proceeding on 10 rectifier locomotives for the New Haven Railroad. Weighing 174 tons each, these units will develop 4000 hp and will operate from an 11,000-volt 25-cycle single-phase a-c overhead trolley or a 650-volt d-c third rail.

### Gas-turbine Electric Locomotives

More than one-million miles worth of experience in revenue freight operation was applied to the design of 15 additional gas-turbine electric locomotives for the Union Pacific Railroad. Construction began in 1953; the first unit will be delivered early this year.

The appearance of these units is somewhat different from the 10 shipped to the Union Pacific in the past. The cab side sheets are recessed to leave an outside servicing walkway with access to equipment through doors in the side sheets. This rearrangement for

improved maintenance was made possible by the design of a roof air inlet that takes relatively clean air for the turbine at the roof line level without filtering. Cooling air for electric equipment is passed through air-cleaning blowers.

In an effort to better the life of major combustion components of the gas turbine, longer combustion chambers were incorporated in the design. An altered control system permits the traction motor fields to be excited from the auxiliary diesel generator during dynamic braking, thereby achieving increased fuel economy. Thus the turbine can be shut down on long downgrades with consequent saving of fuel. The design of these 15 units represents one more step in the development of the gas-turbine electric locomotive as a new form of railway motive power.

### Export Locomotives

During the past few years the tempo of foreign railroad dieselization has increased rapidly. As a corollary, the number and diversity of diesel-electric export locomotives has shown a steady increase, and in 1953 several significant developments were applied to foreign service locomotives.

Forty of the most powerful diesel-electrics yet built for export by General Electric are now operating on the

meter-gage lines of the Central Railway of Brazil. These 1600-hp locomotives use trucks with outside spring hangars—an unusual design feature.

The 27 locomotives now under construction for Indonesia will operate on 42-inch-gage track. They also are rated 1600 hp and make use of outside spring hangar trucks. The running gear arrangement is unique in that a 2-axle idle truck is placed between the two 3-axle motor trucks. Its sole purpose is to carry part of the locomotive weight, thus giving a lower load per axle. When the present modernization program of the railroad is completed, the idle truck can be removed; this will place all weight on the motor trucks and permit the hauling of heavier trains.

### Test Tracks

A new locomotive riding-quality test track permits study of locomotive reaction to abnormal track conditions. One set of rails 819 feet long simulates staggered low rail joints with a difference of three-fourths inch between the high and low points; a second section has a 1½-inch difference between the high and low points of the rail.

Still another set of rails has a three-fourths-inch lateral wave in each rail length, followed by a second lateral wave section where the amplitude is increased to 1½ inches. The effects noted

on locomotives tested to date have resulted in corrective measures for units that are to be used on particularly rough track.

#### Locomotive Dynamometer

The installation of a locomotive dynamometer now permits testing of complete locomotives under conditions closely simulating actual train operation. This makes possible simultaneous readings of horsepower at these points: out of the generator for traction, out of the engine, at the drawbar, and at the rail. In addition, wheel slip, weight transfer, and other phenomena can readily be studied and analyzed.

Strain gages attached to test bars measure vertical and longitudinal forces.

The dynamometers can be arranged to match the wheel pattern of any 4-axle locomotive. At the end of the pit is a buffer stand fitted with strain-gage-equipped test bars to measure drawbar force while maintaining the locomotive in position on the dynamometer wheels.

By separately exciting the fields of the dynamometer generators, arranging them in series, and controlling and shunting each field, the speeds of all the dynamometers can be maintained the same within a three percent range of variation.

#### Use of Mica Mat

A total of more than 2000 traction motors and generators insulated with mica mat are now in service. Experience in the field confirmed laboratory tests demonstrating the adaptability of this material to the severe conditions under which transportation equipment operates.

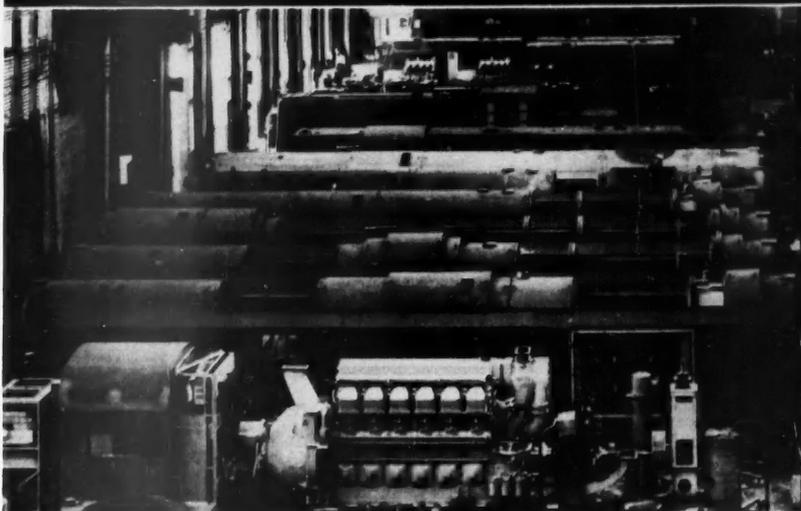
#### New Excitation Control

Static excitation control was successfully tested and is being applied to gas-turbine electric and diesel-electric locomotives. Its use eliminates direct-current commutator machines in the traction-generator excitation circuits. The alternators promise to require much less maintenance.

It is believed that the improved performance of this type of control, together with the longer life inherent in static devices and noncommutator machines, will constitute a real contribution to the increase of locomotive utilization.

#### Wheel-slip Wheel-slide Equipment

After extensive research and development, the new wheel-slip wheel-slide

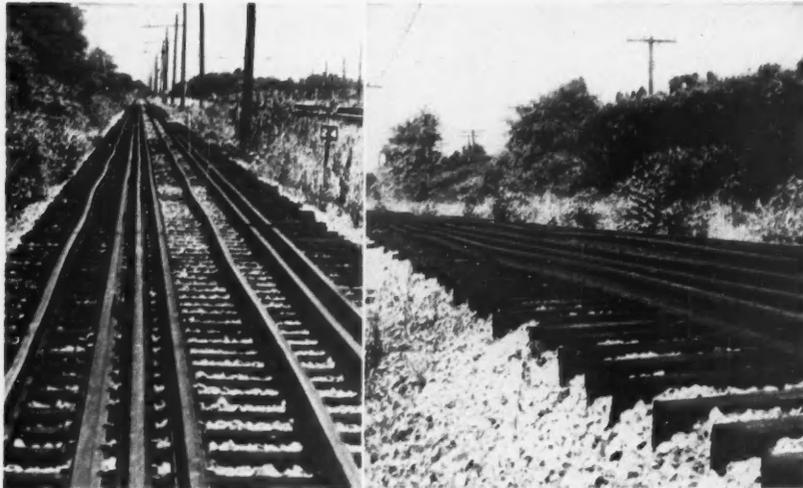


**DIESEL-ELECTRIC LOCOMOTIVE** in foreground, rated 1600 hp, is for Central Railway of Brazil—finished unit (*top*) is ready for shipment—other six are for export to Indonesia.

equipment was placed in production in 1953. It consists essentially of a switch mounted on each axle and connected to a panel in the locomotive cab. Equipment on the panel compares axle speeds and operates a relay if the difference exceeds a predetermined amount. Operation of the equipment gives visual and audible warning to the engineman, and takes corrective measures by removing power from the motor on the slipping axle. If the slip is corrected, power is automatically restored, and the warnings discontinued. If slipping takes place during braking, the equipment gives the warning signals but does not initiate corrective measures. Experience in service showed that the average time for detection, indication, and full recovery from a wheel slip is only three seconds.

#### Diesel-electric Mine Locomotive

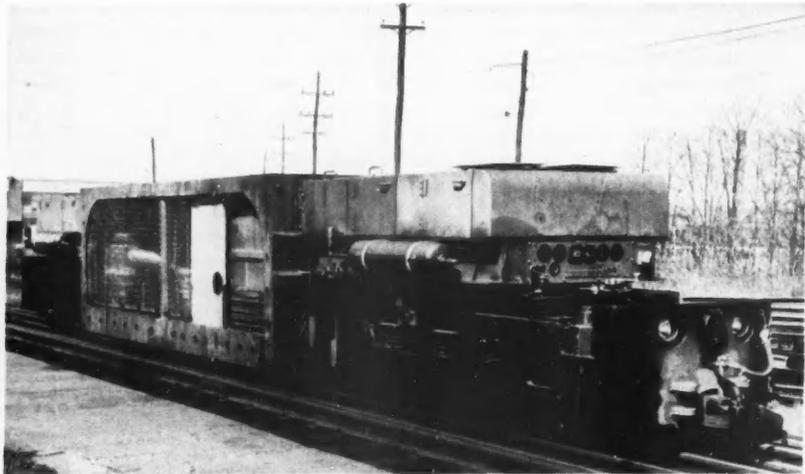
General Electric's first diesel-electric locomotive for underground service was shipped to the U.S. Potash Company in 1953 for use in Carlsbad, NM. It weighs 40 tons and develops 420 horsepower. Designed for operation on 42-inch-gage track, the locomotive is 47 feet 7 inches long. Clearance restrictions limited the width to 7 feet and the height to 6 feet. Unusual features include an exhaust-gas conditioning system and provision for complete disassembly of the locomotive, necessary because it must be lowered into the mine through a shaft measuring  $4\frac{1}{2}$  by  $5\frac{1}{2}$  feet. The locomotive frame is of bolted construction so that it can be completely taken apart and reassembled. The exhaust-gas conditioning system reduces the temperature of the engine



TEST TRACKS PERMIT STUDY OF LOCOMOTIVE REACTION TO ABNORMAL TRACK CONDITIONS.



NEW EQUIPMENT DETECTS, INDICATES, AND CORRECTS WHEEL SLIP IN THREE SECONDS.



FIRST G-E DIESEL-ELECTRIC LOCOMOTIVE BUILT FOR UNDERGROUND MINING SERVICE.

exhaust gas from 1000 to 160 F or less by "scrubbing" the gases in large water tanks. An operator's station is located in the end frame of each truck to facilitate operation in either direction, and dynamic braking is provided for controlling trains on downgrades.

#### Other Developments

Another forward step in the design of traction motors for diesel-electric locomotives is represented by a new motor that went into production during 1953. It is the counterpart for foreign service of the motor that has become a standard on domestic railroads. The new motor can be used on locomotives for gages as narrow as one meter, and on axle loadings up to 44,000 pounds.

A two-year development program resulted in a new design of traction-motor axle-suspension bearing lining. Grooves in the bearing surface return excess oil to the reservoir in the axle cap, thus cutting oil consumption to approximately one-third its former value.

An improved and simplified engine-cooling-water temperature control was developed and applied to diesel-electric locomotives. It consists of a temperature-sensing controller that supplies a signal for radiator shutter control and also modulates excitation for the eddy-current-clutch fan drive. Extensive road tests have demonstrated that engine-cooling-water temperature can be controlled within limits of 10 F for all operating conditions, with complete stability and dependability.

As part of the continual program of locomotive modernization and improvement, a new turbosupercharger was made available for Alco "vee" engine locomotives. Designed from the experience gained in millions of miles of locomotive supercharger operation, the new turbosupercharger has a high efficiency and longer life, can be maintained much more easily and economically, and requires less room in the locomotive than earlier designs.

Cables with heat- and moisture-resistant synthetic rubber insulation, protected by oil-, flame-, and abrasion-resistant jackets, are now being used for the wiring of diesel-electric locomotives. They are used for power circuits in the cabs, for power leads to the traction motor, and for the control wiring.

These cables retain the advantages of the previous types used, including smaller diameters, ease of installation, and better moisture resistance.



J73 SERIES TURBOJET, LATEST OF THE GENERAL ELECTRIC JET ENGINES NOW IN PRODUCTION, POWERS THE NORTH AMERICAN SABREJET.

## Aviation

Shipment of the 10-thousandth jet engine from GE's Evendale, Ohio, plant and the delivery of the same number from the Lynn, Mass., plant was but one of many notable events of 1953. The year also gave rise to significant engineering advances on the J47 series of turbojets, famous as power plants of high reliability. These turbojets power such planes as the North American *Sabrejet*, the North American *Fury*, and the Boeing *Stratojet* bomber, and they serve as auxiliary power plants on the Convair B-36.

One of the engineering advances on the J47 series is a compensating device that synchronizes engine-speed operation, despite changes in mechanical linkage that result from flight conditions. Another engineering advance is a capacitor-type ignition system of superior performance that is reduced in weight 43 percent over previous designs. Also, a twofold increase in life expectancy of the J47-25 turbojet engine will save

over \$100 million for the Air Force and taxpayers.

The J73 series, GE's newest jet engines, also went into production during the year. One, designated the J73-3, is much more powerful than the J47 engine of the same frame size, yet it has a lower fuel consumption per pound of thrust. A turbine engine starter eliminates the need of auxiliary ground starting equipment for the advanced J73-3, while an automatic temperature control limits exhaust-gas temperatures to predetermined values during operation. This engine powers the new Air Force fighter-bomber, the North American F86H.

### Production

Improved manufacturing techniques and new production methods considerably increased jet-engine output during 1953, thus saving millions of dollars. For instance, a new simplified testing procedure consists of disassembling only

one engine out of every 10 subjected to tests. The stripped engine is then re-assembled and tested again prior to shipment. Previous practice required that each engine be strip tested after its initial test runs.

The new component development facilities at the Evendale plant neared completion in 1953. They are designed to establish principles and limitations arising in the research and development of aircraft gas-turbine components.

Notable progress was made in solving some of the problems associated with titanium alloys—lightweight metals of high strength. Already they are being applied to some parts of the new J73-3 production engine.

### Guided Missiles

During a flight that seldom lasts more than a few minutes, a guided missile must transmit to a ground station as much data as possible on its flight performance. To facilitate transmission of this



**FIRST COMPLETELY SELF-CONTAINED** air-turbine-driven hydraulic pump for an aircraft hydraulic system, and the first successful air-

turbine-driven tank-mounted afterburner (above). The latter combines boost, high pressure, and vapor separation elements in one unit.

data, a telemetry system was designed specifically for guided missiles.

The missile-borne equipment is packaged in two cans 4 inches in diameter and 15 to 16 inches long. When combined with its battery power supply, the complete unit weighs about 23 pounds and occupies only 0.2 cubic feet. The unit gives satisfactory operation at a line-of-sight range of over 100 miles. At the ground station, which may be fixed or mobile, data are recorded from an oscilloscope as dashes, dots, or lines by a 35-mm moving-picture camera.

#### Rocket Motor

A 1200-pound-thrust rocket motor is equipped to permit engineers to look inside the motor during combustion-study operation. It has a ¼-inch-wide quartz observation window that extends from the point where the propellants enter the combustion chamber to the nozzle where the gases are exhausted. The combustion process is photographed by means of a continuous-strip camera.

#### Flight Controls

An advanced flight-control system for high-performance aircraft was introduced in 1953. Designed with simplified pilot controls, the system has three-axis damping, automatic G limiting, and means for tie in with automatic-landing and flight-path control systems. The new unit weighs 40 percent less than similar flight-control systems and breaks radically with previous designs.

Single-axis gyroscopes were redesigned to improve their reliability and

ease of manufacture. One of the units is a viscous-damped spring-restrained rate gyroscope that measures rates up to 45 degrees per second. Others are of the torque-motor restrained design.

#### Accessory Turbines

Many singular accomplishments were made in the field of small high-speed aircraft accessory turbines in the past year.

An example of units now in production is the first completely self-contained 60-kva air-turbine alternator drive capable of operating over a wide range of flight conditions. Another is an air-turbine-driven hydraulic pump unit for a 3000-psi hydraulic system, the only known unit of this type that is totally self-contained. Also being produced is the first successful air-turbine-driven tank-mounted afterburner fuel pump. It combines in one unit boost, high pressure, and vapor separation elements, as well as integral aerodynamic overspeed protection. The pump is installed in North American *Sabrejets*.

A small gas-turbine starter was also placed in production. This unit is completely self-contained aboard an aircraft and starts a jet engine in a matter of seconds without the aid of ground power.

Small turbine products now under study or development hold much promise for jet aircraft of tomorrow. These will be applied in such diversified fields as turbopumping, thermal-barrier cooling, boundary-layer control, and auxiliary power generation.

#### Ball-piston Pumps

The first sample of a ball-piston pump weighing approximately 0.5 pounds per horsepower was shipped during the year. It operates at 12,000 rpm and 3000-psi pressure. As a measure of the progress made in this field, a representative unit built two years before weighed 2.2 pounds per horsepower and operated at only 9000 rpm and 1500-psi pressure.

The new high-speed pump can be coupled directly to high-speed electric motors or to air turbines with a minimum of gearing. Development is already under way to produce a unit that will operate at temperatures up to 500 F.

#### Aircraft Instruments

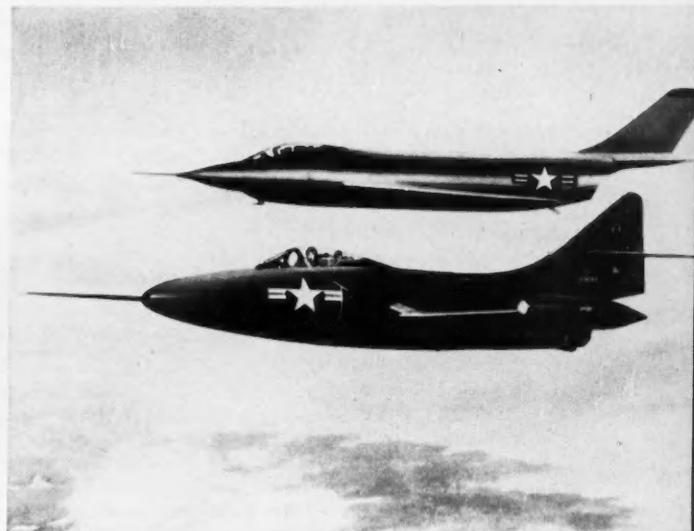
The first true mass flowmeter introduced in 1953 measures directly the mass rate of fuel an aircraft consumes. This was long desired because mass, not volume, determines the heat content of jet-engine fuels.

Improved versatility and performance are features of a new compass adapter for compass-controlled directional gyros. Built-in compensation for compass error affords a threefold increase in accuracy; selected components permit operation of the device in a 93 C ambient temperature.

A 5/8-inch-diameter 400-cycle servomotor for aircraft instruments has twice the efficiency of previous induction motors of the same size. Harmonic losses are reduced in the new design, and larger flux densities result in a



**MOBILE POWER SUPPLY** for aircraft—a 400-cycle a-c alternator rated 30 kva—is complete with its own regulated d-c power supply.



**FLIGHT CONTROL SYSTEMS** in high-performance aircraft such as Navy's F3H and F9F-5 gave rise to new concepts in autopilot design.

higher torque-to-inertia ratio as well as increased efficiency. The motor is lightweight and has a stall torque of 0.11 ounce-inches.

Also developed was an instrument used in performance tests of aircraft gas-turbine rotors. It measures the clearance during operation between bucket ends of a selected compressor stage and a fixing point on the compressor housing.

#### Electric Systems

Continuing the trend set in 1952 toward application of a 400-cycle power system to most new aircraft, new a-c generating equipment was developed.

Last year General Electric made available for this purpose a small constant-speed hydraulic transmission and continued work in the application of pneumatic turbine-drives. An order was received for a complete refrigeration system and an a-c generator drive for an advanced fighter aircraft.

Large production orders were received for a newly developed system that controls and helps protect a-c aircraft generators operating in parallel.

Completed during the year was a detailed study of electric power systems for a proposed jet transport. It has added immeasurably to the application of various drives to electric generating systems. This work is being carried forward in conjunction with several aircraft-engine manufacturers.

Complete a-c power systems for new military aircraft are now available. Included in the system are an a-c gen-

erator complete with rotating exciter, a voltage regulator employing magnetic amplifiers, and a control panel. All components of the system, incidentally, are built to rigid new military specifications.

A 30-kva 400-cycle alternator set mounted in a jeep serves as a ground power supply for aircraft. The alternator is regulated by a magnetic amplifier and co-ordinated with the latter is a regulated transformer rectifier using approximately 6 kva of the alternator's output. Designed to withstand severe environmental conditions, the equipment operates over a temperature range of  $-50$  to  $+65$  C.

A static voltage regulator utilizing magnetic amplifiers was designed to meet all operating and environmental requirements of aircraft. It will withstand accelerations of 10 G's in any direction and has a 5000-hour maintenance-free life expectancy. Weighing  $17\frac{1}{2}$  pounds, the regulator will operate with either single- or three-phase generators rated 15 to 90 kva over a speed range of 320 to 1000 cycles.

Weight reductions in excess of 40 percent accompanied by volume reductions as high as 70 percent are incorporated in a new line of 400-cycle single-phase aircraft transformers without an increase in losses. For example, a 200-volt-ampere 115/28-volt autotransformer weighs 11 ounces and is only 7 cubic inches in volume.

Weighing only 67 pounds is a new completely packaged 200-amp 28-volt regulated transformer-rectifier and mag-

netic-amplifier control. The packaged power unit maintains d-c output voltage within extremely close limits and has a greater capacity than achieved before in similar units.

A capacitor discharge ignition unit for jet engines weighs  $3\frac{1}{4}$  pounds and needs only 69 volt-amperes input. The unit operates from a 400-cycle 115-volt power supply and will deliver rated energy to the spark plug even when its input voltage is reduced 50 percent. It produces a powerful ignition spark of short duration.

#### Other Developments

A new record-playback control is expected to double the production speed of a milling machine that fabricates self-reinforced skin structures for jet aircraft. The control, automatic in operation, directs the machine from information stored on a magnetic tape. It was five years in development.

A hermetically sealed AN-type connector withstands mechanical shock of 100 G's, thermal shock from  $-300$  to  $+500$  F, bonding temperatures as high as 1500 F, operating pressures up to 7000 psi, and potentials greater than 1000 volts. It is impervious to moisture, corrosion, rare atmosphere, fungus, and vibration.

Another AN-type connector, a quick-disconnect type, can be separated quickly with a simple straight-line motion. This connector is ideal for applications where hand room is limited and where equipment requires frequent moving for repair or replacement.

# Marine

The four propulsion steam-turbine gear units now on order for the U.S. Navy's newest aircraft carrier, *USS Saratoga*, will be the most powerful ship propulsion units ever built.

The turbines will have a two-casing three-element arrangement wherein the high- and intermediate-pressure elements will be built into one casing; the low-pressure element will be built into the other casing. The high-pressure and high-temperature inlet end of both the high- and intermediate-pressure elements will be placed adjacent to one another in the center of the same casing, and the steam will flow from the center toward each end. This particular arrangement, while new for propulsion turbines, has been used for a number of central-station reheat turbines. The low-pressure turbine will be a conventional double-flow machine with astern elements built into each end.

## Turbine-generator Sets

The trend toward the use of packaged-type ship's service turbine-generator sets on board ship continues to gain, particularly on naval vessels.

These sets are so arranged that the turbine, gear, generator, condenser, and air ejector are mounted on, or combined into, a self-supporting base structure that requires only three-point support from the ship's foundation. This feature is particularly valuable on board ship because it greatly simplifies the installation and alignment problems.

Supplied for two new naval prototype auxiliary vessels were six more sets of this kind with totally enclosed 750-kw

generators—turbines operating at approximately 10,000 rpm, and generators running at 1200 rpm.

## Cable-laying Equipment

Equipment for a complete electric cable-laying system for installation on a new type cable-laying vessel went into production in 1953. This system consists of a turbine-generator set with d-c and a-c generators, main cable-drum motor, tension-controlling device, absorption resistors, excitation amplidyne, and control.

Designed to permit accurate control of speed or tension under all conditions of cable hoisting and lowering, the equipment provides stable operation throughout the operating range and maintains tension within allowable limits in spite of the rolling and pitching of the vessel.

## Cathodic Protection for Ships

The "mothball" fleet, including ships of all sizes, is now getting hull protection against corrosion from cathodic-protection metallic rectifiers. Protecting the bottoms of the reserve fleet against corrosion are rectifiers that apply d-c voltage between the hull and "sacrificial" electrodes submerged in the mud near the ships.

The cathodic-protection units consist of hermetically sealed oil-immersed selenium rectifiers that withstand the salt-water atmosphere.

## Submarine Control System

A new automatic control system for submarines that uses magnetic ampli-

fiers was developed, produced, and successfully tested for the Navy.

The power amplifier consists of a discriminator, vacuum-tube amplifiers, limit circuits, and power thyatrons that are used as a feedback amplifier. The entire control system is a servomechanism involving hull constants such as mass, compressibility, and hydrodynamic damping. The principal problems were the high accuracy required and the stability requirements of the submarine.

## Radar Antenna Assemblies

Early in 1953 General Electric completed and supervised the installation of the largest radar antenna assembly yet developed and manufactured for naval shipboard use.

The antenna assembly that includes a parabolic reflector 40 by 20 feet and its associated r-f waveguide system is fabricated of stainless steel and weighs 14,000 pounds. This assembly is rotated at speeds up to 10 rpm by a 40-hp gear-motor. Its axis of rotation is maintained vertical to within 15 minutes of arc regardless of the ship's roll and pitch.

An antenna base incorporating roll and pitch gimbals provides structural support for the antenna assembly. Servo systems position the gimbals to maintain the antenna axis vertical. The gimbals are driven by gear-motors coupled to worm and worm-wheel drives at the output shafts. These motors are rated 33 and 14½ hp for roll and pitch respectively.

Special oscillating and rotating joints were developed to transfer r-f signals across the roll, pitch, and azimuth axes.

# Engineering Training and Education

During the 1952-1953 school year some 2540 graduate engineers participated in 130 classes at various locations in General Electric—a 19 percent increase over the 1951-1952 participation. Conducted in 11 carefully selected geographical locations that served the entire Company, the majority of these classes were in the areas of general and specialized technical courses. The general courses were broad fundamental studies for new engineers; the specialized technical courses were more specific,

covering, for example, servomechanisms, synchronous machines, and heat transfer.

Fourteen of the classes were composed of 200 young engineers selected to participate in the Company's advanced technical programs. This year to meet the Company's growing demands in this area 16 classes are under way.

Two educational books scheduled for publication late in 1954 will be of widespread interest. The *Laws and Effects Notebook* now in preparation by the personnel of the Creative Engineering

Program will include some 120 laws and effects of value to design and development engineers. The other text, *Fundamentals of Engineering Analysis*, is now in preparation by staff engineers and engineers from operating departments.

A Teaching Methods Seminar, sponsored jointly by the ASEE and General Electric, was conducted in Schenectady during 1953 for 25 selected college instructors and professors. So successful was the seminar that plans are under way to hold another this year.



SELF-CONTAINED AIR CONDITIONER (LEFT) HAS HERMETIC CONDENSING UNIT. YEAR-ROUND HOME AIR CONDITIONER HEATS AND COOLS.

## Air Conditioning

A new line of self-contained air conditioners having capacities of 3, 5, 7½, 10, and 15 tons went into production during 1953. Their newly developed, completely hermetic condensing unit combines a motor, a compressor, and a condenser all welded into one steel shell, resulting in a much quieter unit. Because there are no belts and no lubrication problems—lubricant is sealed in—maintenance is simplified.

The condensing unit was combined with a cooling coil so that the entire refrigerant system can now be completely assembled, dehydrated, tested for leaks, charged, and tested for performance before it is placed in the complete air conditioner. Additionally, this permits the refrigeration system to be pulled out of a completed air conditioner for servicing or replacement in the field. It was the first time a combination of sealed condensing unit and replaceable refrigeration system was used in air-conditioning units this large.

### Home Heating and Cooling

For heating and cooling homes the year round a new line of equipment was placed in production. Although the Pre-Paired cooling and heating units are separate, they permit compact good-looking combination installations of a warm-air furnace and a cooling unit.

Four sizes of oil-fired furnaces, five sizes of gas-fired furnaces, and four sizes of cooling units offer possibilities for 190 combinations to fit the year-

round indoor climate requirements of any size house in any part of the country. Accessories are available for complete automatic operation. A typical combination requires 8 square feet of floor space. All units are 55 inches high and 29 inches deep so that they will match when placed together.

Whether oil- or gas-fired, the heating units utilize the proved principles of former designs. The cooling units employ hermetically sealed refrigeration systems to obtain the reliability and long life needed for service in the home.

### Weathertron

Last year the heat pump was given the new name of Weathertron. Installed in the home, the Weathertron automatically adjusts itself to all weather conditions, according to the thermostat setting.

Actually an all-electric air conditioner, the Weathertron heats, cools, dehumidifies, and circulates the air. Units are produced in 3- and 5-hp sizes.

### Water Coolers

Water coolers of a radically different appearance were introduced in 1953. They occupy 30 percent less floor space than previous models, are easier to clean, and the interior is more accessible. Although 30 percent less stainless steel is used, more is placed in the front to protect the unit from being handled. Also, the stainless steel top is more attractive and has greater mar resistance



NEW WATER COOLER CONSERVES FLOOR SPACE.

because it is given an electropolish finish.

Further savings were realized by using compressors from standard home refrigerators, and by using static condensers instead of fan-cooled condensers in the smaller sizes of coolers.

The line includes explosion-proof units, larger sizes, and units for location remote from the bubbler. Plans call for coolers with refrigerated compartments for small quantities of beverages, sandwiches, and ice cube trays.



**CONTROL DESK** for "package" TV station permits one man to prepare and broadcast film and network programs. Cost will be one-fourth the outlay for today's average TV station.

## Electronics

In April of 1953 the National Television System Committee (NTSC) demonstrated its compatible color television system. Representatives of both government and industry acclaimed it as highly successful. In July the Committee petitioned the FCC requesting adoption of their system as standard; if adopted, official approval could be forthcoming as early as March 1.

Meanwhile, NBC and CBS began limited color television broadcasts last fall using NTSC's system.

The compatible color television system employs the same monochrome and sound signals used in conventional telecasting plus a third signal known as a *color carrier*. Hence, color telecasts can be viewed on conventional black-and-white television receivers.

Assuming the system is approved, it is probable that some color television receivers will be included in the late 1954 line of many manufacturers. List prices of these sets will be high—probably upwards of \$800. The high costs will result from using a complex all-electronic tricolor picture tube; one type, utilizing three electron guns, will alone cost the television manufacturer about 10 times as much as a black-and-white picture tube. In addition, a color television set will use 35 to 40 receiving

tubes, more than double the number used in a black-and-white receiver.

Ultimately, mass production will bring down the cost of color television receivers. But they are bound to remain more expensive than standard black-and-white sets for a long time. In the words of General Electric's Dr. W. R. G. Baker, chairman of NTSC, color television will come as an evolution, not as a revolution; it is probable that the standard monochrome receiver will continue to be the backbone of television sales for at least the next five years.

### Television Broadcasting

A low-cost packaged television station was a major contribution in 1953 to the future of television broadcasting. With it a single operator can prepare and broadcast filmed or "live" network programs. Costing only one-fourth as much as an average television station, this new packaged unit allows station owners to begin broadcasting with a minimum of expense.

Monitoring, remote-control, and switching facilities of the one-man station are compactly arranged. And because they are, it is possible for a single operator to control a television transmitter; switch between local films,

local slides, and remote or network programs; operate one film-camera channel; and introduce limited local audio announcements. Another important factor in the success of the compact station is its film-camera chain. Once set up, it rarely requires adjustment.

All the electronic components of the Swiss Eidophor color television projector were redesigned during the year. Some of the changes accomplished were a 20 percent reduction in the number of tubes and the addition of functions such as push-button starting, automatic protection against sweep failure, and improved protection against vacuum deterioration. In addition, the Eidophor's electronic and switching equipment was designed for alternate monochrome, or black-and-white, operation.

A new line of television monitors introduced during the year provides much greater linearity and stability of sweeps, and has regulated anode voltage to reduce picture defocusing and to prevent raster-size changes at high brightness levels. Among other improvements is a wide-band amplifier that permits the wave-form monitor to measure proper levels of NTSC color signals and to exhibit proper high-frequency wave shapes.

Switching equipment for medium and large television studios was extended by the addition of a versatile relay-selector system that includes fading and lapping amplifiers. Permitting selection from as many as 12 input signal channels, the system has an arrangement of buffers that eliminates possible "cross talk" between channels during switching.

Simultaneous relaying of both aural and visual portions of television programs is now possible with a new line of television relays. Developed for service in the 2000-megacycle range, they can also relay aural and visual signals separately if desired. The relaying equipment is highly portable, yet is adaptable to rack mounting for station use. It is patterned after a regular broadcast station in that separate aural and visual transmitters diplexed into a common antenna are used.

Developmental work was completed on a built-in ultrahigh-frequency (UHF) television-receiver antenna. The simplest design, a circular wire loop two feet in circumference, gave the best performance of all antennas tested by producing the strongest signal and brightest picture. Located in the rear of the television set, the loop antenna

can be adjusted for optimum reception. It is affected only slightly by people standing near the set.

The continuing trend toward larger television pictures demands larger picture tubes. Coincident with this is a demand for improved light output and contrasts. To satisfy both, a 24-inch rectangular metal-backed picture tube was demonstrated to the industry. It has a 90-degree deflection angle that permits a large viewing area without any increase in length over tubes with smaller picture-size capabilities. Development of other tubes of this type is under way.

A new internal magnetic focus gun improves operation of picture tubes after they have been installed in television sets. It eliminates the external ion-trap magnet and external focus device. Picture tubes with this gun installed have the advantage of a locked-in focus with no manual adjustment required of the user.

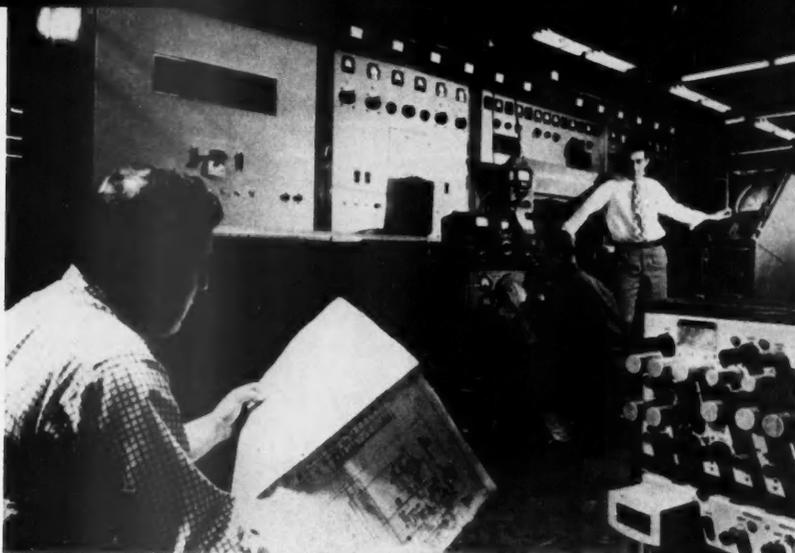
Sample 15-inch round tubes for color television were made available to customers for testing in specially designed sets. These tubes have the maximum brightness consistent with adequate contrast; their design will be adapted to the mass production of larger types.

#### Transmission

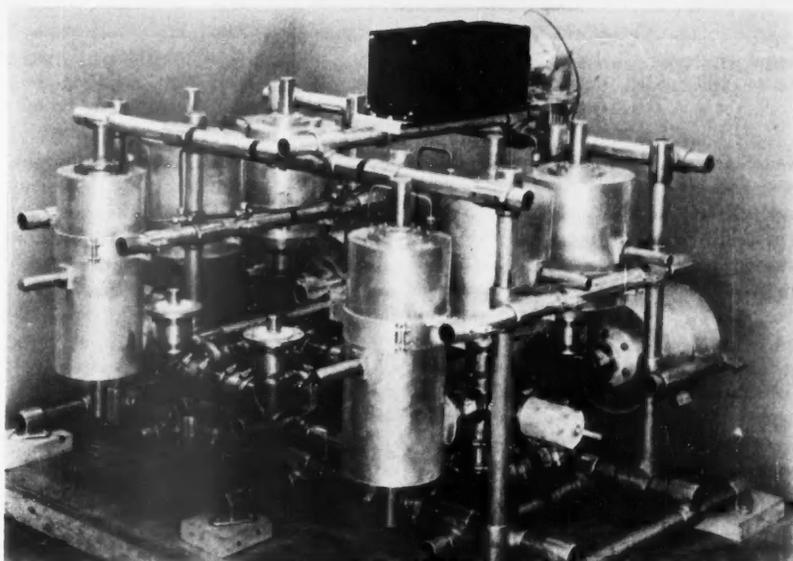
Because the FCC processed applications for television-station construction permits faster than was generally expected, intense pressure by broadcasters for transmitting equipment resulted. The majority of applications were for UHF stations so that pressure was particularly felt in this newly opened part of the radio spectrum.

First of the 12-kw UHF transmitters to go on the air during 1953 was WHUM-TV at Reading, Pa. This transmitter has over 1000 feet of wave guides to transmit its power to the antenna. Following WHUM-TV was a rapid succession of other 12-kw transmitters; the demand was heavy because this type of transmitter has the highest power output ever developed for UHF. With high-gain antennas, they have effective radiated power (ERP) up to 250 kw. And development is already under way on a klystron tube that will reach the 1000-kw ERP ceiling.

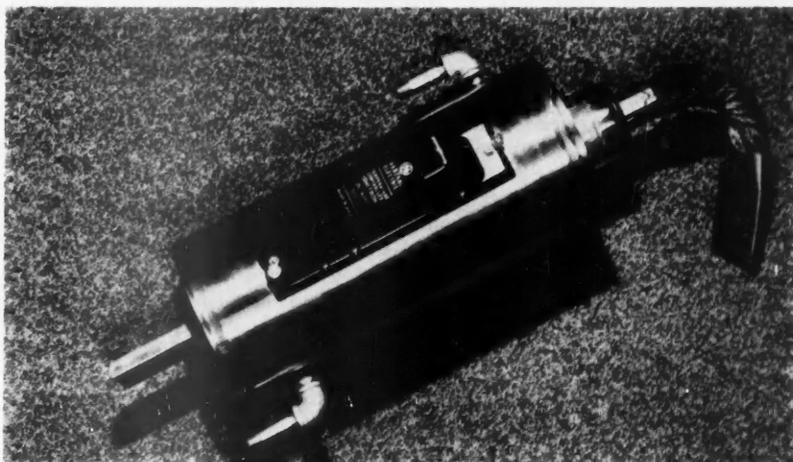
Smaller cities found UHF television coverage surprisingly effective when using a 100-watt transmitter. But for medium-size cities the 1000-watt transmitter utilizing an air-cooled tetrode of



FIRST 12-KW UHF-TELEVISION TRANSMITTER FOR READING, PA., USES KLYSTRON TUBES.



FILTREXER FOR UHF "PLUMBING" EXTENDS OVER 70 CHANNELS ON A SELECTIVE BASIS.



TEMPERATURE-CONTROLLED IGNITRON USES UP TO 95 PERCENT LESS COOLING WATER.



**MULTIPLEX UNIT** for microwave communication (top) is half the size of earlier model (bottom). Both units have two voice channels.



**INDUSTRIAL TWO-WAY RADIO** equipment operating in 4- to 9-mile area keeps truck operator in contact with dispatcher at all times.

ceramic construction has proved most effective.

Much of the delay associated with launching UHF resulted from a lack of test equipment. For example, there was no sweep generator of sufficient power available—a new one had to be developed. Its output is 5 to 10 watts, and its 8-megacycle sweep signal—tunable anywhere in the UHF band—is flat up to and slightly beyond four decibels. The sweep generator made possible quick and accurate tuning of transmitters, diplexers, and similar components.

The UHF spectrum, incidentally, has proved itself a reliable program medium. Numerous field measurements on UHF transmitters have shown remarkable compliance with the FCC's propagation predictions.

UHF television demands more radio-frequency "plumbing," the common name for transmission-line broadcast installation using coaxial and wave-guide components. This need stems from the higher frequencies involved, the use of a single transmission line to the antenna, and the capacity required to handle the high-powered 12-kw klystron transmitter. Development of equipment of this type, commonly called a *filterer*, was a major accomplishment of 1953. To keep efficiency high, components had to be made large.

In the field of very-high-frequency (VHF) transmission the trend is upward to the 100-kw ERP ceiling for low-channel stations and to the 316-kw

ERP ceiling for high-channel stations. Many of the leading 5-kw television stations have boosted their ceiling maximum with the 35-kw low-channel amplifier, giving them a decided increase in coverage. One, WCBS, is the first high-power-output low-channel station in New York City.

WHAS of Louisville, Ky., is the first high-channel television station in the country to reach the FCC's 316-kw ERP, because of installation of the first 20-kw high-channel amplifier. Though rated 20 kw, WHAS has operated at 28 kw (transmitter power) to provide maximum service to its vast audience. With the 20-kw high-channel amplifier an ERP of about 200 kw is reached.

Utilizing water-cooled tetrodes a 50-kw high-channel amplifier for the 316-kw ERP maximum is well along in development.

#### Antennas

In some locations it was found desirable to modify, or contour, the narrow vertical beams radiated from high-gain UHF antennas. Beams that are contoured to suit terrain and population give a better broadcast coverage. Many special pattern shapes were designed that could be readily adapted to standard-production UHF antennas. So successful was this application that contouring is even being applied to some VHF antennas.

Used as special feed harnesses for VHF antennas, new aluminum cables

were introduced early in 1953 when the first high-power VHF-TV broadcasting began.

#### Transmitting Tubes

Advances in the transmitting-tube field were dictated largely by the growth of UHF and VHF telecasting.

Two tubes were developed for the UHF band, one with a peak power output of 250 watts, the other with a 5-kw output. Covering the entire UHF-TV spectrum, the tubes deliver full power output to the top of the band—900 megacycles. They are also suitable for military communication equipment operating in the 200- to 400-megacycle range, and at other frequencies up to 1000 megacycles where outputs of 150 watts and 4 kw of continuous power are required. The larger tube is also suited for such industrial service as dielectric heating.

Developed for the VHF television field was a tube with 25 kw of synchronizing peak power capable of full output up to 220 megacycles.

The metal and ceramic construction of these tubes permits higher operating temperature than previous designs. Seal electrolysis is reduced with the result that insulating paths are shorter, seal breakdown is prevented, and tube life is lengthened.

#### Receiving Tubes

Active development programs are continuing on several new receiving

tubes for color television that should both improve their performance and reduce their cost. At the same time, activity in the UHF-television monochrome field centered on improving performance of existing tubes.

In addition to nine more miniature and subminiature types that were introduced and demonstrated for both military and aircraft applications, a special line of high reliability tubes was developed to meet rigid military specifications.

For application in L-band radar receivers a new metal and ceramic triode that is capable of amplifying frequencies as high as 3000 megacycles has enabled radar receivers to detect targets otherwise indiscernible. Weighing only one-sixth of an ounce, the tube is readily adaptable to coaxial UHF circuitry. Among other advantages the tube's small size and inherent rigidity greatly reduce microphonics while enabling it to withstand shock and vibration.

Developmental work is now in progress utilizing this new triode in such other applications as high-frequency communication receivers, microwave oscillators, and low-noise intermediate-frequency amplifiers. It is also employed to amplify radio-frequency signals in radio telescopes.

#### **Industrial Tubes**

For industrial service three new ignitrons were developed with integral temperature-control devices that cut cooling-water requirements of each tube up to 95 percent. The high-peak-current mercury-pool tubes have ratings and characteristics identical to their predecessors. Besides the large reduction in cooling water required, the temperature-control device automatically provides overtemperature protection.

In the industrial field a new tube—a high performance miniature triode—was designed for electronic computers and put into production. Reliability and long life were prime considerations in its design because 2700 of them are utilized in one installation. Previous experience with an earlier type in widespread use has indicated that less than two percent failures may be expected in 10,000 hours of operation.

#### **Microwave**

New multichannel multiplex equipment for microwave communication systems has improved reliability, greater adaptability and ease of maintenance, and reduced cost. Operating on the

time-division principle, the new equipment is only half the size of the old.

The first shipments of a new line of telephone termination panels were made in 1953. These panels provide a tie in between the microwave system's radio equipment and the many telephone, ringing, telemetering, and control circuits encountered in the field. A new construction permits use of only 3 panels for 22 different applications.

A portion of the time spectrum formerly not used in microwave communications is utilized by a new unit introduced in 1953. It requires no additional radio-frequency bandwidth and can send fault signals from unattended stations in the communications system. Examples of such fault indications are change-over to stand-by power systems or stand-by microwave equipment, failure of a tower light, and illegal entry of a building.

#### **Carrier Current**

High-speed frequency-shift audio-tone equipment makes it possible to multiplex up to 16 telemetering, teletype, or control functions on a single voice channel. Applicable to microwave, radio, carrier current, or wire lines, the equipment is designed specifically for industrial use. When applied to electric power transmission systems, the units can perform such functions as protective relaying, transferred tripping, and supervisory control.

#### **Mobile Radio**

Newly designed radio communication equipment was first made available late last year for the fast-growing field of industrial communications.

For mounting on materials-handling vehicles or in cars and trucks, two-way radio equipment is now housed in compact rugged cases. In this way all moving vehicles of a manufacturing organization operating within a 4- to 9-mile area can be contacted instantly. This allows the flow of materials to be controlled, security patrols to be coordinated, and personnel to be grouped in an emergency.

Conversion kits were made available for quick change-over from 6-volt mobile radio units in the field to operation on the 12-volt ignition systems of various 1953 automobiles. Because many more cars may switch over to the 12-volt system this year the entire line of two-way radio equipment was redesigned to make it more readily convertible from 6- to 12-volt operation.

To convert units with less than 30-watt output the user reverses two plugs. In addition, on the 50- and 60-watt equipment, the transmitter's dynamotor must be changed, requiring less than 10 minutes.

New 15-watt mobile-radio units that operate on either 6- or 12-volt circuits are also available.

#### **Marine Radio**

Since 1949, General Electric has been working to establish VHF-FM radio communications as a necessary adjunct to overcrowded coastal harbor channels. The effort culminated in the FCC's release of rules and regulations governing this practice. Coincident with this release, radio equipment was made available to Great Lakes vessels that simultaneously monitors three radio channels and also provides facilities for transmission and reception on eight channels.

The latest addition to marine communication is a line of lower-power 6-channel equipment for use on vessels in river, lake, and coastal service. Because of its adaptability the equipment can be installed in vessels ranging from pleasure craft and small work boats to large commercial ships.

#### **Radar**

Extremely high-powered search radar systems developed for installation in a Lockheed *Super Constellation* will extend the range of America's air defense system. Previously, there were serious gaps in American radar "fences" because line-of-sight ground radars could allow enemy planes to sneak in at low altitudes. The new equipment consists of a search radar whose antenna is enclosed in a giant belly radome and an indicator console to display the radar data.

#### **Semiconductors**

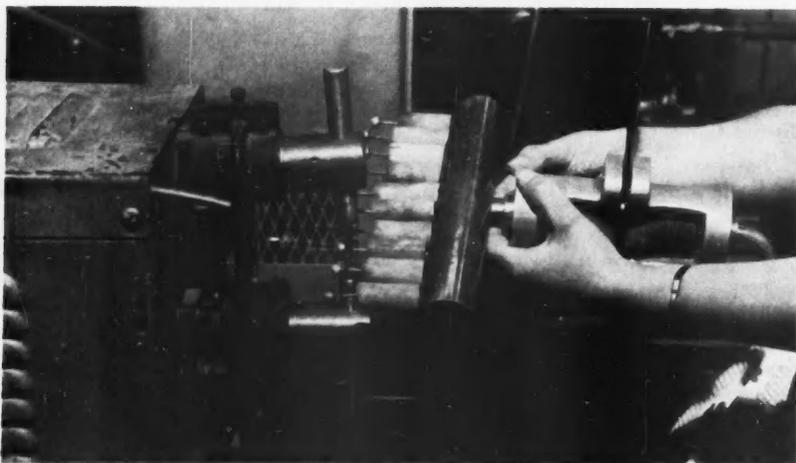
Work in the field of semiconductors during the past year had some highly significant results.

Developed was a semiconductor double-based diode with certain advantages over the vacuum tube. Possessing a low-voltage switch-like characteristic, the diode has smaller internal power losses and a higher current rating than thyratrons in the same size range.

Gold-bonded germanium diodes similar in design to present "whisker" diodes but having improved forward conductance and back resistance were introduced. And developmental power tran-



**RADIO-TELEPHONE COMMUNICATION**, such as on the *Gene C. Hutchinson*, provides multi-channel operation to speed the flow of vital materials via Great Lakes carriers.



**FABRICATION** of junction transistors weighing 0.05 ounces nears final stage as exhaust tubes are pinched off and vent welded. New manufacturing methods cut their cost in half.



**TRANSISTORIZED RADIO RECEIVER**—a developmental project—operates from a ferrite loop antenna. Despite its small size the receiver has good quality and clarity of tone.

sistors were operated with thermal stability and a usable power gain above 50-watt collector dissipation.

Junction transistors came of age as stable and capable amplifying devices suitable for many applications previously reserved for vacuum tubes and magnetic amplifiers.

Incorporated in the new transistors are many important features, among them: vacuum-tight construction with all-welded metal and glass housings, high-frequency cutoff, and high power capability. Their advantages of small size, lightweight (0.05 ounce), and practically unlimited life open up new fields of electronic application.

Newly developed techniques in the manufacture of junction transistors halved their cost compared to competitive devices. This was brought about by unique production methods. The alloy-diffusion process developed by GE is employed to fabricate the transistors' rectifying elements.

A transistorized developmental radio receiver constructed during the year measures 3 inches high, 3½ inches wide, and 4½ inches deep. Operating from a ferrite loop antenna, it utilizes nine transistors, batteries, and a tiny loud-speaker. Despite its small size, it is a fully operating broadcast receiver having good performance, quality, and clarity of tone.

The first instrument developed by GE for testing transistor equipment is a go-no-go alpha cutoff checker that operates at frequencies up to 10 megacycles. It has power supplies flexible enough to handle all p-n-p or n-p-n junction transistors.

#### **Magnetic Materials**

Highly significant developments resulted from studies in the field of ferrites—nonmetallic substances possessing magnetic properties. Since they are unstable and reactive at high temperatures, special methods were developed to grow single crystals by employing the flame-fusion technique used for synthesizing gems. Ferrite samples a half inch in diameter and two inches long were grown, resulting in a further understanding of ferrites. Last year a components factory began production of sintered ferrite bodies.

A powerful tool for investigation of magnetic properties is the high-frequency magnetic hysteresigraph. It is especially important in the study of newer materials, such as ferrites, that have future application in electronics.

# Lighting

The year 1953 saw lighting research and development on the threshold of many important advances. Beyond immediate prospects, the picture seems destined for an increasing program of important new products.

General Electric engineers and scientists predicted substantial progress in the fields of light sources; aircraft and airport lighting; electroluminescence; automotive, street, and highway lighting; and flash tubes. Some of these may become extremely significant.

Developments forecast include filament lamps operating at higher temperatures and high-frequency operation of fluorescent lamps at increased lumen output per watt. We may have rooms with luminous walls as further progress is made in the field of electroluminescence.

Foreseen in the aircraft field are landing lights of still higher intensity using mercury sources instead of conventional tungsten filaments.

Lighting engineers during the past year predicted many new advances in the automotive field. Cars of the more distant future will be equipped with headlamps that are 10 times as powerful as the present all-glass sealed-beam headlamp, and yet will not annoy approaching drivers. Windshields, at this time, will be automatically polarized by a photoelectric cell, and infrared lamps will keep them not only free of ice and snow on the outside but also free of any condensation on the inside. When hood or trunk lid is raised, fluorescent lamps will light the engine or luggage compartment; instrument panels will be lighted by electroluminescence.

On the highway, some predictions envision luminous roadways surfaced with electroluminescent material. But roadways, even if not self-luminous, will be surfaced with materials of much higher reflectance than at present. Also, the trend in roadway lighting will be toward higher illumination levels. Another possibility is a continuous line of low-mounted fluorescent lighting units along the center strip of a divided highway. While the technical engineering problems in these developments come nearer to practical solutions, economic and legal aspects must be worked out to deliver them to the public.



**HIGH-INTENSITY BEACON** mounted on the vertical fin of an airliner increases air safety. A fixture rotates the beam horizontally making it visible from all points of the compass.

## Aviation Beacon

A high-intensity rotating beacon mounted atop the vertical fin of an airliner was introduced in 1953 to further increase air safety. Developed especially for this purpose, the light source for the beacon is a 50,000-candlepower sealed-beam lamp, 4½ inches in diameter. Mounted in a fixture that rotates the beam horizontally, this lamp is visible from all points of the compass. A colored glass dome fitted over the mechanism produces a deep red beam to provide quicker and easier identification of airliners.

## Lighting and Lamps

Six incandescent reflector color lamp bulbs were introduced in 1953. Rated 150 watts, the new lamps do not require color caps because permanent color filters are baked on their five-inch faces. In addition to four basic colors—red, green, yellow, and blue—two produce blue-white and pink tints. To produce other colors and tints, these are balanced so that they will mix properly.

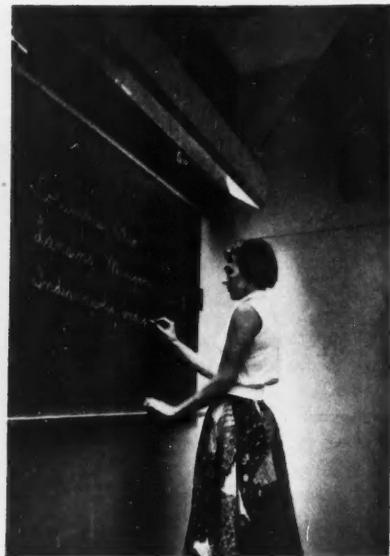
Development of a new 300-watt flood lamp of the all-glass sealed-beam type was announced during the year. Described as a "precision" lamp, its smooth



**FLASHLIGHT** bulb that contains two filaments throws either a spot or a flood of light.



**SIX REFLECTOR** color light bulbs can be mixed to create any color for decorating.



**FLUORESCENT** fixture gives even light over chalkboards and vertical surface displays.

medium-spread beam is accurately designed on the principle of the automobile headlamp. Prisms in the seven-inch lens cause a sharp cutoff of the beam, reducing "spill" light to a minimum. The flood lamp will fill many of the outdoor lighting needs for service stations, parking lots, building flood-lighting, and protective lighting.

A new sealed-beam headlamp was introduced for use on automobiles with 12-volt electric systems. The headlamp is similar in size and appearance to the all-glass sealed-beam headlamps in general use and gives comparable lighting performance.

Five major contributions in the field of flash photography were announced during 1953 . . .

- Improvement in existing flashbulbs, increasing their light output by 10 percent or more

- Improvement in the sensitivity of existing flashbulbs, resulting in their flashing at one-half the electric energy previously required

- Development of a unique extruded-pin base for midget photoflash lamps, causing bulbs to operate more effectively in the sockets of flash units

- Development of a new submidget flashbulb incorporating the improvements mentioned and filling many of the flash requirements of photographers

- Development of a new flashtube for portable equipment powered by dry batteries and producing almost twice as much light as its predecessor.

A new white bulb for use in portable table and floor lamps was announced. A three-light bulb with light levels of 50, 100, and 150 watts, it is intended for use in single-socket portable lamps that lack diffusing reflector bowls.

Developed in 1953 were flashlight bulbs that throw either a flood or a spot of light at the flip of a switch. Like automobile headlamps the new flashlight bulbs contain two filaments, each of which may be turned on independently. One filament in the form of a single loop of tungsten wire produces a broad flood of light for nearby seeing. The other filament, a concentrated coil, throws a narrow beam of light on objects at a greater distance.

General Electric does not plan to fill lamp bulbs with lightning bugs as a new light source for American homes. But during 1953 the light output of the firefly was compared with that of a neon glow lamp. Of course the glow lamp was brighter! Photometric tests revealed that it would take an average of 137,000 lightning bugs to equal the light output of a 60-watt lamp bulb.

The philosophy of group replacement of lamps before burnout, in factories, offices, and stores progressed in 1953. Lamps can be replaced by either of two recommended methods. One calls for replacement when the lamps have been burned a fixed percentage of their average rated life; the other, for group replacement of lamps when lighting has

dropped to an established minimum level. A device for visualizing economics of replacement was developed by G-E engineers.

To solve the problem of efficiently cleaning large installations of fluorescent fixtures, a portable heated washing and rinsing tank was developed. It cuts cleaning time in half.

#### School Fixture

Recognizing that chalkboards in schools need special lighting, General Electric lighting specialists developed a fluorescent chalkboard lighting fixture that at least one fixture manufacturer is now producing. With the addition of typical room lighting, 100 footcandles are produced over a 16-foot chalkboard. The fixture is also useful over bulletin boards, instrument panels, and vertical surface displays.

#### Street Lighting

Keeping pace with developments during 1953 new installations of fluorescent street and tunnel lighting resulted in more comfortable seeing, less glare, and increased public safety.

Both in standard street lighting, as in Oakwood, Ohio, and in unusual cases that require a high degree of glareless light, fluorescent lighting is becoming more important. Recent installations of viaduct lighting on the Alaskan Way, Seattle, and the Virginia Street underpass, Indianapolis, provide a high degree of safety and comfort.



**GROUP REPLACEMENT** of lamps in factories, offices, and stores before burnout occurs provides better lighting at lower cost.



**WASHING AND RINSING TANK** that is portable and heated cleans large installations of fluorescent fixtures in half the time.

The new 4200-foot Squirrel Hill Tunnel at Pittsburgh is another G-E fluorescent lighting installation comparable to the Brooklyn-Battery Tunnel in New York. It is the fifth in the United States to be lighted in this manner, with two continuous rows of slimline lamps along its ceiling near the sidewalls.

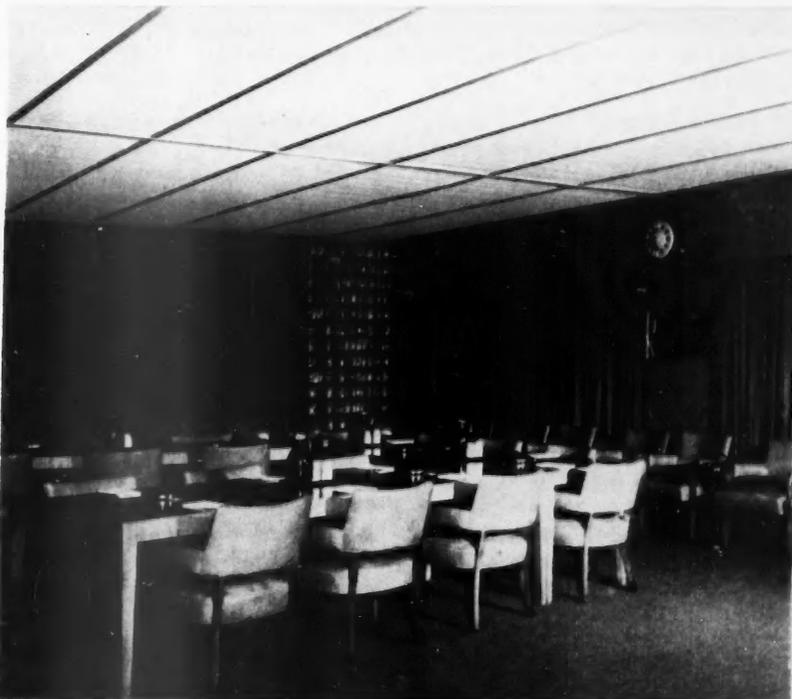
A new photoelectric street-lighting control built around a dip-soldered printed circuit provides sensitive regulation of series or multiple lighting. Photoelectric control turns on the lights exactly when needed because the photocell actually measures the light in the sky. It differs from other devices in that it requires no expensive control wire, no time clocks to reset after power failure, and no complex control circuits.

Designed to permit pole mounting of models up to and including the 30-kw size, a new constant-current transformer is 20 to 33 percent lighter than former units. Grain-oriented strip steel makes possible the lower weight and smaller size.

#### Ballasts

A complete line of clamped-core ballasts was developed during 1953 for small fluorescent lamps. Combination ratings include 4-, 6-, and 8-watt and 14-, 15-, and 20-watt ballasts, as well as ballasts for 22-watt circline lamps and 4-watt ozone lamps. This smaller, lighter, lower-cost design results in a quiet unit well-suited for home lighting fixtures.

The year also saw the development



**LUMINOUS CEILING** that can be dimmed was installed at Ford Motor Company's conference room in Detroit, Mich. It has a range of illumination from one-half to 60 footcandles.

of the first commercial-type static high-frequency converter. This 5-kw unit is capable of operating 48 to 90 slimline lamps at 300 to 600 milliamperes and at 10 to 50 percent more than their normal light output, using only small simple capacitors for lamp ballasting. The larg-

est special application for the new 360-cycle fluorescent lighting system is in the field of experimental plant growth.

#### Utilization Factors

To predict more accurately the results of proposed lighting systems that use



**FLEXIBLE TEST ROOMS** to study fundamentals in lighting design have adjustable walls and ceilings. Extensive measurements of actual and representative lighting systems are made.

contemporary types of luminaires and techniques of application, new tables of utilization factors are required. (The Harrison-Anderson data that have served the industry well for 35 years does not encompass modern luminaires or conceptions of lighting.)

In 1951 a lighting facilities laboratory was set up primarily for the study of fundamentals in lighting design. Extensive measurements with actual and representative lighting systems in the laboratory's flexible test rooms are correlated with data from other sources. From this basic information, new tables of utilization coefficients can be developed for use by lighting application engineers. Selected results of these measurements were presented and compared with other utilization data during 1953, showing the progress being made to thoroughly examine lighting design fundamentals and to rebuild them for contemporary needs.

Retaining the versatility and small size of its predecessor, the color and cosine-corrected light meter was designed to evaluate large area lighting installations using any of our common illuminants.

## Medical

A pair of smaller, more rugged, diagnostic x-ray tubes—introduced in 1953—were characterized by high heat dissipation. These tubes are 35 percent lighter than contemporary tubes of similar ratings, and have less than half as many parts as previous tubes—68 percent fewer parts, to be exact.

Two air-circulating blowers, located between the cable terminals, provide a heat dissipation  $2\frac{1}{2}$  times greater than that provided by tube units not equipped with this type of blower.

Known as the LRT and HRT, the tubes are designed for low-voltage (100 kvp) and high-voltage (130 kvp) radiography, respectively, and are adaptable to any diagnostic x-ray unit of any type, model, or manufacture—whether self or full- or half-wave rectified.

Thanks to the radical decrease in rotor mass and the electrical design of the stator and rotor, the starting speed

of the rotor has been greatly increased, making it possible now for the rotor to achieve full acceleration in only one-half second.

### Photo-timer

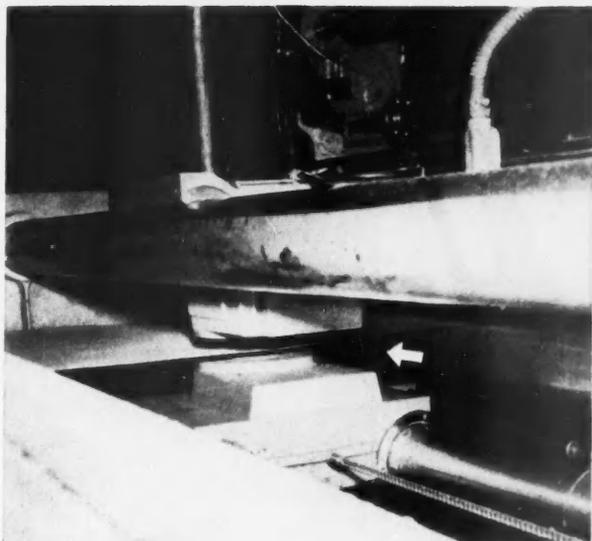
A new photo-timer design that greatly improves spot-film radiography was announced in 1953.

The photo-timing unit is sealed off in an opaque case so that room lights, dust, dirt, barium, and other factors are prevented from affecting the uniform response of the phototubes. This eliminates fluctuations in densities from film to film and inconsistent densities on the same film.

Earlier designs, whether they employ a "phonograph" type moving pickup phototube arm, or the separate side-mounted phototubes, depend for their operation on the scanning of the fluoroscopic viewing screen.

The new design interposes a *second* fluorescent screen between the x-ray source and the viewing screen, shaped in such a way that the light excited from this second screen can be "seen" by two phototubes—one located on each side of the screen.

The second screen is not flat, as is the viewing screen, but is at an angle to the viewing screen. This permits the side-mounted phototubes to pick up the visible fluorescent light emanating from either side of the central, slanting portion of the screen. The screen is backed on both sides, except for an area  $2\frac{1}{2}$  inches square located in the center of the slanted portion, by a special masking material that is not opaque to x-rays but opaque to fluorescence. In effect, this monitors the central portion of the x-ray image, providing the ideal scanning area for accurate photo-timing purposes.



**BETA-RAY** thickness gage (*arrow*), an innovation in chemical plants, makes possible continuous nondestructive tests of sheet materials.



**LAMINATE SURFACES** for desks and table tops of office furniture were produced only after extensive search for suitable adhesives.

## Chemical and Metallurgical

Developed in 1953 was a low-set silicone-rubber compound for coating glass or organic fabrics used in high- and low-temperature applications, either electrical or mechanical. It represents the greatest recent advance in the field of silicone-rubber coating materials, for combined in one compound are exceptional physical properties and ease of handling. High dielectric strength of the compound is affected slightly or not at all by elevated temperatures, nor does it soften or flow. Formulated for applications requiring a low-compression-set rubber, the compound is also useful where high resistance to water is desirable; in addition, it's ideally suited to uniform-shrinkage precision molding. Certain diatomaceous earths can be added to obtain low-compression-set stocks.

Through the development of a low-compression-set rubber, silicone-rubber parts such as gaskets and seals can now be produced in molds originally designed for natural- and synthetic-rubber parts. The new compound has a compression set of only eight percent after 22 hours at 300 F, compared with nearly 100 percent for organic rubber and about 75 percent for general-purpose silicone rubber. Its water absorption is unusually low—one percent after immersion for one week at 70 C.

Another development was a general-

purpose silicone that can be used as a fluid when heat stability isn't required. A low- or medium-temperature release agent, it also serves as a light-duty lubricant for fabrics, glass, ceramics, and similar materials. When suitable catalysts are employed, the fluid can be cured to a resin-like film.

An improved flexible insulating resin—another silicone product—was designed for use in applications requiring resistance to extreme heat or cold. With improved coating speeds this resin provides a good combination of heat resistance, low-temperature flexibility, and bonding properties. Dielectric strength of glass cloth coated with the new material shows no significant decrease after a 30-day 250 C exposure.

### Laminated Plastics

Although it isn't often possible to combine a quality improvement with a cost reduction, this was done with a new low-cost paper-base laminate, fabricated by hot-punching it into a variety of parts for insulation. Priced about 30 percent less than the NEMA-XP grade used for similar applications, it has a flexural strength 50 percent higher. This laminate has become a highly popular insulating material with commercial fabricators for the electrical and electronics industries.

A new grade of decorative laminate is postformed by heating so that bends can be made during installation. Thus horizontal and backsplash surfaces of kitchen drainboards and work surfaces can be made of one plastics sheet, eliminating the dirt-catching joint between the two surfaces. A curved lip at the front forms a dripless edge to hold back spilled liquids.

As a result of extensive work with adhesives made available since World War II, another grade of decorative laminate can now be bonded to steel or wooden desks. When used for this purpose, it is designed to give correct light reflection, color value, and glare reduction. The material improves the appearance of office furniture and increases its life.

A one-piece molded top of decorative laminate has been adapted for use on the General Electric roll-around dishwasher. It replaces a porcelain-enameled steel top with the extra serviceability and beauty of a laminate introduced two years ago. This application may pave the way for its use on many major kitchen appliances.

### Mica Mat

A paper machine installed in 1952 is now producing mica mat in continuous flexible rolls 40 inches wide and



**AGGREGATES** of polytetrafluoroethylene powder (*magnified*) in silicone rubber. The fibrous elastomer is unusually tough and resistant to high-temperature lubricants.



**SOLVENT-RESISTANT** rubber gaskets developed to resist harmful effect of gasoline.

two to five mils thick. The mica product is running 100 percent higher in tensile strength than the original pilot-plant mica mat, and along with increased density it has a 70 percent higher dielectric strength plus a high degree of thickness uniformity. This development was a result of improved processes and the use of the beta-ray thickness gage.

The program for the coming year envisages considerable improvement in all grades of mica mat and the extension of its use in electric apparatus.

#### Resins

Another development is a new heat-resistant phenolic resin that shows promise in the manufacture of laminates for high-temperature applications. Laminates made of glass cloth and this resin retain a considerable part of their physical properties after exposure to elevated temperatures, and their electrical properties actually improve. In aircraft and guided-missile manufacture the low specific gravity, high strength, and high resistance of such laminates should be of paramount interest.

A phenolic-type plastics-reinforcing glass mat has been developed in conjunction with Owens-Corning Fiberglas Corporation. This can be used to manufacture laminates employing either phenolic or melamine resins. Laminates fabricated of this new material and flame-retardant resins exhibit extremely low water absorption, low dissipation factor, and high flexural strength.

Polyester resins designed specifically for use in the reinforced-plastics industry are now available in commercial

quantities. Three of them are rigid-type resins; the fourth is a flexible type. They are being utilized in the manufacture of automobile bodies, corrugated sheet, lamp shades, arctic sleds, and pipe.

A unique product introduced this year is a water-soluble resin with remarkable antistatic properties for textiles. Another is a plasticizer that polymerizes to a higher molecular weight solid when vinyl compounds are heat processed. Two new chemical-resistant resins were also introduced. Their resistance is similar to R-108, but they have better film-forming properties, faster cure, and better compatibility with solvents and alkyds.

#### Fire-retardant Resin

Also developed was an epoxy resin that, while possessing the properties of other epoxy resins, has a heat-distortion point of 170 C and is a self-extinguishing material. With a power factor below 0.5 percent, the resin's dielectric constant is stable over the 25 to 150 C range. In addition it is resistant to 10-C oil and moisture and is useful in many applications on electric equipment.

#### Inorganic Insulation

Now in production is an unusual, essentially inorganic, insulation developed during the year. This material, known as *alpholite*, replaces more expensive high-temperature insulation in transformers. Based on a controllable phospho-asbestos reaction, the compound has found application as phase barriers, cylinders, axial spacers, and core-bolt insulation.

#### Gaskets

Four access and escape hatches of the Douglas C-124 *Globemaster* military transports are now tightly sealed against air leaks by a new kind of cold-resistant silicone-rubber gasket. Remaining flexible after long exposure below -120 F, the silicone compound enables rubber to be used at temperatures lower than ever before possible. It shows less than 25 points durometer increase from 500 F down to -120 F.

Solvent-resistant rubber gaskets that have high-compression properties and are chemically inert were proved useful in aircraft where gasoline was once found harmful. Polytetrafluoroethylene is electrodeposited onto a metallic anode that is made in the shape of the desired gasket. Cured, fused, and stripped from the anode, the plastics envelope is then shaped around the rubber gasket.

#### Beta-ray Thickness Gage

Introduced on two production lines during the year were beta-ray thickness gages, replacing infrequent and destructive spot checks of sheet material with continuous and nondestructive checks. The gages have proved invaluable in evaluating process changes and correcting improper machine operation. Raw paper and fabric are checked continuously, resulting in a gradual upgrading of uniformity.

#### Carbides

Evidence shows that the field of cemented carbides is a relatively un-

touched research area. In 1953 a new series of these man-made metals was announced and an unlimited number of chrome-carbide grades developed. Such developments will help achieve a quicker realization of the much-talked-about automatic factory and also give industry a new insight into high-temperature materials.

The heavy-duty steel-cutting carbide 370—the first of a new series—introduced at the National Metal Congress last fall is capable of removing more cubic inches of steel per minute than any existing carbide, thus speeding up heavy-duty steel-cutting jobs an estimated 25 to 30 percent. In addition, the unique grain structure of the newly created carbide enables it to operate at cutting temperatures higher than ever before practical—up to around 1800 F without tip deformation.

### Chrome Carbide

Development engineers believe that chrome carbide may ultimately solve many problems in the jet-engine industry; there is a probability that it might be used as a high-temperature material for turbine buckets. Seeking materials to handle fissionable products, atomic scientists also may find chrome carbide of considerable value.

Latest chrome-carbide developments give industry a choice of either greater wear resistance with correspondingly less corrosion and erosion resistance—or the converse. Already, chrome-carbide 608 has branched into a new field, that of balls for valves. In hot-hardness tests the material withstood temperatures between 1100 and 1500 F.

### Magnets

A new permanent-magnet plant began operation at Edmore, Mich., in 1953. It will turn out high-quality magnets—screened by the latest quality-control production techniques—for use throughout industry. Magnets of the highest pulling power that can possibly be made with an aluminum-nickel-cobalt alloy—alnico—will be produced.

Also the field of barium-ferrite magnets was probed. Study of this source of magnetic energy may provide the answer to the nation's supply of magnets during critical materials shortage.

### Aluminum Magnet Wire

Developmental strides in joining aluminum to itself and to copper have opened the way for the application of aluminum magnet wire in many types



CEMENTED-CARBIDE CUTTING TOOL SPEEDS HEAVY-DUTY STEEL CUTTING 25 TO 30 PERCENT.



PERMANENT-MAGNET PLANT AT EDMORE, MICH., USES LATEST QUALITY-CONTROL METHODS

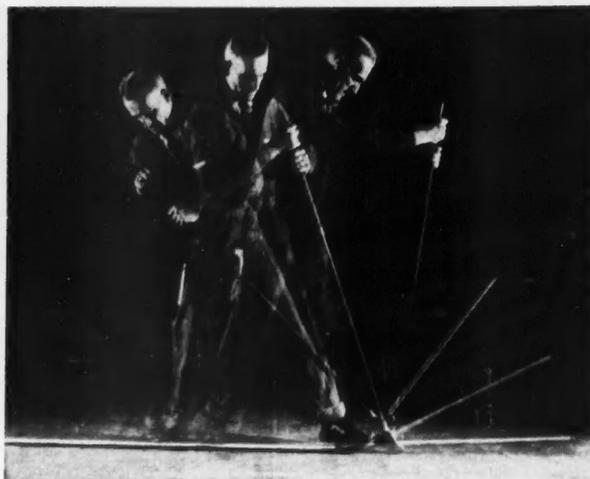
of electric apparatus. Control over potential corrosion problems is possible through knowledge derived from systematic studies of dissimilar metal-joint systems.

### Silicon-iron Sheet

Successful methods for producing single crystals of silicon iron in sheet form with predetermined orientation were developed. Constructed for this purpose was a furnace that promotes continuous growth of a seed crystal into sheet form. Single crystals of silicon iron thus formed are useful in special magnetic circuits. Also they are valu-

able for research into magnetic properties and the nature of plastic deformation in metals, and for study of recrystallization.

General-purpose grades of cold-reduced silicon-steel strip were introduced for use in small motors of high operating efficiency. Produced in coil form, they will replace the older hot-rolled sheet products. These cold-reduced grades have magnetic properties similar to those of equivalent hot-rolled sheet. Thus they satisfy high motor efficiency while maintaining the economy and convenience of continuous strip in the production of laminates.



HEATING WIRE IS STAPLED TO CEILING BEFORE PLASTERING (LEFT). ZINC METALLIZING PROCESS MAKES STEEL CONDUIT EASIER TO BEND

## ... For Building Construction

Now being marketed in a limited section of the United States is a new way of heating homes by electric radiant energy. The system consists of prefabricated lengths of heating wire that are stapled to the ceiling before plastering and to individual room thermostat controls, giving each room its own control for maximum comfort and economy. When the installation is complete, the system is entirely concealed except for the thermostat.

Advantages of electric radiant heating are numerous: Heat from the system is comfortable—there is a temperature difference of less than four degrees between ceiling and floor, and chilly drafts or air currents are not present. Elimination of radiators, wall heaters, convectors, and protruding baseboard heaters allows more usable wall space. Nor is there any need for a chimney, basement, or utility room to house heating equipment. And no fuel-storage areas, pipes, or ducts are required. Because the only moving parts are those found in the room thermostat, this system is noiseless.

### Motor-driven Master Switch

A motor-driven master switch, rated 3 amp, 25 volts, was added to the General Electric remote-control wiring system. It's a 24-volt 25-circuit switch, with each of the circuits capable of operating one remote-control relay that in turn controls one lighting circuit. The driving mechanism of the new

switch is energized by standard remote-control switches that can be installed to control the motor-driven switch from as many different locations as desired. Pressing these switches causes the motor-driven master switch to turn either on or off the 25 lighting circuits connected to it, after which the switch automatically resets itself for the next ON or OFF operation.

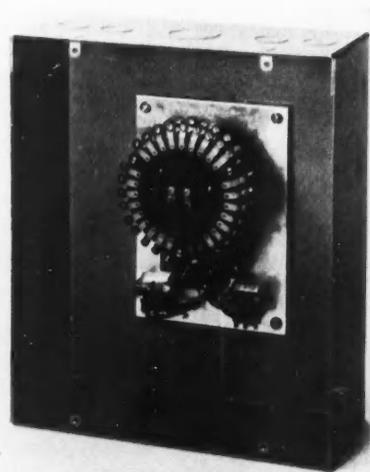
The new switch can be used to control a preselected pattern of lights inside and outside a house or banks of lights in factories, offices, and institutions. It can be installed in parallel, or cascaded—that is, the 25 circuits on one motor-driven switch can be connected to 25 other motor-driven master switches to achieve control of 625 lighting circuits and so on, until all desired lighting circuits are controlled.

### Rigid Steel Conduit

Introduced in 1953 was a rigid steel conduit with improved corrosion resistance and easier bending and wire-pulling characteristics.

This conduit is zinc-coated by a metallizing process that does not harden the conduit or form brittle zinc-iron alloy—the first change in the method of applying zinc to rigid conduit in several decades.

Although never before applied to rigid conduit, zinc metallizing has proved itself by more than 30 years of use on ships, pipelines, bridges, and trestles in damp and corrosive atmospheres.



MASTER SWITCH, motor-driven, controls 25 parallel, or cascaded, lighting circuits.

In addition to the metallizing process, a new antifriction inside coating was added to make wire-pulling easy, and to provide permanent interior protection against corrosion.

### Plastics Wall Plates

Modern functional design was utilized in a line of wall plates for standard wiring devices. Made of sturdy plastics in ivory and brown, the new plates have a smooth-finished contour that eliminates all dust-catching grooves and patterns. Their simplicity of design blends with any interior and makes them easy to clean.



**REFRIGERATOR-FREEZER** of the future has one-half-inch-thick walls, magnetically sealed doors that open from kitchen and dining areas, and an ice-water tap.



**LAZY-SUZAN** shelves give table-top accessibility, and can be raised or lowered even when fully loaded.

## Appliances

Highlighting research and engineering progress in appliances during 1953 was the XR-10, a possible refrigerator-freezer of the future that is horizontal in design, accessible from two sides, and half as deep as the refrigerator in use today.

Of 10-cubic-foot capacity, cabinet-like in appearance, and supported by twin 10-inch-high pillars resting on an open work surface, the unit has all storage space above normal counter height for maximum convenience and elimination of stooping and undue reaching.

Occupying only about one-half the space required by today's 10-cubic-foot refrigerator, the developmental unit has one-half-inch thick walls as compared with the three-inch wall thickness of present-day refrigerators. Thin-wall insulation 10 times more efficient than that in use today made the space-saving possible (see Research, page 10).

In reality, the XR-10 has no back, for one of the sides is designed to be opened from the kitchen area and the other from a living- or dining-room area.

The unit has a tap for ice water, and an ice maker that provides any cube size desired in the quantities necessary, ejected from the unit in either cube or crushed form.

The magnetically sealed doors have no handles but are opened by means of finger grips at the base.

### "Food at Your Fingertips"

In the field of refrigerator production, "food at your fingertips" characterized the combination refrigerator-freezers introduced for 1954. The new-type shelves that turn in Lazy-Susan fashion not only give table-top accessibility but also are adjustable to varying heights, even when fully loaded. They can be raised or lowered in quarter-inch increments to accommodate large dishes and small cans without any wasted space.

Besides the two combination refrigerator-freezers of 10 and 12.1 cubic feet, an automatic defrosting model and five manual defrosting models were introduced.

### Freezers

Two upright freezers—a 15-cubic-foot model with an in-the-door ice-cream conditioner, and an 11-cubic-foot model—were brought out late in the year, as well as two chest-type freezers, in 11- and 7-cubic-foot sizes.

This conditioner holds up to 1½ gallons of ice cream in half-gallon containers at a temperature proper for scooping consistency.

### Automatic Switching Lampholder

A combination lampholder and mercury-button switch that provides automatic control of light in appliances having horizontally hinged parts, such

as top-opening food freezer units, was introduced in 1953. The 90-degree angle normally travelled by a freezer lid does all the work for this switch and socket. The electric circuit is opened and closed with a mercury-button-type switch. Advantages offered to appliance manufacturers are the mounting and wiring of one device having no moving parts to wear out.

### Junction Box for Appliance Wiring

A junction block, or box, made with two outlets for power take-off was designed to be used as a termination point in all types of appliance harness. Made originally for refrigerators, and now extended into the freezer field, this box is a junction point of power supply cord and various component wires that run to lights, butter conditioners, motors, compressors, and controls.

### Clothes Dryers

A new clothes dryer announced in 1953 will sprinkle four to six pounds of dry clothes for ironing within 30 minutes. This is accomplished by means of a drum-width metal sprinkling cylinder filled with water and inserted into special sockets in the dryer drum. When the conditioner dial is turned to SPRINKLE or FLUFF and the time dial set, starting the operation, the motion of



FIFTEEN-CUBIC-FOOT UPRIGHT FREEZER HAS IN-THE-DOOR ICE-CREAM CONDITIONER.



NEW CLOTHES DRYER (RIGHT) CAN SPRINKLE SIX POUNDS OF CLOTHES FOR IRONING.



UNDERCOUNTER DISHWASHER CAN BE LOADED WITHOUT REMOVING OR SLIDING THE RACK.

the rotating drum causes water to be released through perforations in the sprinkler cylinder and distributed evenly into the tumbling clothes.

### Dishwashers

A new quick-loading undercounter dishwasher can be loaded without removing or sliding the rack. It has an open-center upper rack that permits loading of both upper and lower racks at the same time. Glasses can be loaded and washed equally well in either rack, permitting up to 54 assorted size glasses to be washed at one time. The unit also has greater capacity for extra-tall glasses, pots and pans, and oversize dishes.

### Room Air Conditioners

Increased cooling and dehumidification are incorporated in a completely redesigned line of room air conditioners being produced this year. Available in 4 sizes— $\frac{1}{3}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$ , and 1 hp—these air conditioners operate more quietly because of their lower velocity air flow.

New design features of the three larger capacity models include a powerful exhaust for the rapid removal of smoky or odor-laden air, and a single control for five comfort positions—among these a setting for extra dehumidification on muggy days. The  $\frac{3}{4}$ -hp size will also be available with reverse cycle operation. Employing the principle of the Weathertron, this room air conditioner heats in winter, cools in summer.

### Toasters

A simple automatic toasting mechanism permits selection of the desired degree of brown in an automatic toaster introduced in 1953. The unit also pops the toast up to extra heights for easy removal and has a snap-out snap-in crumb tray.

### Clocks

Development of General Electric and Telechron new illuminated alarm clocks was completed during the past year. Design requirements were satisfied with the use of a transparent polystyrene dial illuminated through the edge by a miniature tungsten-filament lamp. Based on the refraction-of-light principle, this method evenly illuminates the plastics dial which in turn silhouettes numerals and clock hands for maximum contrast. Brightness of the dial can be varied from a level high enough for night-light use to any lesser value.

### Radio Timer and Switch

Designed for the low-cost clock-radio market, a new Telechron radio timer automatically turns on the clock radio at a preselected time and also serves as a highly accurate clock. The low cost was achieved by planning for a minimum number of parts and by simplifying the manufacturing process. Although this timer has 44 percent fewer parts than its predecessor, it maintains equivalent function.

Radio timers now have a new enclosed switch that was put into production in 1953 replacing the open type formerly used. Housed in a single phenolic molding, the switch has a reduced number of parts—7 instead of the former 15.

This integral part of the radio timer is designed for convenient assembly as a unit. Its snap action is provided by the functioning of the timer movement itself, resulting in a switch operation practically independent of any switch adjustment.

Made to meet Underwriters' Laboratories specifications for 15 amp, 115 volts, the new switch now enables radio manufacturers to meet their required design specifications with greater flexibility.

### Automatic Blankets

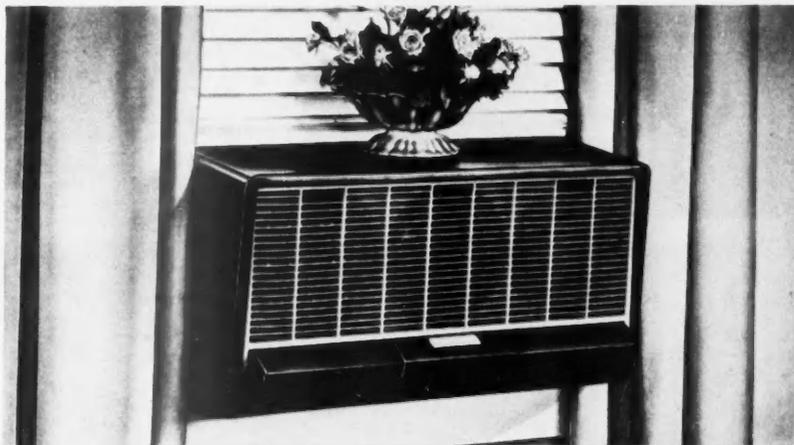
A custom-contoured automatic blanket with new bedside control was developed last year. The bottom corners of the blanket are contoured in the mattress-fitting style that is harder to kick or pull out but does not bind the feet of the sleeper.

### Irons

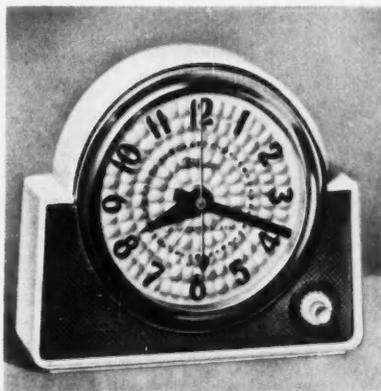
A steam-and-dry iron that can be used with tap water in all but extremely hard water areas, and a lightweight automatic iron were introduced. Both models are lighter and have larger soleplates than former models. Fabric selector dials located on the handles now include settings for the man-made fibers so widely used in fabrics.

### Phone Light

A combination phone light and all-purpose night light provides plenty of light for dialing and makes note-taking easier. The socket and shade are attached to a broad base by a free-directional swivel so that the base may be slipped under the telephone or hung from the wall, and the light adjusted to any position.  $\Omega$



ROOM AIR CONDITIONERS COMBINE INCREASED COOLING AND DEHUMIDIFICATION.



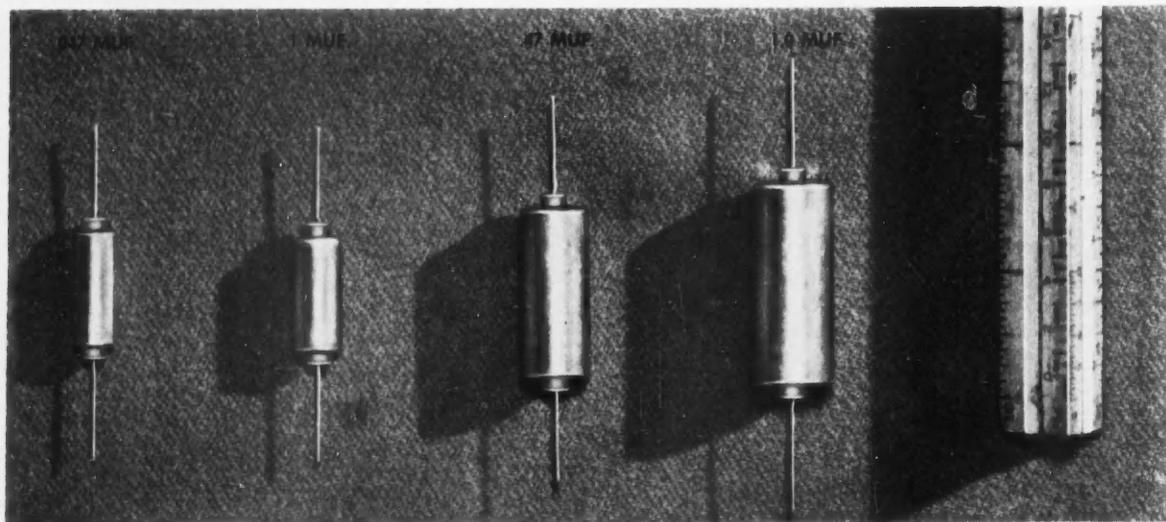
NEW ALARM CLOCKS WITH ILLUMINATED DIALS CAN ALSO SERVE AS NIGHT LIGHTS.



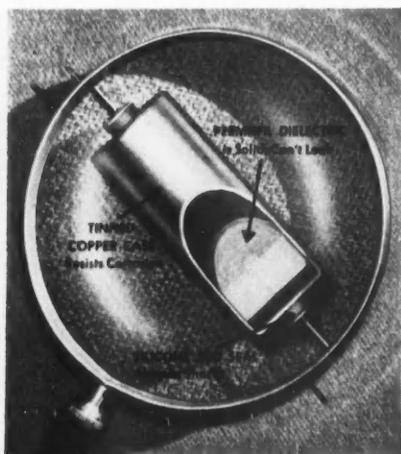
SIX DEGREES OF TOASTING NOW POSSIBLE. AUTOMATIC BLANKET IS CUSTOM-CONTOURED.



# DESIGNER'S



## New metal-clad subminiature capacitors withstand extreme temperatures



**RUGGEDLY CONSTRUCTED** G-E subminiature metal-clad capacitors meet all requirements of JAN-C-25 and the proposed MIL-C-25.

### Permafil solid dielectric permits operation up to 125C without derating

Here's a complete new line of General Electric metal-clad subminiature capacitors designed to meet difficult operating conditions. Now you need no increase in capacitor size for applications with high working temperatures.

G. E.'s exclusive permafil solid dielectric eliminates the possibility of leakage without derating from  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ —and up to  $+150^{\circ}\text{C}$  with proper derating. Silicone bushings give high shock resistance—both thermal and physical—and leads can be soldered right up to the bushing.

Muf ratings range from .001 to 1.0 muf in 100, 200, 400 and 600 volts d-c working. They can be operated at full voltage up to altitudes of 50,000 feet.

If you need even smaller capacitors, G.E. has introduced another line of new Pyranol\* (liquid-filled) metal-clad capacitors. These are designed for operation from  $-55^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  without derating and offer the same electrical advantages as their permafil cousins. For further information on permafil capacitors, send for new Bulletin GEC-987.

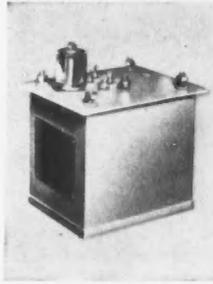
GENERAL  ELECTRIC

# DIGEST

## TIMELY HIGHLIGHTS ON G-E COMPONENTS

### Compact high-voltage components built for extra long service life

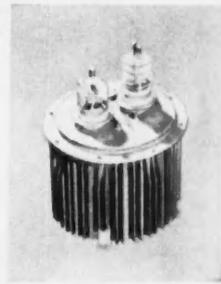
These G-E high-voltage components offer a continuous-service life for long periods under extreme temperatures and mechanical shocks. All are oil-filled and hermetically sealed to resist moisture, dirt and dust. For applications 5000 volts and higher, where corona must be held to a minimum, a wide range of ratings can be tailored to meet your needs. In your inquiry, please include all functional requirements, any physical limitations, and expected quantities. Contact your G-E Apparatus Sales representative for more information.



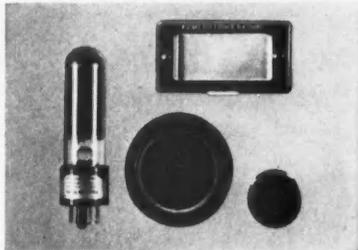
Rectifiers



Reactors

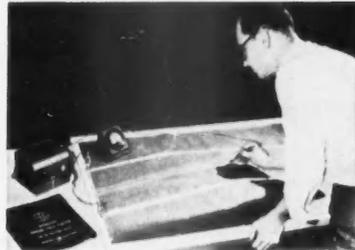


Transformers



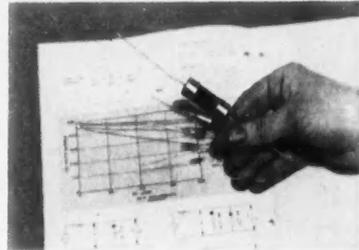
#### Detects, measures light accurately

G-E photovoltaic cells—for applications where electronic amplifiers are not practical—provide extra-high output with stability and long life in capturing light energy and converting it into electrical energy. This self-generating power plant can detect, measure, and control light—and can measure variations in colors. These G-E cells are available in a hermetically sealed series with standard mountings, and in a wide variety of mounted and unmounted sizes. See Bulletin GEC-690.



#### Speeds solution to field problems

The G-E analog field plotter offers a valuable aid to electronics equipment engineers in simplifying complex field studies. Problems in electrostatics, electromagnetics, and many other fields are rapidly solved with this sensitive, versatile plotting board and associated equipment. It needs only a low-voltage d-c supply, and is not affected by line-voltage variations. Explanation and instructions are covered in a 50-page manual accompanying plotter. For details, see Bulletin GEC-851.



#### Cover wide temperature range

From  $-55\text{C}$  through  $+100\text{C}$ —that's the wide range covered by these new G-E miniature selenium rectifiers. Stacks—available for either lead or bracket mounting—have the same outstanding features as larger G-E selenium cells: long life, good regulation, high reverse resistance, and low heat rise. For protection, they are enclosed in either Textolite\* tubes, or hermetically sealed in metal-clad casings. For more data, contact your G-E Apparatus Sales representative.



#### EQUIPMENT FOR ELECTRONICS MANUFACTURERS

##### Components

Meters, Instruments	Fractional-hp motors
Dynamotors	Rectifiers
Capacitors	Timers
Transformers	Indicating lights
Pulse-forming networks	Control switches
Delay lines	Generators
Reactors	Selsyns
Thyrite*	Relays
Motor-generator sets	Amplidyne
Inductrols	Amplistats
Resistors	Terminal boards
Voltage stabilizers	Push buttons
	Photovoltaic cells
	Glass bushings

\*Reg. Trade-mark of General Electric Co.

##### Development and Production Equipment

Soldering irons
Resistance-welding control
Current-limited high-potential tester
Insulation testers
Vacuum-tube voltmeter
Photoelectric recorders
Demagnetizers

General Electric Company,  
Apparatus Sales Division, Section F667-26  
Schenectady 5, New York

Please send me the following bulletins:

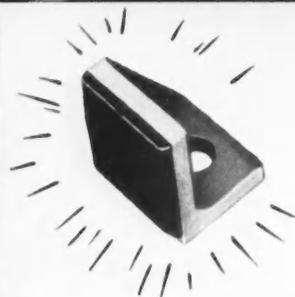
- for reference  
 for immediate project  
 GEC-690 Photovoltaic Cells  
 GEC-851 Analog Field Plotter  
 GEC-987 Permafil Capacitors

Name \_\_\_\_\_

Company \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_

Success stories of  
**CARBOLOY**  
CREATED-METALS



Once, rotating pulverizer blades in industrial stokers couldn't stand the grind of abrasive coal. They wore out fast . . . caused costly shut-downs and repairs. A Carboloy created-metal solved the problem—600% better than hard steel could do. Have you a pulverizing wear-problem? Write for free folder.

## These pulverizer blades outwear hard steel 6 to 1

Abrasive wear used to be a real bugaboo for one coal stoker manufacturer. His pulverizer blades of steel would crush only 3,500 tons, then had to be replaced.

Recently, he switched to blades faced with ultra-hard Carboloy Cemented Carbide. After pulverizing 22,000 tons—6 times as much as the steel—they showed *no appreciable wear!*

Imagine the savings in downtime, maintenance for users; the great reputation and product-demand this stoker manufacturer is building. Like thousands of other makers of machines or products, he knows that where there's wear, there's usually an ideal spot for Carboloy Cemented Carbide—the same created-metal that has worked production miracles in the die and metal-cutting field.

### MEN AND METALS TO SERVE YOU

Cemented Tungsten Carbide is but one of the Carboloy created-metals that might help you create better products.

Perhaps you can use new Chrome Carbide, for example, to combat corrosion, along with erosion and abrasion in equipment parts. Or Carboloy permanent magnets to improve your product's design, lower its size, weight, cost. Or Hevimet to build a

better balance weight or radiation screen. Find out now. Get in touch with a Carboloy engineer for *all* practical knowledge and help available on these created-metals. Look to Carboloy laboratories, too, for exciting new created-metals to come.

Write us today about any of your pulverizing or other special wear problems.

"Carboloy" is the trademark for the products of the Carboloy Department of General Electric Company

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

## First in created-metals for better products

**ALNICO PERMANENT MAGNETS**  
for lasting magnetic energy

**CEMENTED CHROME CARBIDES**  
for exceptional resistance to corrosion, along with erosion and abrasion resistance

**CEMENTED TUNGSTEN CARBIDES**  
for phenomenal cutting, forming, wear resistance

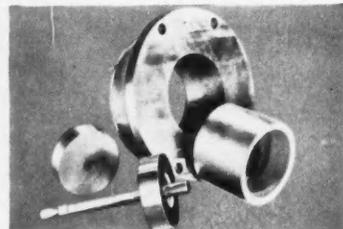
**HEVIMET**  
for maximum weight in minimum space, and for radioactive screening

Plants at Detroit, Michigan; Edmore, Michigan; and Schenectady, New York

## News About Created-Metals

### Carbide Molds Last 3000% Longer

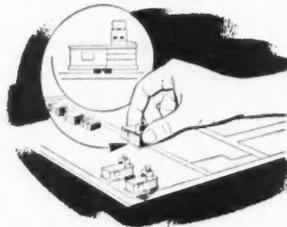
Grinding wheel production increased from 2,500 pieces per mold to more than 86,000—that's what Carborundum Co. re-



ports after switching to tungsten carbide equipped molds.

Wear-resistant Carboloy cemented carbide inserts were tough enough to withstand the terrific abrasive action of molding, under pressure, silicon carbide and aluminum oxide particles. Molds kept wheel dimensions within specifications; when finally worn, were resized and used for producing larger wheels. Write Carboloy Department of General Electric Company. (See address at left.)

### Magnets Simplify Machine Layouts



A novel use of Carboloy permanent magnets has been found in simplifying plant machine layout. To eliminate tedious redrawing of machine arrangements, scale models of machines are mounted on tiny magnets and moved about on metal planning board until optimum arrangement is found. Each model holds itself magnetically in place while the others are being positioned. Write the Carboloy Department of General Electric Company. (See address at left.)



### Revised Bulletin on Chrome Carbide

Recent tests and experiments with chrome carbide have uncovered new facts about its application and its excellent resistance to corrosion, abrasion and erosion.

This information has been incorporated in revised Bulletin WR-104A, bringing it up-to-the-minute on this Carboloy created-metal. For Bulletin write Carboloy Department of General Electric Company. (See address at left.)

**IN CANADA.. IT'S C.G.E.**



Peterborough Works... one of the 13 plants that manufacture General Electric products in Canada.

**... the Oldest and Largest  
Electrical Manufacturer**

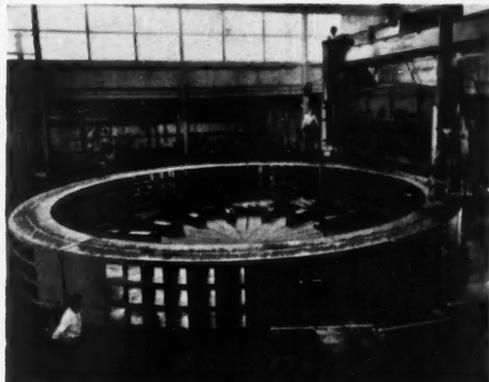
Over 16,000 workers in 13 modern factories and a nation-wide network of sales and engineering offices and warehouses, manufacture and distribute all types of G-E products used to generate, transmit and utilize electric energy.

Whether it's generators, transformers, switch-gear, motors, communications equipment, appliances, radios, television sets, incandescent and fluorescent lamps, wiring materials, or practically any other electrical product, you'll find that Canadian General Electric makes them and makes them well.

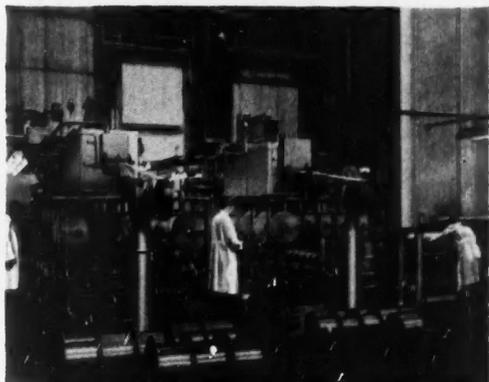


**CANADIAN GENERAL ELECTRIC COMPANY  
LIMITED**

Head Office: Toronto • Sales Offices from Coast to Coast



The largest rail and column boring mill on the continent is in operation at Peterborough Works. Here it turns a 42-foot generator stator frame.



This equipment, processing Formex magnet wire, is only a small segment of the extensive wire and cable manufacturing operations at Peterborough.

# Is Fluorescent Street Lighting Here to Stay?

Every major city in the United States will have an installation of fluorescent street lights by 1963. This prediction, made by R. J. Swackhamer, nationally-known street lighting authority of the General Electric Company, is supported by the fact that since their introduction in Detroit in 1950, more than 1000 fluorescent luminaires are already in use or on order in more than a score of communities throughout the country.

## HIGHER EFFICIENCY

Experience in England and France further substantiates this prediction. Well over 100 installations have been made in England, while the French have about 6000 fluorescent lamps in Paris alone.

The higher efficiency, longer lamp life, lower maintenance and servicing expense of fluorescent street lighting more than offset their higher initial cost.

## BUILD PUBLIC GOODWILL

The community benefits of fluorescent street lighting include greater "shopping magnetism" of the business districts, higher real estate values, increased night time safety and a bolstering of community pride. In addition, the public relations possibilities to the electric utility, inherent in good, modern street lighting are readily recognized.

The enthusiastic acceptance of present installations promises to make fluorescent street lighting a cornerstone of our present era of night living. General Electric Company, Schenectady 5, N. Y. 301-242

MORE POWER TO AMERICA

GENERAL  ELECTRIC



VIRTUALLY GLARE-FREE CHARACTERISTICS and ease of maintenance of the new G-E Form 206 fluorescent luminaire are here demonstrated to R. J. Swackhamer, Mgr. Sales (left) and F. D. Crowther, Mgr. Marketing by P. H. Houser, Development Engineer in the lighting display room at G-E's Lynn River Works.



EXCELLENT ROADWAY "SEE-ABILITY"—even on wet pavements—because light is reflected as wide bands rather than concentrated spots due to the large globe area of fluorescent luminaires which provide uniform distribution of light.

"SHOPPING MAGNETISM" provided by high-level light output and modern appearance of fluorescent luminaires is demonstrated below.



COMFORTABLE SEEING is provided by the low-brightness of fluorescent luminaires even where low mounting height is necessary—such as in the amusement park below (left) and the mile-long, high-speed viaduct (right). Tunnels and underpasses are ideal locations for fluorescents.

