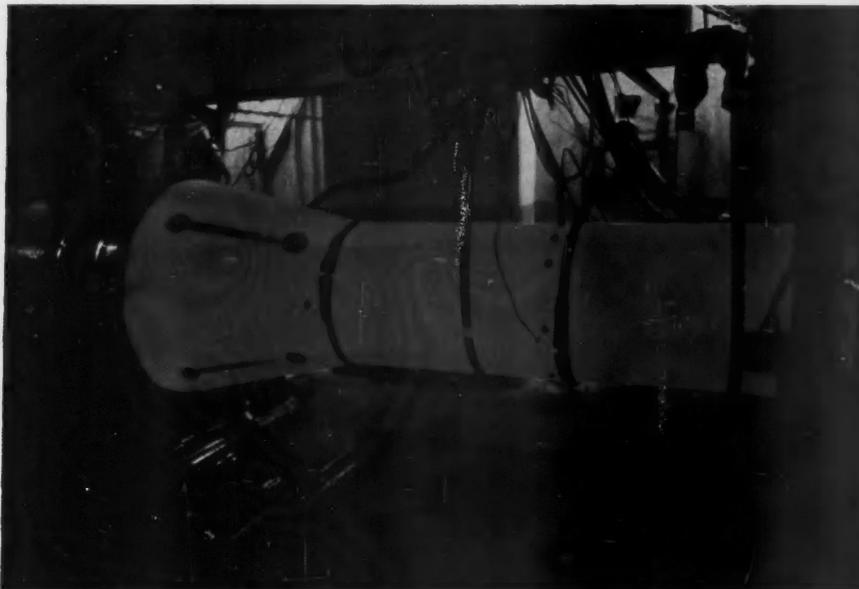


# GENERAL ELECTRIC *Review*

JANUARY 1957



New line of universal diesel-electric road locomotives for foreign use.

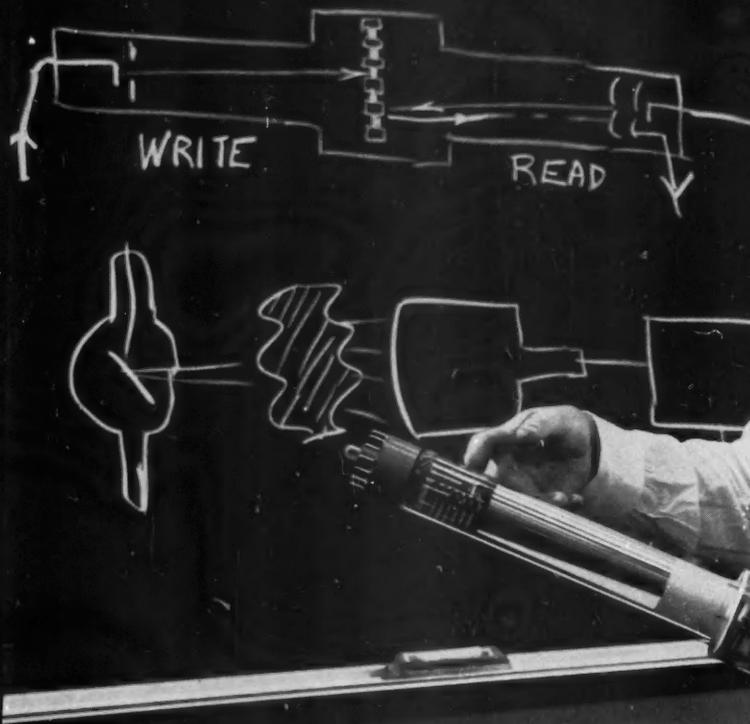


"Hot-rod" turbojet for testing jet-engine materials at above-normal temperatures.

Research and Engineering  
Progress • 1956



High-temperature electronic components.



**Dr. P. E. Pashler, Ph.D.**, University of Toronto (1947), studied on a post-doctorate fellowship at the University of Amsterdam and then served on the University of Toronto faculty before joining the General Electric Research Laboratory in 1950. His research interests have included molecular physics, ballistics, and various phases of electronics. He has been manager of the *Applied Physics Section* since 1955.

## Making electrons more versatile

**Dr. P. E. Pashler of General Electric studies the basic phenomena associated with electronic devices**

Hearing, speaking, and seeing are among the "human" functions that electronic equipment has been performing since the birth of radio and television. Newer electronic systems demand devices that also can read, write, remember, and calculate.

Dr. P. E. Pashler and a group of his associates at the General Electric Research Laboratory are seeking a better understanding of the basic principles of electronic materials and devices through studies of such fundamental phenomena as secondary electron emission and noise in electron tubes.

Among the recent accomplishments of Dr. Pashler's *Applied Physics Section* are the improvement of photoconductors to give camera tubes the special sen-

sitivity and quick response required for x-ray television, and the development of an information storage tube with a tiny memory cell only an inch square that will remember nearly a million "bits" of information.

As we see it, providing scientists with freedom and incentive to extend the frontiers of knowledge is fundamental to the creation of better products, better jobs, and more opportunities for human satisfactions.

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

# GENERAL ELECTRIC **Review**

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JANUARY 1957

VOLUME 60

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## COVER

Ten 1800-hp road locomotives—part of a new line of universal diesel-electric export locomotives—were ordered by Mexico during 1956 (page 44). During test, the “hot-rod” turbojet engine achieves turbine-bucket temperatures in excess of 1600 F (page 46). High-temperature electronic unit (left) operates inside glowing electric furnace, while conventional unit (right) melts (page 12).



General Electric engineers help coordinate planning at all stages of plant expansion.

# ONE SOURCE BUYING FROM GENERAL ELECTRIC

## Sees To Tomorrow's Needs...Today

In a constantly expanding economy, the most satisfactory installation is the one planned with an eye to the future. To ensure the kind of superior electrical equipment that will meet tomorrow's demands, many managements specify one source buying from General Electric. From blueprints on, experienced G-E engineers help provide a flexibility of plant operation with electrical systems and components correctly designed for present needs and future expansion. G-E systems analyzers resolve complex design problems to cut costs and speed the work of the project coordinators in planning the

selection and manufacture of all G-E equipment. Then G-E field service men in supervising installation and initial start-up help expedite job completion. Once in operation, features engineered into the equipment by G-E development laboratories assure many years of efficient, dependable performance. Whatever your electrical needs—in systems or components—General Electric can be of help. For the full benefit of one source buying, contact your G-E representative early in your planning. *International General Electric Co., Dept. 56-33E, 150 East 42nd St., New York 17, N.Y., U.S.A. 1A-56-33E*

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GENERAL  ELECTRIC  
COMPANY

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

Switch to this  
new General Electric

# WHITE MERCURY LAMP

1. Get up to 55% more light just by changing from old type lamps!
2. Get up to 25% lower cost of light, too!
3. Get better, whiter "color" than from any clear mercury lamp!

YOU can use the new General Electric *White Mercury* Reflector Lamps in your present equipment with no change or added investment in operating equipment.

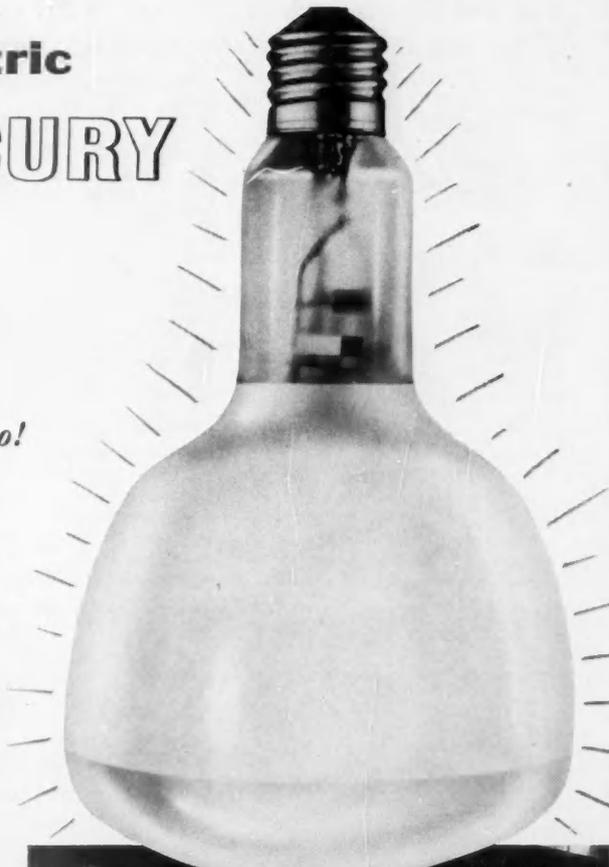
**GET UP TO 55% MORE LIGHT ON WORK FROM YOUR PRESENT FIXTURES:** Because a brand new phosphor generates more white light than ever before you get from 7% to 55% more light on the work, depending upon the lamp type you are replacing. (See below).

**GET LOWER COST OF LIGHT IN YOUR EXISTING INSTALLATIONS:** With this increased efficiency your unit cost of light goes down from 7% to 25% (as shown below)!

**GET LOWER INITIAL COST FOR NEW INSTALLATIONS:** You can get *more* light from the same number of fixtures, or get *equal* light with up to  $\frac{1}{3}$  fewer fixtures!

You get all this with new General Electric *White Mercury* Reflector Lamps because of a specially designed strontium magnesium orthophosphate phosphor. This phosphor converts ultra-violet radiation into more white light than ever possible before. It's also an efficient reflector—sealed in against dirt and fumes.

Gain these advantages *now*. Replace your present mercury lamps with the new G-E H400 RW-1. Also available in the bulged tubular shape, the H400 EW-1. For more information write: General Electric Large Lamp Dept. GER-1, Nela Park, Cleveland 12, Ohio.



The new General Electric *White Mercury* Reflector Lamp is recommended for most mercury installations, unless color discrimination is of significant importance. Ideal for the newer, open-top reflectors shown above, that eliminate the old fashioned "cave-like" effect.

## ADVANTAGES OF NEW G-E WHITE MERCURY OVER OTHER G-E 400-WATT MERCURY LAMPS

### NEW RW-1 vs A-1 (clear glass)

- 55% more light to the work
- 25% lower cost of light
- Less maintenance
- Whiter "Color"



### NEW RW-1 vs E-1 (clear glass)

- 28% more light to the work
- 16% lower cost of light
- Less maintenance
- Well suited for use in upward light fixtures
- Whiter "Color"



### NEW RW-1 vs J1 (color improved)

- 37% more light on the work
- 24% lower cost of light
- Less color improvement



### NEW RW-1 vs RC1 and R1 (reflector shape)

- About 7% more light on the work
- 7% lower cost of light
- Less color improvement for RC-1 users



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## SIX WAYS GENERAL ELECTRIC HELPS CREATE BUSINESS OPPORTUNITIES FOR OTHERS



**By creating new products:** For example, food-waste disposers, first manufactured by General Electric, are now also being made by eleven other companies, and are a source of new business to many thousands of local retailers.



**By helping keep the cost of electricity low** through development of better equipment for producing and using it. The ever-increasing enjoyment of this "household bargain," electricity, creates business opportunities in every community.



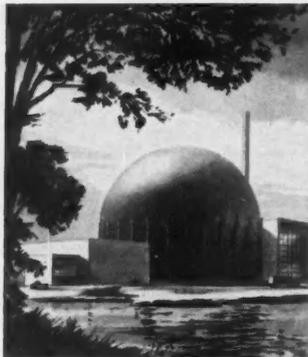
**By working closely with dealers** to help increase their business and payrolls. Marketing counsel, factory service training, advertising support and consumer credit arrangements are all available to these independent businessmen.



**By breaking down the big jobs:** Complex defense projects, for example, are beyond the scope of small businesses, but, through subcontracting, they get jobs they can handle when a large company takes the over-all risks and responsibility.



**By buying locally,** where possible, and thus stimulating commercial activity in the 112 communities where General Electric has plants. Each \$1,000 of purchases and payrolls generates about \$5,000 more in business within the community.



**By pioneering in new fields** that can open up new industries with future business opportunities for many companies large and small. General Electric's current pioneering investment in developing atomic electricity is a good example.

# How progress

Today Americans are putting electricity to work to a degree unmatched anywhere in the world: every decade for the past 75 years, they have doubled the amount they use, and they are now doubling it every eight years.

The electrical industry is therefore one of the fastest growing in the nation because, essentially, it provides products and services many people want, in the way they want them, and



**400,000 local, independent dealers and other retailers:** They have more business opportunities today than ever before in selling and servicing the many new and improved products from General Electric.

# at General Electric benefits other businesses

because electric power is at the very heart of the American economy and national security.

As a part of the industry, General Electric has shared in this growth and, we believe, contributed to it in many ways. And so have hundreds of thousands of other businesses, both large and small.

In the process of serving customers, providing jobs and trying to earn a

return for its owners, General Electric now depends on the skills and enterprise of nearly a half million of these businesses — dealers, suppliers, contractors, service men and others. They, in turn, get from us day-to-day business and opportunities for growth that they might not otherwise have.

In their relationship with us, these businesses expect more than the chance to make a reasonable profit. They want

to be recognized as independent, with the right to operate their own businesses according to their own ideas. We know they want from us, as we want from them, lasting friendly associations based on helpful service, courtesy, integrity.

On these pages are some of the ways we at General Electric are trying to live up to our responsibilities in relationships with other businesses.



**42,000 suppliers — 90% of them small businesses:** These firms, 12,000 more than in 1950, get almost half General Electric's income in exchange for skills and supplies.

**Over 155,000 jobs in electrical contracting:** This is a more than 150% increase since 1939. In that period, jobs in electrical wholesale and retail businesses doubled.

**Over 140,000 jobs in electrical service trades:** The opportunities for small businesses here should multiply even faster as Americans continue to live better...electrically.

**Over 1,400,000 jobs in electrical manufacturing:** G. E. is one of more than 5,000 competing firms, large and small. All stimulate and share in the flow of business opportunities.

*Progress Is Our Most Important Product*

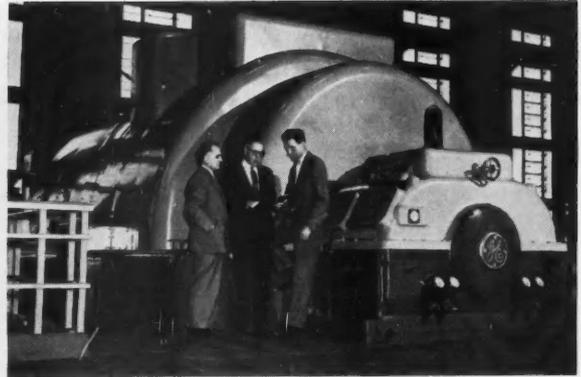
GENERAL  ELECTRIC

At General Electric . . .

## Here's how your engineering background fits you for the broad field of Technical Marketing



**IN PRODUCT SPECIALIZATION** complete knowledge of certain product lines assures their proper application to best serve the customer's requirements.



**IN SALES ENGINEERING** lies the prime responsibility for the integration of all sales and engineering activities between General Electric and the customer.



**IN HEADQUARTERS MARKETING** product planning, marketing research, and sales direction all contribute to successful marketing of General Electric products.



**IN APPLICATION ENGINEERING** electrical and mechanical components are engineered into the customer's product, power system, or manufacturing process.



**IN INSTALLATION AND SERVICE ENGINEERING** customer satisfaction is assured by proper installation and service of equipment supplied by General Electric.

**MAIL COUPON FOR FULL INFORMATION  
ON THESE TECHNICAL MARKETING CAREERS**

Mr. George E. Mullin, Jr.  
Technical Marketing Program  
Building 2 Section 956-B  
General Electric Company, Schenectady 5, New York

Please send me your descriptive bulletin on the Technical Marketing Program, GEZ-515B.

Name \_\_\_\_\_

College \_\_\_\_\_ Degree & Year \_\_\_\_\_

Address \_\_\_\_\_

**GENERAL**  **ELECTRIC**

# WHY NOT EVERY WEEK?

This is the month when engineers throughout the country plan for Engineers' Week in February, the week of George Washington's birthday. Increasing the public's understanding of the role engineers play in today's progress is one objective of Engineers' Week.

As a good engineer—and as a good citizen—your reason for accomplishing this objective extends deeper than the psychological feeling of wanting to be recognized as a vital and integral part of society. It extends deeper because the future of this country depends in a large part on whether the public understands—or does not understand—how the engineer fits into the economy.

For one thing, a lack of understanding would lead to a deterioration in our educational system. If parents can see little or no connection between math and science courses and the benefits they constantly receive in the form of newer and better products, they will soon force their boards of education to dilute or drop these "tough" courses. And with math and science playing a minor role to athletics and "life adjustment" courses, tomorrow's potential engineers will not have the inclination—nor the opportunity—to prepare for the profession. Should the supply of engineers diminish, it will slow progress in America.

Understanding the engineer's role in today's progress has two phases: public knowledge and appreciation of the engineer's technological contributions to our high living level; and acceptance of the engineer as a warm, sympathetic human being.

Engineers' Week offers you an excellent opportunity to engage in both phases. In telling your technological story, present the facts with confidence. But let the public see you as a person just as interested in values as in facts.

Your Engineers' Week program cannot be truly effective until it reaches a large segment of the general public. Meetings that only engineers attend are interesting and stimulating—but isn't the audience already convinced? Make your program of such significance

and interest that you can invite clergymen; the local bar association; managers of local department stores; city officials; and representatives of the board of education, school administration, and teaching staffs. By slanting your program to the layman, you can show the far-reaching effects of technological advances and their importance to daily living.

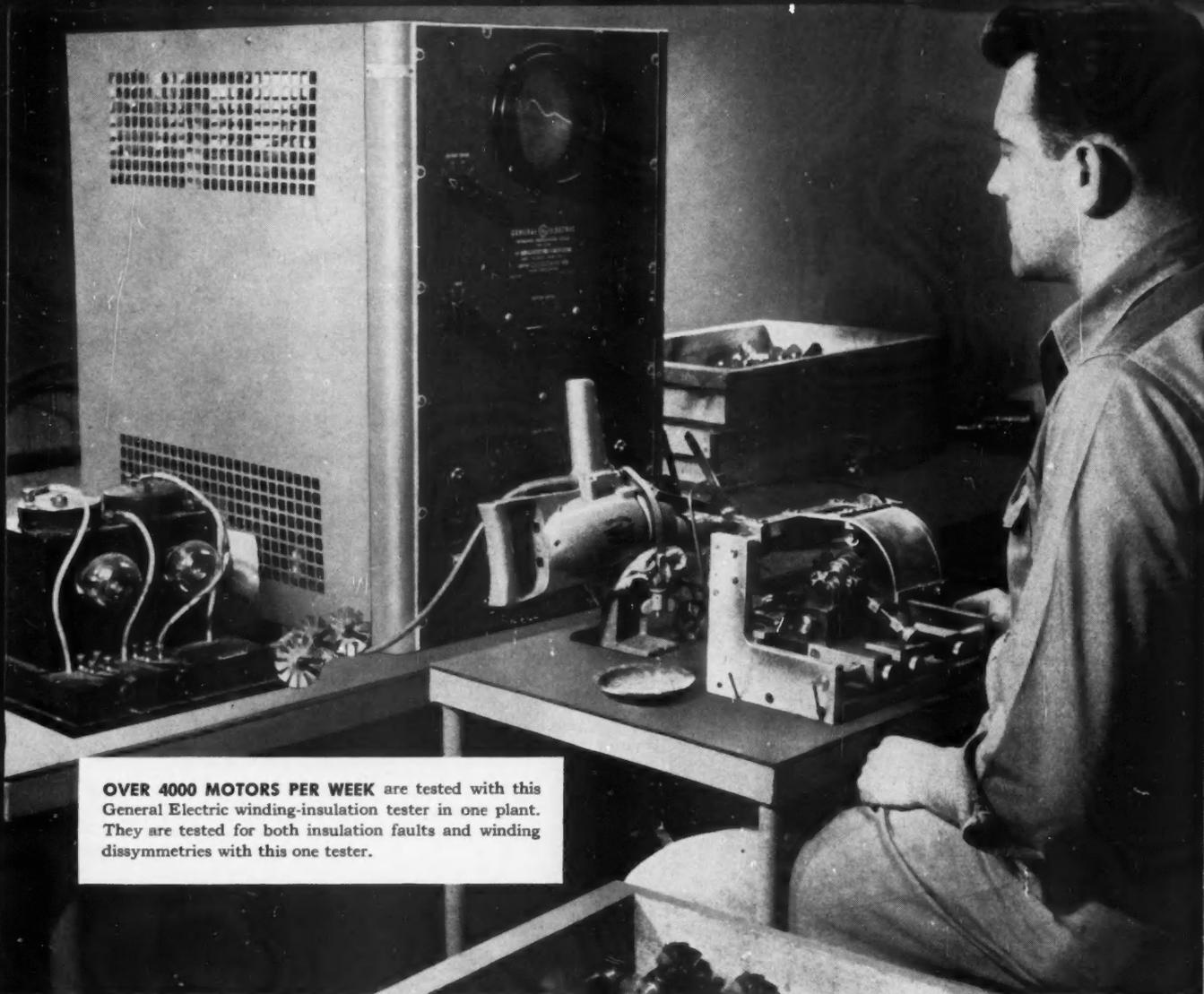
The problem also involves letting people know you as a person interested in his community—a person just as interested in people as in things. Having people understand you will mean increasing your participation in Boy Scouts, your church, politics, and other community activities. It will mean clearly voicing your opinions in matters that affect the rights of your fellow men, and it will mean writing letters to your newspaper stating your position in precise terms. It will also mean enduring the rigors of the 7 to 11 pm dinner-meeting circuit. And it will not be without its sacrifices—hours away from your fireside, as well as possible unpopularity because of your stand on controversial issues.

The outline of the task thus emerges—a task that you cannot do completely between February 17 and 23 of this year, or any other year. Engineers' Week merely provides the stage that helps focus the eyes of the public on you. You have to carry it from there—not stopping on February 23, but pushing on through Engineers' Week of 1958 and beyond.

The task before you demands constant effort. Accomplishment will mean an understanding in the public's mind of the importance of the engineering profession. And with understanding will come true professional recognition. Failure would mean a decline in the quality and quantity of future engineers, a decrease in our level of living, and an increase in society's indifference to the engineer.

Fulfilling this task requires the combined efforts of you and all thoughtful and dedicated engineers who are willing to make every week of the year Engineers' Week.

*Paul R. Heinmiller*  
EDITOR



**OVER 4000 MOTORS PER WEEK** are tested with this General Electric winding-insulation tester in one plant. They are tested for both insulation faults and winding dissymmetries with this one tester.

## Cut Costs With Faster General Electric Winding-Insulation Tester

Decreased testing time and reduced customer complaints are made possible with the General Electric winding-insulation tester because it accomplishes in one short test the same objectives as resistance and impedance balance measurements, high-frequency and high-potential tests.

**IT TESTS SIMULTANEOUSLY** for winding dissymmetries such as a ground, shorted turns, incorrect connections or the wrong number of turns. The balance-and-comparison method of testing is used to

check the insulation of coil windings with repeated surge voltages similar to stresses caused by lightning, switching or other power-circuit transients which are frequent causes of motor failure. It tests for faults in motors, generators, transformers, ballasts, relays and other equipment windings. Tests can be taken at surge peak voltages up to 10,000 volts.

**SIMPLE OPERATION** of the G-E winding-insulation tester makes production testing easy. The tester is built into a steel cabinet for bench mounting and all con-

trols are conveniently located. Several coils a minute can be tested under production conditions. This fast and highly reliable testing procedure saves valuable man-hours and helps assure higher quality products. Priced at \$2910.60\* the General Electric winding-insulation tester will quickly pay for itself from savings realized by its use.

*For further information* call your General Electric Apparatus Sales Office or write to Section 585-58, General Electric Company, Schenectady 5, New York.

\*Manufacturer's suggested resale price.

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# New trends and developments in designing electrical products . . .

General Electric thermistors and Thyrite\* varistors have unique properties that apparently contradict normal electrical laws. Here's how they can be harnessed to improve your product.

General Electric thermistors and Thyrite varistors are ceramic-like semiconductor resistance materials. Each has unique properties — apparently disobedient to normal physical laws — that enable it to perform tasks in electrical and electronic circuits which otherwise would require costly, complex components.

The distinguishing feature of thermistors is their *thermal* sensitivity. Thermistors have large *negative* temperature coefficients of resistance (i.e., their resistance decreases tremendously when heated, instead of increasing slightly like other materials).

Thyrite varistors, on the other hand, are *voltage*-sensitive. Contrary to Ohm's law, a current through a Thyrite varistor varies as a *power* of the applied voltage (i.e., doubling the voltage through a Thyrite varistor can increase the current from 15 to 25 times, instead of the normal 2 times).

The applications based on the unique properties of these materials are almost limitless. In general terms, thermistors are used in the detection, measurement, and control of minute energy changes; Thyrite varistors are used to protect, stabilize, and control circuits.

To give a clearer understanding of the ways thermistors and Thyrite varistors can be applied, here's how they have solved two of the electrical engineer's most vexing problems — temperature compensation and surge suppression.

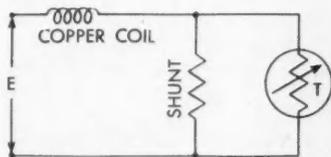


FIGURE 1 — Typical thermistor temperature-compensation circuit

The resistance of a conventional conductor is so affected by ambient temperatures that steady current flow cannot be maintained. For example, as the temperature of copper swings from  $-60^{\circ}\text{C}$  to  $+80^{\circ}\text{C}$ , the resistance increases 53%.

However, when the copper is compensated with a properly selected thermistor, the maximum deviation

from the total average resistance at  $25^{\circ}\text{C}$  is only  $3\frac{1}{2}\%$  — despite the  $140^{\circ}$  swing in temperature.

In the circuit in Fig. 1, the thermistor's negative temperature coefficient of resistance offsets the positive temperature coefficient of the copper to stabilize current flow. In other circuits, thermistors can be utilized for signal and warning devices, sequence switching, and other time delay applications, because of the inherent thermal inertia involved.

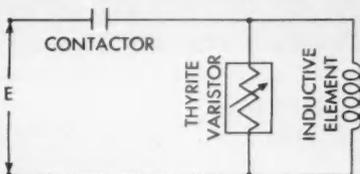


FIGURE 2 — Thyrite varistor surge voltage suppression circuit

Sudden interruptions of inductive circuits cause surge over-voltage, arcing, and high-frequency oscillations — all of which can cause trouble. The circuit in Figure 2 shows how a Thyrite varistor can be connected to hold these effects within safe limits.

With the Thyrite varistor out of the circuit, the surge voltage caused by interruptions of the current may rise to 9 times applied peak voltage (Oscillogram, Figure 3).

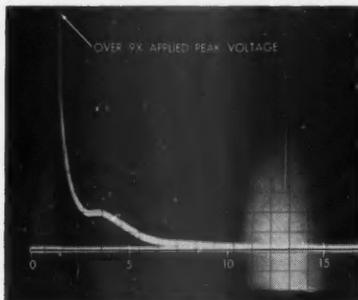


FIGURE 3

But with the Thyrite varistor in the circuit, (Figure 4), the surge voltage is limited to less than 3 times the normal applied peak voltage.

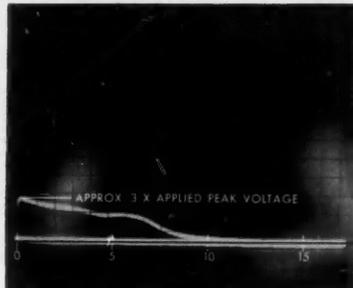


FIGURE 4

The Thyrite varistor draws negligible current at rated voltage, yet offers sufficiently low resistance at the peak current to limit the surge voltage to a safe value and to reduce arcing. Also, the Thyrite varistor quickly discharges circuit energy by providing increasingly higher resistance as the inductive current decays.

If a linear resistor were used to provide the same voltage suppression level, it would have to draw a current equal to more than 30% of the inductive element current.

In addition to surge suppression, a Thyrite varistor can be used as a nonlinear resistance parameter, a potentiometer, and a frequency multiplier. It can also be used as a bypass resistor to protect personnel and equipment from circuit faults.

Technical literature giving complete data on properties, applications, sizes, and shapes of G-E thermistors and Thyrite varistors is available. And, for the experimenter, there are two engineering test kits on each.

To obtain kits, literature, or the assistance of a General Electric Engineer on your problem, write: Metallurgical Products Department of General Electric Company, 11201 E. 8 Mile Blvd., Detroit 32, Michigan.

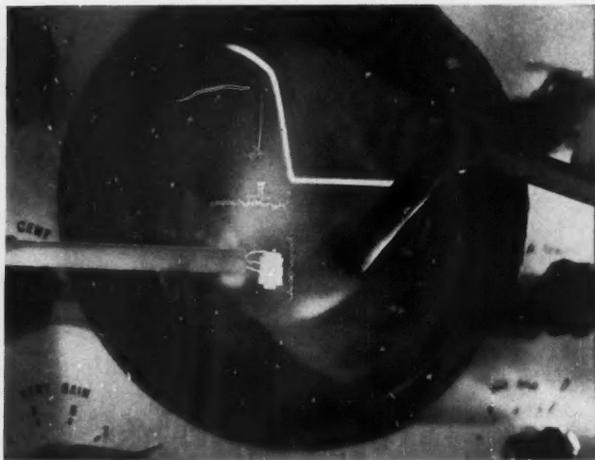
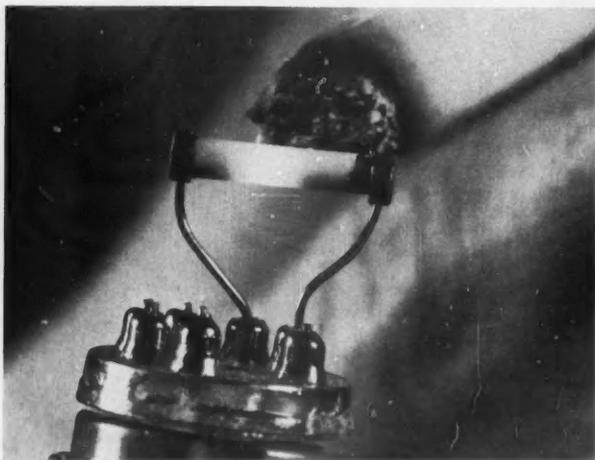
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\*Registered trademark of General Electric Company



**OPERATING RED HOT**, a revolutionary new electronic circuit dramatically demonstrates the penetration of a critical temperature barrier.



**GLOWING RESISTOR** can light a cigarette; oscilloscope pattern in background proves that vacuum tube still works in raw flame of blowtorch.

## Research

The penetration of a critical temperature barrier in the development of guided missiles and supersonic aircraft was dramatically demonstrated during 1956: General Electric scientists exhibited revolutionary electronic devices and circuits operating literally "red hot." The achievement marked a major step toward overcoming the inability of electronic controls to withstand the skin-sizzling heat generated by air friction at

extreme speeds. One of the predicted advantages: extensive weight reductions—made possible by eliminating bulky power-consuming cooling equipment from missiles and aircraft.

New types of vacuum tubes, capacitors, resistors, transformers, inductors, wires, printed circuit boards, and an electric motor proved that they could be operated at temperatures ranging from 900 to 1500 F. The devices were tested

inside glowing electric furnaces and surrounded by blazing blowtorches.

Metals such as titanium and special laboratory-designed ceramics played important roles in the design and construction of the high-temperature components.

And to help show the versatility of the high-temperature electronic components, scientists demonstrated a "hi-fire" phonograph with the amplifier

glowing brightly in a 1500 F oven. It produced sufficient volume to fill the large demonstration room and reproduced with surprising fidelity the hot jazz record used in the demonstration.

They also demonstrated a circuit that picked up and amplified a radio signal even while the equipment was in the direct flame of three blowtorches.

And the researchers operated two multivibrator (electronic pulsing) circuits in electric ovens at temperatures ranging from 1000 to 1500 F. Both demonstrations involved circuits using vacuum tubes, resistors, capacitors, and printboards. And in one demonstration, heaterless tubes operating at high temperatures did not need the power supply normally required to heat filaments in vacuum tubes.

### Semiconductor Studies

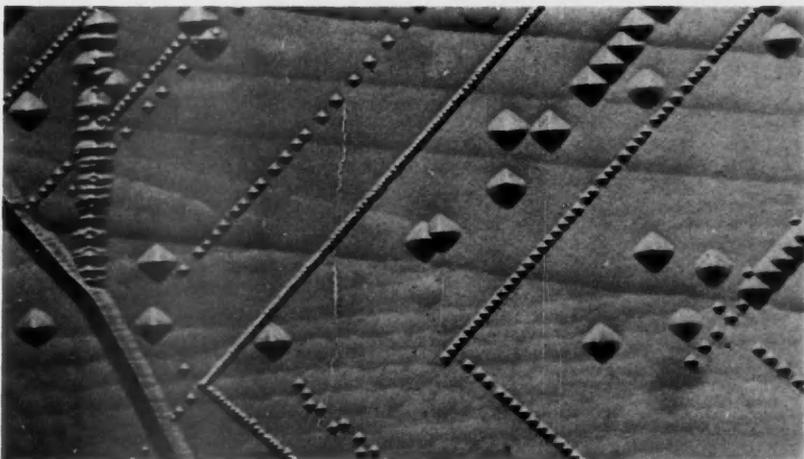
Infrared light and telltale clumps of copper give General Electric scientists a better view of how solid materials behave. Infrared technique, similar to the World War II *Snooperscope* system for seeing in the dark, literally throws new light on tiny flaws in the structure of matter. A technique was developed that diffuses copper into crystals of silicon, permitting the copper to settle in imperfections in what is otherwise a well-ordered latticework of atoms. Under infrared light and at large magnification the copper becomes clearly visible, revealing the location of the imperfections. A perfect crystal may be thought of as layer upon layer of atoms arranged in a fixed array in each layer. If, as in ordinary crystals, a portion of some of these layers is missing, the adjacent layers deform to take up the slack. And the edges of the missing layers in the crystal form dislocations. These flaws in silicon become selectively decorated with copper and can then be clearly seen by the new technique. Many of the electrical, optical, and mechanical properties of practical materials result from the presence and behavior of dislocations.

### Metals and Alloys

Research metallurgists established a world record for the strength of metals. Modifications in methods of making "perfect" iron crystals—first announced in 1954—produced tiny whiskers with tensile strengths as high as 1,900,000 psi. This strength is more than 150 times that of ordinary iron crystals and four times that of the strongest steel wire. The newest iron crystals, less than



**IRON CRYSTAL WHISKERS** have set a record for strength of metals (magnified 13 times).



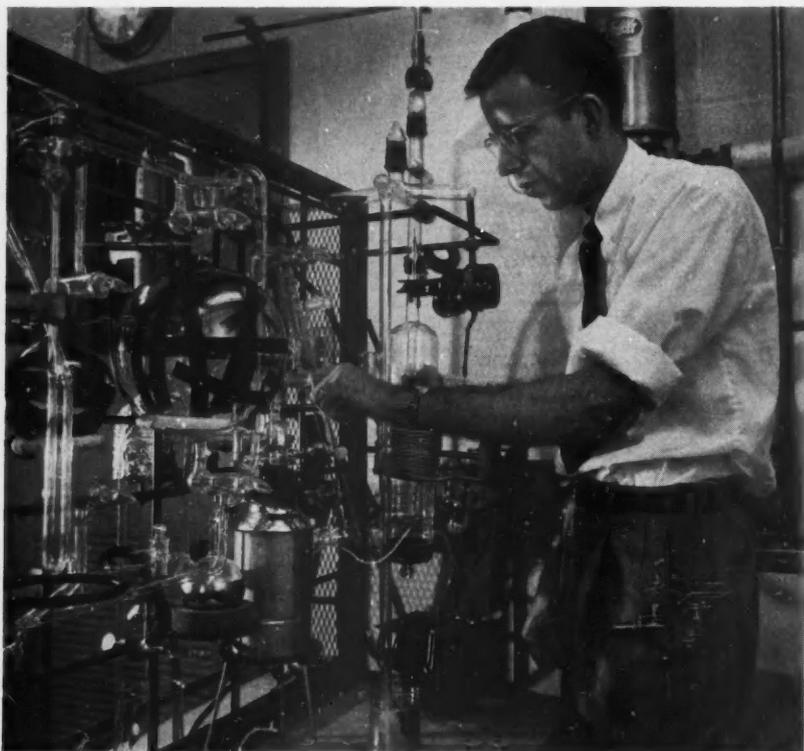
**SELECTIVE ETCHING REAGENT** now permits the observation of crystal dislocation progress.

an inch long and not as big around as a human hair, possess nearly twice the strength of the earlier laboratory-made iron whiskers.

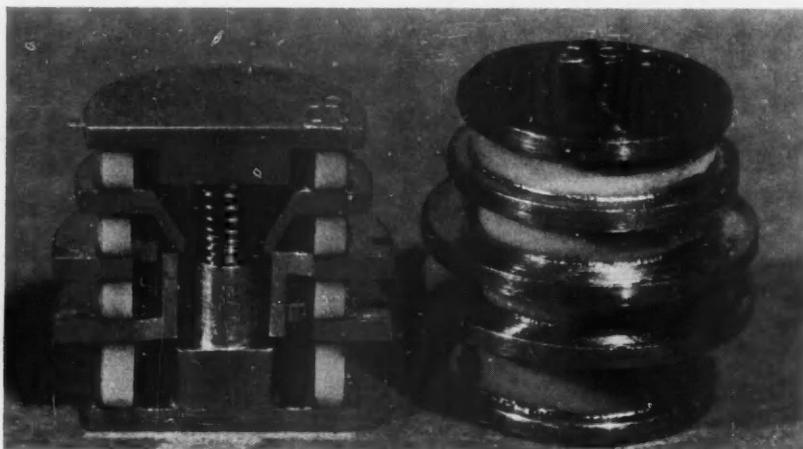
A new technique promises to make advances possible in the detailed knowledge of how tiny imperfections occur and travel through crystalline structures, such as metals and ceramics. The discovery of a highly selective etching reagent permits the movement of individual dislocations to be observed as they travel through the lattice of lithium fluoride. The technique can provide valuable quantitative information to crystal-structure investigators. Because scientists believe dislocations to be the

key to the strength of crystalline substances, such a source of information can lead toward development of stronger engineering materials.

Production of limited quantities of lead metaniobate that gives off small voltages when acted upon by outside physical forces began during 1956. The material, discovered several years ago, has piezoelectric properties that led to its selection as a high-temperature operating material, such as found in guided missiles and jet engines. Barium titanate, an earlier material, becomes inefficient at high temperatures; but lead metaniobate retains most of its properties to at least 300 C. In high-temperature applications



**PLATINUM BATH** shortens vacuum-fusion analysis time of high-temperature metals and alloys.



**VOLTAGE-TUNABLE MAGNETRON** of copper and ceramic disks stands about  $\frac{1}{2}$  inch high.

the material could be used to register accelerations in guided missiles; this information would be employed as part of the missile's guidance system. Another application: vibration warning systems for jet engines. The lead metaniobate would respond to excessive vibration by triggering a warning indicator or by activating a system for throttling back the engine automatically.

A pilot plant for making the highest purity silicon for semiconductor re-

search purposes went into operation during 1956. The desired product contains less than one part per billion of impurity. The plant, constructed largely of quartz to minimize product contamination, can produce several pounds of pure silicon per run. This work will make available relatively large amounts of research-grade silicon. And it establishes the technology that will make possible the commercial exploitation of the process within General Electric to

produce semiconductor-grade silicon.

Using a platinum bath in vacuum-fusion analysis speeds the determination of the oxygen content of high-temperature metals and alloys. Ordinary metals are usually analyzed by dissolving a sample in molten iron contained in a graphite crucible and by extracting carbon monoxide formed in a high-temperature reaction between the oxygen in the sample and the carbon in the melt.

When employing this technique to high-temperature alloys and refractory metals, the iron bath tends to solidify after running only four or five samples. This probably occurs because of the formation of high-melting intermetallic compounds and "kish" graphite. The time necessary to dismantle and reassemble the vacuum equipment reaches nearly prohibitive levels. Platinum as a replacement for the conventional iron bath in vacuum-fusion analysis greatly increases the number of samples that can be run in one crucible. The platinum bath was held at operating temperature for more than 100 hours without solidifying. Result: more samples were analyzed in 2 days than could be completed in 2 weeks with the iron bath.

Metal and ceramic parts can be sealed together, scientists discovered, by inserting between them a thin sheet of certain metals that will form reactive alloys. For example, a thin shim of titanium can be placed between a ceramic part and copper. When heated, the titanium and copper form an alloy that will react with the ceramic, sealing it to the copper. This technique utilizes a wide choice of materials and makes strong seals that can operate for many hours at temperatures as high as 800 C. Titanium and zirconium parts can also be sealed to ceramics by merely using enough molten solder to dissolve a small amount of the active metal. While in its liquid phase, the metal reacts with the ceramic material to form the seal.

#### Electronics

The latest step toward increasing the versatility of the magnetron, a vacuum tube famous for its use in wartime radar, was announced in 1956. Early models of voltage-tunable magnetrons limited the space charge by carefully regulating the temperature of the electron-emitting cathode in the tube. Now a new tube utilizing grid control and electron injection has been devised for a crossed-field-beam control system utilizing a space-charge-limited emitting source. Result: much greater frequency stability

with variations in the heater power supply. And life span also increases because the vulnerable cathode is protected.

The important new concepts in tube design that accompanied the unique tuning method permit housing the new magnetron in a copper and ceramic envelope no larger than a cube of sugar. The completed package resembles a stack of four copper pennies separated by ceramic disks; the entire tube measures less than 1/2-inch high. Operation of the new magnetron compares to that of an a-c generator with a fluid "rotor" composed of electric space charges. The tube operates at high frequencies; and to generate such frequencies, the rotor must rotate at speeds up to 60-billion rpm.

A new information-storage tube promises smaller electronic computers with bigger memories. A thin sheet of glass rests at the heart of the 1-inch-square "honeycomb" tube. Small holes are etched in the sheet and then filled with metal. Information written on one side of the honeycomb by an electron beam scanning method, similar to that used in television, is picked up from the opposite side by a reading gun. Early laboratory models stored it for several minutes—a time confidently expected to be extended. When the holes in the honeycomb are spaced 300 to the inch, each square inch has 90,000 individual storage cells. Each cell will recognize at least 10 different levels of intensity from the writing gun. Logarithmic calculations increase to more than 300,000 the number of bits of information that can be stored at one time. The mosaic principle has long been recognized as ideal for storage tubes, but this storage tube is believed to be the first developed with sufficient resolution and ruggedness to be suitable for most applications. Possible applications, other than computers, are television cameras and scan converters where radar information is collected and then displayed on an ordinary television screen.

The 1956 development of a tiny "brain cell" for computers may well be a landmark in the progress of miniaturization of electronic components. A transistor, transformer, and memory cell were packed into 1 cubic centimeter. The complete assembly was designed to operate in a computer in the same way that a neuron apparently functions in the human brain. About 10 billion such cells compose the average human brain; thus an electronic counterpart could



**INFORMATION-STORAGE MESH**, magnified on TV screen, operates in new computer tube.



**HIGH-SPEED PHENOMENON** is observed by camera capable of 100,000 frames a second.

theoretically be built from an equal number of the new devices. One drawback: the man-made brain would fill 100 railroad freight cars.

A new way of combining messages for transmission over a single frequency band is being studied. The plan: to use carriers of distinctly different wave form, thus each message would be "recognized" at the receiver by appropriate electric filters. Such a system is particularly attractive for applications

not only where a great many message sources must be assigned channels but also where the expected use of the individual channels is low.

### Ceramics

Supplementing metals for high-temperature applications with ceramics led to the comparison of the deformation properties of these two classes of materials. Precise studies were made of plastic flow of aluminum oxide, syn-

thetic sapphire, at temperatures above 1200 C. An interpretation of the results in terms of the same dislocation theory so successful in explaining the plastic behavior of metals led to a much improved understanding of the plastic behavior of ceramics. For example, the plastic flow in sapphire results from the movement of crystallographic dislocations similar to, but much more complex than, those that exist in metals. Marked differences occur between sapphire and metals in dislocation-mobility temperature dependence. For practical purposes, no plastic deformation is possible in sapphire at temperatures below about 1200 C. At that temperature, flow starts at a stress of about 20,000 psi; but at higher temperatures, the yield stress decreases very rapidly. However, the yield strength of metals is much more insensitive to temperature.

#### Silicones

Silicones, which grew from a laboratory curiosity into an industry, still concern the research chemist. A recent project in this field includes studies of how to provide silicone polymers with "handles." These handles would allow polymers to become more easily attached to other plastics.

New information has been obtained on the effects of irradiating silicone with high-energy electron beams and on the chemistry of the silicone irradiation process. Electron irradiation also was shown to be effective in curing silicone gums with carbon-black fillers added.

#### Light Studies

Progress made on the amplification of light helped to realize amplification ratios of 60 times. The amplifier was made responsive to visible light in the blue end of the spectrum as well as to ultraviolet light and to x rays as previously revealed.

Continued investigations on phosphor materials revealed rapid-response phosphors now under development for color-television applications.

Electroluminescence was demonstrated to be a property common to a widespread class of materials. A variety of new materials was shown to become electroluminescent and to produce light with a diversity of conditions of excitation and in a wide range of colors and brightnesses.

#### Magnetic Phenomenon

Discovery of a magnetic phenomenon that produces effects never before seen

in permanent magnets was announced this year by General Electric scientists. Until placed in a strong magnetic field, an ordinary bar magnet is just a piece of metal. Then, depending on how it is placed in the field, it becomes magnetized in a certain direction. For instance, with sufficient magnetization either end of a compass needle will seek north. Ordinary magnets spoil when subjected to large magnetic fields that demagnetize them. Magnets displaying the new phenomenon are magnetic when made and nothing but high temperatures can destroy their magnetization. They have only one direction of magnetization; they maintain it for life. Thus, only one end of the compass needle will seek north. Large fields applied in opposite directions can reverse their polarities temporarily; but as soon as they are removed from the field, they revert at once to their original polarities. They are the first really permanent magnets.

#### Other Developments

A liquid-hydrogen bubble chamber, normally operated at about  $-387$  F, helps research scientists track fast-moving nuclear particles. It accomplishes this by making it possible to take stereoscopic photos of the bubble trails that are formed in the liquid hydrogen. The fact that the 800-fold higher density of the hydrogen originates many more nuclear events plus ranges of resulting particles that lie within the chamber gives it a great advantage over the old gas-filled Wilson cloud chamber.

In isolating components that produce undesirable odors in irradiated foods, a new method of chemical analysis—vapor-phase chromatography—is used. Developed in England and this country and now attracting wide scientific recognition, this method speeds work in other diverse fields such as silicone chemistry, radiation chemistry, and combustion research. It involves carrying a volatilized sample in a stream of inert gas through a specially packed column. The sample becomes fractionated because the column retains each component for a different length of time.

Corona discharge in tiny air voids proved to be an important factor in the electrical breakdown of solid insulators. This phenomenon results in rapid deterioration of the insulation—particularly when organic in nature—and ultimate failure. Research has shown the importance of the conductivity of the surface surrounding these voids. The discharge magnitude appears to be re-

lated to field inhomogeneity in the gap that in turn is determined by the charge distribution on the dielectric surface. The first corona discharges deposit charges in small areas on the surface and produce distortions in the field. Subsequent discharges, because of this effect, are larger in magnitude and lead ultimately to breakdown. With higher surface conductivity, however, the charge spreads over the surface during the time between discharges, with a consequent reduction in field inhomogeneities. Irradiating the gap with ultraviolet light also greatly reduces the discharge magnitude.

A camera capable of a speed of 100,000 frames per second will make possible the study of high-speed phenomena—not otherwise observable. The camera creates an image consisting of a pattern of dots. Then it records the next image by shifting the second pattern of dots just far enough to avoid landing on top of the first. The relatively small distance that the film must travel to provide this motion makes possible the high-speed camera operation.

The first unit of a new hypersonic facility, a helium wind tunnel, was placed in service last year. The tunnel will make available fluid-mechanics information in the vicinity of Mach 20.

Detailed study of the photoelectric emission and absorption of alkali metal halides, such as rock salt, now makes possible deducing the electronic "band gap" in this class of materials. Many of the more important electrical properties of solids are related to the band gap—the energy required to form free electrons and positive "holes." Although this process is well understood in materials such as germanium and silicon used for transistors and rectifiers, the recent studies aided understanding the process in materials like rock salt.

A series of ionization gages employing the beneficial properties of ceramic-titanium-metal construction has been made that show new usefulness. Ceramic-metal gages with the characteristics of the conventional glass gages can be attached to a vacuum chamber or electron tube and baked out at temperatures up to 800 C. A magnetron-type gage has recorded rapid transient-pressure conditions in the presence of varying magnetic fields. A magnetron-type ionization gage has measured pressures of  $10^{-11}$  mm of mercury with a high degree of sensitivity. And indications show that such a gage would be useful in measuring pressures as low as  $10^{-13}$  mm of mercury.

# Power

In 1956 an integrated attack began on the myriad problems that will confront private and industrial producers and users of electricity in the near, if not immediate, future. Already, significant conclusions emerge from many technical and economic studies under way.

For example, no savings can be expected from higher residential voltages until the load per home grows to about twice that of a home having all presently available major appliances. Extra-high-voltage power transmission, even for short distances, is more favorable today than 10 years ago. For voltage regulation, using switched capacitors and regulators together instead of separately offers greater economy. Conclusions also point to gas-turbine power plants as being highly attractive for economically meeting future peak loads. Proper use of high-voltage interconnections that allow pooling reserves of several power companies will gain additional economic advantages for generating units even larger than 450,000 kw.

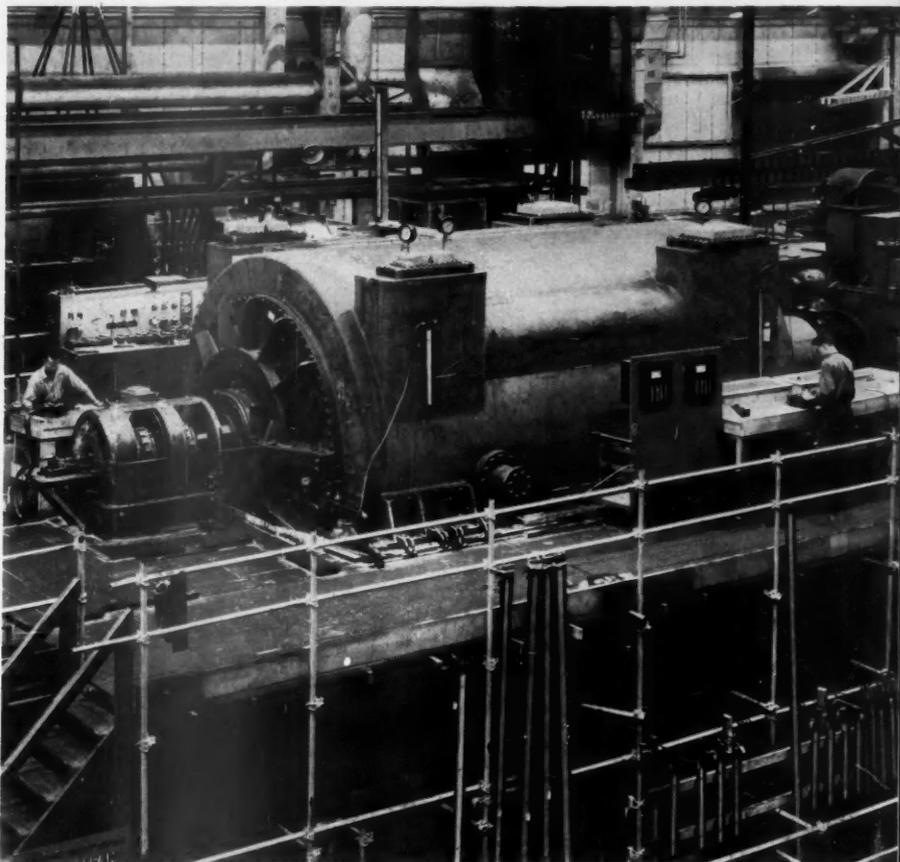
Scientific methods now determine the most economic turbine-generator-boiler unit to be used in expanding the generation system of a utility. These methods, by the way, are being made available to the utility industry.

In a well-integrated power system—or a group of interconnected systems—a turbine-generator may have a capacity 10 percent that of the total load. Some future large steam-electric generating stations will utilize auxiliary power equipment containing 4.16-kv breakers with an interrupting rating of 350,000 kva.

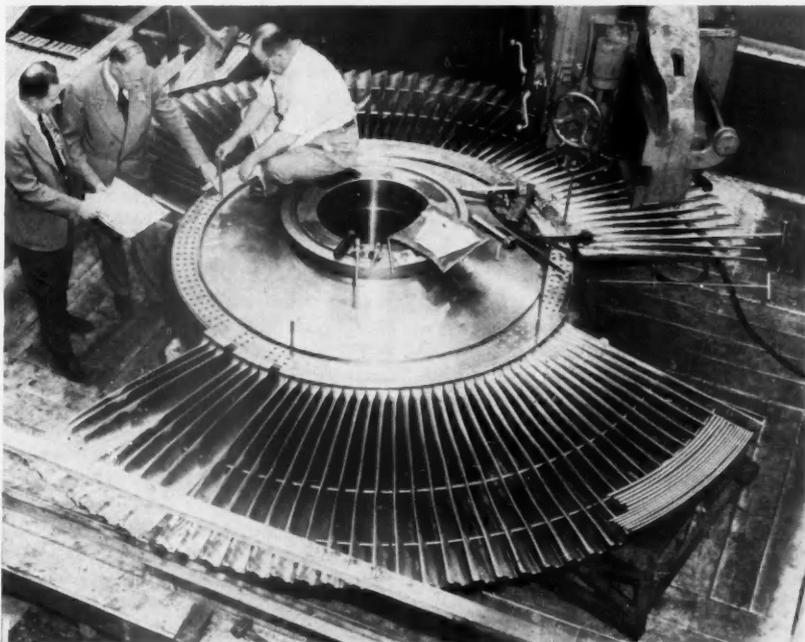
Conductor-cooled turbine generators, reported on later in this section, have inherently higher reactances that tend to keep down the interrupting requirements of high-voltage switchgear. However, the reduction of transient stability margins must be recognized in future power-system design. Regenerative feed-water heating can make industrial generation economically feasible where it otherwise might not be.

The predicted shortage of engineers in the power field will be somewhat compensated for by standardizing practices.

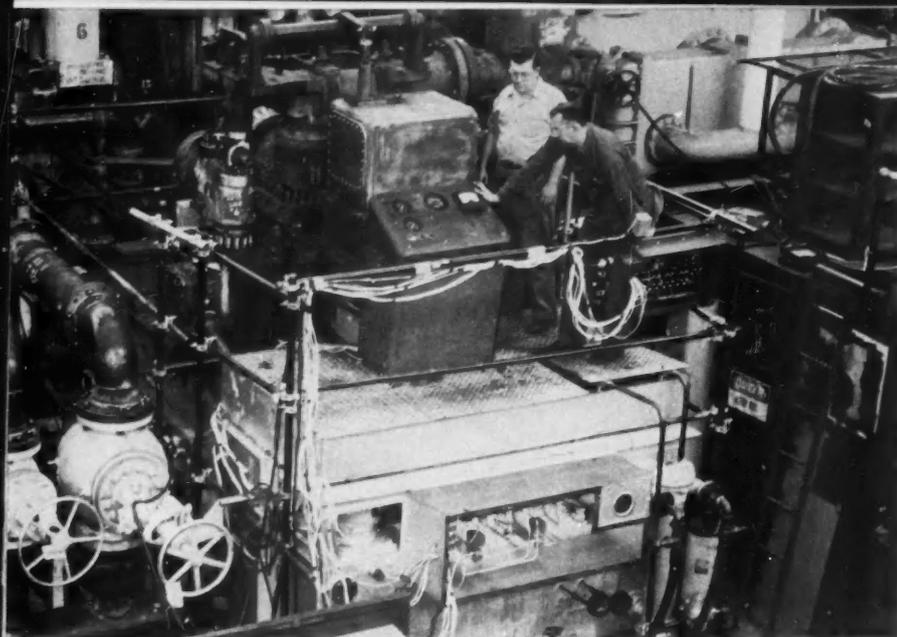
Economics of high-voltage transmission indicates a trend toward widespread adoption of higher power-transmission voltages by America's electric utility companies. Many engineering



**TURBINE-GENERATORS** with gas-conductor-cooled stator and rotor generate nearly twice the capacity within the same frame size as those cooled by conventional methods.



**LONGEST STEAM-TURBINE BUCKETS** in operation weigh 75 pounds each, and they individually withstand centrifugal forces of 330,000 pounds when operating at 1800 rpm.



**BOILER FEED-PUMP TURBINE** increases net kilowatt output to transmission lines. The turbine can also be operated remotely with supervisory instrumentation controls.



**LARGE-SCALE DIGITAL COMPUTER** quickly and precisely evaluates effect of individual com-

advances in generators, transformers, and switchgear have caused this shift, as has the tremendous load growth of the past 10 years. For distances of 50 miles and more, transmission at higher voltage levels is justified provided the load is sufficient. Economically attractive dual-conductor transmission loadings are 25 percent higher than those obtained with single-conductor transmission.

A fundamental analytical study of radio interference with high-voltage electric power transmission, begun 3 years ago, continued during 1956. Recent calculations completely account for the large reduction in radio interference observed with bundled conductors.

Switching surges relative to lightning and 60-cycle high-potential values also received intensive study. Object of investigations: determine not only surge magnitudes and characteristics but also suitable standard switching surges for testing electric apparatus.

To meet the need for more a-c network-analyzer components, 12 additional generator units went into operation during the year. With the generators now totaling 36, facilities in one location are greatly increased for analytical investigations of electric utility, industrial, aircraft, marine, and railroad electric power systems.

#### **Turbines and Generators**

As evidence of expansion in the electric utility industry, two 450,000-kw cross-compound steam turbine-generators now on order will have approxi-

mately a 75 percent larger capacity than the 260,000-kw unit reported in this section one year ago.

Both of the new units are being built for the American Gas and Electric Company. Rotating at 3600 rpm, both primary and secondary shafts carry triple-exhaust elements. The cycle operates in this manner: Steam enters the high-pressure section of the primary shaft at 3500 psig, 1050 F; it exhausts at about 1050 psig, is reheated to 1050 F, and then enters the first reheat section on the secondary shaft. After expanding down to 330 psig, the steam is reheated again to 1050 F. This time it divides into parallel paths to the second reheat sections of both turbines—one on each shaft. Finally, it flows through triple-flow low-pressure sections on each shaft and into separate condensers.

The cross-compound unit has duplicate generators. Each will be rated 264,705 kva at 0.85 power factor and 16,500 volts at 30 psig hydrogen pressure; each will carry 291,176 kva at 0.85 power factor and 45 psig hydrogen pressure.

During the year a 3600-rpm steam turbine-generator with gas-conductor-cooled armature winding was installed in the Ohio Power Company's Philo Station. By means of a high-pressure centrifugal fan, gas circulates through the winding. It enters the coils through fully enclosed, insulated inlet connections on the collector end. Rated 156,000 kva, the generator also has a conductor-cooled rotor of gas-gap pickup design: cooled gas admitted to the rotor winding

at various axial locations maintains a nearly uniform winding temperature.

A large steam turbine-generator with liquid cooling went into service last March at the Cleveland Electric Illuminating Company's East Lake Station. The generator is rated 260,000 kva at 30 psig of hydrogen. Liquid circulated through the hollow conductors comprising its stator winding does the cooling. Extensive load tests confirm indications of conservative temperature rises in both the armature and field windings.

Experience is being gained in operating the first supercritical steam turbine—installed at the Philo Station of the Ohio Power Company. A tandem-compound double-reheat turbine rated 125,000 kw at 4500 psig and 1150 F, it contains several new features.

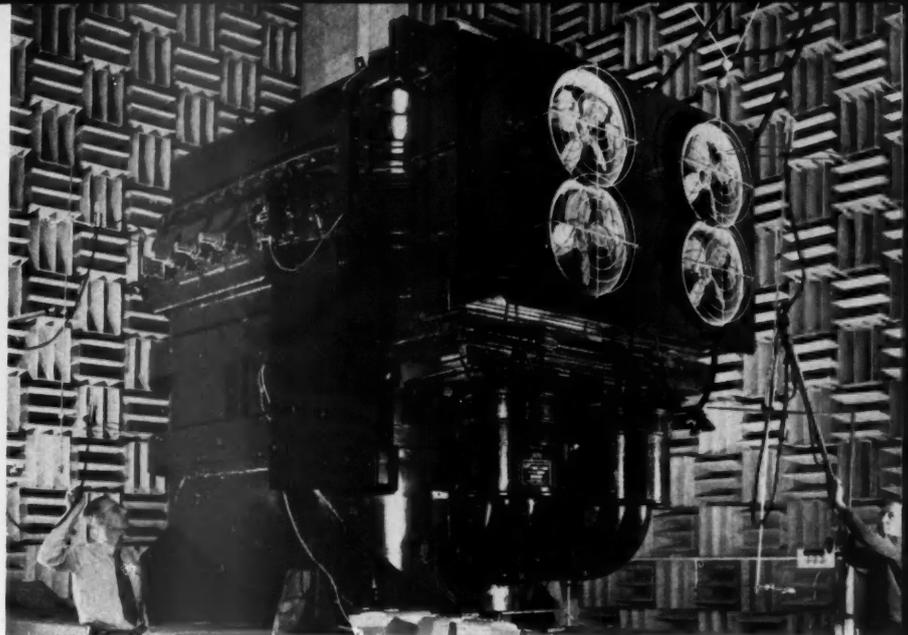
To keep pace with the trend of steam-turbine design, high-temperature turbine-bucket dovetails, uniquely designed, were placed in production in 1956. The more efficient dovetails introduce less parasitic weight. Additionally, a damaged bucket can be removed without disturbing other dovetails in the row.

Developed for use with large conductor-cooled steam turbine-generators is a high-current collector for field currents that approach 3000 amp—double the field-current capacity of collectors required for the largest conventionally cooled generators.

The increasing power capacity of large steam turbines requires longer buckets in the low-pressure stages. To accurately



Component design changes in medium-size steam turbines, eliminating time-consuming calculations.



**GAS-INSULATED TRANSFORMER** tested in sound chamber has noise level well below same-size oil-filled units. Nontoxic, the gas has a dielectric strength comparable to oil.

know their stresses in development of design, resistance-wire strain gages measure the maximum stress under simulated service conditions. Leads are brought down from the low-pressure wheel, through slip rings, to a multi-channel tape recorder.

Placed in commercial operation in 1956, 2 rows of last-stage buckets with a nominal vane length of 43 inches completed a 3-year development program. The buckets were installed in the 207,000-kw 3600/1800-rpm cross-compound steam turbine-generator of the Chicago District Electric Generating Company. Weighing 75 pounds, each bucket withstands a centrifugal force of 330,000 pounds when operating at 1800 rpm.

Initiated last year, a development program aims to provide a better understanding and an improved load-carrying capacity of large tapered-land thrust bearings. More than 40 full-scale tests carried out on a special test machine have already led to significant improvements of large high-speed thrust bearings.

Another 1956 investigation includes extensive disk-bursting in a recently installed vertical overspeed chamber. Purpose: evaluate the effects of materials and designs on the performance of rotors under abnormally severe conditions. High-overspeed testing of full-size rotors will be the ultimate goal. Now under construction is a mammoth horizontal overspeed facility in which such full-size rotors can be spun—even to destruction, if desired.

Many metallurgical developments in-

roduced in steam-turbine design involved activity in the application of the new steel-processing techniques, vacuum melting, and vacuum pouring. Also, superalloys of high strength and temperature resistance were installed in selected turbines to accumulate service experience. Placed in service in a unit of 1150 F throttle temperature was the first austenitic steel rotor. And a relatively large program now under way will study the effects of wet high-oxygen steam from a boiling-water reactor.

Pinholes, a serious problem to producers of large steel castings, needed investigating. Studies revealed that the use of titanium as a deoxidizer reduced pinholing in elbow and valve-body castings, a definite improvement as compared with the best deoxidizing agent previously used.

A new technique was devised for visualizing water flow in pipes, conduits, and turbine casings. It comprises the electrolytic formation of insoluble silver-chloride particles directly on the surface to be studied. Flow of these particles reveals the paths followed by the water stream.

Pressure vessels can now be tested without the use of flammable fluids. By adding a wetting agent and penetrants to water, pipes and conduits can be tested with equal or superior results.

Mechanical-drive turbines figured prominently in important applications during the year.

Advanced-design turbines for boiler feed-pumps for turbine-generators rated 150,000 kw or higher increase net kilo-

watt output to transmission lines. Other economic advantages include moderate reductions in station heat rates.

For land and sea applications, steam turbine-generator sets were constructed to supply current for driving canned pumps in reactor circuits. They are equipped to afford maximum resistance to the severe operating conditions generally encountered in nuclear applications.

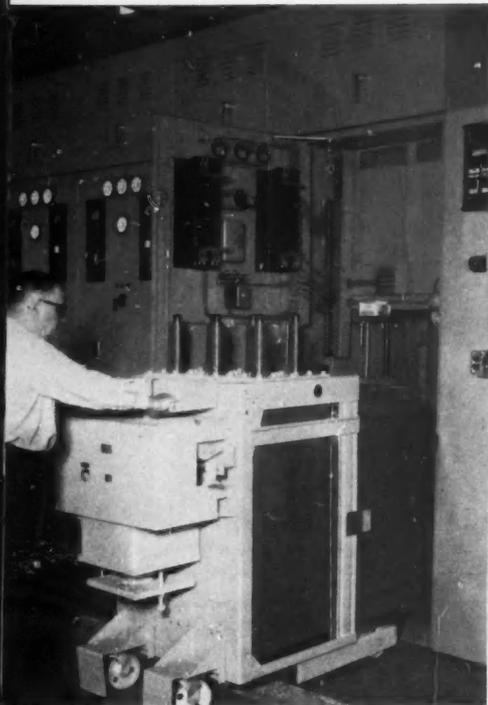
The problem of quickly stopping a 40,000-hp mechanical-drive turbine was solved during the year by using double-flow reversing stages to slow the turbine down to 100 rpm from its initial speed of 3600 rpm. Specially designed friction brakes then bring it to a complete stop, all within 10 seconds.

A 40,000-kw unit installed at a paper plant in southwestern United States represents the highest pressure and temperature rating of any turbine serving the paper industry. It operates at steam conditions of 1450 psig and 1000 F.

Now a large-scale digital computer quickly and precisely evaluates the effect of individual component design changes in medium-size steam turbines. Previously, precise evaluations of slight design changes were not practical because of the many time-consuming calculations required.

In 1956 orders continued coming in for hydraulic turbine-driven generators. Among these were four 88,400-kva 100-rpm generators for the Noxon Dam project on Montana's Flathead River.

A most significant achievement in this field was factory assembly and testing of



**INTERRUPTING RATING** of metal-clad switchgear was increased 50 percent to 750 mva.

a 60,000-kva hydrogenerator. At a test center that went into operation during 1955, the new unit was subjected to the most extensive electrical, mechanical, and ventilating tests ever performed on a machine of this size.

Two 50,000-kva hydrogen-cooled synchronous condensers, with special lagging reactive kilovolt-ampere requirements, are being built for a Midwest utility. They will control voltage on a new high-voltage transmission system.

#### Gas Turbines

The largest simple-cycle single-shaft gas turbines ever built were shipped toward the end of 1956. Rated 16,500 kw, they are the first two of a new design of which seven are now on order. Two others will be modified to operate on a regenerative cycle. Operating at 3600 rpm, the simple-cycle units are directly coupled to 17,647-kva hydrogen-cooled generators. For other gas turbines, alternative generator units—either air- or hydrogen-cooled—will be supplied. These units, representing a major advance in gas-turbine technology, will be watched with great interest.

Scheduled for delivery this year are five other large gas-turbine electric generating units—four for Canada and one for Venezuela. The Venezuelan unit,



**BUSHING GUARD** keeps squirrels from short-circuiting distribution transformers.

rated 21,500 kw, will be the largest ever built in the Western hemisphere. The four Canadian turbines—totaling in excess of 75,000 kw—will be installed at Alberni, Vancouver Island, for the British Columbia Power Commission.

#### Transformers

Each year power-transformer ratings set new marks. In 1956 the Detroit Edison Company ordered a 370-mva transformer—the largest unit yet undertaken by General Electric. Three-phase and forced-oil air-cooled, it will step up the main generator voltage of the St. Clair power plant from 17 to 135 kv.

The first power transformer to operate with atomic-electric power produced on a permanent commercial basis was installed at the Shippingport, Pa., nuclear station of the Duquesne Light Company. Rated 115,000 kva, the unit will transform nuclear generated electric power from 15,000 to 138,000 volts. With a capacity of 60,000 kw, the Shippingport station is the country's first large atomic-electric plant. It is a joint undertaking of the Atomic Energy Commission and the Duquesne Light Company.

Gas-insulated power transformers also figured in the year's developments. Two 3-phase units shipped during the year employ sulfurhexafluoride as the in-



**LIMIT SWITCHES** on voltage regulators permit linemen to adjust units in service.

ulating and cooling medium and are rated 2000 kva at 69 kv. The gas used has a dielectric strength comparable to oil, is nontoxic, and won't burn.

Near completion during 1956 were two of the largest General Electric 3-phase autotransformers ever equipped with high-voltage bushing-mounted load-tap-changers. Designed to facilitate high-voltage system expansion, the units will serve Niagara Mohawk Power Corporation's Gardenville Station. Forced-oil air-cooled units, each is rated 125,000 kva at voltages of 230, 120, and 13.2 kv.

Intense research into autotransformer insulation problems helped introduce the autotransformer to higher voltage classes. Six units shipped in 1956 represented the largest kva-rated single-phase self-cooled autotransformers yet built by General Electric. With a maximum rating of 200,000 kva, they will step down voltages from 345 to 230 kv.

Power transformers can now be safely insulated two full steps below basic insulation level. Protection by the latest station-type lightning arresters, new knowledge of transformer oil, and better understanding of switching surges made possible this reduction in power-unit insulation on systems 138 kv and above.

Early in 1956 the power transformer containing the 25-millionth kva of

forced-oil air-cooled capacity was shipped.

For power transformers with ratings up to 1-million kva, new load-tap-changing equipment can be applied. Of double-break oil-blast type, the contactor is ruggedly constructed with hardened cams and antifriction bearings designed to function reliably for the life of the transformer.

Additional improvements were attained in application of grain-oriented silicon steel for power-transformer cores. Flatter steel with less losses result from a newly developed annealing process. Further gains in improving core performance materialized with new miter-joint construction and better inter-laminar insulation.

To test sheets of steel for electromagnetic energy losses prior to their use in power-transformer cores, a single-sheet tester was introduced. It renders a simpler, quicker, and more accurate way to measure the quality of core steel. First of its kind ever built, the tester evaluates total core loss in watts per pound in laminations, prior to assembly.

For solving problems of sound in power-transformer applications, 1/7 scale models produce effective results. Effectively increasing the dimensions of the General Electric Sound Laboratory sevenfold, the models have enabled engineers to verify definite relationships between transformer size and attenuation of sound with distance.

Where applied, aluminum tubing used in forced-oil air coolers increased the rating of oil-to-air heat exchangers. The tubing is designed with a novel combination of internal and external fins. Beneficial results include a reduced number of coolers required on large power transformers as well as reduced auxiliary power consumption.

Ultrasonics entered into a new transformer technology during the year. By means of this technique, electric discharges in insulation structures can be detected and more accurately located. The technique utilizes the ultrasound produced by a corona, or spark discharge.

In cooperation with national technical societies, a functional test code was developed to determine the useful life of insulating material for ventilated dry-type transformers.

An electronic data-processing machine, covering 4000 square feet of floor space and capable of 29,400 "logical" decisions per second, was built in 1956 for installation early next month. It will

extend the speed and efficiency of design and engineering work and ensure optimum design of large custom-made power transformers. Data will be taken from magnetic tape at the rate of 15,000 characters per second, or at 20,000 characters per minute from punched cards.

Operation of heavy industrial electric equipment, such as arc furnaces, can cause lighting flicker on residential loads. Power-transformer design engineers helped two utilities solve this problem. Impedances were obtained that minimize transfer of voltage variations to residential load caused by the arc-furnace loads.

Especially designed to meet the needs of rural and small urban distribution systems was a new line of mobile unit substations. This standard line offers both 1500- and 2500-kva units in the voltage ratings most common on rural systems. In addition, kva ratings of conventional mobile substations were greatly increased during the year.

In the distribution-transformer field, a production-line technique innovated 7 years ago expanded in 1956 to cover single-phase units up to and including 100 kva. The impulse-testing technique simulates lightning or switching surges to detect defective equipment.

Height reductions averaging more than 5 inches were made in pole-type distribution transformers rated 25 to 100 kva. Thus, higher rated units can now be mounted with existing bolt holes, while cleared adequately from overhead wires.

Requests from several Midwest utilities, hard hit by epidemics of outages on rural lines caused by squirrels and birds, resulted in development of a new bushing guard. A 12-inch sleeve of synthetic rubber-like material, it fits over the high-voltage cover bushing and primary lead.

Tough enamel-insulated wire was extended to both high- and low-voltage windings of distribution transformers. Thinner and stronger than fiber-wrapped or varnished-insulated wire, it permits closer nesting of transformer coils for more compact, efficient design.

For self-protected transformers—both single and 3-phase—new circuit breakers were introduced in sizes from 37½ to 100 kva. They have rugged construction, increased reliability, and simplified calibration adjustment. Their smaller size contributes to transformer designs of lower height, thus reducing congestion on utility poles.

One major development in distribution transformers was the introduction

of panel radiators for vault-type network units. Use of wide, flat vertical panels simplifies cleaning and repainting and minimizes collection of corrosive dirt.

Meeting the highest accuracy classifications, major reductions occurred in the size and weight of high-voltage potential transformers. A cascade arrangement greatly reduces the amount of heavy, bulky insulation required.

Current transformers also figured in developments of 1956 with the introduction of two new butyl-molded types in the 8700-volt insulation class—one for indoors, the other outdoors. The latter utilizes the new nontracking butyl insulation. Butyl instrument transformers now comprise 13 basic types, covering nearly all voltage classes from 600 to 15,000 volts.

### Voltage Regulators

A load bonus feature permits single-phase step-feeder voltage regulators to carry additional current when operating at less than  $\pm 10$  percent regulation. These regulators now carry up to 160 percent current—400-amp maximum—when set at  $\pm 5$  percent regulation. By means of limit switches conveniently located on the position indicator, regulation range adjustments can be made externally while the regulators are in service.

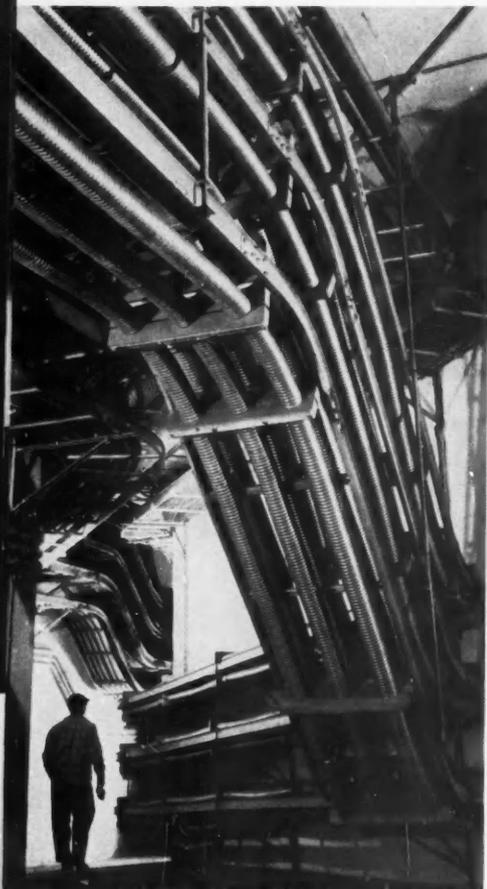
New load-tap-changing switches applied to 3-phase step voltage regulators rated 1000 kva and below, reduce peak operating noise by 20 decibels. Additionally, contact-tip life is doubled.

### Switchgear

During the past year many important advances occurred in switchgear. In June the first installation of 13.8-kv 750-mva metal-clad switchgear with air-magnetic-type power circuit breakers went into service. No increase in unit width was required to raise the rating 50 percent, while floor space increased less than 10 percent.

A new rating—75 mva—was added to the line of 4.16-kv air-magnetic circuit breakers. This breaker has all the features of the higher rated breakers of the line. Substantial reductions were made in the weight and closing power requirements of most air-magnetic breakers in both the 4.16- and 13.8-kv lines.

Aluminum extensively replaced copper in buses and connections of metal-clad switchgear equipment, and high-accuracy butyl-molded window-type current transformers were introduced. A



**ARMORED CABLE** feeds large power blocks to NACA's supersonic wind tunnel.

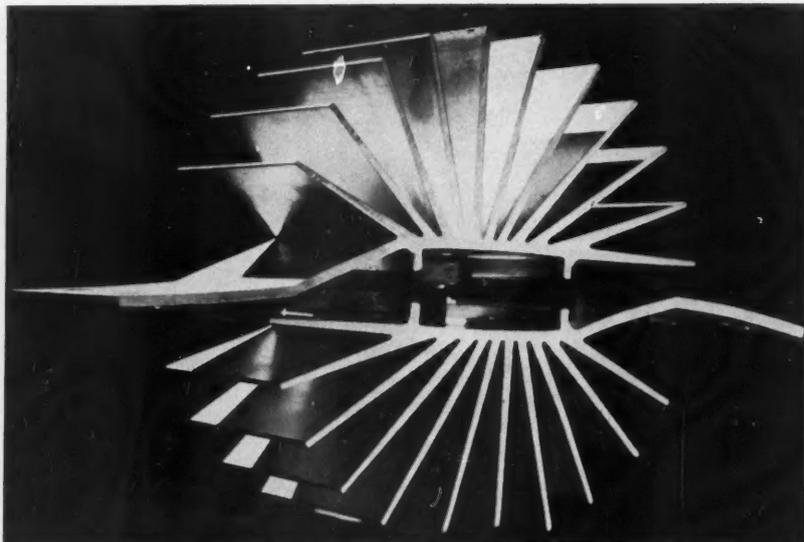
transition compartment minimized amplification and transmission of transformer noise to switchgear in unit substation equipment.

A 34.5-kv 1500-mva interrupting capacity air-blast circuit breaker—available in 1200- and 3000-amp continuous ratings for outdoor or indoor service—augmented the station equipment line. Longer life and reduced maintenance result from a low-arc-energy high-pressure cross-blast interrupter and a direct-drive pneumatic operating mechanism.

A new line of automatic circuit reclosers was introduced for 4.8-, 14.4-, and 23-kv service with ratings through 200 amp. The hydraulic timing system makes them compatible with other types of hydraulically controlled reclosers.

Current-limiting power fuses for 2.3- and 4.6-kv service were redesigned to reduce their physical size by nearly one half and nearly double the maximum available current ratings.

Opening up a completely new area



**GERMANIUM CELL** haloed by silver-plated aluminum fins forms the heart of an air-cooled magnetic-amplifier-controlled plating rectifier occupying about 9 square feet of floor space.

in protective relay design, transistors entered the switchgear field for the first time last year. A sensitive transistorized relay was designed to protect large turbine-generators against unbalanced loading of as little as 7 percent of full load.

Designed primarily to protect motors from damage due to unbalanced voltage, a new negative-phase-sequence voltage relay was introduced.

Reliability of supervisory control indication and telemeter-selection systems operating over direct-wire channels was further increased last year. And automatic throwover equipment detects an open- or short-circuited channel and immediately transfers both sending and receiving equipment to a healthy channel.

#### Capacitors

Military and commercial projects brought on sudden demands for large banks of energy-storage capacitors. It precipitated a new approach to capacitor packages as high as 10-million joules that have exceptional economy and electrical characteristics. Results: Costs were reduced about half and means were provided for obtaining high current and extremely high discharge rates.

Now available in all types of open rack equipment is the 50-kvar power capacitor described in this section one year ago. Package pole-type switched equipment is supplied in ratings up to 600 kvar. Economies in switching also resulted: the same number of switch

and control devices handle twice the kvar.

Physical size of the 25-kvar capacitor decreased about 38 percent last year. Improvements in dielectric materials and the capacitor's construction, along with new manufacturing techniques, aided this accomplishment.

Last year several electric utilities made trial installations of self-clearing protective gaps to shunt capacitors. Successful application of low-voltage series capacitors in the neutral of transformer primaries depend on these gaps—available for transformers rated 2400, 4800, and 7200 volts.

#### Cable

Armored cable figured prominently in construction of a new wind tunnel operated by the National Advisory Committee on Aeronautics (NACA) at Lewis Flight Propulsion Laboratory in Cleveland, Ohio. Special large-size varnished-cambic interlocked armored cable carried in ladder racks feeds power to various components of this supersonic wind tunnel.

To match the increasing use of higher temperature insulation, General Electric now offers an aluminum sheath in place of lead with any standard construction of cable. Tests prove that—in addition to withstanding higher temperatures—aluminum-sheathed cable is lighter in weight, resists creep and fatigue, has good corrosion resistance, and provides a positive barrier to moisture.

For circuits up to 15 kv, thermo-plastic-jacketed cable using polyvinyl

chloride was introduced as standard covering for butyl-insulated power cables. It offers great advantages, particularly for cable exposed to ozone, oil, and sunlight. Also, cable jacketed with polyvinyl chloride has greater resistance to moisture and chemical fluids, while being less expensive than other types.

Increased use of butyl-insulated solid dielectric cables created a demand for longer continuous lengths that can be laid underwater without splicing. For this type of service, 15-kv continuous 3-mile lengths of cable were produced. The excellent moisture resistance of butyl insulation allowed cable construction without a lead sheath.

Begun in 1956 was a program to investigate many of the variable factors that could lead to failure in aerial cable. A comprehensive series of simulated lightning tests on developmental full-scale outdoor-aerial-cable installations are expected to provide answers to many fundamental and practical questions.

Electrical stability and high resistance of silicone-rubber glass-tape generator leads permitted reducing insulation thickness. In the 15-kv class, for instance, a 20 percent reduction was made. By means of acceptable cable arrangements, generator leads of this construction can carry loads up to 400 mva.

#### Arresters and Cutouts

Magne-valve principle was first applied to separately mounted distribution-type lightning arresters in 1956.

In the new distribution arrester, lightning surges are harmlessly discharged to ground in the same manner as other valve-type arresters. However, the system power-follow current is interrupted by a magnetic force created within a unique magnetic gap. With ratings of 9, 10, 12, 15, and 18 kv, the arrester comes either as a directly connected unit with ground-lead disconnect or as an externally gapped arrester.

Other magne-valve lightning arresters of the station type were introduced with reduced height and a self-supporting construction. They are designed for high-voltage applications in ratings of 169, 182, and 195 kv.

Open-dropout fuse cutouts introduced last year provide longer service life. In the design, bronze replaced galvanized steel hardware to eliminate costly corrosion damage. The cutout comes in ratings of 7.8 and 15 kv with continuous current-capacity of 100 amp.

#### Bushings and Insulators

Based on a new porcelain composition, one of a line of high-strength suspension insulators has a rated strength of 36,000 pounds. The insulator is particularly adapted for supporting long, heavy spans and for bundled-conductor supports on high-voltage systems. Compared with other insulators of this rating, it is 10 pounds lighter and has twice the mechanical impact strength, as well as being smaller in size and costing less. Another new unit, rated 25,000 pounds, has similar improvements including the highest impact strength rating ever offered in a suspension insulator. This insulator now makes it possible to add up to 25 percent more leakage distance in a given string length or to shorten insulator strings.

Sought for nearly 40 years, interchangeability of high-voltage bushings—92 and 230 kv—was finally achieved in 1956. Actively promoted by General Electric, the new designs resulted from cooperative compromises on the part of transformer and circuit-breaker designers representing manufacturers of this equipment. Interchangeability between transformers and circuit breakers can easily be effected by changing connections at the top and bottom ends of the bushing.

Basic study of the corona-pulse pattern and its associated radio noise resulted in a definite correlation between noise level and corona-pulse distribution. Examining the pulse pattern in laboratory tests can determine the main source contributing to corona or noise.

#### Rectifiers

In 1956, germanium rectifiers came of age: the electrochemical industry accepted them as highly reliable and efficient a-c to d-c power-conversion equipment. Germanium rectifiers are supplying 90,000 amp at 65 volts d-c to an aluminum electrolytic reduction line. A larger germanium equipment, rated 250 volts at 140,000 amp, is being manufactured for a chlorine-line installation.

An air-cooled germanium rectifier—another development in this field—supplies direct current to electroplating tanks. Heart of the new plating rectifier is a germanium cell surrounded by a halo of silver-plated aluminum fins. This new unit offers the first automatic control at a price competitive with manually controlled rectifier equipments. Available in ratings of 6 volts, 750 amp, or 24 volts, 4000 amp, it occupies less than 9 square feet of floor space.

Redesigned package mercury-arc

power-rectifier equipment for electrolytic service combines anode switchgear, pumpless ignitron tanks, water-to-water heat exchanger, auxiliary control equipment, and cathode switchgear within a single, compact metal-enclosed assembly. Equipment of this type is available for output voltages up to 850 volts d-c and continuous current of 6000 amp.

#### Distribution Systems & Busways

Incorporated in a new design low-voltage switchboard (600 volts) is a completely standardized bus structure designed to withstand the stresses of today's higher short-circuit levels.

The complete switchboard with strong insulators having high tracking and arcing resistance has withstood proved short-circuit rating tests of 50, 75, and 100,000 amp. Of modular type, the switchboards come with fusible switch and circuit-breaker protective devices.

Distribution panelboards developed during 1956 have quick-make quick-break fusible switch-type units rated 30 to 200 amp and an interrupting ability 12 times the rated current at full-rated voltage. With proper fuses, the panelboards are suitable for applications on systems at the 100,000-amp level.

A line of plug-in-type busway—available with copper or aluminum busbars—shows an achievement originally thought impossible: an approximate .50 percent reduction in voltage drop. Large power magnitudes can be transmitted through extensive factory areas to loads requiring good voltage regulation.

#### Meters

Many of the features introduced by General Electric in the design of watt-hour meters—such as magnetic suspension and current and potential coils insulated with butyl rubber—are used in a new line of extended-range polyphase watt-hour meters. They also incorporate all the latest advances in the art of electric energy measurement. These meters will replace present 15- and 50-amp types. Although size was decreased, standard mounting dimensions remain unchanged to maintain interchangeability with older types.

Only one third as large and one quarter as heavy as its predecessor, a new printing demand meter has a  $3\frac{1}{3}$  greater capacity—999 discuret numbers per demand interval. Simple in design, the meter offers increased reliability and less maintenance effort. Also, its single pressure-sensitive wide-temperature-range tape can be serviced easily.



**D-C MOTOR DRIVE** at the new Weirton Steel Company supplies 28,000 hp. The installation makes steel strip at 80 mph, with thickness control within precise limits.

## Industry

American industry continued its prodigious growth of past years, with its technology becoming more complex in 1956.

So great are demands in the motors field that work began on extensive laboratory and engineering facilities in anticipation of motor requirements of the future.

The metals industries now produce steel strip continuously at a rate of 80 mph, with a controlled thickness within several ten thousandths of an inch. And a punched-card system partially regulates the rolls of a reversing mill to an accuracy of five mils.

Television, too, found wide usefulness in close-up viewing of industrial operations. For example, a closed-circuit TV camera, located near the cutting tool of a large boring machine, provides the operator with a continuous view of the tool tip as it shears through metal.

### Motors

Last year marked the introduction of an advanced line of industrial d-c motors, generators, and motor-generator sets. The new machines are designed to meet the growing requirements of industry for greater versatility and faster speed of response in adjustable speed drives—particularly for automated processes. Compared with previous general-purpose motors, they possess an average of 33 percent more horsepower per pound.

Several sizes of large d-c torque

motors were developed and produced during 1956 for applications requiring accurate angular positioning of director mechanisms. Torque motors are unique for extremely low-speed operation, usually about 2 or 3 rpm, and for short length of travel, usually a fraction of a revolution.

Two unusually large high-speed synchronous motors were built for centrifugal-compressor applications. One motor is rated 7000 hp at 1200 rpm; the other, 3500 hp at 1800 rpm. They probably represent the largest salient-pole motors yet built for service at these speeds.

An induction motor with integral clutch and brake is now available for textile looms. A high-inertia rotor and flywheel make nearly constant loom speed possible. The mechanical design assures fast and accurate braking.

Severe-duty enclosed motors, designed for such extremely moist or corrosive atmospheres as those found in the chemical and paper industries, have these protective features: all-cast-iron construction; threaded parts specially treated to facilitate disassembly after lengthy operation; neoprene shaft seal; and through-bolt washers to prevent entry of moisture and foreign matter.

A new line of quiet-operating motors with guaranteed values of noise-level and octave-band analyses became available last year. And a boiler-feed-pump motor line with a basically new en-

closure incorporates new ideas in bearing construction, fan design, and quiet operation.

Large induction and synchronous motors can now utilize a newly developed Class A insulation system that possesses a greatly increased resistance to environmental attack. Although developed for rubber-mill installations where a high concentration of carbon black is present, this system can also be used in many other applications where severe environmental conditions may result in premature winding failures.

Extending present motor lines for particular industries provides larger, more efficient drives for special applications—such as the press-drive motor.

An extensive laboratory and engineering facilities program launched in 1956 provides for future progress on such motors. An engineering laboratory installed in Schenectady will develop new products and improve existing ones at reduced cost. The laboratory will concentrate on better long- and short-range solutions of the continuing principal technical problems of insulation, bearings and lubricants, and magnetic materials. The advance engineering facility will be staffed with engineers having outstanding competence in analysis, development, and testing of medium induction motors. The group will concentrate on the conception, development, and evaluation of new components plus new products for the department.

A device plots directly on 8½ x 11-inch graph paper the electrical and mechanical characteristics of a single-phase fractional-horsepower motor. Curves indicate motor speed, output torque, line current, input watts, and line or capacitor voltage. One such device is intended for use with 2-, 4-, and 6-pole 115-volt motors having torque outputs between 5 ounce-feet and 150 ounce-feet. Other versions, some suitable for use with polyphase motors up to about 10 hp, are being constructed.

A simple low-cost motor, developed last year, starts gasoline lawn-mower engines. Mounted on the crankshaft, the motor gives instant engine starting when plugged into a 110-volt a-c outlet.

Stainless-steel and cast-iron motor components protect another new fractional-horsepower motor from water, salt, alkali, and acids in dairy, food, chemical, petroleum, and other severe-duty applications. This motor is non-

ventilated, ball bearing, and totally enclosed.

A submersible water-pump motor, available in ½- to 5-hp ratings, operates efficiently in pushing rather than pulling water from a well. Earlier gasoline pumping used similar motors. Two new features are epoxy-resin encapsulation of stator windings and water-lubricated bearings. Submersible water pumping has proved more efficient than conventional systems in deep-well pumping.

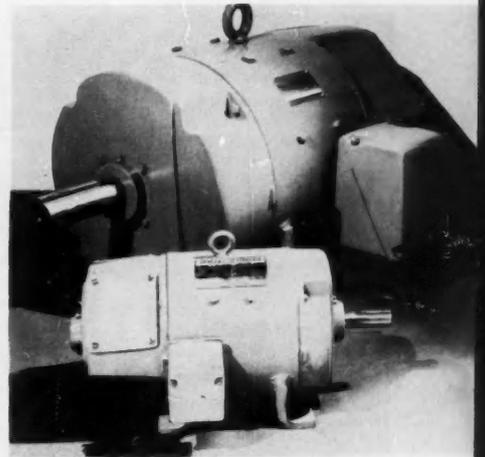
For gasoline pumping above ground, a completely redesigned fractional-horsepower motor was offered to gasoline-pump manufacturers for the first time in 1956.

For console and room air conditioners, a smaller, lighter motor was developed last year. The 25 percent shorter motor enables designers to make air-conditioning units smaller. Made in ratings from 35 maximum hp to ⅙ hp in single-frame size, it offers quick-connect terminals, low operating current, and high corrosion resistance.

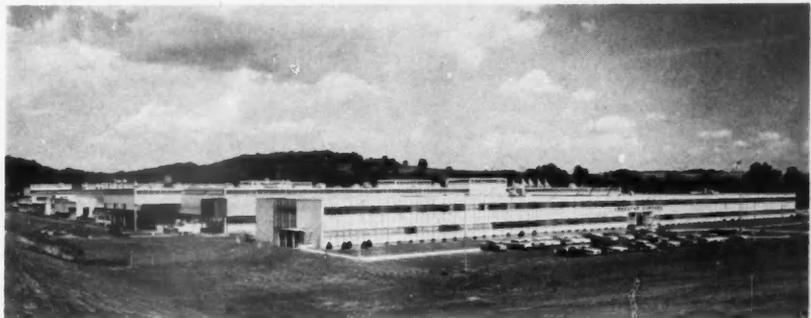
A new line of appliance motors was announced in 1956, designed specifically for the requirements of domestic laundry and kitchen appliances—washers, dryers, ironers, food-waste disposers, and dishwashers. The motors utilize new materials wherever possible and are adapted to new automatic manufacturing techniques. Polyester-film slot liners improve insulation life and at the same time increase temperature rating.

A design was completed for gear-motors on automatic pinspotters for the bowling industry. Each pinspotter requires three gear-motors. One motor with shafts in three different planes runs at different speeds to perform three operations simultaneously. The new design solves two major problems: demanding duty cycles with more than a million starts and stops per year; and oil leakage prevalent in previous designs. Rearrangement of the distribution of power throughout the gear train allows better balance of the load and permits heat-treatment of key stress-bearing elements to increase load-carrying capacity. And gear reliability was also substantially increased. Another major design advancement utilizes slingers and catch basins to permit lubrication of gears and bearings at a considerable distance above the main reservoir level. Seals now handle a minimum of oil splash, virtually eliminating leakage.

Recent materials and techniques made possible the production of motors for operation under high-pressure water at



**INDUCTION MOTOR** on gasoline-powered lawn-mower engine gives instant starting. New d-c motors have about 33 percent more horsepower per pound than their predecessors.



**CONTROL PRODUCTS** from small resistors, rheostats, and brakes to large-grouped motor control and special operators' desks went into production at new Roanoke, Va., plant.

moderate temperatures. Where the leads join the coils, a polyethylene film is employed as a watertight seal at the junction. Newly devised methods are employed for compounding the coils and forming the lead connections to the coils after insertion in the stator. An epoxy-encapsulated seal is used on cable connections where the conductor is brought through the motor housing.

#### Control

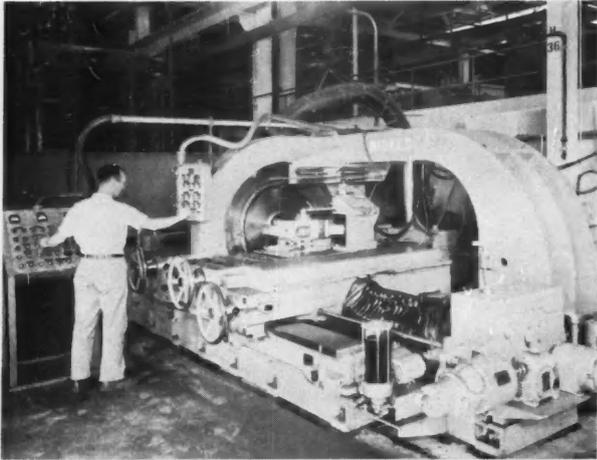
New static switching systems—utilizing static-magnetic and solid-state elements—highlight developments in control. The systems accomplish functions normally performed by contact-making devices, such as relays.

In one system, units containing these elements combine with static-power supplies, static amplifiers, and static regulators to provide completely static control. They accept electric signals from sensing elements that measure speed, load, position, and pressure; or they accept signals from operators' control panels. Using built-in intelligence to interpret these signals, the

static switching units control a power amplifier, that in turn performs the required function. Applications for static switching systems involving frequent operation, continuous processes, and complex systems hold promise, plus those that must meet adverse atmospheric conditions.

Another static switching system—one with static units that are multifunction elements—especially adapts to complex control systems. Receiving directions from a dispatcher, it controls a conveyor switching system that routes finished appliances to one of nine warehouse areas. Some conditions that made static switching desirable for this application include: frequency of operation, reliability, and memory—that is, the control must return to the same state upon application of power after shut-down.

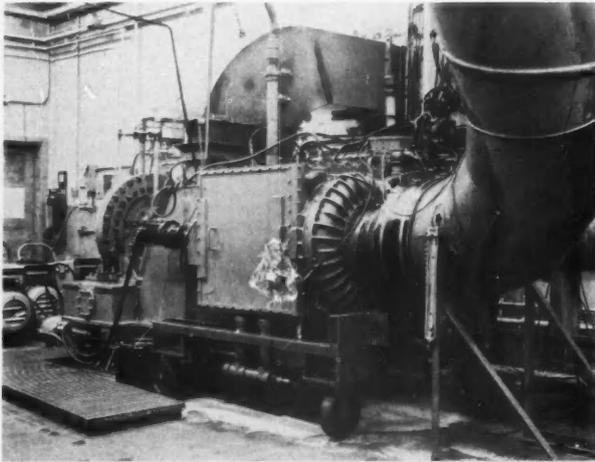
To match the growth of industry, 3-phase induction regulators were modernized to handle twice the load of previous units. These regulators offer freedom from brushes and harmful wave distortion, minimum floor-space



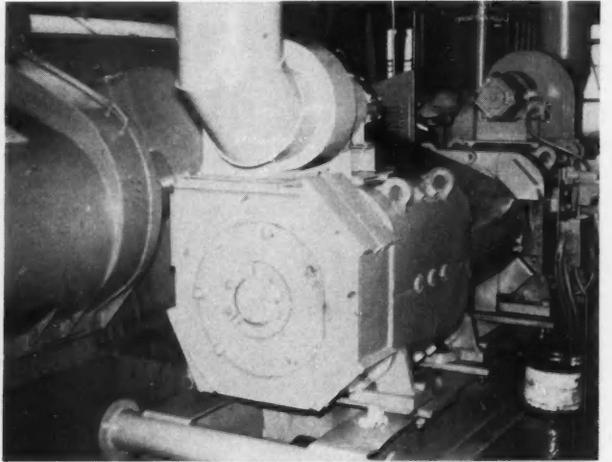
**CENTER-DRIVE LATHE** simultaneously contours both sides of jet-engine rotor disks that possess thin web sections.



**ELECTRIC SHOVEL**, standing 16 stories high and weighing 2700 tons, can take a 90-ton bite of earth and drop it up to 300 feet away.



**ORION RIGEL ENGINE**, a combination 6-cylinder opposed-piston 2-bank supercharged diesel and gas turbine, delivers 600 hp.



**OIL-WELL DRILLING RIGS** are now driven by diesel-electric locomotive motors and generators that were modified for this service.

requirements, completely packaged units including controls, maximum reliability, and high short-circuit strength. Despite the twofold increase in capacity, the new voltage regulators require only 30 percent more floor area and are only 20 percent taller than their predecessors. The smaller units rated for single-phase or 3-phase loads of 150 kva or less were also redesigned.

Developed last year, a long-time magnetic delay element employs the unusual properties of magnetic core materials with hysteresis loops. Essentially an amplistat circuit, the delay unit can provide timing intervals roughly 50 times longer than conventional inductance-resistance circuits using the same size reactors. It can be applied to control systems where reliability and maintenance requirements make me-

chanical or thermal methods unattractive.

A new plant in Roanoke, Va., began production of control items ranging from small resistors, rheostats, and brakes to large-grouped motor control, steel-mill control panels, and special operators' desks. An industrial-control laboratory located at the plant furnishes engineers with an evaluation of products, application data, and consultation services. The laboratory also maintains measurement standards, regulates processes, and runs quality-control tests on incoming materials.

#### Protective Breakers

A compact molded-case circuit breaker in a new industry frame size, the KM, comes in ratings from 125 to 800 amp at 600 volts a-c; 125 to 600 amp at

250 volts d-c. Functionally, it replaces the KL, L, and M frame sizes in a device 30 percent shorter than the L frame. The interrupting ratings are 50,000 amp at 240 volts a-c; 25,000 amp at 480 volts a-c; 25,000 amp at 600 volts a-c; and 25,000 amp at 250 volts d-c. The KM breaker recently completed Underwriters' Laboratory tests.

The L frame breaker covering 125- to 600-amp ratings at 600 volts a-c, 250 volts d-c was redesigned. It now includes 700- and 800-amp ratings and also comes with nonautomatic trip units for switching functions.

In the field of industrial safety switches, two enclosure designs broaden the applications of the switching mechanism. The first design—a raintight enclosure for outdoor installations—meets NEMA Type 3 enclosure requirements.

It is available from 30 through 400 amp at 240 and 600 volts. Designed to meet NEMA Type 12 and JIC enclosure requirements, the second design employs a completely sealed corrosion-resistant enclosure. The enclosure has a synthetic gasket around the cover and operating handle. This heavy-duty switch comes in ratings from 30 through 200 amp at 240 and 600 volts.

Space requirements for 30-amp 600-volt safety switches were cut 50 percent by a compact interior design. The 60- and 100-amp ratings, reduced in depth 1½ and 2½ inches respectively in standard and heavy-duty lines, meets all Underwriters' Laboratory clearances.

Several engineering changes in motor-control disconnect switches increase installation ease and flexibility. The complete line is now fitted with handle operating rods that adjust in length. These enable switches to be mounted on the backs of boxes without building up a base support. Further space savings were also achieved by reducing the width of the 60-amp switch 30 percent and the width of the 100-amp switch 20 percent. Ratings from 30 through 200 amp at 240 or 600 volts are available in this line.

#### Steel and Other Metals

With increased capacity and high-speed output in the steel and aluminum industries, automation becomes more important to keep pace with new production standards.

A new Weirton Steel Company installation makes steel strip at 80 mph, with thickness controlled within several ten thousandths of an inch. A d-c motor drive supplies 28,000 hp. Believed the fastest and most powerful 5-stand tandem cold-strip mill, it required special design and manufacturing for each item of equipment.

Static switching equipment was added to the master control on a 4-stand tandem cold-sheet mill installed last year. This equipment replaced frequently operated relays. Combined with new static circuitry, it replaced the large motor-operated rheostat that programs mill operation during acceleration and deceleration. Results: longer life, smoother and more reliable performance, and better electrical design.

For hot-strip finishing mills a new speed regulating and instrumentation system was installed. It gives operators more sensitive control and materially reduces gage variations from end to end of the strip. Setup switches and instru-

ments on the operator's control desk, utilizing fluorescent materials, are illuminated with black light. This permits a darkened pulpit, giving the operator a better view of mill-rolling conditions. At the same time, the necessary auxiliary equipment and instrumentation are at hand.

Punched-card programming became more prevalent in rolling-mill and processing-drive systems. In a reversing roughing mill partially controlled by a punched-card numerical system, the roll opening can be set to a 0.005-inch accuracy. In this mill a hot slab makes a number of passes through the rolls, set to a smaller opening for each successive pass. The punched card designates the pass speed as well as the roll opening. With this device, the operator controls the sequence of events but not the setting of the rolls or speed of movement. Consequently, with more accurately positioned rolls and performance variations eliminated, a more uniform pattern results. Production and accounting information can also be included on the same cards and later processed in standard accounting equipment.

A twin-drive slabbing-mill system was aimed at cutting initial capital investment and maintenance costs. An improved twin-drive arrangement, with the upper motor located nearest the mill, results in easier accessibility for maintenance of the motors and the bearings. A complete ventilating system in each motor simplified the foundation and eliminates the duct work typical of previous installations. Forged flange couplings, an integral part of the motor shaft, provide increased strength for shock loads associated with this application. Well-fitted enclosing covers, held by latches rather than bolts, can be quickly removed. A hoist for servicing the guide bearing of the extension shaft, a hydraulic jack to split the coupling, good interior lighting, platforms, and built-in ladders make maintenance easier.

When equipped with suitable amplidyne-controlled electrode regulators, new arc furnaces for melting steel operate at double the former maximum electrode speed of 60 inches per minute without encountering stability problems. An amplistat was adapted for use in the field circuit of the amplidyne for the largest size furnaces. It gives the higher degree of amplification required for obtaining the necessary sensitivity and close control of the electrode current. Result: a much faster melt-down

higher quality product, with increased output and operating economy.

A 12-inch capacity vacuum arc-melting furnace for production melting of molybdenum and its alloys was developed last year. The consumable electrode furnace will produce a 2000-pound pure ingot every 3 hours in continuous operation. The same-type furnace processes iron or nickel-base alloys, titanium, and zirconium. Eliminating impurities from the atmosphere, it also removes impurities that are gaseous at melting temperatures, reduces segregation, and produces a superior grain structure. The unit will handle 8-, 10-, and—with modifications—16-inch ingots measuring a maximum length of 5½ feet, weighing 850 to 5000 pounds.

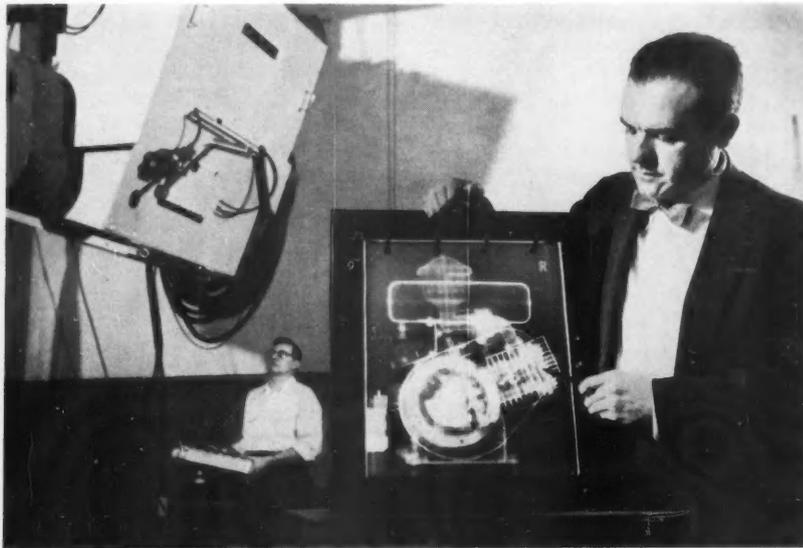
Placed in service during 1956, a pin-hole detector spots 0.001-inch holes in steel strip moving at 2000 fpm. The shutter assembly for preventing light leakage around the edge of the steel strip was substantially improved.

#### Metalworking Industries

Mounted near the cutting tool on a large boring machine, a closed-circuit TV camera gives the machine operator his first continuous view of the cutting operation. The monitor screen, mounted near the controls, eliminates the interruption of work to check for tool breakage. A similar technique on a gantry-type drill permits the operator to read any one of three control verniers directly from his chair. Three cameras, one receiver, and a 3-position selector switch are used.

Many tracer or magnetic-tape systems completed during the year will control over 60 large aircraft skin-, spar-, and profile-milling machines for the Air Force Machine Tool Procurement Program. Selsyn-tracer systems control some of the world's largest spar-milling machines. The selsyns, linking template follower and cutting head, control 12 motions on each machine and greatly simplify machine design and template mounting. The magnetic-tape systems operate from position instructions obtained from numerical parts data translated by computers and computing directors into machine-motion signals for the tape system. Signals are then recorded on magnetic tape for machine playback as many times as needed to produce the desired number of parts.

In a center-drive lathe developed last year, jet-engine rotor disks with thin web sections are simultaneously faced on both sides. Synchronized tracer



**X-RAY STOP-MOTION PICTURES** now give designers an inside look at the complete action of a running motor. The exposures require only 10 to 15 millionths of a second.

drives keep both cutting tools opposite one another regardless of face contours. Electronic speed control provides constant surface-cutting speed at all wheel diameters, maintaining constant chip thickness as spindle speed changes.

The machinability computer developed during 1956 was extended to solve speed-cut-depth problems in milling, as well as prior applications in forming, grooving, and related plunge-cutting. The computer assures quick detail on problems in face, slab, end, straight and staggered-tooth slotting, and straddle milling.

#### **Manufacturing Industries**

Developed last year, the first commercial computer for manufacturing scheduling handles 50 different products being fabricated at 24 work stations. The analog device—adaptable to budget synthesis, materials requirement, and operating reports—compares in size to an office desk and uses less power than a TV set.

Halogen-leak-detection equipment can now be used to measure leakage rate. A special calibrated glass capillary tube devised last year reproduces minute leaks in the order of 0 to 10 ounces a year, accurate to  $\pm 10$  percent.

A new gear-motor provides 24-hour service on grinders for the plate-glass industry. A continuous glass strip can now be simultaneously ground to high standards on both sides, reducing distortion.

#### **Mining**

The world's biggest electric shovel, standing 16 stories high, went into coal-

mining service last year. In contour stripping, the shovel takes a 90-ton bite of earth from above the coal seam, drops it on a spoil pile up to 110 feet high and up to 300 feet away, and goes back for more at a rate approaching 2-million yards per month.

Engineering the shovel-drive systems required an electronic computer study. Because of the shovel's 2700-ton weight, the earth cannot support it; thus it travels on the coal seam. Designed for continuous performance, it works 24 hours per day, with Christmas as its only idle day.

Electric equipment includes two special motor-generator sets with driving motors rated 1000 and 3500 hp. The peak power exerted by the hoisting motors is 5000 hp. The swing equipment develops 1800 hp maximum; and the crowd motor, 900 hp. In addition, four 250-hp traction motors develop a power effort of approximately 2500 hp for propelling the shovel at a rate of about  $\frac{1}{4}$  mph.

#### **Gas and Petroleum Industries**

Last year marked the adaptation of standard diesel-electric locomotive motors, generators, and control devices to drive oil-well drill rigs. Several applications were made to barges for offshore drilling. A portable land rig recently went into service. Most rigs have two to eight diesel-generator sets, with either one or two generators assignable to a motor. Thus, with several loads on the rig, the operator can flexibly assign power. The standard d-c series-wound

locomotive traction motor was modified into a shunt machine for safety and satisfactory light-load operation. The frame was altered to provide foot-mounting, and some changes were also made in the ventilation scheme.

Portable gas-turbine-driven centrifugal pumps were supplied for crude-oil pipeline pumping. Three-part portable units, for integral operation at a pumping point, house turbines rated 5000 hp at 110 F ambient temperature, together with control, accessories, and communications facilities. Radio control makes the units useful as unmanned remote stations.

Texas Eastern Transmission Corp. installed four 7600-hp regenerative-cycle 2-shaft gas turbines on natural-gas pipelines. Natural-gas-fired at 1500 F average inlet temperature, these turbines are an improvement on 5000-hp turbines installed 4 years earlier on pipeline pumping. Fifty units, all the same general design, have logged 800,000 hours in natural-gas pipeline service.

Compressor-drive steam turbines for oil refinery and chemical process industries continue to increase in horsepower and speed. Design improvements include high-strength liquid-quench solid-rotor forgings and fatigue-resistant tapered buckets having both entrance and exit edges tied to their bases.

#### **Rubber and Plastics**

Last year a new 4-roll calender for making plastics film or coating fabric was equipped with an independent adjustable drive for each roll. With the adjustable speeds a wider variety of products can be produced on a given machine.

Another plastics-film drive uses an extruder as the casting machine, followed by 18 individually driven tempering sections. The reel drive winds a set length of film without regard for machine speed or film thickness.

A new insulation system for large synchronous and induction motors for tire plants was produced for service in conducting air—laden with fine carbon blacks. Tape used in this insulation system adds a moisture seal to the system.

#### **Paper and Textile**

A continuous bleaching and mercerizing line set up last year handles 10 miles of in-process cloth. Coordinated, individually adjustable d-c drives power each of the line's 50 sections. Result: higher productivity, lower cost, and greater reliability.

In the man-made fiber field, speed

monitors for spinning machines represented a most significant electrical development. These systems provide high transient accuracies and great flexibility.

Control equipment in the paper industry enables a new paper-making machine to continuously manufacture a 25-foot-wide paper web at the rate of 30 mph. New drive systems for winders increased the speed and accuracy.

Introduced in 1956, a static speed-regulating control system will improve paper-making operations. Hermetically sealed silicon transistors and amplifiers replace electronic tubes and rotating exciters. A new control based on a potentiometer permits varnish impregnation of kraft paper without help from machine operator.

#### Vehicle Drives and Testing

Development testing was completed on a compound engine that attains diesel-engine efficiency and gas-turbine flexibility for driving a tank or other vehicle. The entire power plant is a combination of two centrifugal air compressors and a 6-cylinder opposed-piston diesel engine built in two banks of three cylinders each to save space. The hot gas produced by the combination of diesel engine and compressors, known as a gas generator, drives the free gas turbine which in turn is connected to the transmission of the tank or other vehicle. The diesel engine itself provides no mechanical power except small amounts for auxiliary purposes. After nearly 6 years' work and the efforts of nearly 150 people, the engine, named *Rigel*, was developed for Army Ordnance Project Orion.

Army vehicles, from jeeps to the biggest tanks, are tested at Detroit Arsenal; test equipment includes cells for entire vehicles and single components.

Last year a test involving a vehicle operating under simulated desert conditions demanded that test instruments be isolated from the hot cell. Accordingly, an unusual gear-coupling arrangement was designed to vertically transmit power down from the test vehicle to an absorption dynamometer on the floor below. The vertical drop was 82½ inches; the gear consisted of four 27½-inch-diameter rotors having 6½-inch face widths. Subjected to extreme torque at speeds down to 15 rpm, still the gear carried full load at 2500 rpm. At the dynamometer end of the linkage, reduction gears created high speed under extremely light loads. A new 2-speed

coupling was designed for that location. A total of 14 gears, 6 dynamometers, and 6 lubrication systems, ranging in rating from 2970 to 6070 hp, were installed at these test facilities.

#### Industrial X Ray

The x-ray microscope became a commercial product during 1956. Providing greater depth of focus than optical microscopes, it achieves a 3-dimensional effect—something the optical microscope doesn't do at higher magnifications. The microscope eliminates vacuum mounting required by the electron microscope. Potential applications: study of radiation effects on genes, identification of particles in the crime laboratory, study of polymer texture and chemical effects of organic contaminants, and identification of metallic inclusions. An electron beam less than 1 micron in diameter focused on the target produces an x-ray image that can be magnified 1500 times. An observer views images directly on a fluorescent screen or photographs them on film for immediate development.

Slow-motion x-ray movies and stop-motion pictures of running engines gave Detroit Arsenal designers their first inside look at complete cycles of engine operation. A 5- to 15-million-volt betatron, furnishing 416 radiation pulses per second, enables the equipment to photograph internal motion in an engine operating at several thousand rpm. Exposure requires 10 to 15 millionths of a second; and thousands of short exposures are synchronized accurately with the moving parts.

Artillery rockets in production are inspected for explosive charge density by a new x-ray robot. Cadmium selenide "eyes," reacting to x rays, spot defects—telling their size and location to the robot's "brain." The brain, a digital computer, directs a mechanical arm to mark the appropriate area on the rocket's case. The defective rocket is then salvaged for reworking. Devoted now to 3½-inch rockets for ground-to-ground combat, the robot will probably be assigned to inspect other ammunition production lines: artillery shells, mortar shells, land mines, and grenades.

These cadmium selenide eyes, sensitive to both x rays and light, are being mass-produced for the first time. Responding to all tungsten-filament radiation, they are extra sensitive to the red area. A hermetic seal provides the only positive protection against water damage.

#### Wire and Cable

Many flour and cereal processors now improve their factories' appearances with a new armored cable jacketed with smooth white polyvinyl. The jacket prevents insect nesting and can be hosed down during housecleaning.

Where mechanical strength, sulfur resistance, and easy splicing are needed in oil-well heaters, an aluminum-sheathed cable is now in use. Dropping the heaters to the bottom of oil wells stimulates the flow of paraffin or asphalt-base material, and oil production increases from 5 to 25 barrels or more per day.

A lead-cured heavy-duty flexible cord was developed for exceptional mechanical, moisture, heat, and chemical resistance. The cord helps assure steady service from portable tools encountering frequent exposure to abrasion, crushing, impact, grease, gasoline, acid, and alkalies.

#### Industrial Heating

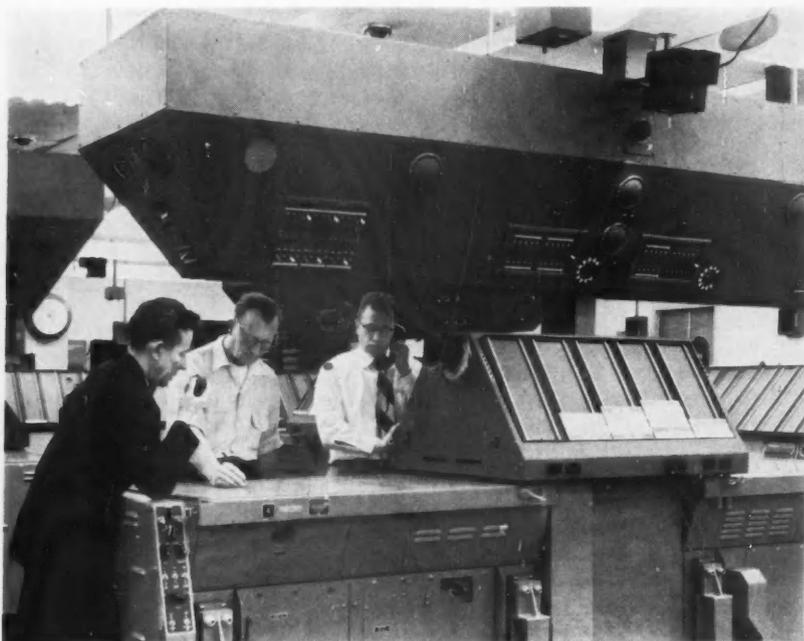
From dishwashers to baby incubators, industrial machines or domestic appliances demanding leakage currents as low as 200 ma and operating temperatures up to 300 F can be equipped with a new low-priced tubular heater seal of plastics resin and ceramic bead. Suitable also for industrial equipment, the seal controls creepage distance—adding nothing to heater dimensions.

#### Welding Products

A carbon-dioxide-shielded torch, produced last year, is rated 800 amp continuous even though it has no cooling system. The torch also possesses a spatter-resisting tip.

Two new rectifiers for specific welding applications were announced. The 1540-amp unit, rated 100 percent duty cycle for the submerged-arc process and melting furnaces, has a continuous actual output range of 600 to 1600 amp. The 800-amp unit—for gas-shielded consumable electrode welding—offers quiet operation, a combination cleaning-cooling fan, and heavy silicone insulation. Infinite voltage control to 800 amp adapts to any wire size or speed and any gas condition.

Plug-in components achieve maximum flexibility on a nonsynchronous welding control unit developed last year. Maintenance or timing changes are easily made with the unit in production service. Hermetically sealed long-life relays and improved circuitry have increased timing accuracy and advanced over-all performance.



**RADAR SCOPES** at New York's International Airport spot planes within a 100-mile radius.

## Electronics

During 1956 the television industry continued to improve the technical quality and reliability of the medium.

In color television, stress was placed on developing picture tubes that would bring color-TV sets within range of the average American's pocketbook.

During the year many studies attempted to determine the feasibility of moving very high frequency (VHF) stations to the ultrahigh frequency (UHF) channels. With this in mind, engineers focused their attention on comparing existing VHF services with the coverage afforded by high-power UHF stations.

Significant contributions also took place in the television-relaying field. For the first time, separate aural and visual signals were combined at radio frequency and transmitted through a single antenna.

### Television Broadcasting

An effective radiated power (ERP) of 1-million watts enables station WIN-T of Waterloo, Indiana, to transmit programs—via a 100-gain UHF antenna—to Fort Wayne, 16 miles away. This represents a fourfold increase in the station's power and offers better television reception and increased coverage of the Fort Wayne area. Directional power gain of

100 is provided by a tandem arrangement of two 5-bay helical antennae.

A similar antenna installation not horizontally directionalized and now in progress at WGBI, Scranton, Pa., for use with the station's 45-kw transmitter will achieve 2-million-watt ERP.

A unique and flexible wave-guide switching system used with a 45-kw UHF transmitter and a 10-bay 50-gain helical antenna offers nine quickly selectable combinations of transmitter power and antenna gain. Ease of variation in power split between antenna sections for null fill-in characterizes this system.

By capitalizing on new and improved components now available—especially germanium rectifiers—a standard 50-kw broadcast transmitter was developed for remote-control operation. Meeting the demand for increased reliability, engineers reduced the number of tubes from the usual 40 or so to 16. A corresponding saving in operating cost accompanies its use.

Highly popular for UHF transmission, the helical antenna provides many desirable characteristics as a result of its traveling-wave nature. Causing the velocity of wave propagation along the helix to increase with frequency successfully

extended the antenna's beam-forming frequency band width. To accomplish this, simple but properly related disks were placed along the helical conductor. Now the helical antenna in its present form can be used in a greater number of lower frequency applications.

In television studios, microphone booms are often undesirable. For these occasions a small microphone and transmitter is needed that can be concealed in the performer's clothing, thus eliminating such equipment as microphone cables and booms. Receivers out of camera range would pick up transmitted signals. For this purpose, a new experimental radio microphone utilizes a transistor tetrode operating at 26 megacycles. This transmitter package includes a battery capable of satisfactory operation for several hours.

A new low-cost compact vidicon camera channel was developed for either a live-studio or film camera. It includes a circuit that automatically maintains a constant output over a wide range of light levels, thus making an attending operator virtually unnecessary. The device contains necessary circuits for gamma and aperture correction, improving picture quality. Despite the channel's small size and low cost, its performance equals most higher priced units.

A compact 2000-megacycle television relay combines the separate output of aural and visual transmitters through a single antenna. The system's high-quality signals meet all Federal Communications Commission (FCC), and Radio Electronic Television Manufacturers Association (RETMA) specifications.

### Closed-Circuit TV

Full-color close-ups of a missile at launching were viewed last year for the first time over closed-circuit television. At the Army's Missile Test Center, Cape Canaveral, Fla., observers watched the takeoffs of the huge *Redstone* missiles on color-TV sets in nearby pillboxes. Engineers who watch the color variations in the missile exhaust flash can predict the success of the launching or the need for adjustments.

Earlier during the year, the nation's first large-scale closed-circuit TV for education was installed in Washington County, Hagerstown, Md. The project was encouraged by the U.S. Office of Education, Fund for Advancement of Education, Joint Council on Educational Television, and National Educa-



**SLOW-SCAN TV** aids signature comparison.

tion Association and received the support of industry through RETMA. Nearly all regular school subjects will be taught. By 1958 all 47 schools in Washington County will be participating in the program.

With a compatible system developed during 1956, slow- and fast-scan television can be economically combined. Although not reproducing the same quality action as fast-scan television, slow-scan TV most economically televises over long distances pictures without motion. Such pictures can be transmitted on lines that approach telephone transmission in band width and be received by slow television monitors. This development will open new TV application areas.

In an unusual application of black-and-white industrial television, camera equipment aids in deactivating bombs at the Seneca Ordnance Works, Romulus, NY. From a distance a technician closely views the televised operation transmitted from a camera encased in an explosion-proof housing. At the slightest trace of smoke, he halts the operation remotely and the bomb is sprayed with water.

Closed-circuit color TV finds greater application where the dimension of color supplies complete and accurate information. This applies equally to the fields of science, industry, medicine, and education. Controlled from a remotely located monitor, the color-TV camera



**TV CAMERA** in explosion-proof housing transmits picture of bomb deactivation to monitor.

can be located in hazardous areas or those not practicable for human observation. Signals can be furnished to extension monitors for small-group viewing or projected on theater-size screens.

#### TV Tubes

To solve the difficult problem of converging 3-beam color tubes, a toroidal-type deflection yoke was developed. Simple in appearance, it possesses the symmetry needed for this operation. As a result of careful mechanical construction and selection of its impedance level, the yoke provides satisfactory electrical operation. Excellent pictures can now be expected from these yokes.

Monochrome picture-tube development moved another step toward a higher deflection angle by an increase from 90 to 110 degrees. Now receiver cabinets with shorter depths and improved styling can be built. Reducing the tube's neck size from  $1\frac{7}{16}$  to  $1\frac{1}{8}$  inches increased the angle without essentially increasing deflection power.

A new picture tube adapted to small, lightweight low-cost receivers was developed with reduced weight and cost. It was fabricated by improving container-glass techniques previously unsuitable for encasing picture tubes. Simultaneously, devising a heater-cathode structure made possible a receiver having a single 0.3-amp series heater circuit.

In the area of newly introduced ceramic tubes, pilot production began on

a microminiature triode for UHF. Four developmental types for military applications were also announced in the high-temperature electronic-equipment field.

#### Program Control

The automation of broadcasting operations became a reality in 1956.

Offering flexibility combined with split-second switching, a new automatic program-control system employs an 8-channel punched-paper tape as its control medium. The system handles up to seven program sources. Other components include a reader-control unit and a control-tape editor. The latter makes preparation of program-control tapes a stenographic rather than a technical activity.

An audio-peak-limiting amplifier now permits a substantial increase in average program level without danger of any audio peaks exceeding a predetermined level. The new design virtually eliminates an effect known as "thump" in the trade. Incorporating a unique gain-control recovery circuit, the amplifier makes full use of the 20-decibel limiting range by minimizing pumping effect.

#### Military Electronics

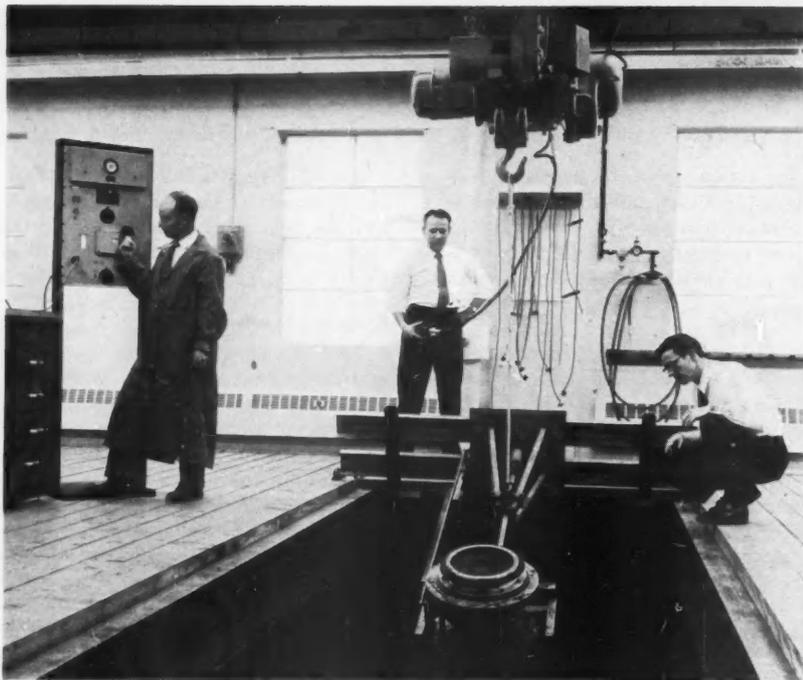
New concepts and design were developed and produced to meet the military electronics systems' needs for the Armed Forces. This included miniaturization and circuitry concepts incor-



**DATA-PROCESSING EQUIPMENT** speeds listings of spare parts on government forms.



**NERVE CENTER** of automatic ground-control



**SONAR TEST TANK** provides efficient testing of barium titanate sonar transducer element.

porating advanced techniques of automation.

The introduction of an airborne, automatic electronic navigator system relieves the jet-fighter pilot of another mental burden by eliminating the need for manual navigation. It combines the features of light weight—only 150 pounds—with compactness and accuracy. Designed for the military, the system also has applications for commercial aircraft.

For radar systems under development, magnetic circuitry that replaces

conventional electron-tube circuits promises improved reliability of radar systems. Two examples of such progress include a magnetic radar modulator and a magnetic frequency multiplier. Together these units increase the radar's reliability, eliminate a maintenance problem, and provide instant operation.

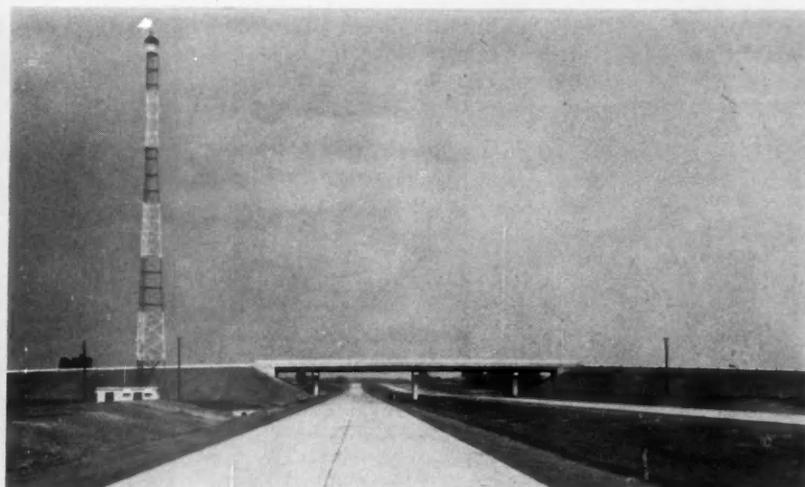
During 1956, engineers who designed airborne equipment achieved their objectives of miniaturization and weight reduction in the redesign of electronic components along standardized design principles. The new units include an

encapsulated transformer that eliminates individual wiring and permits automatic or mechanical installation; 7- and 9-pin tube-socket adapters for automatic or mechanized assembly on printed wiring boards; and right-angle subminiature tube sockets that accommodate all subminiature tubes having octal bases.

To cut costs, hook-up wires were standardized in 1956, aided by a machine that color-codes wire. This eliminates ordering in advance a number of differently colored wire items. A significant economy, standardization lessens the purchasing and stocking efforts and shortens the time needed to get wires on the assembly line.

As a possible replacement for cadmium-plated machine screws and nuts, aluminum alloy fasteners are being considered in the manufacture of light military electronics equipment. Such a change suggests many advantages. Chief among them would be the relative lower cost; comparable or greater tensile strength; and corrosion resistance, lightness, and availability during national emergency. Tests indicate that aluminum alloy with a chromate surface is as corrosion-resistant as cadmium-plated brass.

Automation progressed in preparing spare-parts breakdowns on government established forms. This complex and repetitive operation entails listing thousands of parts descriptions, nomenclatures, and control data, all tied in with drawing numbers. To eliminate much of the repetitive labor, a system that performs with accuracy and flexibility all the necessary parts-listing functions was devised and then installed a



intercept system improves defense capability.

**MICROWAVE** relay station along Indiana Toll Road aids officials and maintenance crews.

year ago. Employing a minimum of commercial equipment, it also includes a card inverter, a programming control unit, and an auxiliary keyboard—all unique in the data-processing field.

In the heavy military electronics field, a mobile radar mortar-locating equipment utilizes the 2-beam intercept principle of location. The equipment locates hidden enemy mortars and other high-angle low-velocity artillery. And it can direct "friendly" fire by locating points of impact.

One year ago a new radar installation was made in Civil Aeronautics Authority route-traffic-control center at New York City's International Airport. It increases the range, under all weather conditions, for controlling aircraft from the traffic-control center to more than 100 miles. Initially designed for the Air Force, the radar's range far exceeds that of any other in use at commercial airports. It assists air-route traffic-control service in its primary objective of promoting safe, orderly, and expeditious movement of air traffic in all weather.

In conjunction with shorter range radar located elsewhere, the new radar will monitor—under both Instrument Flight Rules and Visual Flight Rules—the arrivals and departures of aircraft at the New York airports at LaGuardia, Idlewild, Mitchell Air Force Base, and Floyd Bennett Naval Air Station plus the New Jersey fields at Newark and Teterboro.

Developed under Army Signal Corps' sponsorship was a Doppler-type radio-direction finder with new and unusual features. It determines the directions of arrival of radio signals in the frequency range of 1 to 30 megacycles. Up to four

independent receiver-bearing indicator units can be operated from a single antenna array and scanner. As in previous units that utilize the Doppler effect, the new direction finder is comparatively insensitive to site errors or to misadjustments of the antenna array. It has many military applications, such as navigation and air-sea rescue. Within its frequency range, it can take radio-direction bearings on stations all over the world.

Developed under contract with the Air Force's Development Center, Rome, NY, was a new synchronous communications system. The amplitude-modulated system competes favorably with its single-sideband-modulated counterpart and exhibits a decided advantage with regard to system complexity. Incorporating a receiver that differs in many respects from conventional design, the synchronous communications system employs dual demodulation. One oscillator has the exact phase of the carrier modulated at the transmitter while another oscillator is in quadrature to this phase. Both the amplitude data, representing intelligence, and the phase data are extracted from the received signal. Phase information distinguishes intelligence from interference and allows rejection of all or part of the interference.

To increase the efficiency and effectiveness of U. S. Navy sonar equipment, a new type of sonar transducer element was developed of barium titanate. A non-strategic material with increased ability for handling underwater sound energy, barium titanate exhibits lower mechanical and electrical losses than former materials. This permits smaller transmit-

ting equipment to be used aboard ship.

Also developed at the Rome Air Development Center, a new ground-control intercept system will provide the United States with improved air-defense capability. Operating on the principle of electronic automation, the equipment represents a significant breakthrough in the art of ground control of interceptors in the Air Defense Command.

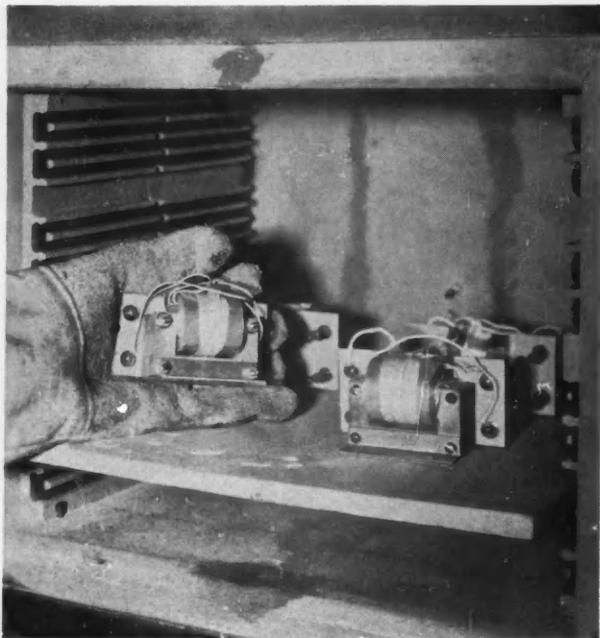
#### Communications

Redesign of 450-megacycle mobile radio equipment resulted in a transmitter-receiver unit that occupies 35 percent less space than its predecessor and comes in more than twice as many package and option variations. And elimination of many low-volume produced items for the previous mobile and base-station equipment has increased output per unit of factory floor area.

The Air Materiel Command approved its largest leasing contract for standard commercial 2-way radio equipment. Air Force bases throughout the country will utilize the equipment in staff cars, carryalls, station wagons, ambulances, and fire trucks, to name a few.

A major breakthrough for 2-way radio took place in the trucking industry. One of the nation's largest truckers, Ryder Systems, Inc., will install thousands of 2-way radios. Los Angeles joined Chicago and Evansville, Ind., to become the nation's third city to install General Electric's radio-controlled traffic coordination system.

Newly introduced tone-squelch system for mobile radio equipment permits two or more users in the same area to share a channel without having to listen to messages other than their own. And



**HIGH-TEMPERATURE** transformers operate for 500 hours at 520 C.



**HIGH-SPEED** mechanism prints more than 2500 lines per minute.

taxi passengers will be spared the ordeal of listening to the multiple conversations of other cab companies on the same radio frequency.

Power transmission-line load capacities and oil circuit-breaker interrupting ratings continue to increase. To keep abreast of this increase, a new 1600-amp line trap—a carrier-frequency impedance device—insures normal operation of the carrier channel. Capable of handling a 1600-amp continuous current, the trap has a 44,000-amp short-circuit symmetrical current rating of 44,000-amp rms, which may be fully offset.

Sealed components furnish complete weather protection for a new line-trap tuning pack, now much smaller and lighter in design.

Wide-band line traps were developed in all standard ratings to provide, in a single line-trap assembly, carrier-channel trapping throughout a 400-ohm band width of 90 to 200 kc.

In the areas of telemetering, control, and relay, transistorized transmitters and receivers now incorporate many circuit improvements.

Designing standard packages to meet most requirements has improved the application of Quadriphase microwave equipment and reduced special engineering costs. Also, the line of termination units used with this multiplex equipment now permits applications of the Quadriphase system such as in teletype,

phase-comparison and transfer-trip power line relaying, automatic control of multiple VHF base stations, and dial trunking. Many packages and units were installed on the 157-mile-long \$500,000 combination microwave-VHF communication system for use by the State Police and maintenance crews on the Indiana Toll Road.

Programs in 1956 aimed at developing important new or improved microwave thermionic and nonthermionic components hold promise for revolutionizing the microwave art. For example, development of several categories of multi-megawatt klystron and traveling-wave amplifiers, if successful, will not only greatly extend military radar performance but also have other far-reaching effects. Low-noise traveling-wave tubes—suitable for receiver applications in radar, countermeasures, and radio astronomy—surpass present designs. Another traveling-wave tube, a medium-power amplifier utilizing the hollow-beam technique, operates over a 5 to 1 frequency range and provides power outputs exceeding 100 watts from 60 to 300 megacycles.

Studies stressed development of microwave devices such as high-power duplexers, ferrite antennae, and linear accelerators. Investigations into microwave instrumentation techniques for hypersonic shock-tube studies were carried out, producing significant results.

For operation in the 2400- to 3300-megacycle band, a traveling-wave amplifier tube provides a 65-watt continuous-wave power at a gain of 20 decibels. This tube requires a 450- to 500-gauss magnetic focusing field and a ½-gpm cooling water flow.

#### Electronic Circuits

Tests made with a small 2-winding transformer, operating for 500 hours at 520 C, demonstrated the feasibility of operating electronic transformers at the high ambient temperatures associated with atomic reactors, missiles, and ultrasonic aircraft.

The ability of basic materials to maintain their characteristics and function effectively determines the success of transformer operation at these temperatures. The high-temperature transformer accordingly utilizes magnetic steel with a Curie temperature well above 500 C, silver- and nickel-clad copper conductors, and ceramic insulations.

High-temperature operation was also a paramount consideration in capacitor development. Several materials were found to have suitable dielectric constants and resistivities for operation at 500 C and above. As a result, sample capacitors were used satisfactorily for more than 1000 hours at 600 C, with 250 volts d-c applied. Others were used in electronic circuits operating at 680 C.

Improvements made in high-frequency capacitors used in the tank cir-

cuits of electronic power oscillators have resulted in a 35 percent size and weight reduction. Simpler and more direct paths for current in the capacitor's internal structure permit higher currents with lower heating losses.

High-quality miniature tubular capacitors, encased in molded plastics, now come in ratings of 0.1 microfarads, 400 volts d-c. Offering high insulation resistance, they operate in ambient temperatures of 125 C.

### Magnetics

Pilot-plant production began on tiny memory toroids— $1/125$  inch in diameter. A new class of ferrite materials with remarkable rectangular hysteresis loops, they are being applied in the memory matrix of electronic computers. Other designs incorporate square-loop ferrites in counter circuits, switching devices, gates, and transistorized driving circuits for magnetic devices.

Ferrite's initial and largest use is in the deflection systems of television receivers. Big-screen television and the demand for smaller, lighter cabinets require constant improvement of the ferrite components. Studying fundamental ferrite chemical behavior disclosed that conditions during high-temperature baking of ceramic ferrite materials have a substantial effect on their magnetic properties. This knowledge enabled processes to be developed that improved magnetic performance 100 percent.

Another recent application uses ferrites as nonreciprocal attenuators in traveling-wave tubes—important because it permits simultaneous satisfaction of otherwise conflicting requirements. With low loss to the forward-growing wave, attenuation reduces gain, efficiency, and power output; a high loss to the backward-reflected wave prevents oscillation and minimizes variations of gain caused by load mismatch.

The memory-retaining properties of ferrites can be fully utilized in computers. Magnetic switches that were developed last year consist of a disk of the square-loop material with several holes in it having windings that encircle the core. These cores can be used in shift registers, other magnetic memories, and "logical" circuits, because the device retains information while also passing it on to other computer sections.

Subminiature magnetic cores—smaller in size than a grain of rice and applied in a new switching circuit—meet the stringent requirements of airborne digital-computer systems. Although used

for the first time in these systems, the cores have wide use in such circuits as rapid-access storage, binary counters, and logical and switching operations.

### Semiconductors

Completely transistorized, a 6-meter tranceiver now utilizes a tetrode transistor as a 52-megacycle oscillator in the transmitting position and as a super-regenerative detector in the receiving position. With improved transistors the tranceiver's original useful  $1/2$ -mile range has increased considerably.

Designed for frequencies previously unattainable with semiconductors, a germanium tetrode was developed that utilizes the meltback principle. Its ability to operate as an amplifier at 120 megacycles—the highest frequency yet reached by any transistor in a comparable state of development—may permit future use of transistors in many areas now limited to vacuum tubes.

An audio amplifier with an output in excess of 100 watts utilizes two developmental fused-junction p-n-p transistors in push-pull operation. Power gain of the amplifier exceeds 15 decibels, with distortion at full output about five percent. Used as a heat sink, the chassis facilitates cooling the junctions.

A developmental transistor receiver gets its power from a series of photovoltaic cells mounted on the back of its transparent case. Operating into a headphone, the standard superheterodyne receiver's transistors function at extremely low operating points. When light falls upon the receiver, a small rechargeable storage battery connected across light-sensitive cells remains charged. It operates for reasonable periods in the dark or in poor illumination.

Combining meltback and diffusion techniques resulted in the fine control of the diffusion process and the freedom from surface effects. This method was used to produce high-frequency p-n-p germanium and n-p-n silicon transistors.

Now being produced at a high-volume rate, a bilateral high-efficiency germanium-alloy junction p-n-p transistor needed only two changes in a former series for development. With low distortion and high gain at high current, the transistor's symmetrical geometry permits amplification in both directions. Its applications include pulse circuits and 2-way switches.

Single-crystal germanium was also vapor-deposited on single-crystal substrates of germanium and silicon by the decomposition of gaseous germanium

iodide. Investigations will determine the feasibility of using this technique to produce p-n junction devices.

### Computers

Newly developed computer elements using transistors include high-quality operational, transistorized d-c amplifiers. Their small size and power consumption and increased reliability offer several advantages over vacuum-tube d-c amplifiers. General-purpose analog computers accordingly become more flexible for extended applications.

Development started in 1956 on the big visual display (BVD) tube—a flat display device with matrix selection. A gaseous-discharge device of flat sandwich-type construction, it can be used as a bright large-area display. An array of virtually isolated cells—16 per linear inch—that contain a luminescent phosphor and a crossed 2-wire-matrix connection system comprises BVD tubes.

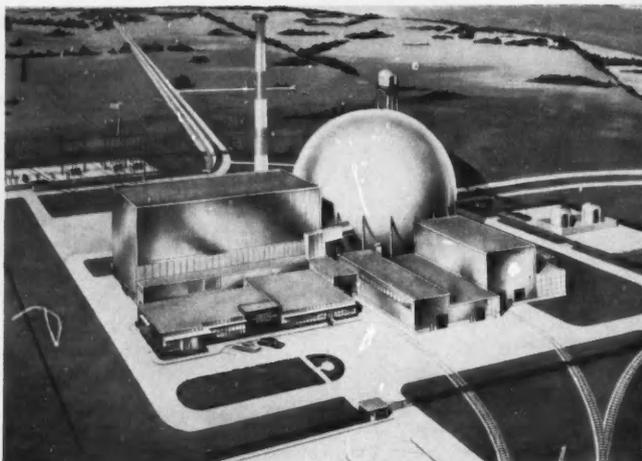
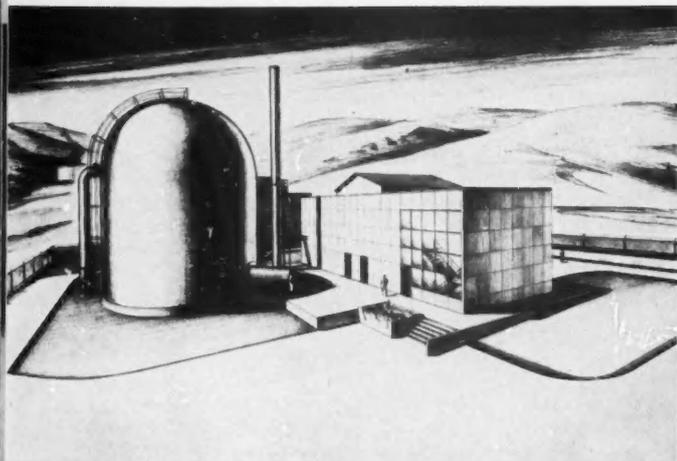
To match high data computer outputs, a high-speed electromagnetic printing mechanism now prints more than 2500 lines a minute even with smaller memory sections. Eliminating recording and data playback reduces error and error-checking equipment. Designed specifically for analog computers, the principle of ferromagnetography can be applied to digital computers for printing such data as pay checks and utility bills.

### Industrial Tubes

Made of metal and ceramics, a hard-soldered voltage-tunable magnetron can be operated up to a 60,000-foot altitude without pressurization. Used in a suitable circuit, the tube provides an average continuous-wave power of  $1/2$  watt. The magnetron's frequency is a linear function of anode voltage over the range of 2000 to 4000 megacycles.

A water-cooled magnetron for electronic cooking and dielectric heating weighs less than five pounds and supplies up to 2 $1/2$ -kw continuous-wave power at a 915-megacycle frequency. When used with an electromagnet in series, the tube minimizes power-output variations that result from changes in line voltage.

An ignitron tube for locomotive rectifier service carries an average current maximum of 675 amp and a peak inverse voltage of 4000 volts. It has two ignitors, an auxiliary anode, and a unique system of baffles that prevent the mercury pool from breaking contact with the ignitors. Twelve of these tubes can supply a 5000- to 6000-hp electric locomotive.



**DEVELOPMENTAL** boiling-water reactor part of Vallecitos Atomic Laboratory will aid in design of such plants as Dresden Station.

## Nucleonics

The first privately financed atomic-electric power will be generated this year at General Electric's Vallecitos Atomic Laboratory near Pleasanton, Calif., 40 miles southeast of San Francisco, it was announced in 1956.

General Electric will operate the atomic-electric power plant in conjunction with the Pacific Gas & Electric Company at the laboratory site. Steam for the 5000-kw plant will be supplied by a developmental boiling-water reactor—part of this laboratory being built for peacetime development of atomic energy.

The laboratory will include a radioactive materials facility, a critical experiments facility, and the developmental reactor which, plus producing steam, will be used to test various components, materials, and operating techniques in the atomic energy field.

In March the design features of a new 12,500-kw single-cycle boiling-water reactor were revealed. It is expected that this design will meet the needs of foreign and domestic customers.

Water boiling within the reactor and forced circulation result in several advantages: simplified design, higher thermal efficiency, automatic control of response to load changes, and greater safety of a self-limiting reactor should excessive nuclear reactivity occur.

General Electric also announced that it would build two reactors of this type for the American and Foreign Power Company's use in Latin America.

Spain's first atomic reactor will be a General Electric 3000-kw swimming-

pool research reactor. The Spanish Nuclear Energy Commission is purchasing the reactor in conjunction with its atomic energy agreement with the United States. Also Venezuela announced that its first reactor, a 3000-kw research type, will be purchased from General Electric and installed near Caracas for use primarily in medical research. And two test reactors are being built for the Lockheed Aircraft Company's nuclear aircraft-research center near Dawsonville, Ga.

Progress continued on the design of the 180,000-kw Dresden Nuclear Power Station that General Electric will build near Chicago for Commonwealth Edison Company and the Nuclear Power Group, Inc. Ground will be broken this year, with operation scheduled for 1960.

### Hanford Atomic Products Operation

Gains occurred in all phases of research, engineering, and plutonium production at the Atomic Energy Commission's Hanford Atomic Products Operation at Richland, Wash.—under General Electric operation for 10 years.

In 1956 the vast Purex plant went into operation. Purex—a large-scale continuous-flow highly efficient chemical separations plant—now works with the other chemical separations facilities to process the increased production from the eight Hanford reactors.

### Pile Cooling

During the year, Hanford engineers studied organic pile coolants. Water, the

coolant used since the piles were first started, limits the level of operational temperature by pressure and corrosion phenomena. Use of higher boiling organics, such as biphenyl and monoisopropylbiphenyl, reduces corrosion and allows higher operational temperatures while maintaining low operating pressures. Materials liquid at room temperature and suitable economically and radiolytically are being sought. Organic materials are particularly attractive as coolants only because the damage rate is much less than in applications utilizing organics as both coolants and moderators. In-pile and out-of-pile loops for heat transfer, radiation damage, and fouling studies are in the process of being developed.

Removing suspended solid particles from the tremendous quantities of Columbia River water required to cool Hanford reactors can be accomplished by flocculation of the particles by adding activated silica or aluminum sulfate and collecting the large floc particles on rapid sand filters. But new synthetic organic polymers now available are even more efficient. One such synthetic reduced unit chemical costs in the water-treatment plants approximately 26 percent below that of other methods and suggested radical simplification of conventional water-treatment-plant design.

Cooling water leaving the Hanford reactors is retained in large basins to permit certain short-lived radioactive elements to decay substantially. The water being hot, ordinary paint



**PROBE** and related equipment quickly detect radioisotopes in soil.



**TERMINAL VELOCITY** of particles is measured by counting meter.

coatings do not adequately protect the tanks from corrosion. A small-scale impressed-current cathodic-protection system went into operation late in 1954. Aluminum and graphite anodes have proved unsatisfactory in the hot water, but good results are being obtained with high-silicon cast-iron anodes.

An automatic monitoring device was developed that measures and records the concentration of seven predominant radioactive isotopes in reactor cooling water. One portion of the sample evaporates directly in an aluminum cup delivered automatically from a magazine; the second and third portions are chemically treated to remove interfering isotopes and then evaporated in separate cups. Each sample is presented in turn to a gamma counter with a single-channel analyzer and then to a beta counter. A programmer automatically controls selection of the energy channel and other operations. This method saves manual analytical effort and permits more frequent sampling plus more detailed examination of the isotopes' mode of formation and the variables influencing the amount of radioactive material produced.

#### Waste Storage and Processing

Seeking new methods for reducing the volume of radioactive waste, produced at the rate of thousands of gallons daily, constitutes a continuing challenge at Hanford.

In the self-evaporation technique the volume of radioactive wastes leaving the processing plants reduces to the point where the heat generated by the fission products in the wastes is sufficient to boil them and also to concentrate the moisture from the humid air above the



**BIOLOGISTS** study radiation effects on fish; gamma counter records radioactivity in mice.

waste solution. Heat also presents problems in a self-evaporation technique. Severe temperature gradients build up in the solution and cause masses of superheated liquid to reach the surface. This releases steam at rates that cause momentary high pressures and thus require excessively large condensers. The "bumping" due to pressure gradients ceases by agitating the solution. Engineers employed the "gas lift," a well-known principle that involves the introduction of a non-condensable gas into the lower end of a totally submerged vertical pipe. Some waste heat is actually converted into useful work—it circulates the liquid.

Besides self-evaporation, another technique—chemical treatment—was used to reduce the volume of radioactive waste storage. Certain chemicals



are added to the older radioactive wastes, forming precipitates that settle out readily. Some of these precipitates carry the long-lived fission products. Because the resulting clear liquid in the upper portion of the tank contains only inert chemicals plus shorter lived fission products, it is safely sent to the ground.

Thus far, more than 20-million gallons of storage-tank space for waste solutions have been recovered by these two methods.

Hanford's location and underground soil structure ideally accommodate large discharges of low-level radioactive waste into the ground. Thus tests constantly determine the types and amount of radioisotopes present in the soil and ground water. One method, slow and cumbersome, involved collecting samples from various depths in wells.



**PLASTICS MAN** radiation-protection suits of improved design meets needs in new areas.

A probe is merely lowered in a well to a maximum depth of 500 feet; a graph of radioisotope density versus depth is plotted as the probe descends; radioisotopes are determined by the "tuning" of the electronic equipment associated with the probe. It provides more information in a few hours than one man could obtain in a month.

The waste solutions contain large quantities of several fission products suitable as radioactive sources. Because industrial use of radioactive material will rapidly advance, techniques are being studied for their isolation, purification, and packaging.

#### Fuel Element Studies

A vacuum-welding box was developed at Hanford for welding such materials as zirconium, uranium, and other metals having an oxygen and nitrogen affinity. It will permit handling radioactive materials and other hazardous substances such as potassium sodium NaK. Many sodium-bearing capsules of various shapes have been filled and welded. It will also be used to weld, prepare metallographic samples, and assemble test fuel rods that use NaK as a coolant.

Because some reactor fuel alloys are pyrophoric and toxic at room temperatures, a vacuum-melting furnace

melts these alloys without endangering personnel. The development of this furnace will permit the recasting of prototype reactor fuel materials.

#### Irradiation Data

One of the problems of interpreting irradiation data at Hanford in the past has been the lack of accurate temperature information on a sample or a variable temperature of irradiation. To solve this problem, an in-reactor assembly was developed that controls sample temperature to 0.5 percent in the heart of the Materials Testing Reactor at temperatures up to 1000 C. The sample is heated principally by the absorption of gamma energy. A controlled heat path to a lower temperature sink regulates the sample's temperature.

Specialized metallographic techniques were devised for studying the microstructure of irradiated metals. One utilizes replicas of the specimen surface and this has several advantages: replicas are nonradioactive, serve as a convenient specimen record, do not deteriorate with age, and permit both optical and high-resolution electron microscope examination.

#### Biological Studies

At Hanford the need to measure the sizes and other characteristics of small particles continues its challenge as in other industrial operations. Evaluating the potential health hazards from radioactive particles depends in part on the ability to measure their size, density, and shape. These properties of particles affect the length of time they will remain airborne, the distances they will travel under given meteorological conditions, their ability to be filtered, and their respirability. One property of a small particle that combines the characteristics of size, density, and shape is the velocity at which it settles steadily in air.

If the terminal velocity of a particle is known, its size and density can be approximated. To measure terminal velocity, engineers devised a meter that allows a radioactive particle to fall through tranquil air in a long pipe. Near the bottom, two widely spaced counters detect the passage of the particle and signal the passing through a counting rate meter. Signals appear on a moving-strip chart as two peaks, the distance between peaks accurately indicating the speed of fall.

Because many of the biological functions of pigs closely resemble those of

man, Hanford's biological scientists are carrying out extensive research with these animals. A pig's food requirements, skin texture, and weight of some species are similar to man's. And because a pig's thyroid gland approximates man's in size, it is valuable in tests involving radioiodine—a Hanford waste product.

Aquatic biologists use fish to study the effects of radiation from deposited radioisotopes. Radiophosphorus given to 12-inch trout determined how much of this isotope can be taken before serious radiation damage results. The isotope was given repeatedly to build up and maintain a certain dose rate. To minimize handling, the trout were trained to snap at dead minnows held just above the water. The radiophosphorus was injected into the minnows which were fed to the trout. The concentration of the isotope required to kill the trout was more than a thousand times that found in fish living in the Columbia River below the reactors.

Using an air pistol to fire a capsule containing radioactive dusts, biological scientists investigated the hazards associated with the inhalation of materials common to the processes at Hanford. Mice are so placed in a chamber that only their noses are exposed; firing the pistol produces a radioactive atmosphere for them to breathe. By such means, researchers explore inhalation hazards.

The radioactive content of live mice figured in another development at Hanford. A special gamma scintillation counter periodically "counts" the mice. Scientists can thus tell how rapidly the radioactive material leaves the body—information valuable in estimating the hazards of radioactive materials inside the body and for removing such substances.

#### Calorimetry

Advances in temperature measuring and control methods opened the way for Hanford scientists to use calorimetry for precise measurement of gamma-ray sources. Individual gamma rays carry enough energy to produce significant effects in the material that absorbs them. But modern thermistors—resistors with a high rate of resistance with temperature change—permit temperature measurements of as little as 0.001 C and are practically trouble-free in operation.

#### Determining Radioactive Cobalt

Hanford chemists faced the major problem of accurately determining



**SUBMARINE ADVANCED REACTOR** prototype will be housed in a submarine hull located at KAPL's West Milton, NY, site.

amounts of radioactive cobalt on the order of a thousandth of a millionth ounce in the presence of many other radioactive elements. To further complicate the problem, the samples required approximately 75 pounds of lead shielding to protect the chemist from the gamma radiation. The task was accomplished by using special gamma-ray spectrometers that could discriminate between both time and energy. They were set for gamma rays above a certain energy level and also for rays that are emitted within a millionth second of one another.

#### Corrosion Testing Techniques

A principal difficulty in corrosion testing has been the lack of compact testing equipment to operate under varied test conditions and evaluate the different factors that control liquid chemical corrosion. To overcome these obstacles, Hanford engineers devised a testing apparatus in which a metallic sample can be corrosion tested as a heat-transfer surface in a solution under different conditions. The sample temperature may be varied up to the limit of the heating source, while the solution temperature may be varied up to the pressure limit of the gasketed seal. Also, the boiling rate may be varied, and the unit will operate at atmospheric pressure, under vacuum, or under pressure.

#### "Plastics Man"

Applications of the "plastics man" radiation-protection suits of vinyl plastics were extended. They have been used in situations where they were formerly

considered impractical: welding process piping, working from a high step ladder, and working from a scaffolding.

#### Aircraft Nuclear Propulsion Progress

Progress in the development of a nuclear propulsion system for aircraft, being conducted for the Air Force and the Atomic Energy Commission, was substantiated by a statement made by representatives of the AEC in 1956 Congressional hearings: "In January a turbojet engine was, for the first time, powered exclusively by heat from an experimental reactor operating on the ground at our testing station in Idaho. More ambitious tests will follow."

Successful radiation and heat tests were conducted after finding that many materials susceptible to damage at temperatures under 500 C also are susceptible to nuclear radiation damage.

Two important electronic assemblies used in power reactor controls have been inside an Oak Ridge National Laboratory graphite reactor since June 1956. They have been subjected to 90 percent of the maximum reactor radiation and to temperatures ranging up to 450 C. Operation of these components for 1000 hours is a feasibility demonstration of significant importance to the program.

#### Atomic Submarine—KAPL

Construction of test facilities for the Submarine Advanced Reactor (SAR) prototype began at the West Milton, NY, site of the Knolls Atomic Power Laboratory (KAPL)—operated by General Electric for the AEC. The SAR pro-

TOTYPE will be housed in a section of a submarine hull located near the sphere that houses the prototype for submarine USS *Seawolf*.

The SAR plant will be the first two-reactor system for submarine propulsion.

The vessel USS *Triton* is designed as a radar ship capable of operating in conjunction with a fast carrier task force. Tests of this prototype will be carried on at the West Milton site inside a hull section, which also will serve as a safety pressure container to prevent the release of fission products in the remote event of a nuclear incident. Unlike the prototype for the *Seawolf*, this hull will not be enclosed in a steel sphere because of design differences in the two reactor plants.

The Submarine Intermediate Reactor (SIR) power plant, designed and constructed by KAPL, was installed aboard the *Seawolf* at Groton, Conn. All reactor tests were completed satisfactorily. Leaks detected in the heat-exchanger equipment have necessitated repairs prior to sea trials.

Test operations are continuing on a scheduled basis on the SIR prototype plant at West Milton. The reactor has operated for more than 5000 critical hours with good results. Through use of the General Electric turbine, about 20 percent of the power requirements at the site are supplied by reactor power. Surplus power is being sold to the Niagara Mohawk system.

#### New Reactor Systems

A number of studies relating to the development of new reactor systems for

economic power production were made during the past year by KAPL scientists. One of these is a fast reactor system that can breed more fissionable material than it consumes. Although this type of reactor has a big potential for the nuclear power industry, the cost of the fuel-reprocessing cycle must be kept low to realize advantages. One project is developing a fuel element and reprocessing cycle based on oxide systems that may make such a low-cost fuel cycle possible.

Another type of system under study—a thermal reactor for central-station application—can use natural uranium as its fissionable material source. A circulating slurry of the fissionable oxides and fertile materials in liquid metal comprises its fuel system.

#### **Fission Cross Sections**

Another KAPL project concerns the study of Uranium 235. Recent measurements revealed variations never observed before in the neutron-fission cross section of this material. These variations show how the uranium changes its tendency to undergo fission, thereby releasing nuclear energy as the energy of reactor neutrons changes.

The uranium studied was deposited in very thin layers on the plates of a large ionization chamber, probably the largest being used for such measurements. Neutrons from a 100-mev betatron irradiated the chamber. The energy of the neutrons is determined by electronic timing devices that measure the transit times of individual neutrons as they travel from the betatron over a known distance to the ionization chamber.

The data achieved by KAPL scientists are several times better than that reported at the Geneva Conference for Peaceful Uses of Atomic Energy in 1955 by Russia and the United Kingdom, which were noticeably superior to United States data at that time. Such data are important in the design of new reactors of improved efficiency.

#### **Transuranium Elements**

With the advent of high-flux high-burnup power reactors, the transuranium elements, many just recently discovered, will become increasingly important in the nuclear power field. These elements are produced by the successive capture of neutrons or by the beta decay of plutonium and its capture and decay products. To investigate the effects that these elements may have on reactor operation, their possible uses,

and more basic knowledge, KAPL scientists, jointly with Atomic Energy of Canada, Ltd., studied the heavy nuclides produced in plutonium irradiated for a very long time in the Materials Testing Reactor.

The study included chemical separation and careful purification of several elements—plutonium, americium, curium, berkelium, californium, einsteinium, and fermium found in the irradiated plutonium. These heavy nuclides may some day become convenient sources of neutrons, replacing the present radium-beryllium and polonium-beryllium sources.

#### **X-Ray Diffraction Studies**

The effects of neutron irradiation on the physical properties of crystals are now rather well known, but the exact nature of the irradiation-produced defects and their distortion of the crystalline lattice are not at all understood. Because x-ray diffraction gives information concerning the atomic arrangement in crystals, it is a natural tool for the study of radiation damage. In the course of such studies at KAPL, a new set of x-ray effects was discovered. The effects result from the displaced atoms, vacancies, and other small defects produced during irradiation. The outstanding effect is a diffuse scattering that surrounds the usual sharp crystalline reflections. Theoretical work suggests that the diffuse spots are caused by lattice distortion around the irradiation-produced defects and that a study may reveal distortion details.

#### **Instrumentation**

An intensive development program started last year has an important objective: providing instruments for use in reactor power-plant measurements. The instruments include detectors for measuring temperature, pressure, flow, and liquid level, as well as the intermediate means and devices necessary to complete the measurement sets. Designed for high accuracy and extended periods of operation under difficult ambient conditions, the devices will aid in designing higher efficiencies and reduced size in power plants.

#### **Thermoelectric Pump**

A liquid-metal pump and heat-exchanger unit has circulated liquid sodium at rates up to 19 gpm with no electric power input to this equipment. No moving parts are involved. This is believed to be the first time a unit has

made use of thermoelectrically generated currents to produce pumping of liquid metal for heat-exchange purposes.

An electromagnetic pumping force was obtained from a large thermoelectrically produced current circulated about a 60-inch-long copper loop within the assembly. Temperature differences obtained across a chromel and a constantan strip positioned between the hot and cold tubes within the unit produced the necessary voltage to develop the current and resulting magnetic flux. About 60,000 Btu's per hour were transferred by the equipment during a continuous testing period of more than 1000 hours. This suggests possible equipment to circulate extremely high-temperature electrical conducting fluids where impracticable with conventional pumping.

#### **Magnetic Flowmeter**

A d-c magnetic flowmeter for measuring the volume flow rate of liquid metal in a reactor system meets high-intensity shock and vibration requirements. Two magnets of 4-inch diameter and 10-inch length produce a magnetic field across the pipe section. Magnet temperatures are kept low to maintain the highest possible level of flux density by special insulation; although the system operates at 850 F, the insulation limits magnet temperature to 300 F.

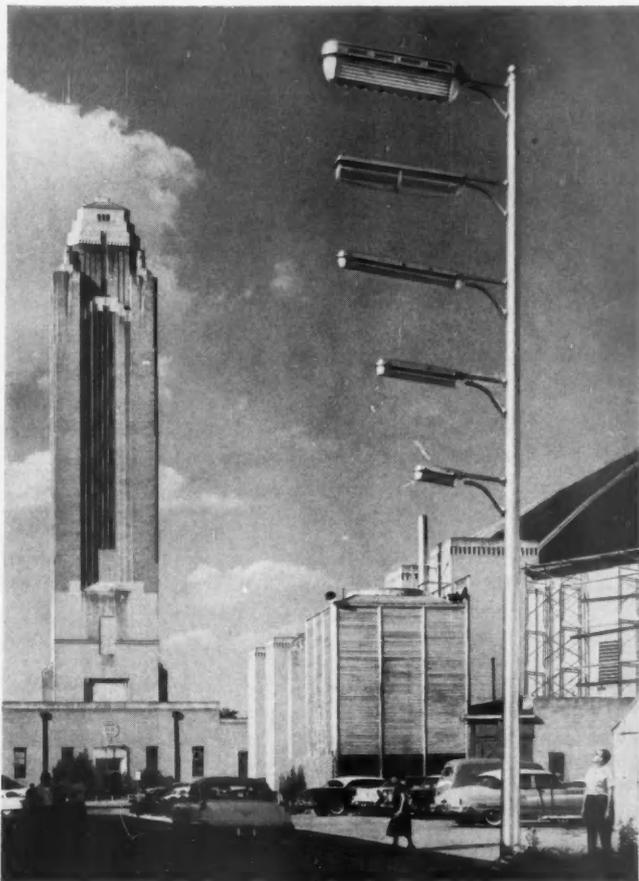
#### **Refractory Reactor Materials**

In the pursuit of higher thermodynamic efficiency together with the low cost of fuel in nuclear reactors, KAPL scientists are studying ceramic materials important to the nuclear field. A large-capacity resistance furnace, suitable for differential thermal analysis studies to 3000 C, was constructed for use in studying reactions of fuel compounds at high temperatures.

In addition, melting points of materials are being determined or refined. For example, recent literature on uranium dioxide indicates a melting point ranging from 2400 to 2900 C. KAPL's most recent data indicate a melting point of 2750 C  $\pm$  40 C.

#### **Radiation Damage to Metals**

Reactor radiations, neutrons in particular, are known to change the properties of metals. Despite similarities between the effects of radiation and those of other similar metallurgical variables, such as cold-working and alloying, enough dissimilarities exist to consider radiation as a new parameter.



**FAMILY OF FLUORESCENT LUMINAIRES** serves virtually every urban, residential, and highway streetlighting application, improving visibility.



**LENGTHWISE DENTS** in a series along one side of 8-foot fluorescent "power groove" lamp give increased light output.



**LIGHT-MULTIPLIER ATTACHMENT** boosts the sensitivity 64 times on a new mass-produced photographic exposure meter.

## Lighting

A "power groove" lamp, announced during 1956, nearly doubled the light output of present tubes of equal length. A series of lengthwise dents or grooves along one side of the 8-foot-long fluorescent tube makes the increased light possible. In cross section, the new tube is nearly U-shaped at the grooves, permitting a maximum circumference of the tube while constricting its inside area. The scientific principle involved: control of the electrons and the mercury pressure within the tube by means of the bulb's shape.

These lamps raise the velocity of the electrons, yielding greater resonance radiation to excite the phosphor and reduce absorption of this radiation. Thus, more resonance radiation reaches the phosphor to enhance its fluores-

cence. Cool areas controlling the mercury vapor pressure are also provided.

The power groove lamp is used in new installations—not as replacement in existing fixtures.

### Facilities

Late in the year, ground was broken for a \$5-million advanced lamp-development laboratory at Nela Park, Cleveland, Ohio. As its goal, the laboratory will improve the old methods and discover new ways of producing light through fundamental and applied research plus advanced engineering. Also the effects of artificial illumination and new fields of light application will be investigated. Ultimately, 250 persons will work in the 3-story 100,000-square-foot building.

A refractory metals laboratory in-

stalled one of the largest grating spectrographs in the country. This instrument, using a 35-foot grating, analyzes refractory metals for lamp use. The machine can determine impurities concentrations as low as 0.001 of 1 percent in metals such as tungsten and molybdenum. The same laboratory also acquired a consumable-electrode vacuum arc-casting furnace for the production of refractory metal ingots from metal powders.

### Bulbs and Lamps

For the first time, 40-watt rapid-start fluorescent lamps can flash on and off in the same manner as incandescent light bulbs. The new ballast and circuit continuously heats the lamp cathodes while the lamp current switches on and off. The flashing fluorescents in a variety of

colors will be used primarily in enclosed plastics-faced signs.

The 1956 line of colored light bulbs unveiled a totally new concept of home lighting. Designed to create a variety of atmospheres with tinted light, the bulbs give an impression of a color tone to a room—enhancing existing colors in draperies, furniture fabrics, walls, and complexions.

Some 1957 automobiles are equipped with four sealed-beam units of 5¾-inch outside diameter, rather than the usual two units of 7-inch diameter. A pair of units on each side of the car are mounted in a single housing. These operate together to form the upper- and lower-beam patterns of the system. General Electric engineers first urged the adoption of individual lamps for upper and lower beams in 1933. The present system, providing both beams from a single lens-reflector-filament combination, necessitates a compromise in the results. The dual system, however, has each unit designed for its particular function, without concern about its effect upon the other beam.

A 1000-watt mercury lamp with an interior phosphor reflector directs two thirds of its light down and one third up. Thus, the phosphor reflector portion of the lamp serves to control a large portion of the light, directing it downward. It is used in medium and high mountings in industrial installations.

The "twinkle lamp" creates flashing colored-lighting effects simulating a nighttime spectacle of countless fireflies. This new Christmas lamp, about the size of the smallest Christmas bulb, resembles a tight rosebud. Designed for use in transformer-operated string sets that permit multiple burning, the lamps come in clear glass and in four colors—red, yellow, green, and blue.

### Streetlighting

Last year a complete line of fluorescent streetlighting luminaires was introduced for virtually every residential, urban, and highway application. The smallest unit, 2 feet long, produces 2700 lumens; the largest, 6 feet long, has an output of 64,000 lumens. The low brightness source that practically eliminates driver glare produces better visibility. Fluorescent luminaires provide a wide band of pavement brightness that greatly improves silhouette visibility—the major means of seeing on lighted roadways.

The introduction of a packaged power supply also marked a further advance in

mercury streetlighting. The coordinated factory-wired substation starts mercury lamps in series, regulates lamp current, and eliminates the need for expensive ballasts at each streetlight.

### Outdoor Lighting

A new fluorescent floodlight provides for better illumination and more economical lighting of the nation's poster panel advertising. Two extruded aluminum reflectors, each employing an 8-foot fluorescent lamp, provide a 16-foot-long light source that can be precision aimed, eliminating hot spots and shadowed areas on the advertisement.

A new 1500-watt incandescent floodlight with external wiring and a faceted rear reflector and with lower operating temperatures provides both a 10 percent increase in efficiency and 20 percent higher average maximum-beam candlepower and optimum uniform-beam candlepower distribution.

### Photography

A new method of oxygen filling makes a tiny flashbulb 66 percent more powerful than its predecessor. Rated 7000 lumen seconds, the bulb stretches shooting distance by 30 percent. And the increased light output of the clear bulbs made possible the introduction of blue flash bulbs in this size for photographers who use daylight color film.

With a gold-tipped projection lamp—specifically designed for horizontal burning—home movie and slide projectors can now show a lower and cleaner silhouette. Because it is undesirable to burn vertical-design lamps in a horizontal position, General Electric engineers developed this radically new design concept. The prefocused filament actually burns vertically while the lamp is positioned horizontally, and three pins in the base ensure positive lamp alignment.

The world's most sensitive mass-produced photographic exposure meter was introduced late last year. It has four ranges of sensitivity and direct reading in exposure values. Simplified arrangement of numbers in the windows clearly indicates the desired setting for both still photographs and movies. And a light-multiplier attachment boosts sensitivity 64 times.

Designed expressly for a movie camera, a direct-reading camera-mounted exposure meter went into production during 1956. The instrument is calibrated at 1/35-second shutter speed at 16 frames per second for use with

color or black-and-white film rated ASA 10 or 32. The pointer indicates directly in *f*-stops and requires no presetting of dials or use of light numbers and reference indexes.

### Fluorescent Ballasts

A molded-rubber ballast reduced the transformer capacity required for fluorescent streetlighting in series circuits by more than 50 percent. A new toroidal winding design plus a compact rubber-covered construction permits the expansion of series fluorescent streetlighting applications. Also the rubber-covered ballast can be mounted within the luminaire for open-circuit voltage applications up to 5000 volts.

In addition to providing important materials savings to fixture manufacturers, a new 1¼-inch-high ballast case allows the design of slimmer fluorescent lighting fixtures. Previous ballast height was 2⅝ inches.

Introduced during 1956 the first weatherproof ballast can be mounted fully exposed to the weather. This eliminates the need for special ballast enclosures in the operation of fluorescent lamps on poster panels, billboards, and other outdoor applications.

### Radio-Traffic Control

Chicago's new radio-controlled traffic coordination system uses radio signals to supervise traffic flow at many intersections. The traffic controller at each intersection picks up coded radio signals transmitted from the highest point in the city. The controllers translate these signals into data that set up the optimum timing of the traffic lights to facilitate the movement of traffic. The system eliminates expensive and inflexible multiconductor wires that were previously installed either overhead or underground.

### Other Developments

An adjustable dimmer allows adjustment of a new night light to the desired amount of illumination for nurseries, sick rooms, and many other similar applications.

A 3-way drum-type lamp switch now eliminates moving the switch of a floor or table lamp through all positions to reach HIGH. Mounted at any convenient place in the body of a lamp, the drum revolves 360 degrees in either direction. From the OFF position, the lamp can be switched into Low by turning the drum one way or into HIGH by turning it the opposite way.

# Marine

The year 1956 may turn out to be a significant one in maritime history. For in September, the gas turbine proved to be a great advance in marine propulsion. Before maritime and shipbuilding officials, it powered the gas-turbine vessel GTS *John Sergeant*—a converted Liberty ship and the world's first large merchant ship propelled solely by a gas turbine—at a speed of 18.046 knots in sea trials off the Virginia coast.

A regenerative-cycle 2-shaft unit normally rated 6600 hp, the gas turbine was adapted to marine propulsion by making certain construction changes.

A unique feature of the vessel's power plant, variable-angle second-stage nozzles permit proper distribution of energy between the high- and low-pressure turbines over a wide range of operating conditions. The result: improved efficiency and greater maneuverability.

Consumption of fuel—Bunker C oil treated aboard ship—was 0.533 pounds per shaft horsepower. According to Maritime Administration officials, this surpasses the fuel rate in steamships of comparable size.

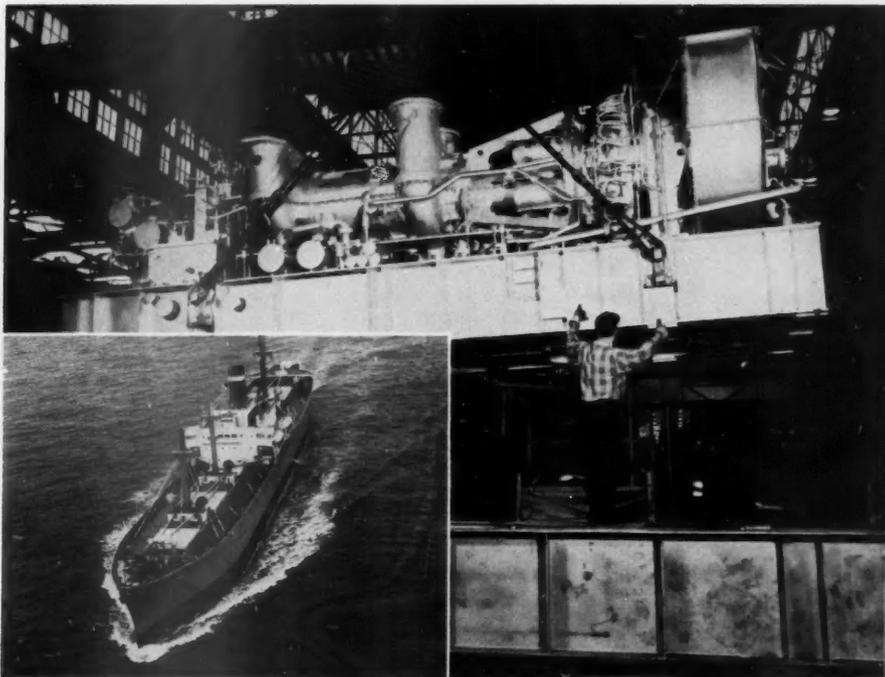
Coupled with a large controllable-pitch propeller, the gas-turbine power plant brought the *John Sergeant's* speed from 17 knots to a full stop in 2 minutes, 47 seconds, without any vibration.

With a single-lever control that synchronizes power output and propeller pitch to best advantage, the ship can be agilely maneuvered at sea or in and out of port from either the engine room or bridge. This feature plus fewer auxiliaries promises a reduction in engine-room personnel.

Lengthening the bow by 25 feet—the only other significant change—differentiates this ship from other conventional 11-knot Liberty ships. This increases her sea-keeping abilities at the higher speeds.

All in all, the ship's gas turbine performed beyond expectations in its initial marine application. It operated without mechanical difficulty during the sea trials. The ship now makes regular service runs for the Military Sea Transportation Service.

One of four Liberty ships used in Maritime Administration experimentation, it will aid in determining the feasibility of upgrading these vessels to modern maritime standards and in evaluating different power plants for



**TWO-SHAFT GAS TURBINE**, rated 6600 hp, regenerative cycle, powers the rejuvenated Liberty ship, GTS *John Sergeant*. Controllable-pitch propeller offers more maneuverability.

possible adaptation to the United States fleet.

## Military

While development of radically new kinds of propulsion highlighted activities in the merchant marine during the past year, another area revived an old type—a single-cylinder steam-propulsion turbine. For the first time since World War I, it will be employed aboard an ocean-going vessel of United States registry: a roll-on roll-off ship for the Military Sea Transportation Service. By reducing the cost of handling cargo, this type ship is expected to renew inter-coastal shipping.

## Naval

Builders and preliminary acceptance trials were run on the USS *Saratoga* (CVA-60) last summer. Main propulsion equipment—both turbines and gears—performed exceptionally well.

As required by the Navy in this type of test, crashbacks were made from full-power ahead to full-power astern. For  $\frac{1}{2}$  hour a locked-shaft test was carried out on the ship's number one shaft, while the other three screws were under full-power ahead.

When the shaft was released, the turbine returned to normal operating conditions—under steam conditions of

1200 psi at 1000 F—in less than 15 minutes.

The order for the turbines and gears for this ship was awarded as a result of new design features that make the total weight of each unit approximately one half of what they would have been had they been built to World War II design. Since this first order, not only has the *Saratoga* been equipped but also the *Ranger* and the *Independence*. Propulsion equipment is on order for the *Kitty Hawk* and the CVA-64, as yet unnamed.

Additionally, 15 new destroyers are being equipped with turbines similar in design but smaller than those in the *Saratoga*.

Three geared turbines are also being supplied for the *Triton* (SSRN-586) and its land-based prototype. This submarine will be the first atomic powered radar picket submarine to be put into active duty for the Navy.

A new servomechanism principle for power drives was developed in 1956. Stator and rotor of the driving motor are integrated with the equipment to be controlled, eliminating costly gearing. One application: aiming naval guns and missile launchers that are optically or radar directed. The device tracks smoothly without the former precision gearing, and it more accurately positions a 4-ton load in a current application.

# Rail

Ten years ago General Electric's prototype gas turbine-electric locomotive existed only in the minds of a few designers. Last year, the 25 "turbines" on the Union Pacific Railroad ran a total of more than 2½-million miles and produced more than 8½-billion gross ton miles of freight transportation. Representing nearly 10 percent of all the Union Pacific's freight traffic for the year, this figure indicates that the newest form of rail motive power has graduated from the experimental phase.

The 15 General Electric 8500-hp locomotives—the most powerful internally powered locomotives ever constructed in the United States—now being built for the Union Pacific produce almost twice as much power as the 25 now in service. Although nearly 133 feet long, the locomotive measures 150 feet shorter than the five diesel-electric units required to deliver the same amount of horsepower.

The new locomotives—designed for single-end operation—consist of two units semipermanently coupled together, with a 23,000-gallon fuel tender. Because they will work at high elevations, these locomotives are rated 6000-foot altitude and 90 F ambient air temperature. Under such conditions the turbine will deliver 8500 hp to the generators.

## Rectifier Locomotives

The past fall marked the beginning of delivery on an order for 12 rectifier-type electric locomotives for the Virginian Railway. The design, basically similar to the 10 built for the New Haven in 1955, enables the present locomotives to haul heavy coal trains over the mountain grades of the Virginian's mainline between Roanoke, Va., and Mullins, W.Va.

In appearance, the locomotives resemble the diesel-electric road switcher, having an engineman's cab located between two hoods. Designed for normal operation with the short hood leading, they operate equally well in the reverse direction. Rated 3300 hp continuously, each unit is geared for a maximum operating speed of 65 mph.

Single-phase a-c power at 11,000 volts, 25 cycles feeds through the pantograph trolley directly to the main transformer on the locomotive. Tap switches, mounted on the transformer tank, vary the secondary voltage fed to the 12



**RECTIFIER-TYPE LOCOMOTIVES** entered a new field in the fall of 1956 when the first of 12 units went into heavy freight service hauling coal trains on the Virginian Railway.

ignitron rectifier tubes. The rectifiers in turn supply direct current to the six traction motors mounted in the two 3-axle trucks.

Two, three, or four of these units can be operated in multiple as a single locomotive to meet service requirements. And as required, they perform either road or switching service.

In service, these locomotives will perform the same duties as the 6800-hp motor-generator locomotives built by General Electric in 1948 for the Virginian. When all of the rectifier locomotives are in service, the railway plans to retire 36 30-year-old electric locomotive units.

## Export Locomotives

Shipment of 30 91-ton 1200-hp diesel-electric locomotives to the Manila Railroad completed the diesel electrification of this important 42-inch-gage rail system serving the Island of Luzon in the Philippines. Twenty locomotives are of the road-switcher type and 10 are streamlined passenger units.

Introduction of the new universal line of diesel-electric locomotives for export occurred early in 1956. This line consists of nine basic designs including 400- and 600-hp switchers and 900-, 1200-, and 1800-hp road locomotives.

Designed for low weight per axle and close clearances to meet the restrictions on many foreign railroads, these locomotives offer maximum versatility for switching, freight, and passenger service. The largest locomotive of the line, however, can be built with axle weights up to 65,000 pounds for handling the heaviest mainline freight traffic.

The first two units of the 1800-hp locomotive—the road-switcher type with an engineman's cab near one end and two equipment hoods—were completed in April 1956. Powered by a 12-cylinder supercharged V-type diesel engine developing 1980 gross horsepower, each locomotive weighs 240,000 pounds. Geared for a top speed of 75 mph, they possess multiple-unit control that permits several units to be operated together as one locomotive.

After a month's test in heavy freight service on the mainline of the Erie Railroad, the units were shipped to Mexico for demonstration on the National Railway's lines. In 2 months of successful operation, they covered many miles hauling both freight and passenger trains. Each unit traveled over 31,000 miles in the 2-month period. This performance so favorably impressed the National Railway officials that they



**INDUSTRIAL LOCOMOTIVE**, newly added to the standard diesel-electric line, produces a total of 840 hp for traction purposes.



**ANALOG COMPUTER** investigates locomotive systems' stability and transient response and solves heat-transfer and design problems.

retained the units and placed an order for eight more.

Other models of the universal line are under construction for railroads in Chile and Argentina.

#### Computers

Computers have assumed an important position in the solution of problems relating to the design and application of transportation equipment.

At first a digital computer solved 1-branch-system problems, such as calculating torsional critical speed of a diesel engine coupled to a d-c generator. Soon the expanding work required a large machine to solve 4-branch-system problems.

In 1956 a new computer with increased storage capacity was installed. It will also calculate bending moments and deflections in a locomotive platform—a problem complicated by the cross sections and the distributed and concentrated loads. A still larger and more versatile digital computer will soon be placed in service.

For problems involving linear and nonlinear differential equations, analog equipment is used. These computers perform investigations regarding stability and transient response of locomotive-control systems and solve problems in heat transfer and vibration.

#### Rapid-Transit Cars

The Metropolitan Rapid Transit Authority of Boston placed the first order for the new high-speed rapid-transit car equipment demonstrated in Chicago in 1955.

In September 1956, they ordered 50 of these General Electric-equipped lightweight cars for subway-elevated service from the Pullman-Standard Car Manufacturing Company, delivery to begin this spring. A total of 200 motors and 50 all-electric-control equipment will power the cars.

Packing nearly twice the horsepower in the same-size motors, the new equipment will accelerate to 40 mph in less than half the time now required. The sustained acceleration allows higher schedule speeds—saving 20 to 30 seconds each mile. The new cars, assigned to the Forest Hills-Everett route, will replace 40-year-old equipment. The 55-foot-long cars will have a seating capacity of 48 passengers. And they will operate as 2-car sets in trains up to 6 cars long.

#### Industrial Locomotives

In the past year a new locomotive was added to the standard line of industrial diesel-electric locomotives. While externally the same as the line's other

members, this new 80-ton locomotive is more powerful and is capable of performing both line haulage and switching service.

The locomotive—powered by two Cummins V-12 turbosupercharged diesel engines—produces a total of 840 hp for traction purposes. Four single-reduction geared traction motors give it a maximum speed of 60 mph. This enables the locomotive to develop as much as 48,000 pounds tractive effort when starting a train. Side-equalized swing-motion trucks similar to those found on large mainline locomotives achieve smooth riding.

The Pacific Lumber Company, Scotia, Calif., placed the first order for the new locomotives. This company replaced their steam motive power with two of the new units. One hauls 50-car log trains from the loading point to the mill—a distance of 12 miles—saving nearly 20 minutes in the run. The other works 10 hours a day as a switcher around the mill.

Equipping these locomotives with a rail-washing system utilizes their greater power more effectively. Water from a tank located in the platform is pumped through nozzles and then sprayed onto the rail just ahead of the locomotive wheels.



LOCKHEED'S F104A *Starfighter* is powered by J79 turbojet engine and a commercial version of the J79 will propel the Convair 880.

## Aviation

In 1956 General Electric engineers tackled a challenging problem: development of nose cones for the USAF's intercontinental ballistic missile program, which includes *Atlas* and *Titan* and the intermediate-range ballistic missile *Thor*.

To accomplish this difficult task, relatively meager knowledge in the fields of aerothermodynamics, aeroballistics, hypersonics, and other fields is being extrapolated into unknown areas. Unique shock tunnels and ballistic firing ranges under construction will simulate conditions encountered by the nose cones in flight.

Work also began on the guidance system for the intercontinental missiles. This has been described as one of the most ambitious and forward-looking programs ever attempted, and a special organization completely dedicated to developing the guidance system has been set up.

Throughout the year, trial runs were made on the 27,000-pound-thrust rocket engine that will launch the 11-ton 3-stage Project Vanguard rocket into space during the International Geophysical Year beginning this July. Designated the X405, it burns a hydrocarbon fuel and liquid oxygen and will operate for about 150 seconds. The gimbal-mounted engine permits changing thrust direction as much as 5 degrees.

A small servomotor, the result of high-temperature studies under way for some time, operates in 500 C temperatures. Not yet ready for volume production, the 2-phase 400-cycle motor operates at 57 volts and utilizes a new ceramic stator insulation, silver rotor conductors, and nickel-clad wire.

During the year a hybrid rocket-propellant system was developed involving a liquid oxidizer of 90 percent hydrogen peroxide and a solid fuel—polyethylene. Virtually free from explosive starting, the new system has a high degree of safety and simplicity. A single valve in the peroxide line permits intermittent operation and throttling.

Capable of operating at 260 F, a new 1-pound constant-displacement pump, operating at 11,500 rpm, pumps normal propyl-nitrate fuel.

A number of extremely high-precision gears has been made for application in guided-missile projects. A recent check of a 720-tooth gear indicated that every tooth was in its exact location and space with respect to every other tooth within 0.00055 inch.

### Jet Engines

On April 17, 1956, Lockheed's F104A *Starfighter*, powered by a General Electric J79 turbojet engine, was unveiled to the public at Palmdale, Calif. It is the

Western World's fastest jet fighter.

The J79 engine powering the *Starfighter* is the first supersonic jet engine manufactured by General Electric, builder of America's first jet engine. Utilizing several novel principles, the engine combines a small frontal area with high thrust output, low weight, and good subsonic fuel economy to make it more powerful per pound than any other engine in its class.

Characteristics of the J79 jet engine give it unusually wide versatility, not only for fighter applications but also for bomber, missile, interceptor, and commercial transports. Four J79 jet engines powered America's first supersonic bomber, U.S. Air Force's delta-wing B58 *Hustler*, on its first flight late last year. Designed for supersonic speeds and altitudes above 50,000 feet, the B58 has an approximate 55-foot wing span and measures about 95 feet long and 30 feet high. Another J79 model under development at this time will power several advanced aircraft of the U.S. Navy. General Electric's first commercial engine, the CJ805, will power the Convair 880—a fast medium-range airliner.

Production of over 35,000 J47 jet engines came to an end last March after the engine had accumulated more than 12-million hours' flight experience.

A "hot-rod" engine was developed for

the express purpose of evaluating jet-engine materials, particularly turbine-bucket materials, at temperatures far in excess of those in production engines. When the engine is operated in a test cell, turbine-bucket temperatures greatly in excess of 1600 F are achieved.

Successfully tested last year, a 5½-ounce turbine wheel that generates 20 hp utilizes 76 titanium buckets loosely pinned around its disk. Developed for an air turbine-driven hydraulic pump, the wheel directly drives a 25,000-rpm radial-action ball-piston pump delivering 8 gpm at 3000 psi.

A new and lighter fuel pump weighing only 30 pounds can deliver fuel to the afterburner of a jet engine at the rate of 120 gpm and 850 psi when sudden accelerations are required. Turbine driven, it replaces heavier equipment involving combinations of electric and pneumatic systems.

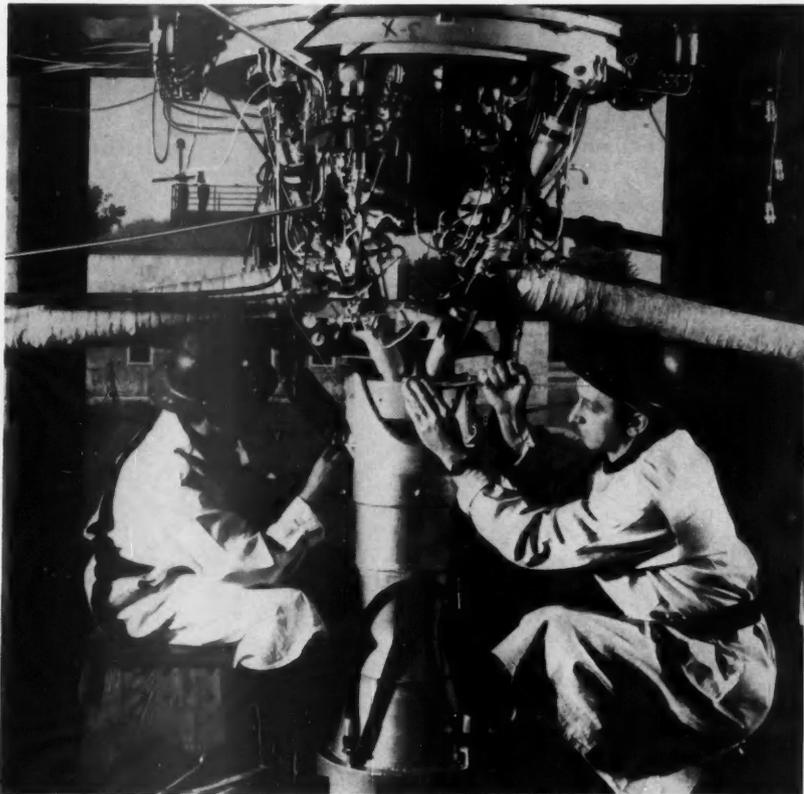
Nearing completion is a turbine-driven fuel-boost and transfer pump. A small turbine, driven by air drawn from the jet-engine compressor, connects directly to the pumping element. Located within the fuel tank, the complete unit incorporates a separator to insure delivery of vapor-free fuel.

In conjunction with Standard Oil of Indiana, a new smokeless propellant was developed for use in a jet-engine starter. Weighing only 60 pounds, the complete unit starts and assists jet engines to idling speeds within 25 seconds. The starter cartridge burns for about 10 seconds.

To meet the higher thrust and temperature actuation requirements of advanced aircraft, a lightweight turbo-actuator operates consistently in ambient temperatures to 600 F. Driven by air drawn from the jet-engine compressor, a small turbine powers a linear actuator that can be located near jet exhaust nozzles.

Delivery of a new-type integrated electronic-control mobile test truck for the Air Force started during the year. It serves as a mobile base shop to troubleshoot, calibrate, and maintain electronic control systems used on certain types of General Electric jet engines.

In 1956, production usage of a water-based magnetic-particle inspection system indicated that its sensitivity is equivalent to standard petroleum-based methods. At least as sensitive as those systems using petroleum distillate, it costs much less. A series of tests were made with equipment that included an automatic machine used to inspect com-



PROJECT VANGUARD'S 27,000-pound-thrust rocket engine is adjusted prior to trial run.

pressor blades in assembled rotors.

Extensive television coverage is being provided in development test areas with considerable reduction in test hazards and cost. Cameras are sufficiently small so that an observation post inside some parts of the test apparatus can sometimes be established.

#### Armament

Probably the biggest news of 1956 in aviation armament came in the field of ballistics with the announcement of two projects: the 20-mm air cannon *Vulcan* and the airborne missile-path follower.

Currently the world's fastest-firing machine gun, *Vulcan* has six rotating barrels that can fire thousands of rounds of ammunition a minute, a factor of extreme importance in modern high-speed combat. *Vulcan* has less barrel whip due to its centralized recoil, can be field stripped in ½ hour, and will operate at high and low temperatures with standard lubricants.

With the airborne missile-path follower—a device that follows the path of a shell after it leaves a gun—the trajectory paths of all types of rockets and missiles can be measured while in

flight. Up to now, ballistics experts have had to be content with information of a mathematical or empirical nature.

Other equipment measures and records over-all accuracy of an aircraft armament system while in flight. With the armament flight evaluator, an operational Air Force unit can measure fire-control system accuracy without the use of drones or other supporting aircraft. By means of a new technique, airborne fire-control operators can determine the alignment of radar sight lines and bullet paths with a device that automatically corrects errors.

One third the size of older types having equivalent angular momentum, a fully floated, integrating gyro carries a new torque coil permitting easy assembly. Additionally, its damping system uses low-viscosity fluids, and a thermostat holds temperatures to unprecedented accuracies.

#### Helicopters

The T58 turboshaft engine, shown publicly for the first time last year, will soon be flying in the Sikorsky S58 and the Vertol H21 helicopters. In advance of actual flying, however, the engine



**AIR CANNON VULCAN** fires thousands of rounds in a few minutes.



**TURBOSHAFT ENGINE**, the T58, will soon be flying in helicopters.

underwent exhaustive testing to prove engine-helicopter compatibility in a specially constructed rotor test stand at the General Electric Flight Test Center in Schenectady.

Pound for pound, the T58 is the most powerful turboshaft yet announced producing more than 1000 hp; and it weighs only 325 pounds including gearing. Designed and developed for the Navy's Bureau of Aeronautics, the T58 measures less than 5 feet long and 16 inches in diameter. Specific fuel consumption is 0.69 pounds per hp-hr at normal rating. As to range and capacity—a T58-powered helicopter can stay aloft 50 percent longer and carry 100 percent more payload than its piston-engine counterpart. While the T58 will be used initially for helicopters, it can be used for various other aviation or nonaviation applications.

Another small lightweight gas-turbine engine now under development for the Air Force has the official designation J85.

#### Fuels

With the amazing potentials of unusual fuels becoming apparent, design and construction of an advanced fuels

facility was undertaken. In operation since early last year, the facility is equipped to handle evaluation and system development of advanced fuels in three areas.

Gears and jackshafts were also built for three test stands to measure performance characteristics of guided-missile oxygen pumps, fuel pumps, and gas turbines. The test-stand ratings range from 2200 hp at 12,700 rpm to 4000 hp at 30,000 rpm.

#### Aircraft Instrumentation

At the Flight Test Center, 12 direct-data channels are transmitted from the airplane to the ground station on one UHF radio frequency. On the ground, data are continuously recorded and displayed on a 12-channel direct-writing oscillograph. In a recent automatic flight-control development test program, this telemetry system reduced the time cycle by one third.

Under development for aircraft navigation systems is a single-axis gyro with magnetic-suspension gimbal bearings. The entire gyro, including the magnetic-suspension bearings, is small and light enough for lightweight navigation systems in fighter aircraft. It has 200 times

the angular momentum and 1/50 the drift of similar-size gyros.

A true mass-rate flowmeter system was designed for application on variable afterburner engines. It measures separately the flow of fuel to each engine and totalizes flow to all engines on a multi-engine aircraft. The system operates directly from the aircraft's 400-cycle power supply.

Progress continued in studies of advanced engine-instrumentation display systems for jet aircraft. Samples under construction will supply engine, altitude, speed, and range data in a simplified manner, thus saving pilots' time in reading instruments and calculating data.

An improved electric tachometer remotely indicates engine speed of either propeller-driven or jet aircraft. Designed to operate on the same basic principle and to provide performance superior to its predecessor, the improved tachometer has fewer and less complicated parts.

Dials of hermetically sealed aircraft instruments are uniformly lighted by an integral lighting system required by the military services and aircraft manufacturers. Light is "piped" to the instrument dials through specially designed light-transmitting plastics parts.

## Flight Control

A new concept in airplane flight-control systems enables a pilot to obtain maximum airframe performance safely, allowing him to function more effectively as a weapon-system manager. Called PAL for pilot-aircraft link, the concept involves numerous innovations that greatly simplify the problem of enabling a pilot to exert his will on the aircraft performance.

Recently completed also was the design of an overdamped angular accelerometer. The new unit measures 2.6 inches in diameter, 2.1 inches in length, and weighs 0.63 pounds. This accelerometer performs the functions normally done by both the rate gyro and canceller in conventional damping systems.

## Electric Systems and Components

Placed on the market for the first time were complete aircraft generating systems that included the constant-speed hydraulic drive that produces constant frequency with varying engine speeds.

Methods have been derived for predicting electric torque requirements of any proposed aircraft system. These analyses assist the drive designer in obtaining the lightest weights and lowest costs consistent with safe performance of the airplane's system.

The functions of a hydraulic ball-piston constant-speed drive and a statically excited generator are combined in a new constant-frequency power package. Smaller and lighter than conventional-drive and generator combinations of the same rating, the 20-kva 8000-rpm drive delivers a full 32 hp over an input speed range of 4300 to 7500 rpm. This power package is used on the Grumman F11F-2.

Improvements in an electric control system for a 60-kva 400-cycle air-turbine constant-speed drive provide frequency stability nearly 10 times better than formerly obtained with a mechanical control. The turbodrive supplies power for all 400-cycle electronic equipment on the Boeing B52. The new control system, a combination of electric and hydraulic components, maintains bus frequency at 400 cycles  $\pm 1$  cps over a wide temperature range.

Work in aircraft excitation and protective control continued to produce new static equipment. Designs of new products embody recent static developments for several new aircraft. For example, recent equipment includes such features as complete static excitation and magnetic-amplifier-type over-



**RADIO TELEMETRY SYSTEM** aids the ground personnel in gathering test data from planes.

voltage and undervoltage relays.

In the field of ground-power equipment, a completely static regulator-exciter for 45-kw 60- and 400-cycle generators led to the first major production order for static-excitation equipment. This design contributed to a smaller and lighter generator package.

Airborne transformer rectifiers developed in 1956 incorporate silicon rectifiers and new magnetic circuit techniques into their regulating systems. Employed for the first time is a device combining the function of both the transformer and amplitat previously used in regulated power supplies.

A new aircraft electric generating-systems development laboratory reached completion at Waynesboro, Va. Three drive stands, each rated 200 hp, are equipped with ignitron rectifiers and speed regulators that permit testing of complete aircraft electric systems, including protective control.

## Servos and Hydraulics

Last year an improved all-electronic servo analyzer was developed for use in wide-range servo-system and component-response evaluation. The analyzer eliminates the use of mechanical devices employed in previous servo analyzing machines. Additionally, plug-in capacitive units extend its normal 2000 to 1 frequency-range coverage.

A unique and highly efficient test

table now in operation tests performance and endurance of hydraulic pumps, motors, control valves, and actuators at temperatures to 700 F; flow rates of 10 gpm; and pressures to 5000 psi. Completely automatic, this highly flexible test table will do much to help prove the worth of hydraulic equipment destined to operate in high ambient temperatures.

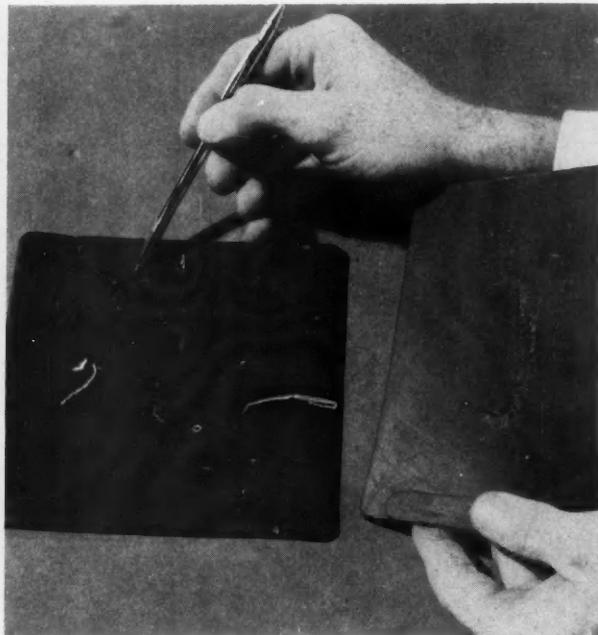
Tests were completed on industry's first 24,000-rpm hydraulic pump. It will be available for installation on U.S. Air Force's heavy bombers. With a pumping rate of 8 gpm, the pump will improve reliability and weigh less than hydraulic systems now in use.

## Computer Center

Consolidation of the various analog computer units into one central location at Schenectady resulted in a highly flexible facility for use in solving the many problems of control-system dynamics. Some investigations have included jet-engine simulation and controls, nuclear reactor controls, aircraft and missile dynamics and controls, and hydraulic and gunfire controls. This center operates on a self-service basis—each engineer operates the necessary computer equipment to solve his particular problem. Consultations are provided in computer techniques, applications, and mechanizations, in addition to scheduling and maintenance of equipments.



**MAN-MADE DIAMONDS** were put in pilot production during 1956.



**CHEMICAL MECHANISM** gives insulation carbon-tracking resistance.

## Chemical and Metallurgical

Man-made diamonds were produced in limited quantities last year for use on industrial grinding, polishing, cutting, and sawing tools. The all-important gap between the first laboratory discovery and pilot-plant production was bridged in an amazingly short time. The diamond project's present assignment: reduce cost to that of diamonds now being mined.

The sizes and types of diamonds being produced are suitable for 80 percent of industrial applications in the United States. By replacing imports with a totally independent supply of a vital raw material, the availability of the man-made stones will have an important impact on American industry and defense.

### Silicones

Available in fabricated sheets, tubing, gaskets, or special molded shapes, conducting silicone rubber now has applications ranging from high-frequency shielding to miniature resistors, heating, and special nonstatic uses in hospitals. Recently brought into a practical realm, the easily modified compound permits a variety of materials for specific applications to be produced in a continuous process.

Conducting-silicone-rubber gaskets will provide extreme-temperature seals in electronic ovens and help suppress both electric and radio-frequency energy.

A new silicone fluid, designed as a lubricant, includes an operating range from  $-100$  to  $+450$  F. Combined with a lithium soap base, this fluid becomes a general-purpose grease lubricant and contributes high hydrolytic and thermal stability, excellent viscosity and temperature characteristics, and resistance to shear breakdown.

A silicone-rubber-cloth coating compound for ducting that carries air as hot as  $700$  F and remains flexible at  $-120$  F was commercially produced last year. Applications include hot-air ducts, jet-engine starter hose, flexible connectors for metal ducting, and aircraft fire-wall seals.

The first silicone-rubber compounds having the same shrinkage as organic rubber permit close tolerances and use of the same molds utilized for organic-rubber parts. Food and drug industry applications are now permissible, since the improvement was achieved without toxic additives.

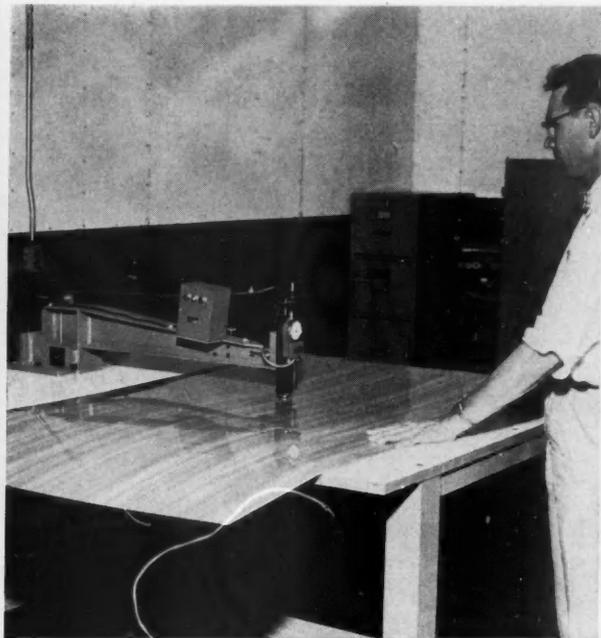
### Insulation

A recently discovered chemical mechanism prevents carbon tracking in organic insulations such as butyl rubber, epoxide and polyester resins, neoprene, and other elastomers. First application: 15-kv outdoor current transformers, withstanding the most severe weather. Possible future uses: lightning arresters, cutouts, high-voltage bushings, bus structures, and distribution and power transformers.

Two new insulating tapes were developed: a silicone-rubber bias-glass-cloth tape for use on rotating equipment; and a highly flexible mica-mat tape for d-c and low-voltage a-c armatures and field coils.

Slot liners and phase insulation in small motors are provided by a polyester film coated with selected resins. A thin, uniform coating of resins improves mechanical properties and heat life of the film.

A small-diameter magnet wire for coils permits soldering without stripping of the insulating coating. A new enamel, based on isocyanate curing agents and thermally stable resins, provides insulation and allows easy soldering.



**INSTRUMENT** measures thickness on continuously moving sheet.



**ULTRAFINE** iron particles are used in permanent-magnet studies.

Semiconducting irradiated polyethylene tape was developed to satisfy the needs of the power-cable industry for a material to distribute electric stresses in cable.

#### Resins

New thixotropic synthetic resins for making viscous paints which thin out when agitated or stirred by a brush were developed. The reduced resistance to brushing or rolling paints and enamels based on these new resins make the painter's job less tiring. When agitation or brushing halts, the paint returns to its original highly viscous state; thick films can thus be applied on vertical surfaces without the problem of running.

The Food and Drug Administration approved certain grades of irradiated polyethylene for food packaging.

#### Molding Materials

Two general-purpose phenolic molding compounds were introduced during the year. In addition, an improved impact strength was demonstrated in a third compound, which displays a uniformity and finish equivalent to many general-purpose types. Modular impact and high-heat-resistant materials have been added to a diversified line of phenolic molding compounds.

Plastics parts fabricated from irradiated carbon-black filled polyethylene

are being produced experimentally. The physical properties of the carbon-black filled material are superior to conventional high-pressure polyethylene, from which it is derived.

#### Laminates

A cold-punch electronic grade laminate, developed mainly for printed circuits, was introduced early last year. Easily fabricated at room temperature, the high-insulation paper phenolic-sheet material resists dimensional changes and allows precise registration of assemblies. It permits the use of automatic assembly equipment and higher fabricating speeds.

A long-standing problem in the laminated plastics industry was solved last year: thickness measurement. A new instrument can make the measurement on a continuously moving production sheet, accurately measuring thickness at any spot on the sheet to 0.0002 inch.

#### Magnets

Ultrafine iron and iron-cobalt alloy particles less than a millionth of an inch in diameter were prepared during the year. By aligning and compacting the particles to various packing densities, it was possible to reproduce the permanent-magnet characteristics of the better commercial permanent-magnet alloys. This fundamental study constitutes a major breakthrough in permanent-magnet technology.

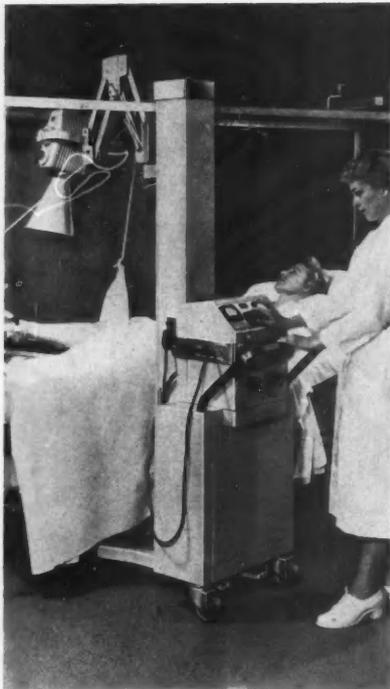
#### Metals and Alloys

Two new man-made metals, both cemented carbides—one for milling high-strength cast irons, the other for precision steel cutting—were developed last year. By resisting cutting wear and breakage for longer periods, both of these new cemented carbides promise to cut tooling costs in metal-working operations.

Fabricated last year, the longest solid cemented-carbide shearing knife tip yet produced by powder metallurgy measures 67 inches. The knife is used for shearing stacks of abrasive photographic paper.

A vacuum-melted nickel-base alloy originally developed for and used in aircraft gas turbines has been adopted for long-time operation in heavy-duty land gas turbines. Strong enough to resist high stresses at high speeds, buckets made of this alloy are now being used in 7600-hp and 16,500-kw turbines. Sixteen such machines for pipeline pumping and power generation will be equipped with buckets fabricated from this alloy.

Drill rod was hardened to a depth of  $\frac{1}{16}$  inch using 2 kw rather than the 30 kw required by induction heating. A controlled arc heats the rod submerged in a liquid bath. The liquid bath quenches the rod when the arc is interrupted. This process can potentially be extended to surface-harden steel and large gear teeth.



**MOBILE X-RAY UNIT** with electronic timer maneuvers easily for bedside x-ray use.

## Medical

A new small-film chest x-ray machine exposes a patient to almost 75 percent less radiation than formerly required. Improving image clarity, exposure speed, and operating economy, it combines the Fairchild-Odelca camera with the General Electric x-ray generator and tube.

A large mirror, similar to those in astronomical telescopes, permits a wide aperture:  $f$  0.7. Short exposure time plus better film reduces retakes necessitated by movement of patient. Adaptable to serial film work, the camera can take 1 to 6 frames per second in studies of lungs, heart, stomach, kidneys, and intestinal tract on either 4x4-inch or 70-mm film.

### X-Ray Unit

A new x-ray unit, priced under \$5000, embodies complete diagnostic facilities—an 81x27-inch angulating table, independent tube stand, double-focus rotating-anode x-ray tube, and a 200-ma 100,000-volt full-wave transformer. Other features include: automatic recip-

rocating filter to prevent scattered radiation from fogging the film, and a screen that moves 41½ inches longitudinally, 10 inches transversely, and 4 to 18 inches from the table.

### Timer Improves Bedside Unit

Split-second timing of x-ray exposures by an electronic circuit minimizes exposure variations in a new bedside x-ray unit, an improvement over conventional mechanical, spring-driven devices. Producing up to 90 kv at 15 ma, the portable unit achieves a sharp image within a 1.5-mm effective focal spot.

### Automatic Cycling

Another diagnostic x-ray unit offering automatic spot-film cycling was developed. A push button begins a series of events during fluoroscopy when radiographs are taken of several body areas without special attention from the radiologist. Lower in cost than its predecessors, this unit operates at currents up to 300 ma.

## Air Conditioning

Eighty-three General Electric ceiling units service the world's first completely air-conditioned men's clothing plant, dedicated in Philadelphia in 1956. The 7-story block-long plant, owned by H. Daroff and Sons, will no longer face the threat of 2 to 3 weeks' lost time that confronts the clothing industry during the hot summer months. Air conditioning now dispels the high heat and humidity caused by steam presses and hot irons, and cloth can be more precisely cut and fitted in this atmosphere.

### Heating and Cooling of Homes

At Tyler, Texas, construction on a \$15-million plant for the production of home heating and cooling equipment was completed. All air-conditioned, the plant contains 350,000 square feet and employs several hundred people.

A new thermostat senses changes in outdoor temperature and transmits this information to the indoor thermostat. This provides automatic adjustment of heat within the home to sudden changes in outside temperatures.

Heating and cooling units for the home were made smaller and more compact in the past year.

### Weathertron

The heat-pump industry, increasing in size every year, installed about 6000 units during 1956. A 40 percent price reduction per 1000 Btu's of heating at the distribution level has occurred since General Electric introduced the Weathertron. And for the first time in the heating industry, the warranty is now for 5 years. The current line of Weathertrons opened up a large new geographical area for installations. The range of available models will be widened in 1957.

### Heat-Load Calculations

A new thermal-response method aids in the application of air-conditioning equipment. Varying outdoor conditions of temperature, solar radiation, and wind are treated as series of square waves or pulses. The response of the major structural building components to a square wave of unit time and amplitude are calculated. Response factors multiplied with the amplitude of the outdoor conditions for the corresponding time provide the momentary heat flow into or out of the building. Actual weather data recorded on business-machine cards are used for the calculation.

## Education

Announcement of the Honors Program marked another step in advanced educational programs for engineers and scientists. The program permits a college graduate to obtain his Master's degree at a recognized university in 1½ years while earning a major part of his salary. The student works a maximum of 26 hours a week in a General Electric operating department. And if he works during academic vacations, he earns 70 to 80 percent of his normal salary. Classes are held at universities near General Electric plants. And the Company pays tuition, fees, and other academic expenses. Because of university residency rules, the employee takes his assignments at one Company location until completion of studies.

After obtaining his Master's degree under this Program, the employee may continue his formal education in one of two ways: begin his professional career as a permanent member of an operating department and continue his education toward a doctorate; or continue academic work in the Advanced Study Program, taking work assignments in Company locations related to his chosen field.



**UNDERGROUND FREEZER** warehouse uses rigid conduit to carry cables in electric system.

## ...For Building Construction

Electric service-entrance equipment for residential and small commercial and industrial applications saw many changes during 1956. One of two new 2-pole common-trip circuit breakers with a 70-amp rating for 120/240-volt a-c service has several uses: as a plug-in main breaker in load centers and as a branch breaker to protect circuits that carry heavy current loads such as unit kitchens, double-oven ranges, or sub-fed lighting panels. And it can serve small single-phase 220-volt motor circuits—such as those used in some types of air-conditioning equipment—from plug-in lighting panelboards.

The other 2-pole plug-in breaker, a switching neutral design for use in gas-line-station-pump circuits comes in 15- and 20-amp ratings for 120-volt a-c applications. Both circuit breakers have interrupting ratings of 5000 amp a-c.

Introduced also was a new line of an all-in-one meter socket—load center combinations for single-phase 3-wire 120/240-volt a-c service. Designed primarily for areas where the electrical contractor must supply the meter socket, the new device requires only one unit for installation and thereby reduces the installation cost. These meter-socket combinations are available with 100-amp main breaker or main fuse puller, 100-amp main breaker or fuse puller and 16 branch circuits, and 70-amp main breaker and 14 branch circuits.

Additions made to fusible equipment

for service entrances include: a 100-amp fuse-puller switch with double-load lugs (60 and 100 amp) especially suited to rewiring jobs; a 100-amp device with 4 parallel-connected fuse pullers and 8 plug-fuse branches that allow connection of several 240-volt appliances such as range, dryer, and air conditioner as well as carry adequate circuits for lighting and convenience outlets; and a line of devices—intended primarily for apartment houses—with 60-amp main fuse pullers, series connected, and accommodating 12 plug-fuse branches.

For farm service-entrance applications, a new emergency power-transfer switch, installed in the incoming line wires as the main service disconnect, permits the distribution of electricity from an emergency power source.

For kitchen-center installations, a 21x3x5-inch 100-amp circuit-breaker load center was developed for convenient mounting in a narrow space. Yet it permits the distribution of 10 single-pole or 5 double-pole circuits, or combinations of both.

### Shallow-Fill Junction Boxes

Three new junction boxes were added to a line of fittings for underfloor distribution systems. For single-duct, double-duct, and triple-duct systems, these boxes are designed for use in light-construction buildings where requirements for floor fill do not exceed 2½ inches. All the boxes are of 1-piece cast-

ings and have 4-, 8-, and 12-duct entrances respectively plus 4 bushed holes at the corners of each box to take 1¼-inch conduit.

### Armored Cable

An improved armored cable employing thermoplastic insulation on individual conductors was introduced during 1956. The insulation eliminates the need for braids by providing color-coding throughout. Tough, flexible, and resistant to water, acids, oils, alkalis, aging, and combustion, it makes stripping quicker and easier with no time wasted in trimming braid.

### Conduit

At the Inland Cold Storage Company's underground freezer warehouse, Kansas City, Kansas, General Electric's rigid conduit carries cables from an above-ground substation down through 70 feet of solid stone and the ceiling of a former quarry into the distribution load center.

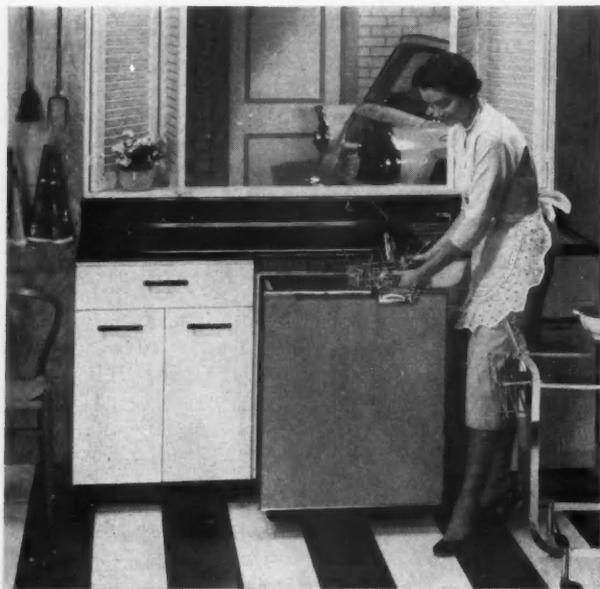
In all, approximately 9½ miles of conduit were used for the electric distribution system which supplies power to the refrigerating equipment as well as the lighting and other electric equipment. More than 300,000 square feet of storage space is refrigerated by this equipment. Subjected to extreme conditions, the conduit must not only withstand alkalis and acids in the soil and rock but also resist moisture and humidity in the storage and refrigeration areas; frequently ice covers the conduit.

### Weatherproof Outlet

A new weatherproof enclosure with an aluminum hinged cover and special gasket seals out moisture from electric outlets. With a protecting ground, the device offers added safety for outdoor living involving wider use of decorative outdoor lighting and electric cooking appliances, hedge trimmers, power mowers, and other tools and appliances.

### Remote-Control Cable

A new 19-conductor low-voltage control cable with thermoplastic insulation can be used for low-voltage remote-control switches, motor-driven switches, and other complex wiring applications not exceeding 30 volts. Color-coded for polarity and circuit identification, the cable has one white conductor as a common return and 9 red and 9 black conductors that comprise the circuit set. Numbering the sets consecutively and each conductor continuously for its entire length provides identification.



**AUTOMATIC DISHWASHERS**, portable and undercounter types of improved design, offer housewives increased efficiency in the kitchen.



**AUTOMATIC CLOTHES CONDITIONER** with axially directed high-velocity airflow system dries clothes 23 percent faster than formerly.

## Appliances

A completely redesigned line of automatic dishwashers, both portable and undercounter, was introduced during 1956. Capacity was increased—two units each hold service for 10, and another for 12—without significant changes in over-all dimensions. The unit interiors are coated with a plastics material that reduces chipping and deterioration and insulates against washing noise and heat.

Improved washing results from a redesigned stainless-steel impeller driven by a 1/3-hp motor. The impeller throws a pattern of water over the dishes at a rate of 80 gpm, but the complete cycle requires only 10 gallons of water. And the drain pump not only removes water from the dishwasher but also liquefies soft food particles and flushes them out of the dishwasher. This operation eliminates all prerinsing and scraping of dishes except for hard food wastes such as bones.

### Automatic Washer

A new automatic clothes washer has two washing actions and, independently, two spin speeds. The regular family wash requires vigorous activation and fast spinning; but delicate garments need

gentle activation, and slow spin reduces wrinkling for all synthetics. A 2-speed governing-type friction clutch permits reduction of both activation and spin speed to about one half their normal values.

For low-speed operation, the clutch includes a pair of speed-regulating shoes with their centrifugal force balanced against governing springs, which are effective in holding a predetermined reduced speed with good regulation. For full-speed operation, locking shoes bypass these governing shoes. The 2-speed features are combined with a torque-limiting clutch required for basket-spin acceleration, resulting in a single multipurpose clutch.

### Clothes Conditioner

An axially directed high-velocity airflow system is used on a new automatic clothes conditioner. Clothes can now dry 23 percent faster than with previous General Electric models and without increasing the temperatures. The blower pulls fresh air over the heating elements and into the drum from the rear; the large volume of air circulates directly through the clothes without exposing them to the direct heat of open heating

coils or a heated drum surface. The automatic control, introduced in 1955, was adapted to the high-velocity airflow system. Without reducing its capacity, the unit was decreased in width from 31 to 27 inches.

### Automatic Roasting Thermometer

Overdone and underdone roasts fade into the past with a new automatic roasting thermometer. The housewife sets an indicator on her range to the desired "doneness," inserts the temperature-sensing probe into the roast, plugs the probe into a receptacle inside the oven, closes the oven door, sets the oven thermostat to the correct oven temperature, and turns on the oven. When the indicating pointer reaches the preset temperature, a buzzer signals that the roast is done. The probe utilizes a thermistor as the temperature-sensing element. As the resistance of the sensing unit decreases with increasing temperature, the current in the circuit increases and causes the actuator bimetal to deflect. This deflection then transfers to the indicating pointer, causing it to move across the face of the meter.



**PERFECT ROASTS** cooked to desired "doneness" can now be a reality with automatic roasting thermometer that plugs into electric range.



**PORTABLE TELEVISION** continues in popularity with demands met by two new models—a 9-inch set (top) and a 17-inch set (right).

#### Room Air Conditioners

A new motor-starting technique for room air conditioners eliminates the use of a start relay and start capacitor. The new hermetic motor provides reliable starting characteristics, lower starting and running currents, lower power input, higher power factor, less service failure potential, and simplification of motor circuitry.

Nearly all room air conditioners remove condensate by the use of a fixed slinger ring on the condenser fan. The fan dips into the collected water, spraying it into the hot condenser air to evaporate and be carried outside. During winter operation for either heating (reverse cycle) or ventilation, freezing outside temperatures may freeze the water and lock the fan. General Electric engineers eliminated this problem and increased the efficiency by replacing the fixed slinger ring with a pulley on the fan motor shaft to drive a special rubber hoop that passes through the water reservoir. Now if the hoop does freeze in the reservoir, the pulley and fan motor can still rotate normally.

An electronic air filter, adaptable to all current models, removes microscopic airborne particles like dust, pollen, and bacteria-laden dirt from all air passing through it. The basic filter element consists of a permanent plastics frame with spring-steel wire electrodes and an inexpensive, disposable ac-

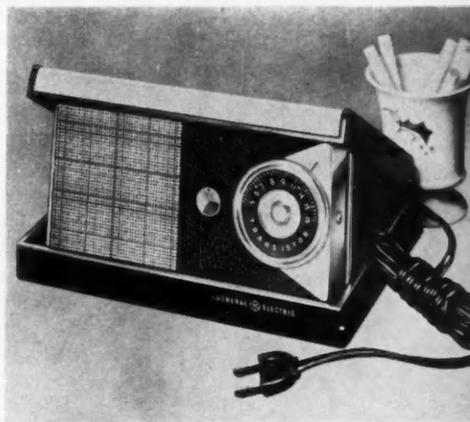
cordion-folded filter media of dielectric fibrous material. A power pack provides direct current at 3000 volts.

#### Television Receivers

The past year may well be remembered by the television industry as the "year of the portables." General Electric, in 1955, opened a new market with the 14-inch portable. In mid-1956, with the consumers' demand for portable sets firmly established, two new models were introduced—a 9-inch and a 17-inch set. In the 9-inch set, the picture tube consists of a single piece; conventional picture tubes have the faceplate and funnel welded together. The extensive use of aluminum and plastics, printed circuitry, and subminiature parts further reduced size and weight and heat-dissipation problems.

General Electric introduced its first 21-inch color sets late in 1956. Because sets involve use of an aperture mask tube, engineering effort concentrated on circuit simplification and reliability. Result: more than 10 receiving tubes eliminated, complete use of printed circuits, satisfactory black-and-white pictures without annoying drift, and uniform color-picture quality.

A new germanium rectifier was specifically designed for television-receiver power supplies. Because of its inherently higher efficiency, a higher d-c output can be obtained from a rec-



**POCKET-SIZE RADIO** using six transistors has 10 times the sensitivity of its predecessor.



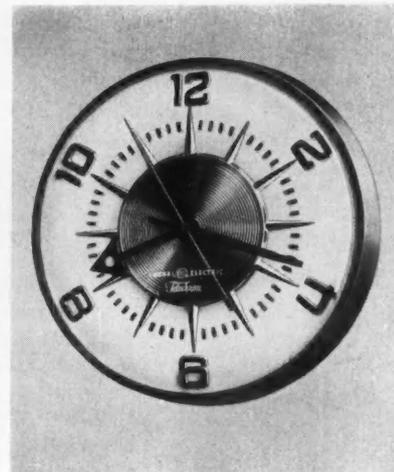
**PREAMPLIFIER** with transistor input rewards hi-fi fans with more sensitive reproduction.



**OVEN COMPARTMENT** and fully automatic toaster are offered in a single compact unit.



**FAST-HEATING SPEED IRON** with temperature control heats within 30 seconds.



**METALIZED PLASTICS DIAL**, vacuum formed, enhances new kitchen wall clock.

tifier having smaller dimensions than its predecessor.

#### Radio Receivers

Six transistors are used in a new pocket-size portable radio that has 10 times the sensitivity of its predecessor. Rechargeable cells, available as an accessory with the carrying case, are inserted into the radio in place of standard mercury or carbon pen-light batteries. The cells can be recharged as many as 200 times simply by plugging into an a-c outlet. The radio will play an average of 50 intermittent hours per charge at medium-volume level for about 10,000 intermittent hours.

#### Hi Fi

Transistors appear in a General Electric phonograph pickup preamplifier for the first time. The transistor input gives low-hum and low-noise level, freedom from microphonics, wide frequency response, and low distortion. A high-gain double-triode voltage-amplifier tube brings the input level of the preamplifier up to the required input sensitivity of most power amplifiers.

A wide angle of dispersion at all frequencies is one of the features of a new high-frequency loudspeaker that is designed to operate with any 8-ohm single-cone speaker. The new loudspeaker possesses a frequency response, substantially flat, from 1500 to 15,000 cps.

#### Housewares

A fully automatic toaster and an "oven" were combined into a single

unit. It has two separate toasting sections: a vertical section toasts two regular slices of bread; and an oven drawer toasts buttered bread, canapes, English muffins, or the like. A selector dial determines the toasting operation of the unit desired, and another dial controls the degree of brownness for both sections.

Salt or other additives are unnecessary in a new automatic vaporizer. The unit produces steam in 90 seconds, operates for 8 hours without refilling, and has an automatic shutoff. It can also warm baby bottles.

A new fast-heating speed iron heats within 30 seconds. A fabric-selector dial located on the handle assures the housewife of the correct ironing temperature for all fabrics, including the new synthetics.

#### Clocks

Several new clock appearances were developed during 1956. For a wall clock, a wrought-iron scroll harmonizes with the popular motif of modern furniture. In a kitchen clock, the vacuum forming of metalized plastics dials gives them the appearance of metal yet the versatility of molded plastics in the shaping.

Alarm-clock users can now gain an extra 40 winks by simply pressing a bar on the top of the clock when the alarm sounds. At the end of a 10-minute interval, the alarm will repeat. If the user desires, he can obtain successive snooze periods by merely pressing the bar.

Accurate timing is obtained with a

cased television timer that automatically turns sets on and off. Timing is obtained in ¼-hour increments so that each complete ¼-hour program or multiple of ¼-hour programs can be timed as desired. Because of its portability, the timer can be used in conjunction with tape recorders as well as with a number of other household appliances.

#### Timers

New timers, substantially thinner and smaller than their predecessors, allow clock-radio manufacturers to utilize them in a variety of applications.

An improvement of 25 to 100 percent more torque for the same input in timing motors is possible with a new rotor alloy. Operating characteristics of this alloy now approach those that are obtainable from a permanent-magnet rotor but without the self-starting problems.

#### Other Developments

Reaching, hunting, and fumbling for hard-to-get-at switches on lamps and appliances is eliminated with a new feed-through switch. It can be attached anywhere along the length of a service rip cord without stripping the cord, has feather-touch control, and operates silently. A small neon lamp in the switch glows when the switch is in the Off position.

An inexpensive extension-cord set with a practically indestructible 3-outlet service block will be ideal for workshops and other areas where hard usage can be expected. Ω

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**B**Y now more than twenty companies and foundations have established programs by which their employees' contributions to their colleges are matched dollar for dollar.

Each program is predicated on three assumptions:

- that the employee benefits continuously by a college experience paid for only in part, recognizes the fact, and wants to help make this same experience available to others;
- that the company also benefits continuously by the quality of experience of its college-graduate employees and wants, therefore, to share in making this experience available to others;
- that the college must continue—in the face of new and increasing demands—to offer the college experience, and must have the support of both types of beneficiaries to do so.

If these assumptions are correct, matching programs can be powerful factors in the support of American colleges and universities. Yet such programs can only be successful if college alumni recognize their growing obligations and act upon them.

There are many things alumni can do to help their colleges. But the first and easiest thing is to give regularly and substantially to the college gift fund.

**GENERAL  ELECTRIC**

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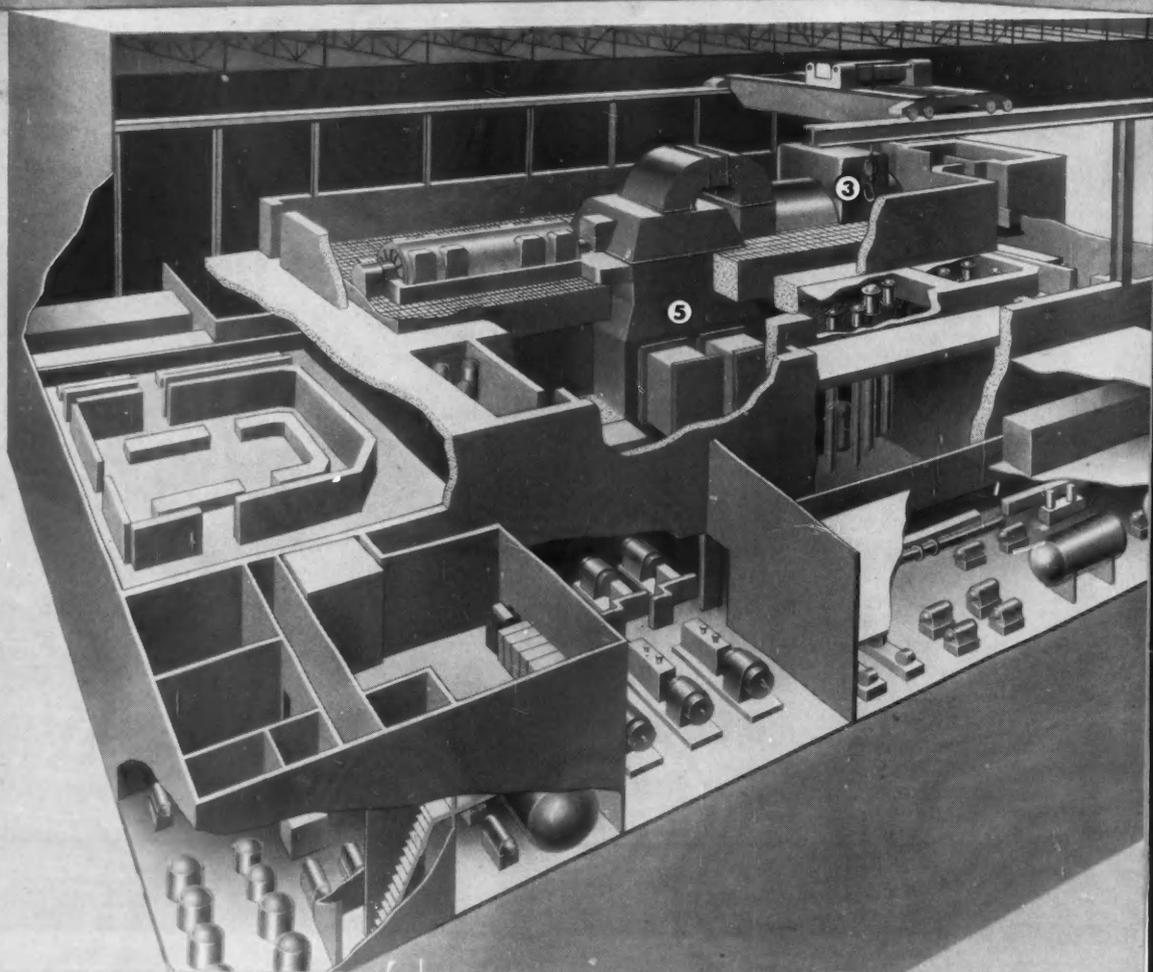


PROGRESS REPORT ON DRESDEN STATION

# General Electric moves into final design stage on Dresden Nuclear Power Station

**STEAM FOR COMMONWEALTH'S DRESDEN STATION** will be produced by a dual-cycle boiling water reactor (1). A mixture of steam and water is separated in a steam drum (2) and steam sent directly to the first stage of the turbine (3) at a pressure of 970 psia. In the dual or secondary steam cycle, water flows to four secondary steam

generators like the one shown (4). There heat is removed to produce 500 psia steam for admission to the turbine at a lower stage. The water is condensed (5) and returned to the reactor. Fuel storage building (6) will contain spent fuel until ready for shipment to reprocessing centers.

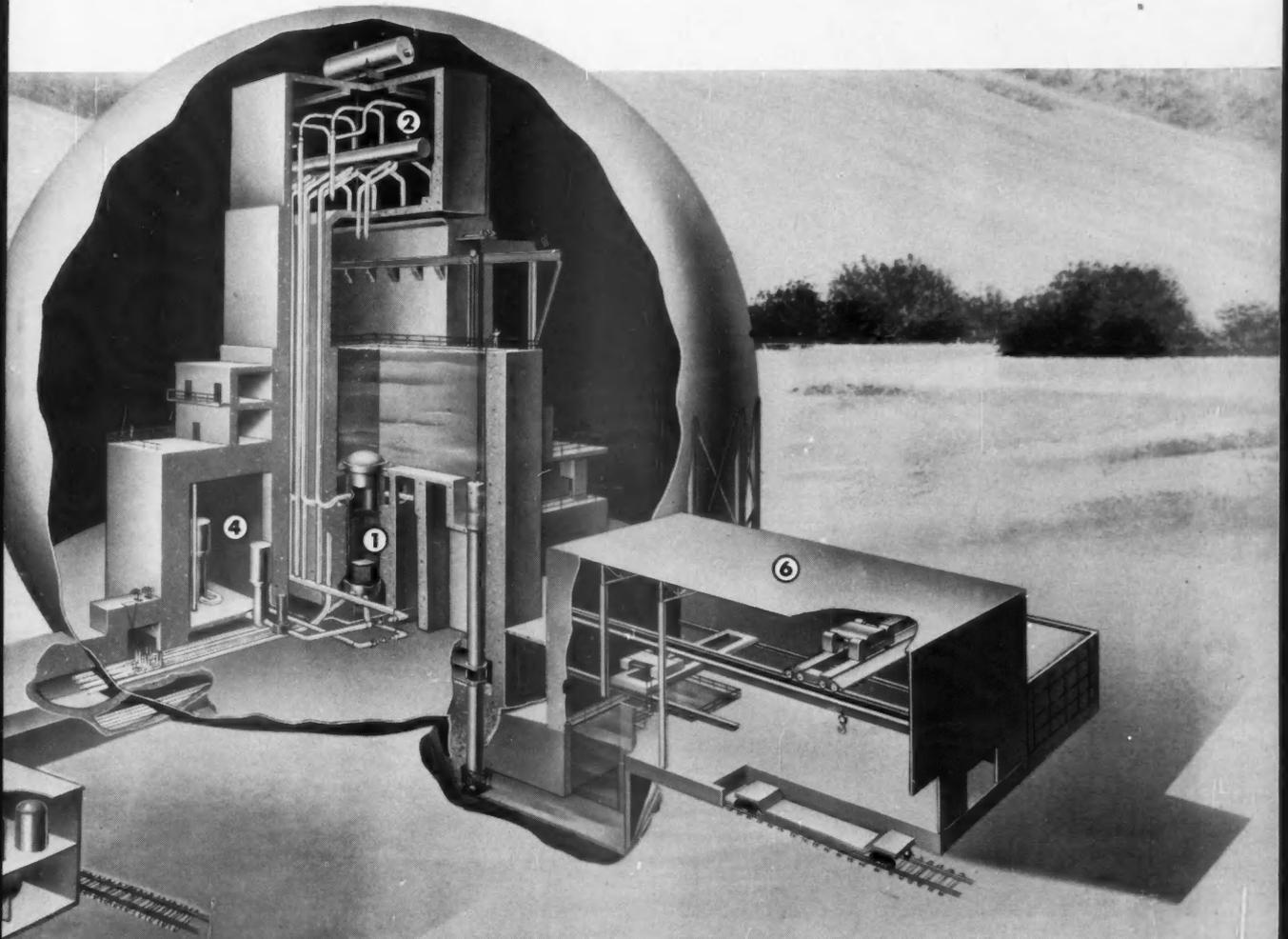


**Work to finish final design** on Commonwealth Edison's Dresden Station is progressing rapidly. Preliminary and design scope work has already been completed. Detailed construction designs are now 25% accomplished on the dual-cycle boiling water electric generating plant which will supply 180,000 kilowatts of electricity for Chicago by 1960.

**Manufacturing is already under way** as orders for major components—the 400-ton reactor vessel, a 190-foot-diameter sphere, turbine-generator, primary steam drum, secondary steam generators, and recirculating pumps—have been placed. Test loops have been built and experiments are being run to pretest some of the station's components.

After months of intensive design work, General Electric engineers and scientists report progress on the world's largest all-nuclear power station proceeding "on schedule." Atomic Power Equipment Department, General Electric Company, San Jose, California.

**FOR FURTHER INFORMATION** contact your nearest General Electric Apparatus Sales Office or write to: General Electric Company, Section 192-9, Schenectady, N. Y. for bulletins GER-1301, "The Dresden Nuclear Power Station"; or GER-1287, "A Review of Boiling Water Reactor Plants for Atomic Power Generation."



*Progress Is Our Most Important Product*

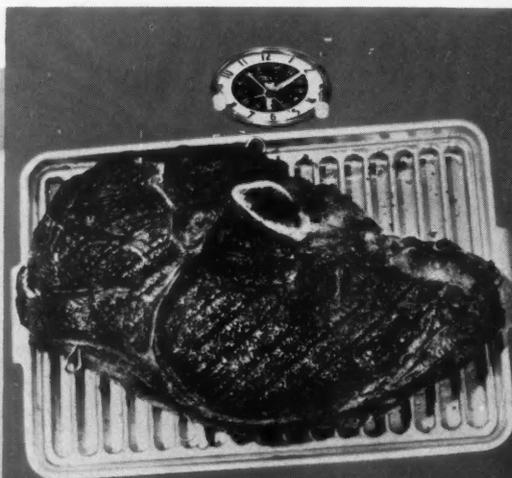
**GENERAL**  **ELECTRIC**

# Telechron Timers and Motors Help Keep America on Time!

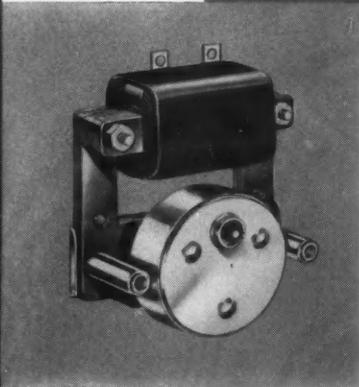
*Telechron clock-radio timers help wake America to music, operate appliances—automatically.*



*Telechron range timers time cooking for America then call the cooks when the food is ready—automatically.*



*Telechron TV timers turn TV on and off, remember America's favorite programs—automatically.*

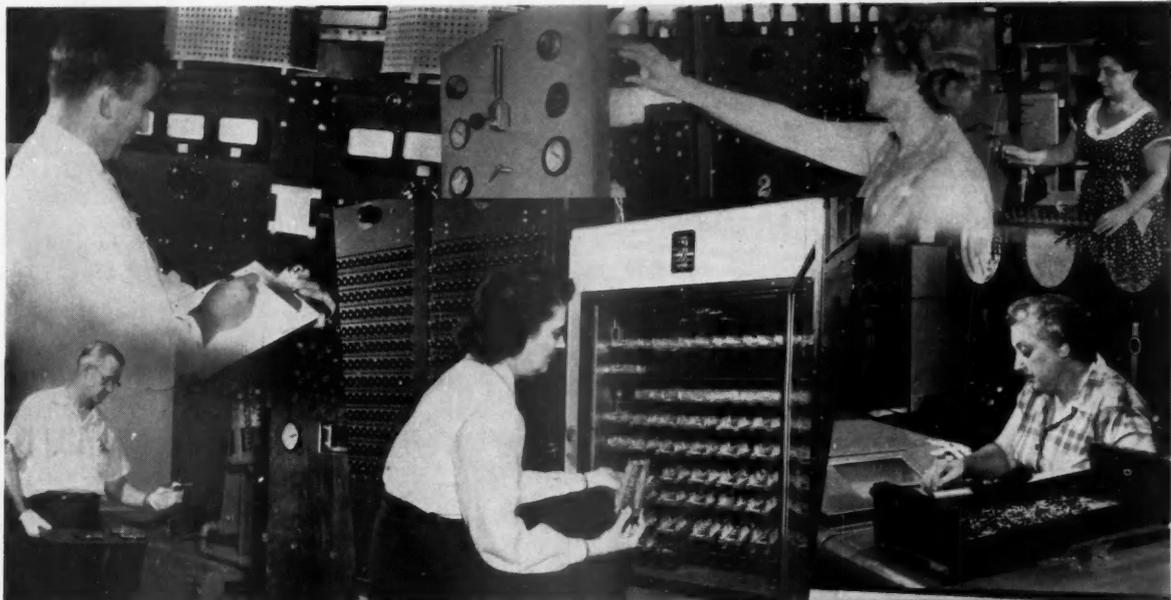


*Telechron timing motors come in a variety of sizes, torque ratings and operating frequencies to meet virtually every timing need in clocks, time switches, heating controls, precision instruments, fans, air conditioners, washing machines, other appliances.*

Write, wire or telephone for complete information.  
Telechron Timers and Motors, Clock and Timer Dept.,  
General Electric Co., 221 Homer Ave., Ashland, Mass.

## TELECHRON

MARK OF TIMING LEADERSHIP



*A progress report on General Electric semiconductors:*

## **DURING THE PAST 12 MONTHS, 8 IMPORTANT CONTRIBUTIONS IN THE SEMICONDUCTOR INDUSTRY**

1956 witnessed a year of great progress for General Electric Semiconductor Products.

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

- ★ Introduced a new silicon rectifier which operates at 150°C with full rating, delivers 250 ma at 400V PIV, without heat sink,
- ★ Produced a new germanium tetrode in a new, smaller package, for high frequency operation. Amplifies at 120 mc,
- ★ Developed a new silicon unijunction transistor—does the work of two transistors, simplifies circuitry, improves reliability,
- ★ Incorporated new techniques in transistor manufacture and design making possible the dependable, economical transistorized pocket radios,
- ★ Produced a new full line of high frequency transistors for computers and switching circuits,
- ★ Announced price reductions made possible by improved controlled processing manufacturing technique which cuts costs, improves product quality,
- ★ Manufactured an improved medium power germanium rectifier with an 85°C rating,
- ★ Shipped bulk quantities of small, highly-efficient silicon rectifiers capable of handling up to 50 amperes at 300 volts and 150°C.

In 1956, a combination of teamwork, skill, and hard work spotlighted General Electric as the company to watch for the latest developments in the semiconductor industry.

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

*But 1956 is history!*

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

*Here is our Promise  
for 1957—*

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

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

*Look to General Electric for the significant advancements in semiconductors. For further information, see your local representative, or, write: General Electric Company, Semiconductor Products Department, Section S357, Electronics Park, Syracuse, New York.*



## More scope for selection

### IN THE FULL LINE OF GENERAL ELECTRIC CABLES

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

This is one of the important reasons why General Electric wire and cable engineers have been able to help many industries with their electrical expansion and modernization plans. Another reason is General Electric's knowledge of the requirements of other basic components of power distribution systems—transformers, load centers, switch-gear, etc.—and the importance the right wire or cable plays in satisfactory system performance.

All this adds up to experience . . . the kind that can benefit you. Next time you have a cable selection problem it will pay to take advantage of General Electric's knowledge and experience.

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

\*Registered Trade-mark General Electric Company

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

# New 800-ampere circuit breaker is 30% smaller, cuts equipment size and cost

**General Electric breaks through the size barrier with the new KM circuit breaker. Now you can standardize on one compact frame size instead of three.**

Equipment such as panelboards, switchboards and motor control centers can now be reduced in size and cost. The new KM circuit breaker has the same interrupting ratings as the L frame, yet is 6½ inches shorter and only requires the mounting area of the K frame! It actually replaces three different frame sizes in ratings from 125 to 800 amperes—

the KL, L and M frames. As a result, panelboards and other equipment formerly requiring L frame breakers can be reduced in width at least six inches, saving valuable floor and wall space.

All the features available on General Electric molded case circuit breakers are built into the new KM. Trip units are interchangeable and there is a selection of enclosures and accessories for every application.

With the addition of the KM, General Electric has a complete line of circuit breakers, from 15 to 800 amperes, 120 to 600 volts, to meet your every requirement for capacity and performance. The KM is UL listed and deliveries will start shortly, so act now to take early advantage of size and cost savings in your equipment. For complete information, write Section GER, Circuit Protective Devices Department, General Electric Company, Plainville, Conn.



## RATINGS

POLES	AMPS	VOLTS
2	125-600	600 a-c, 250 d-c
	700-800	600 a-c
3	125-800	600 a-c

## INTERRUPTING CAPACITY—SAME NEMA RATING AS L FRAME

voltages	240 a-c	480 a-c	600 a-c	250 d-c
IC in amperes	50,000	35,000	25,000	20,000

(RMS asymmetrical)

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

*Designing tomorrow's turbine-generator today*

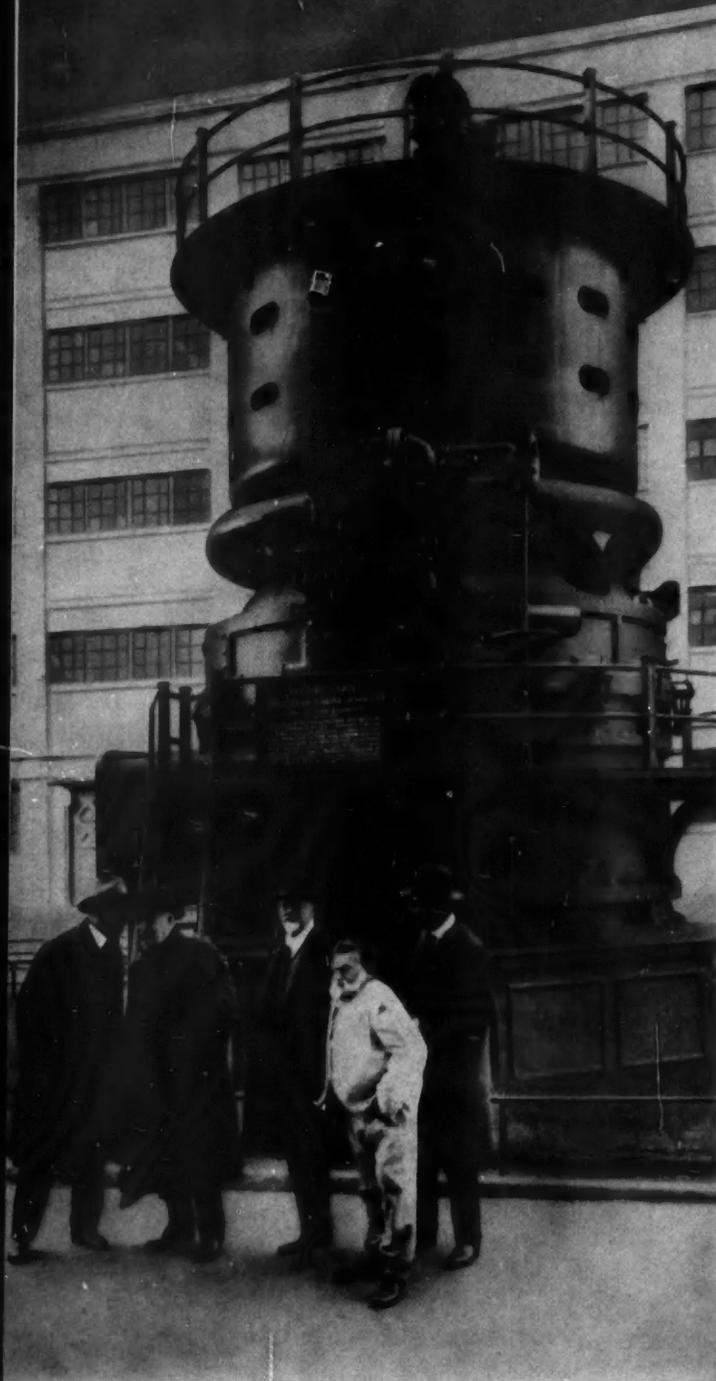
## 5000 to 450,000 KW... a tribute to 53 years of turbine-generator progress

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

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

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

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



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

*Progress Is Our Most Important Product*

**GENERAL**  **ELECTRIC**