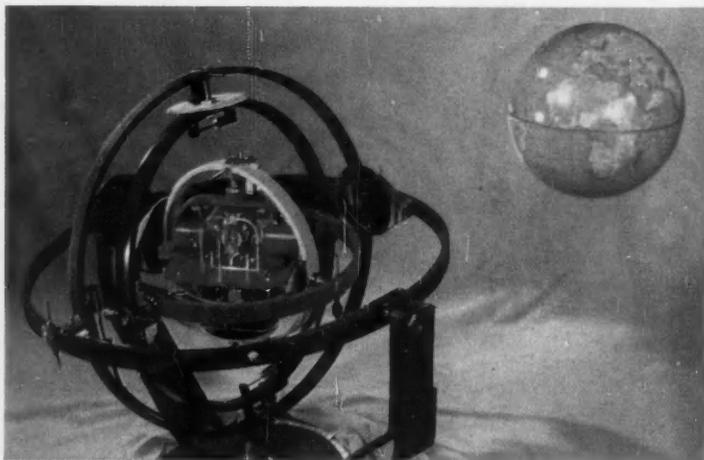
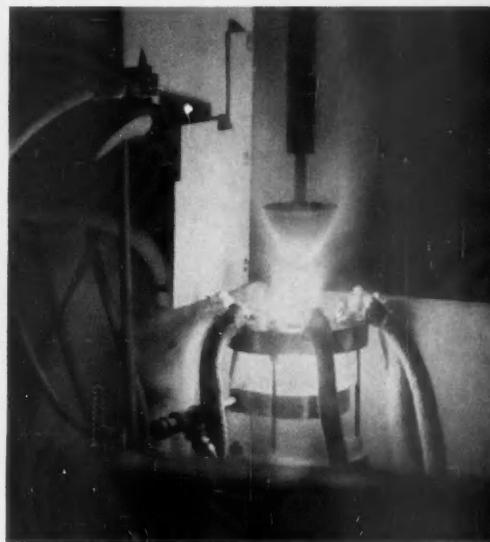


# GENERAL ELECTRIC *Review*

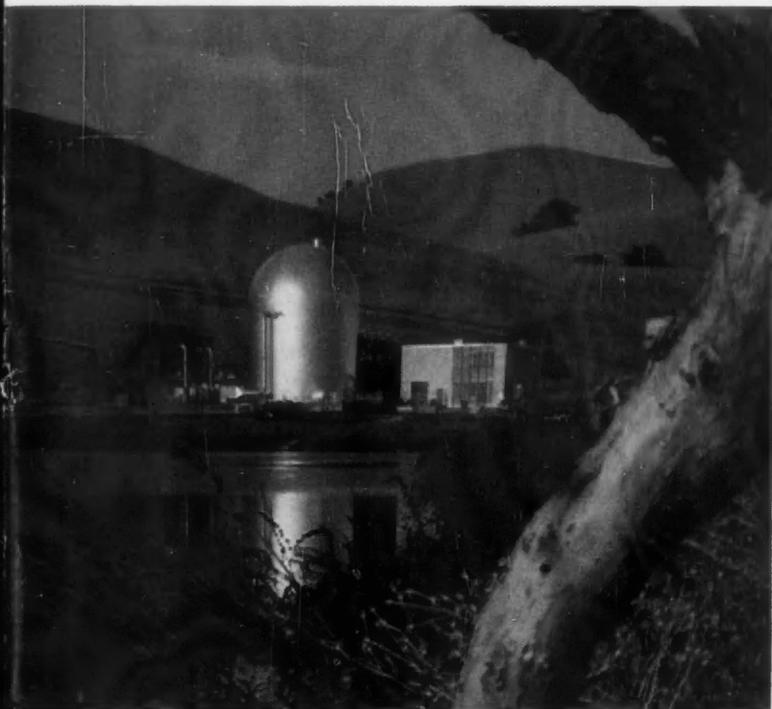
JANUARY 1958



All-altitude reference helps engineers analyze three-gyro system.



Missile nose cones developed by fluid-stabilized arc.



Vallecitos Atomic Laboratory boiling-water reactor powers 5000-kw turbine-generator.



Borazon—man-made crystals hard as diamonds.

Research and Engineering Progress • 1957

**Virgil L. Stout, Ph.D.**, University of Missouri (1951) joined the staff of the General Electric Research Laboratory in 1952, and now serves as manager of the *Physical Electronics Section*. He has specialized in the study of electron emission and gas-metal reactions.



## Reactions in vacuum

**General Electric's Dr. Virgil L. Stout helps improve vacuum tubes by learning basic facts about cathodes and anodes**

A key to basically better vacuum tubes is improved cathodes — surfaces that will emit more electrons with greater reliability. Several years ago at the General Electric Research Laboratory, experiments showed that cathodes using titanium as the base material had a very short life. In finding the fundamental reasons for the disadvantages of titanium in cathodes, Dr. Virgil L. Stout and his associates uncovered new knowledge explaining the metal's advantages as an electron collector.

Titanium, when used as an anode, was found to provide an unexpected bonus. In its reaction with barium oxide molecules, which evaporate from the cathode, titanium not only absorbs the unwanted oxygen but also lets the barium return to where it

started, thus maintaining the cathode's efficiency.

Dr. Stout's basic scientific contributions have helped his associates develop many electronic devices — among them a family of extremely small and efficient titanium-ceramic vacuum tubes that can operate at red heat and radar frequencies.

At General Electric, such research is motivated by a belief that providing scientists with the tools, the incentives, and the freedom to seek out new knowledge is the first step toward progress for everyone.

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

# GENERAL ELECTRIC Review

JANUARY 1958

VOLUME 61

NUMBER 1

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## RESEARCH AND ENGINEERING PROGRESS • 1957

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## COVER

A laboratory model assists in the analysis of the intricate 3-gyro unit, which is the key to an all-attitude reference system for aircraft (page 46). In permitting extreme temperatures, the water-stabilized electric arc helps solve problems of missile re-entry into the atmosphere (page 46). The country's largest privately financed atomic research facility, Vallecitos Atomic Laboratory in California, is supplying steam from its boiling-water reactor to power a 5000-kw turbine-generator (page 30). Science has created a compound, Borazon, not found in nature, which is as hard as the diamond and is stable at twice the temperature a diamond can withstand (page 8).

The GENERAL ELECTRIC REVIEW is issued in January, March, May, July, September, and November by the General Electric Company, Schenectady, NY, and is printed in the USA by the Magua Company. It is distributed to scientists and engineers throughout industrial, consulting, educational, professional society, and government groups, both domestic and foreign. . . . The GENERAL ELECTRIC REVIEW is copyrighted 1958 by the General Electric Company, and permission for reproduction in any form must be obtained in writing from the Editor. . . . The contents of the GENERAL ELECTRIC REVIEW are analyzed and indexed by the Industrial Arts Index, The Engineering Index, and Science Abstracts and are available on microfilm from University Microfilms, Ann Arbor, Mich. . . . For back copies of the REVIEW—1903 through 1954—contact P. and H. Bliss Co., Middletown, Conn. . . . Six weeks' advance notice and full address as well as new are necessary for change of address. . . . Send communications to Editor, GENERAL ELECTRIC REVIEW, Schenectady 5, NY.

**GENERAL  ELECTRIC  
COMPANY**

**CAPACITOR DEPARTMENT**

JOHN STREET, HUDSON FALLS, N. Y. . . . . TELEPHONE 4-3341

TO: Readers of the GENERAL ELECTRIC REVIEW  
SUBJECT: ENERGY STORAGE AND DISCHARGE CAPACITORS

Many of you are working on circuit problems involving the storage and discharge of large amounts of electrical energy. Here at the Capacitor Department we have been solving these difficult problems for more than 30 years. During this time, we have supplied numerous customers with large banks of energy storage and discharge capacitors.

For the past few years we have concentrated heavily on projects concerned with the A.E.C.'s fusion program. Some of the installations supplied for this program are rated in the millions of joules. An example is the large energy storage bank we recently installed at the General Electric Research Laboratory in Schenectady.

Still, we'd like you to know that our experience in designing and building energy storage capacitors is by no means limited to major installations. Our organization has been arranged so that we can handle a job of any size - from complex government contracts to modest commercial projects.

Our accumulated Research and Development may very well mean a solution to your particular design problems. For example, if you are working on a circuit involving low inductance, you will be interested to know that we have developed a capacitor which is rated at 50 kv and 1 microfarad with a ringing frequency of 1.6 mc. Low inductance, however, is only one of the many application problems we deal with every day. If you will write or call us we will be happy to discuss your circuit's requirements regardless of their nature.

Perhaps, however, you'd simply like additional information about energy storage. If this is the case just fill out the coupon below. We'll be glad to send you a copy of Capacitor Facts No. 4, "The Application of Large Capacitors for Use in Energy Storage Banks." I'm sure you will find it interesting.

Sincerely yours,

*D F Warner*

D. F. Warner  
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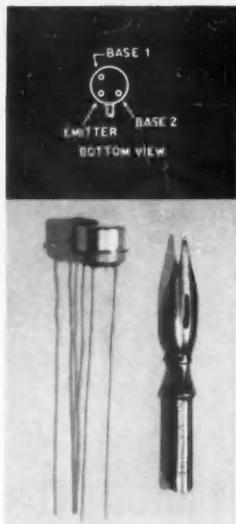
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## G-E Unijunction Silicon Transistor

**NOW FULLY CHARACTERIZED AND PROVED  
FOR USE IN SIMPLIFYING CIRCUITRY**

The unique advantage of the unijunction transistor lies in its open-circuit-stable negative resistance characteristics. The unijunction is the nearest solid state equivalent to the grid-controlled thyatron and is very sensitive to voltage levels. It is primarily useful in switching and oscillator applications. Not only will one unijunction do the job of two transistors (and with less circuitry) but the circuit will be more stable over a wide temperature range.

Technical data and application ideas are available to help you in studying the unijunction—the first device other than the transistor itself to reach commercial success. The six unijunction types can be obtained from most G-E Distributors, or write *General Electric Company, Semiconductor Products Dept., Section S50127, Electronics Park, Syracuse, New York.*

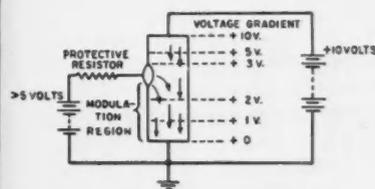
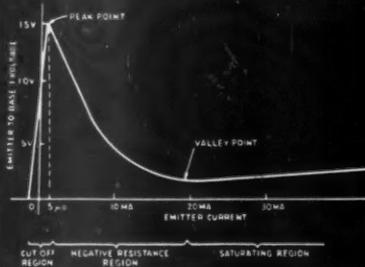
### SPECIFICATIONS OF THE SIX SILICON UNIUNCTION TYPES

#### Absolute maximum ratings (25°C)

RMS power dissipation	250 mw
RMS emitter current	50 ma
Peak emitter current	2 amps
Emitter reverse voltage	60 volts
Operating temperature range	-65°C to 150°C
Storage temperature range	-65°C to 200°C

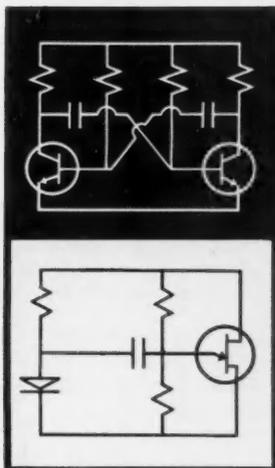
#### Major electrical characteristics (nominal)

	2N489	490	491	492	493	494	
Interbase resistance at 25°C junction temp.	5.6	7.5	5.6	7.5	7.5	5.6	kΩ
Intrinsic standoff ratio	.56	.56	.62	.62	.68	.68	
Modulated interbase current	12	12	12	12	12	12	ma
Emitter reverse current (T <sub>J</sub> =25°C)	.07	.07	.07	.07	.07	.07	μa
(T <sub>J</sub> =150°C)	28	28	28	28	28	28	μa



The unijunction consists of an "N" type silicon bar mounted between two ohmic base contacts, with a "P" type emitter near base 2. When the emitter is forward biased, emitter current flows, lowering the resistivity of the bar between emitter and base. Inherent regeneration results in a negative emitter to base 1 impedance. As the emitter current increases past the valley of the curve, the conditions for inherent regeneration cease to exist. The peak point of the curve shows the beginning of the negative resistance region.

Among the many simplified circuits possible with the unijunction (cutting transistor requirements in half) are a frequency divider, matrix switching circuit, low level d-c current-sensing circuit, temperature control element, phase and/or amplitude sensitive switch. The conventional multivibrator circuit (above right) requires even more circuitry than is shown if it is to be as stable as the comparable unijunction circuit shown below. A relaxation oscillator usually takes 4 resistors, 2 transistors and a capacitor. A single unijunction, a resistor and capacitor will do the equivalent job.



*Progress Is Our  
Most Important Product*



**GENERAL  
ELECTRIC**



Interview with General Electric's  
Hubert W. Gouldthorpe  
Manager—Engineering Personnel

## Your Salary

Although many surveys show that salary is not the prime factor contributing to job satisfaction, it is of great importance to students weighing career opportunities. Here, Mr. Gouldthorpe answers some questions frequently asked by college engineering students.

**Q. Mr. Gouldthorpe, how do you determine the starting salaries you offer graduating engineers?**

A. Well, we try to evaluate the man's potential worth to General Electric. This depends on his qualifications and our need for those qualifications.

**Q. How do you evaluate this potential?**

A. We do it on the basis of demonstrated scholarship and extra-curricular performance, work experience, and personal qualities as appraised by interviewers, faculty, and other references.

Of course, we're not the only company looking for highly qualified men. We're alert to competition and pay competitive salaries to get the promising engineers we need.

**Q. When could I expect my first raise at General Electric?**

A. Our primary training programs for engineers, the Engineering Program, Manufacturing Program, and Technical Marketing Program, generally grant raises after you've been with the Company about a year.

**Q. Is it an automatic raise?**

A. It's automatic only in the sense that your salary is reviewed at that time. Its amount, however, is not the same for everyone. This depends first and foremost on how well you have performed your assignments, but pay changes do reflect trends in over-all salary structure brought on by changes in the cost of living or other factors.

**Q. How much is your benefit program worth, as an addition to salary?**

A. A great deal. Company benefits can be a surprisingly large part of employee compensation. We figure our total benefit program can be worth as much as 1/6 of your salary, depending on the extent to which you participate in the many programs available at G.E.

**Q. Participation in the programs, then, is voluntary?**

A. Oh, yes. The medical and life insurance plan, pension plan, and savings and stock bonus plan are all operated on a mutual contribution basis, and you're not obligated to join any of them. But they are such good values that most of our people do participate. They're an excellent way to save and provide personal and family protection.

**Q. After you've been with a company like G.E. for a few years, who decides when a raise is given and how much it will be? How high up does this decision have to go?**

A. We review professional salaries at least once a year. Under our philosophy of delegating such responsibilities, the decision regarding your raise will be made by one man—the man you report to; subject to the approval of only one other man—his manager.

**Q. At present, what salaries do engineers with ten years' experience make?**

A. According to a 1956 Survey of the Engineers Joint Council\*, engineers with 10 years in the electrical machinery manufacturing industry were earning a median salary of \$8100, with salaries ranging up to and beyond \$15,000. At General Electric more than two thirds of our 10-year, technical college graduates are earning above this industry

median. This is because we provide opportunity for the competent man to develop rapidly toward the bigger job that fits his interests and makes full use of his capabilities. As a natural consequence, more men have reached the higher salaried positions faster, and they are there because of the high value of their contribution.

I hope this answers the question you asked, but I want to emphasize again that the salary you will be earning depends on the value of your contribution. The effect of such considerations as years of service, industry median salaries, etc., will be insignificant by comparison. It is most important for you to pick a job that will let you make the most of your capabilities.

**Q. Do you have one salary plan for professional people in engineering and a different one for those in managerial work?**

A. No, we don't make such a distinction between these two important kinds of work. We have an integrated salary structure which covers both kinds of jobs, all the way up to the President's. It assures pay in accordance with actual individual contribution, whichever avenue a man may choose to follow.

\* We have a limited number of copies of the Engineers Joint Council report entitled "Professional Income of Engineers—1956." If you would like a copy, write to Engineering Personnel, Bldg. 36, 5th Floor, General Electric Company, Schenectady 5, N. Y. 959-7

LOOK FOR other interviews discussing: • Advancement in Large Companies • Qualities We Look For in Young Engineers • Personal Development.

# PROGRESS IS NOT AUTOMATIC, BUT...

Evidence of great progress in material things is all about us. The engineer and scientist can be proud of their contributions. Products are larger or smaller, more powerful or consume less power, more complex or simpler.

As you look at your company's accomplishments of the past year—you'll see ours recorded on the next 51 pages—you could easily be lulled into the feeling that progress is inevitable.

This confidence in automatic progress can be attributed, in part, to the rapid growth and development of a young nation—rich in natural resources and ingenuity.

Another factor nourishing the "inevitability of progress" theme, particularly at the turn of the century, was the anti-Biblical pantheistic philosophy of Hegel and others.

Today, in some areas, a tendency exists to place emphasis on the State as the motivator of progress. One observer of the American scene, commenting on the liberal spending habits of suburbia's inhabitants, says: "Not only do [they] accept the beneficent society as normal; they accept *improvement*, considerable and constant, as normal too." The opinion that the government knows exactly how to keep progress going and would step in to prevent it from slipping prevails in suburbia and other areas.

Although absolute and inevitable progress is not automatic, three long-term forces, as we see it, underlie the strength and growth of our economy . . .

. . . *The assured growth in our population*—As the youngsters born in the 40's and 50's set up households in the 60's and 70's, they will provide a great new market. Although a liability in many parts of the world, population growth so far has been an asset in an economy such as ours. But sheer masses of people will not sustain prosperity or progress alone: increasing productivity should go hand in hand with an increase in population. Investments in automation and other technological improvements offer valuable means of achieving an acceptable solution to this challenge. If such progress is hampered by the limited thinking of businessmen, professionals, union officials, politicians, or any other elements of our society, we'll be in for an era of ruinous shortages and sky-rocketing inflation.

. . . *The desire of the American people for better living equipment*—Americans have decided that steadily rising levels of living along with economic stability are desirable and achievable. This decision is evidenced by burgeoning consumer credit, the sharp rise in insurance and pension funds, the intense political activity for the so-called "government stabilizers" in our economy. If business ignores these signposts, the

people will turn to superficial political and economic approaches that will prove destructive.

. . . *Our rapidly expanding technology*—Prior to World War II, relatively small investments were made in research and development. But from these meager beginnings grew the nucleonics and electronics industries and the gas-turbine jet-engine business. Research and development expenditures of business totaled \$4½ billion during 1955 and rose to more than \$7 billion last year. With the inevitable time lag between investment and return, the former hasn't yet paid off. But the results are obvious: the impact on the future will be tremendous. This rising pressure of new ideas, new products, and new services is a potential "built-in stabilizer" in our economy and will keep us moving ahead.

As professional people in business, we can manage our economic, social, and professional actions—and the inter-relations between all three—to help insure progress for all by . . .

. . . *Encouraging innovations*—We must give our enthusiastic support to the pioneering products and the pioneering ways of doing business—initiated by the truly dynamic enterprises in our competitive economy. This means not only giving our professional support for projects in which we are involved but also helping our fellow citizens gain a better appreciation of the way innovation will benefit all—how it will make more of the good things of life available from a proportionately smaller input of "personal horsepower."

. . . *Working efficiently and creatively*—As true professionals, we must give our full skill, care, effort, and above all, our thoughtful consideration of the common goal—simply doing our job better. For in the long run progress cannot come without increased productivity.

. . . *Encouraging an understanding of our free-business system*—We must become more alert to the social and political forces in our country. We must know more—and encourage others to know more—about the economic, political, and ethical principles that energize this *people's capitalism*. We must constantly help all concerned to develop the economic information and political sophistication needed to understand business and intelligently analyze the attacks against business. The role of profits and their importance to everyone must be better understood. Our children must be trained to understand and appreciate true value, not the superficial ones so prevalent today.

The something each of us puts in as a professional furnishes the ingredient that makes possible the something we get in return: continuing progress both for individuals and all mankind.

*Paul R. Heinmiller*

EDITOR



**BORAZON UNAFFECTED AS DIAMOND BURNS:** Picture sequence, taken at 30-second intervals, shows how a small gem placed on a resist-

## Research

The time-honored belief that "only diamond scratches diamond" became obsolete in 1957 when General Electric announced the discovery of an entirely new material never found in nature. *Borazon*, the Company's name for its cubic boron nitride, scratches diamond with ease and remains hard at temperatures of more than 3500 F, while diamond literally burns up in air at about 1600 F. Scratch tests and other experimental methods prove that the new material is in the same general range of hardness as diamond and thus many times harder than the next-ranking materials in the hardness scale. In lapping tests, borazon powder polished away the surface of a large diamond at the same rate as diamond powder.

The new material was discovered by a member of the research team whose work produced man-made diamonds, and similar techniques were used to produce the diamond-like crystals of boron nitride (Cover).

Borazon is an example of the kind of result that can be expected of an extensive research organization operating in the climate of our free-enterprise system. Stimulated by the cross-fertilization of ideas so important to scientific advancement, the scientist who developed borazon had one other advantage of the large organization: backed not only by research and development facilities but also by a manufacturing organization, he could reasonably expect that his discovery's potential—whatever it might be—would eventually reach the public marketplace.

A unique electronic device called a thermionic converter has achieved direct conversion of heat energy into electric energy. Experimental models

have already changed more than 8 percent of the applied heat energy to electric power. The device takes advantage of the fact that electrons can be "boiled out" of a hot metal surface and used to produce an electric current directly.

Thermionic converters combine several known scientific principles in a unique manner. Two electrodes within the tube-like device are maintained at high but different temperatures. New approaches to the design of the electrodes, the materials used, and the gas environment within the envelope have resulted in a more efficient flow of electrons than ever before observed.

Scientists have long used the thermocouple for measurement and control functions requiring low-efficiency conversion of heat into electricity without rotating machinery. One obvious difference between this device and the thermionic converter: in the converter the metals are separated by a gas at very low pressure. An electrical flow exists between the electrodes, but there is less flow of heat than through a metal. Thus the electrodes can be at different temperatures, and the efficiency becomes greatly increased. Ultimately thermionic converters may be able to change more than 30 percent of heat energy directly into electricity.

### Silicon

Knowledge in other fields of chemistry advanced significantly. For example, progress in silicon technology foreshadowed new developments in rectifiers, transistors, and photosensitive devices.

To aid these various programs, a pilot scale unit was constructed for making high-purity silicon by a chemical process. This process requires that silicon

tetraiodide be formed from commercial silicon and iodine in a fluid bed reactor. Impurities are rejected from the iodide by solvent recrystallization followed by fractional distillation. High-purity silicon is then formed from the iodide by decomposition on a hot silicon surface.

Silicon made this way has a resistivity of more than 1000 ohm-centimeters when evaluated by crucible-grown crystals. Lifetime has ranged up to 350 microseconds.

### Hypersonics

In support of the Company's missile development work, important new facilities were put into operation this year. A hypersonic helium tunnel began producing aerodynamic information at extremely low temperatures and reached Mach 28 in helium. At the same time a hypersonic shock tunnel, one of the largest in existence in the US, set a new record for equipment of this type by producing flow conditions approaching Mach 20, at temperatures close to 10,000 K.

### Flame Propagation

Science has long sought means to identify and measure the intermediate transient substances that exist in flames, presumed to be important in flame reactions and hence in the flame-propagation mechanism. In a hydrogen-oxygen flame, for example, the free radicals OH, H, and O should be present in concentrations very much larger than equilibrium. Although emission spectroscopy shows the presence of OH, no reliable concentration measurements were made until lately. The detection and measurement of H atoms by an indirect method in the burned gases from flames were accomplished only very recently by British scientists.

General Electric scientists have now succeeded in making direct measure-



ance heater disappears at temperatures exceeding 1600 F. General Electric's man-made material—in the same range of hardness—stays intact.

ments of OH concentration by means of a light-absorption method, and O and H concentrations were measured in the flame gases by following chemical reactions whose rates depend on these atoms in a known manner. All 3 substances were shown to be present under some conditions in concentrations much higher than corresponds to thermal and chemical equilibrium. The new technique allows a much wider variation in the experimental conditions than the British method does and gives promise of a better understanding of the flame-propagation mechanism.

Although the formation of a detonation from an ordinary flame readily occurs in certain explosive mixtures and has been observed and studied for a long time, the mechanism of the formation is poorly understood. In this process a combustion wave, or flame, with a velocity of a few meters per second and a negligible pressure ratio across the wave becomes a coupled shock-and-combustion wave with a pressure ratio of 15 or more and a velocity of about 2000 meters per second. A detonation can accordingly be extremely destructive—especially just before the constant-velocity wave is formed. Studies have recently been made of this aspect of the subject.

Further investigations reveal some important features of the detonation during its late stages.

Interferograms taken of a hydrogen-air detonation originating from a flame, using a 0.2-microsecond spark light source, show a boundary layer associated with the flow produced by a series of gradually steepening pressure waves, which in turn precede the flame. This causes the strengthening of the pressure wave, or shock, near the wall of the tube that results in a higher temperature there; the interferograms also indicate that this heating eventually causes ig-

nitiation of the mixture at the wall. The combustion can then propagate inwards and backwards, consuming the heated but unburned mixture between the pressure wave and the following flame, strengthening the shock eventually so that it can ignite the mixture over the whole tube cross section.

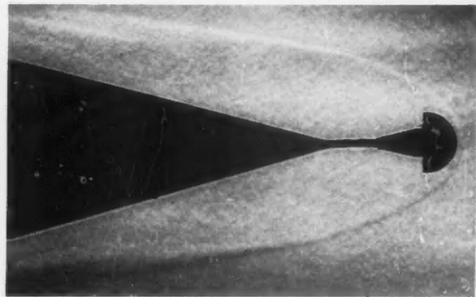
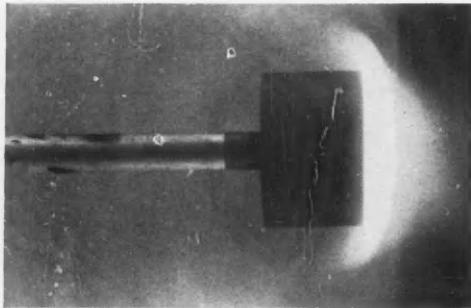
#### Viscosity Measurement

In simple fluids, the response to shear forces depends on 2 properties: density and viscosity. In more complex fluids, such as those containing high-polymer particles, the viscosity may change with the rate of flow or the rate of change of the flow. The latter behavior is impor-

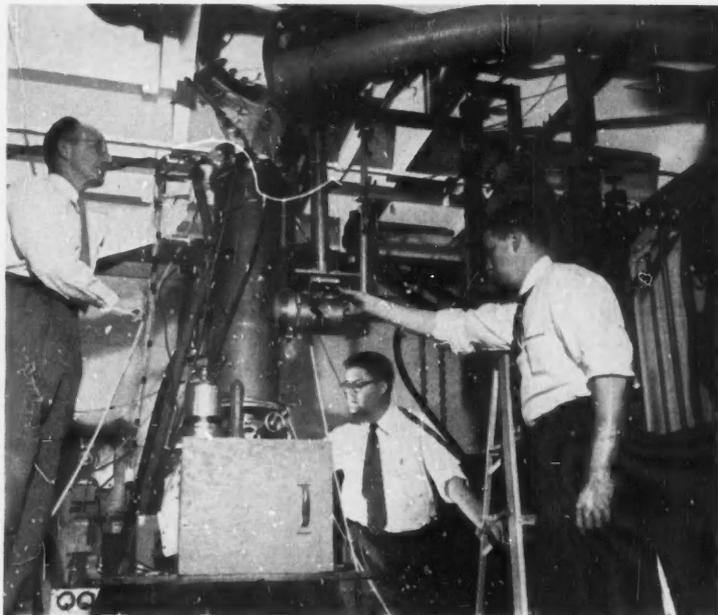
tant not only for its technological implications—as in vibration dampers, for example—but also as a research tool, because the change of the viscosity is usually a reflection of a specific time-dependent molecular process. General Electric scientists developed a device that can measure the changes in viscosity of a solution versus the frequency of its oscillating flow. The curve that results from these measurements reveals the polymer's molecular weight and even the distribution of molecular weights if all the molecules of the sample are not of the same weight. The ease with which the new apparatus gives results over an interesting frequency



**THERMIONIC CONVERTERS**, designed in many experimental versions, have already achieved the direct conversion of more than 8 percent of the applied heat energy into electric power.



**MISSILE NOSE MODEL** is tested in hypersonic shock tunnel at Mach 10, in helium tunnel at Mach 28.



**BOMBARDMENT** of high-purity copper with electrons at less than 10 degrees above absolute zero provides improved test of radiation damage at low temperatures.

range suggests that it should be useful in a considerable number of problems.

Recent studies of discharges within insulating materials reveal marked differences between those containing natural and artificial voids. Compared with artificial voids, the voltage necessary to cause breakdown with natural voids proved to be 2 to 4 times the calculated figure. This assumes that the field in the void was uniform and that the natural voids were in the form of prolate spheroids rather than cylinders.

### Magnetism

Not all regions of a ferromagnetic material are magnetized in the same direction. Between 2 regions magnetized in different directions there is a transition zone called a *domain wall*, in which the magnetization changes its direction. The theoretical ideal geometrical configuration for these walls was formulated in the 1930's, but until last year only approximations to this ideal behavior had been seen. Now these ideal configurations have been observed in small "whiskers" of iron. Some entirely new kinds of walls, not predicted theoretically, were also seen.

When a magnetic field is suddenly applied to a ferromagnetic material, the domain walls move. The larger the field, the faster they move. In small, nearly perfect, iron metal whiskers, the walls can be observed for the first time moving at velocities of Mach 10, or 10 times the

velocity of sound in iron. Moreover, the walls appear to have trouble breaking through something similar to a sound barrier, just as does a jet plane.

Bombarding solids with high-energy radiation disarranges their normal atomic structure and may cause profound changes in their physical properties. Although much empirical information about such property changes exists, knowledge of the fundamental mechanisms involved in this radiation-damage process is limited, with poor agreement between theory and experiment.

Studies were made of the resistivity changes induced in high-purity copper by bombardment with electrons ranging from 0.8 to 1.5 million volts and with ambient sample temperature less than 10 degrees above absolute zero. Such low-temperature bombardments produce the simplest kind of radiation damage, and the results provide a better test of theory than earlier experiments.

Research in ceramics has led to the vapor growth of "perfect" crystals of aluminum oxide (melting point 2000 C), the hardest and strongest oxide from which whiskers have been grown. These crystals—grown between 1700 and 1900 C—are tiny blades several millimeters long, about 10 microns wide, and less than a micron thick. The measured strength is near the theoretically reported value of more than 2-million psi; the highest previously reported was for iron whiskers at 1.9-million psi.

Whiskers of forsterite, typical dimensions  $3 \times 0.1 \times 0.004$  mm, were grown in the vapor phase at temperatures from 1400 to 1700 C. A tensile strain of 1.5 percent was observed. Ordinary crystals usually break at elastic strains of less than 0.1 percent.

Molybdenum trioxide whiskers, grown at 700 to 750 C and about 20 microns wide and 5 mm long, exhibited a tensile strain of 1 percent. When examined under the electron microscope, they appear to have extremely smooth surfaces.

All these oxide whiskers are transparent and can be bent elastically. A striking illustration of an organic whisker is trioxane. Fibers several inches long can be grown in the vapor phase, its ultimate length apparently being limited only by the dimensions of the vessel. These fibers, about 20 microns thick at their tip, can grow at rates up to 0.5 cm per second in the axial direction.

Announced during the year was the development of a new, doubly oriented, silicon iron sheet that is expected to find use as a soft magnetic-core material in many kinds of electric equipment, owing to the opportunity it offers for reducing core losses and noise. It differs from material now available commercially in that 4 directions of easy magnetization, instead of 2, occur in a 90-degree relationship in the plane of the sheet. Thus a magnetic circuit of square or rectangular shape, consisting entirely of the easy directions of magnetization in iron,



**REDUCED CORE LOSSES** characterize doubly oriented iron sheet (left), are less than for best sheets now used as soft magnetic core.



**FUSION RESEARCH PROGRAM**, using giant capacitor bank, seeks safe, inexpensive power from hydrogen bomb process.

can now be completed. Although not commercially available, a limited quantity is being prepared in the laboratory for evaluation.

#### Analytical Techniques

Analytical chemistry techniques were developed for the automatic titration of metals to eliminate many tedious gravimetric procedures in determining alloy constituents. Ethylenediaminetetraacetic (EDTA) acid forms sufficiently stable complexes with many metal ions to permit direct titrations. However, use of this reagent involved 2 serious disadvantages: 1) EDTA forms stable complexes with so many metals that all constituents of an alloy generally interfere in a titration and 2) the means previously used for determining the end point of the titrations are suitable only for small amounts of material. The first disadvantage was overcome by the application of ion exchange resins as a means of rapid separation of a large number of elements, the second disadvantage by designing and building an electronic circuit that automatically terminates the titration at the end point.

The methods commonly in use for the analysis of alnico, as an example, require 2½ days of work by 2 analysts. With the new technique 1 analyst can easily perform the same determinations in a day with equal accuracy. The procedure can be applied to many combinations of metallic constituents, making a

single analytical technique now suitable for a large variety of alloys.

A cobalt-nickel base alloy, Cast J-1650, was developed for high-temperature high-stress applications. This alloy, used in the cast condition, has a higher strength than materials currently employed in jet engines and other high-temperature applications. It combines high strength with good oxidation resistance.

Despite the many scientific advances in magnetism, it is not understood why iron, as well as nickel and cobalt, is only half as magnetic as it could be.

Further experimental evidence is improving the understanding of this aspect of ferromagnetism. General Electric scientists are studying the ferromagnetic behavior of metals while their atoms are pushed closer together by means of very high hydrostatic pressures. Preliminary measurements were made at 45,000 psi—a point where the saturation magnetization of iron decreased by ¼ percent. Plans call for extending these measurements to 750,000 psi (when the atoms will be 1 percent closer together) by applying techniques developed in making diamonds.

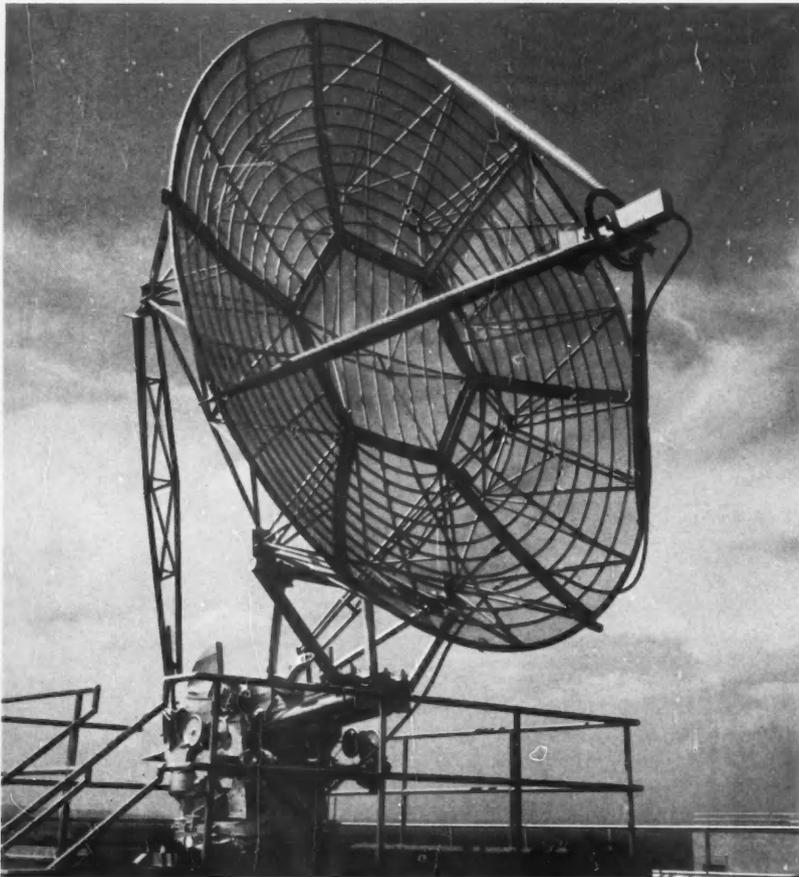
Materials—under repeated application of temperature, deformation, or load—can fail by a mechanism known as fatigue. By investigating the resistance of a variety of metals in the low-cycle range of fatigue failure, it has been established that the plastic strain range in

each cycle is particularly important. This range can be related to the number of cycles required for failure by a very simple empirical relationship, such that the number of cycles withstood varies inversely with the square of the plastic strain range. That this relationship appears to hold down to ¼ cycles, a condition equivalent to a simple tension test, also proves significant. Thus, a quantitative agreement between fracture ductility in tension and the resistance to failure in fatigue has been demonstrated.

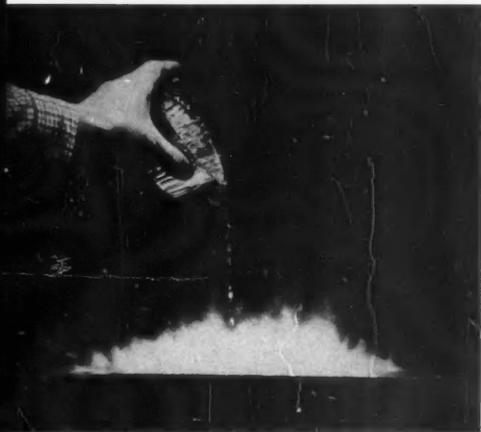
#### Fusion

Safe, inexpensive power from the fundamental process of the hydrogen bomb represents the goal of a "substantial research program to study the fusion process," under way at the Research Laboratory for more than a year. In announcing this research program, Dr. Guy Suits cautioned that, in his opinion, a realistic appraisal of the process would take at least 5 additional years; 10 years might be required to bring it to a point of technical feasibility, and pilot plant production might not occur for another 10 years. "But we are convinced that the ultimate importance of safe and inexpensive power from hydrogen makes it essential for us to study the problem right now," declared Dr. Suits.

A number of new observations have been made of structure changes that occur in hollow and solid electron beams



**TROPOSPHERIC SCATTERING**, given special attention in a study of the propagation of radio waves, is traced by an antenna at the Research Laboratory, Schenectady.



**VOLATILE LIQUID** is poured on vibrating plate during vibration-pattern studies.

confined by a magnetic field. When a spread occurs in the forward component of the electrons' velocity, the density of electron paths in a beam may become nonuniform. This could happen either because of a spread in initial angle of the electrons or because of a potential de-

pression in the beam. Additionally, changes in beam shape and transverse velocity components of the beam electrons might result from the drifting of electrons in crossed electric and magnetic fields; in this case the electric fields would be provided by the space charge of the electrons themselves. Not only have thin beams been found to be unstable but they also divide into an array of vortex-like current filaments under sufficiently high beam current. A connection between this and phenomena in the aurora borealis has been suggested.

A new mechanical device that simulates the motion of an electron inside an electron tube uses ball bearings as the "electrons." Fed into the device through a funnel, the electrons are rolled out onto an inclined plane by means of a rotating cylinder. As they travel down the plane, it is raised and lowered to represent the action of the grid in a tube. Upon reaching the end of the plane, they drop off into a beaker, representing the anode in an electron tube. A camera

mounted overhead records their path. This apparatus permits the study of electron bunching that occurs as a result of the voltage imposed on the grid.

#### Radio-Wave Studies

Studies are under way into the mechanisms that affect radio-wave propagation at distances of 100 to 500 miles, with special attention being given to the scattering that occurs in the troposphere (ground level to 30,000 feet). In conjunction with the USAF and the Cambridge Research Center, a team of scientists at the General Electric Research Laboratory in Schenectady is studying transmissions at 915 megacycles beamed from Bedford, Mass., some 135 miles away. Receiving stations are being operated by other groups at Syracuse and Buffalo along a great circle course some 400 miles long. Short-time fading characteristics, available bandwidth, and the effects of such variables as atmospheric temperature and water-vapor distribution are being investigated. It is hoped that these studies will result in valuable data for communications engineers and in a better understanding of the phenomena underlying radio-wave propagation.

By using a new type of cathode, *extended interface*, improved operating characteristics have been achieved in vacuum tubes. The design takes its name from a sponge-like metal layer that serves as the cathode base. The electron-emitting material penetrates throughout the sponge and forms the surface on top of it. Among the successfully used materials are a sponge layer of titanium-nickel alloy and an emitting material of barium-strontium oxide. The advantages of these cathodes include higher electron-emission densities, greater resistance to cathode poisoning, and ability to operate satisfactorily in relatively poor vacua. Developmental models of these cathodes are being evaluated in gas thyratrons, traveling-wave tubes, and triodes in power-tube applications.

An effort to improve electron-tube reliability by eliminating variables caused by material collection on grid and anode electrodes has resulted in the use of materials and operating conditions that produce new and useful electrical characteristics. Tubes made for operation in this manner have fewer parts and function with fewer components than conventional tubes. Clean electrodes can be obtained in electron tubes by using active metal surfaces and high degassing and exhaust temperatures.

Cleanliness can be maintained for long periods by using the electrodes with only oxide-coated cathodes having a passive base metal. Tubes with clean electrodes exhibit low levels of grid and anode emission. A diode having a clean anode surface can be made to operate reliably in the emission-limited region; a triode having a clean grid surface can be made to have a built-in grid bias of 2 volts or more.

#### **Ionization Gage**

A new ionization gage has been invented that can measure gas pressures considerably smaller than the  $10^{-10}$  mm limit of the best available ionization gage. This gage has been tested down to  $2 \times 10^{-12}$  mm Hg; calculations indicate that it should operate down to pressures of  $10^{-15}$  mm Hg, a pressure not much greater than that estimated to exist in interstellar space. In appearance, it resembles an empty milk bottle, because all of the electrodes except the filament are transparent tin-oxide layers deposited on the inner surface of the glass bulb. Electric and magnetic fields force the electrons emitted from the filament to perform very long trajectories. The average electron travels approximately 600 miles before reaching the anode, greatly increasing the probability of collision with atoms of the residual gas.

A whole new class of microwave tubes, known as extended interaction devices, is being explored. In this type of tube, a moving electron stream interacts with a traveling electric field in a long resonator rather than with a fixed field, as has been the case in previous types, thus providing interaction over an extended range of time and distance. Microwave devices have previously offered either high stability and very narrow bandwidth—as in the klystron—or low stability and broad bandwidth—as in traveling-wave tubes. With extended interaction it is possible to achieve an intermediate bandwidth plus high stability, high gain, and high efficiency.

#### **Semiconductors**

During 1957, a silicon carbide rectifier operated at temperatures up to 1200 F. Similar devices made with other semiconductor materials, notably silicon, had previously operated only up to the 400–500 F range. This silicon carbide rectifier also operated at temperatures as low as  $-100$  F.

Semiconductors are now being employed in fundamental studies of the

kinetics of precipitation of impurity elements from supersaturated solid solutions. Because elemental semiconductors can be made with such great chemical purity and high crystalline perfection, it is possible to separate clearly for careful study several different mechanisms of precipitation that go on simultaneously in most other materials. To date, the role of dislocations in catalyzing the precipitation of copper in germanium and silicon has been worked out. Current effort is directed toward understanding the effects of concentration and thermal history upon precipitation rates of impurities in semiconductors.

A simplified theory has been developed for the growth of precipitate particles of various shapes from a supersaturated solution. In addition to making possible the calculation of precipitation rates under various conditions, the theory revealed several previously unrecognized features of precipitation processes. Particularly, it has shown that under diffusion-limited conditions, spheroidal particles grow with constant eccentricity and that plate- and rod-like particles possess a growth law qualitatively identical with that of spherical particles.

#### **Vibration-Pattern Studies**

A thin layer of a volatile liquid instead of a sprinkling of sand or dust on a vibrating plate provides greater visibility in vibration-pattern studies. A magnetostriector beneath the center point impresses up-and-down motion on the plate, causing flexural waves to spread in all directions. Energy imparted to the plate is dissipated partly in the metal itself, partly in the liquid layer, and partly in the surrounding air.

Maximum activity in the liquid is observed directly above those points on the plate where up-and-down velocity is greatest. With a relatively thick layer of liquid on the plate, large quantities of fog appear.

With less liquid present to help absorb energy by boiling, a large fraction of the energy radiates into the air. When the liquid almost completely boils off the plate, the airborne sound becomes strong enough to exert appreciable radiation pressure upon the droplets above. Radiation pressure then causes long delicate upward strands of fog, resembling tongues of flame.

#### **Photoconductors**

Insufficient control over the chemical purity and structural perfection of the

semiconductor has hampered studies of most photoconduction materials. But recent work has revealed that very close control over the impurity content of nickel-doped germanium can be obtained. This has made possible quantitative studies of the performance of this material as a photoconductor. Now, it's possible to measure how the photoconductivity depends upon the concentration of the nickel impurities and upon their electric charge. The results of these measurements have been shown to be consistent with a theory of impurity-controlled photoconduction.

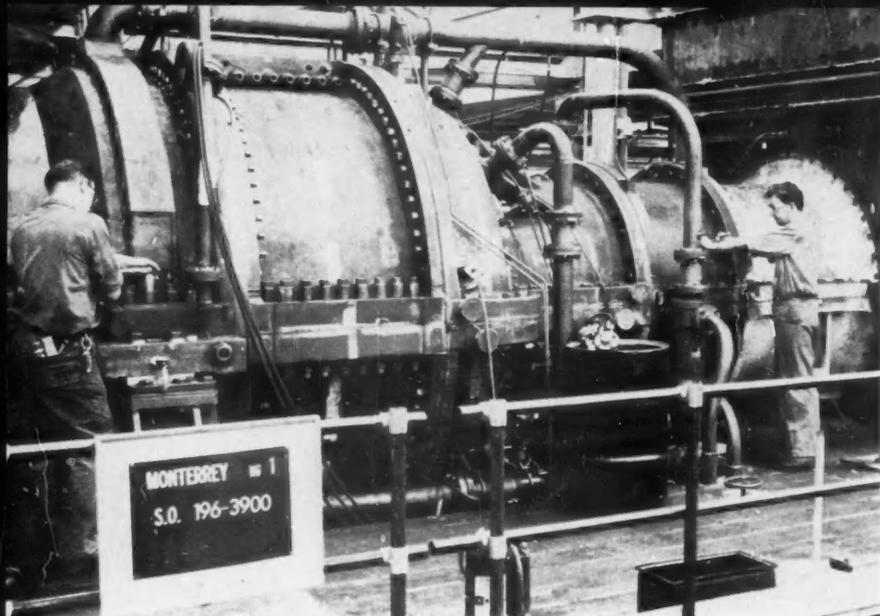
#### **Phosphor Films**

Extension of the development of thin, transparent phosphor films makes practical a former type of color cathode-ray tube. This tube, called the *penetron*, has a face plate coated with 2 thin layers of phosphor, each capable of emitting a different color. By shooting electrons into the first layer only, it emits its characteristic color. By shooting higher energy electrons that go through the first and into the second layer, another color is produced. Thus voltage applied to the electron gun controls the screen color. Changing the color increases the amount of information that can be displayed. The new tube is characterized by greater color purity and lower operating voltage.

#### **Gas Tubes**

A new process was developed for making clean gas-discharge tubes for operation in critical environments. Tube assemblies of forsterite ceramic and titanium are outgassed and sealed together in an atmosphere of the noble gas with which they are to be filled. The gettering action of the hot titanium results in a very pure gas filling. Also, as a result of the high processing temperature, gas has little chance of evolving from the tube parts during life and contaminating, or reacting with, the cathodes.

Some examples of the gas tubes constructed by this new process: voltage regulators, voltage reference tubes, thyratrons, trigger tubes, and spark gaps. They have exceptionally constant and reproducible characteristics, can be operated at ambient temperatures up to 500 C, are more rugged than conventional types, and in addition they can withstand high neutron-radiation flux densities.



**GAS TURBINE**, rated 16,500 kw and one of the largest ever built, operates in Mexico.

## Power

The year 1957 witnessed a trend to take greater advantage of the economies of large generating units. Now on order are several units in the 300,000-kw class, with some electric utilities planning units of 500,000 kw. All these larger units are of the cross-compound design.

The use of larger-size units and higher steam pressures—the first supercritical-pressure steam turbine-generator went into operation last year—has made turbine-driven boiler-feed pumps more attractive.

Gas turbine-generators, particularly as peaking units, are receiving increased attention. Successful operation in 1957 of large gas turbine-generators indicates that, as peaking units on even the largest power systems, they'll be economically attractive.

The use of 345 kv is increasing, even for transmission distances under 100 miles and of larger conductor sizes for increased circuit loadings at all voltages. For more than 200 miles, a step to perhaps 460 kv may be justifiable. Underground d-c transmission for metropolitan areas may hold promise as an alternative to extra-high-voltage a-c cable; but, otherwise, the conditions in this country do not yet appear favorable for d-c transmission.

More knowledge was gained of the controllable design factors that affect the radio-interference level of transmission lines.

Shipped to the Pacific Gas & Electric Co. in August of 1957 was a penalty-factor computer that handles a 24-source system. It is based on the design of a similar computer that during the last 2 years has saved the American Gas and Electric Company approximately \$200,000 a year in transmission losses.

Theories of coordinated economic operation of interconnected areas will be applied in a new multiple-area dispatching computer, being built for the Niagara Mohawk Power Corporation.

For industrial power systems, more new information was obtained on the surge-voltage protection of motors and on grounding for safety.

Digital-computer techniques were developed for calculating load-power flow throughout a system and for determining economic generator-unit size.

Additional installations of automatic dispatching systems (ADS) extended automation in the electric power industry during 1957. The ADS considers the significant factors incident to the loading of an electric utility's generation: for example, system load, capacity and maneuvering rates of turbines and boilers, line losses, spinning reserve, and cost of power production from each generator. No manual adjustments for economic loadings are required as the total system load changes.

A new miniaturized a-c network analyzer contains 4 sources of adjustable

power to simulate generating stations and 40 line-and-load units to represent transmission lines and the ultimate loads. All connections are made by patch cords and jacks; a single instrument measures voltage, current, and power flow at an interconnecting point.

### Steam Turbines and Generators

Higher ratings characterize the large steam turbine-generator units for power plants planned in 1957: the average rating of steam turbine-generators has increased to 155,100 kw. At the same time, however, pressures and temperatures generally are holding the levels reached during the past few years. In anticipation of higher temperatures, laboratory tests continue in the search for suitable materials.

The latest Federal Power Commission report, issued last October for the operating year 1956, shows continued reduction in coal-consumption rates as new steam power plants go into service. During that period, 4 plants operated under 9200 Btu per kilowatt-hour; all 4 of these plants employ General Electric large steam turbine-generator units—3 of them exclusively.

Digital-computer methods were developed to calculate a probabilistic model of a generation system so that reliability in meeting load requirements can be predicted. This program, together with economic analyses, is of great value in determining the optimum generation-expansion patterns.

Placed in operation in New Jersey at the new Linden Station of the Public Service Electric and Gas Company, was a 250,000-kw double-automatic-extraction steam turbine-generator unit. It will supply processed steam for the nearby Bayway Refinery of Esso Standard Oil Co. and electric energy for the Public Service system. In return for the process steam, the Bayway Refinery will provide residual fuel for the Linden Station's boilers.

During 1957, several orders were placed for cross-compound 4-flow steam turbine-generator units in nominal capacities to 300,000 kw. Permitting duplication of both the double-flow low-pressure sections and connected generators, these units afford maximum flexibility of arrangement in power stations.

Progress was made in development of instrumentation for measuring turbine-bucket vibrations in service. A stationary capacitance-gage system, with 88 gages distributed around the diaphragm,

scans in proper sequence the vibration mode of a running turbine wheel—without the necessity for any attachments to the rotor. Combined output of the gages appears in wave form on an oscilloscope.

Extensive laboratory studies of the potentialities of water as a coolant for conductors in turbine-generators were made in 1957. They indicate that *purified* water has the necessary dielectric strength and that it is desirable for its superior heat-transfer properties and simplicity. Development work with all types of conductor cooling over the past several years has demonstrated the unquestioned superiority of liquid cooling.

Extended last fall was the application of a new insulation system for high-voltage stator windings of large steam turbine-generators. A major advance, the new insulation incorporates mica mat and some mica flake bonded with a duplex thermosetting resin. It possesses high mechanical strength over the full range of operating temperatures.

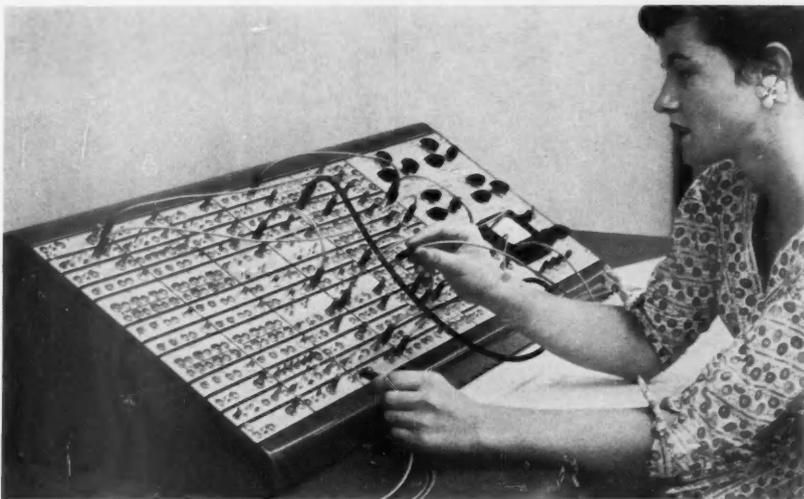
Intensive work continued on bursting tests of large steel discs. A better understanding of required rotor-forging properties has resulted. Forgings of new composition and heat treatment made in cooperation with forging manufacturers have contributed further to definite improvement of the characteristics in steam-turbine and generator-rotor forgings.

Ultrasonic testing equipment and techniques have been improved. Three new ultrasonic devices were developed. One automatically records results of inspection of rotor forgings at a high sensitivity level; the second permits inspection of rotors from the inside out; and the third, an ultrasonic micrometer, accurately determines the exit area of steam-turbine diaphragm nozzles.

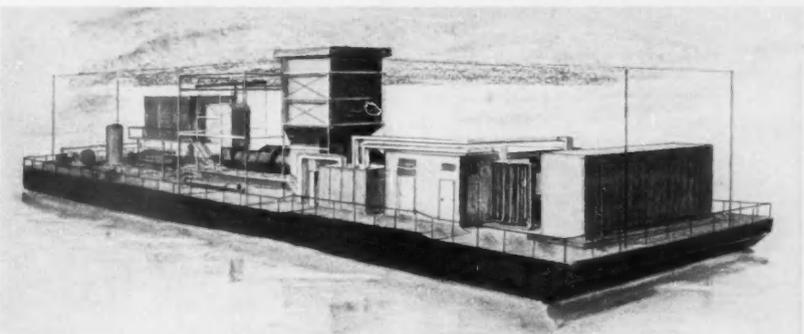
Simulated service testing of full-scale bucket dovetails is now possible with a new 200,000-pound universal testing machine.

Also, the speed with which a new prebonded strain gage can be installed—combined with its greatly increased reliability—makes these gages much more useful for testing turbine buckets.

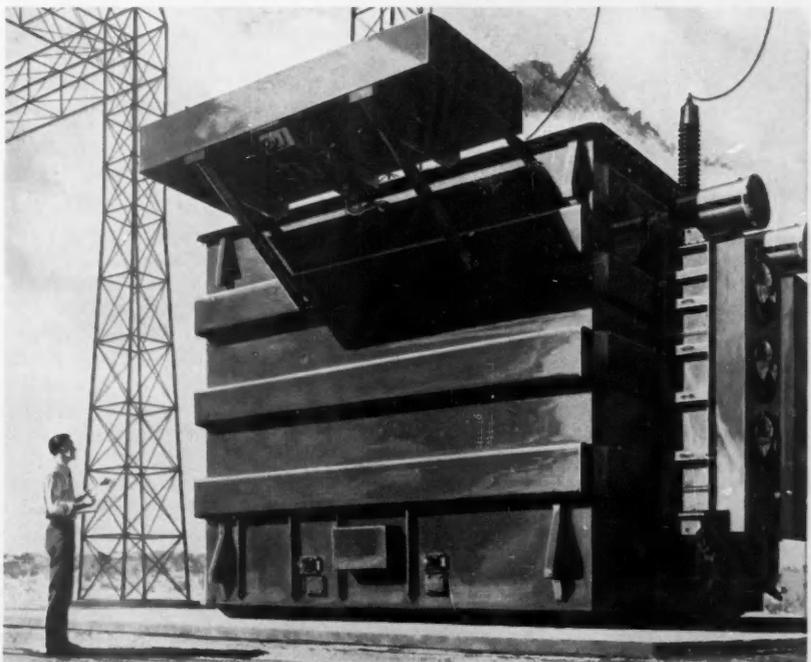
Recently accepted was an order for a 500,000-kw steam turbine-generator unit—the largest known capacity machine, built or on order, anywhere in the world thus far. It will be built for the Widow's Creek Station of the Tennessee Valley Authority. The unit will be of the 3600/1800-rpm cross-com-



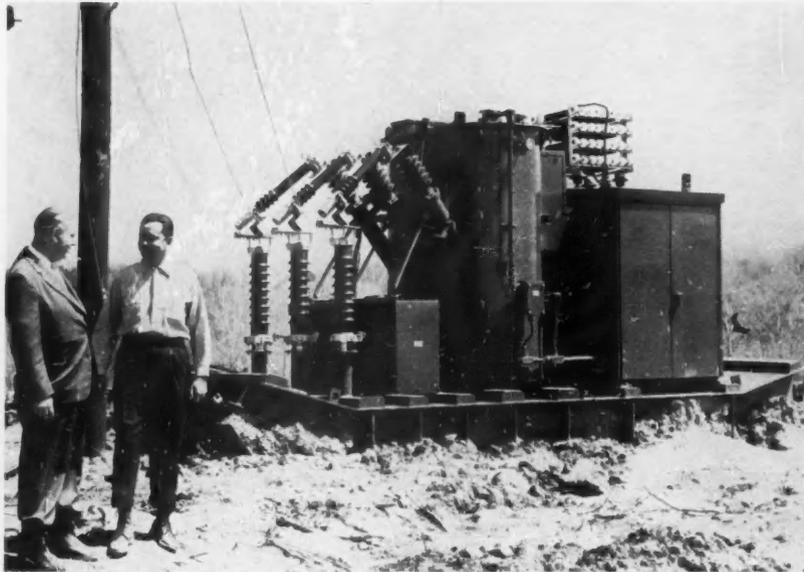
**NETWORK ANALYZER**, miniaturized a-c, saves power companies many times its cost.



**GAS-TURBINE POWER PLANT** on barge operates from a central power plant on shore.



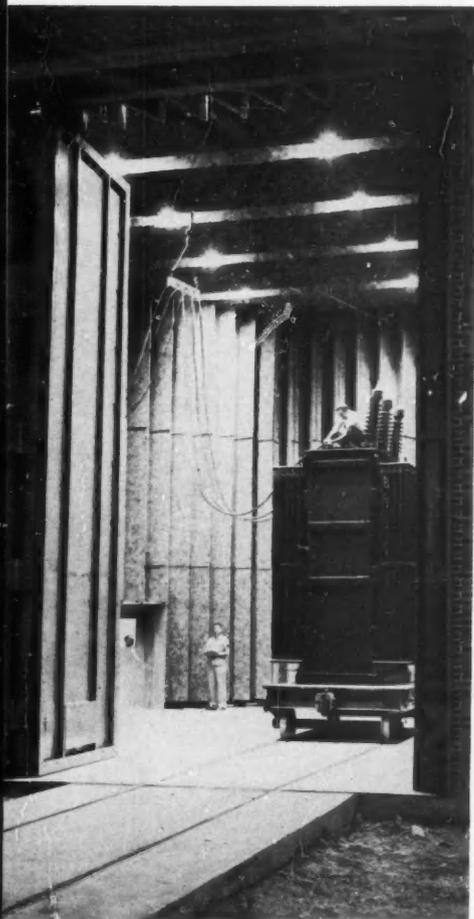
**OIL-PRESERVATION SYSTEM** seals the power transformer from direct oil-to-air contact.



**MOBILE SUBSTATION** mounted on skids was shipped for use in open-pit coal mines. The unit, which can be towed over rugged terrain, supplies power to giant stripping shovels.



**NEW TEST FACILITY** determines and evaluates corona and radio-noise characteristics.



**SOUND LABORATORY** advances studies of audio reductions on medium transformers.

pound reheat design with steam conditions of 2400 psig, 1050/1000 F.

#### Hydro-Generators

Last year 2 hydro-generators went into operation at Dalles Dam on the Columbia River. Rated 82,105 kva at 85.7 rpm, they are the first units of 14 being built for this station.

At the Barnhart Island powerhouse on the St. Lawrence River, the first of 16 hydro-generators was installed last year. Rated 60,000 kva, 94.7 rpm at 13,800 volts, they are being shipped at the rate of 1 unit approximately every 6 weeks.

#### Gas Turbines

The largest simple-cycle gas turbines ever built went into service generating power during 1957. Rated 16,500 kw, they burn natural gas and residual oil for fuel.

Two of these giant gas turbines are in Mexico, 2 in British Columbia with 2 more still to follow, and 1 in Venezuela. The machine in Venezuela has a unique feature: it's a portable barge-mounted unit, arranged for remote automatic operation from a central power plant on shore. An even larger simple-cycle single-shaft gas turbine, rated 21,800 kw, will be installed at Caracas, Venezuela, and will begin operating this year.

Another pioneering development in this growing field was the installation last year in Georgia of a combined steam-and-gas-turbine plant.

#### Transformers and Regulators

An oil-preservation system was introduced late in the year for large power transformers. It is sealed from direct oil-to-air contact and operates at atmospheric pressure. Lack of oil-to-air contact preserves the insulating and cooling properties of the oil; prevents moisture entry, oxidation, and sludging. Also maintenance is negligible because there are no gas cylinders to be replaced, no controls to adjust.

Power transformers with customer-preferred features can now be shipped 6 to 12 weeks faster. Utilizing design features chosen after an extensive survey of electric utility preferences, the new line of transformers offers uniformity in appearance, mechanical features, and accessories. Because of standard features, drawings approved for substation construction are now ready when the order is placed. Available in any rating from 5000 to 50,000 kva, they include 3-phase units with and without load-tap-changing at 69, 115, and 138 kv.

A new aphonic enclosure was made available for reducing medium- and power-transformer audio sound levels 15 to 21 decibels. The resulting audio-sound energy is in the order of only 3 percent or less of the original energy. Fitted over the main tank as an integral part of the transformer, the enclosure—or hood—makes use of air space and noise-absorbing batts between the hood and tank to help muffle sound.



**AIR-BLAST CIRCUIT BREAKERS** improve interrupting efficiency and operating speed with newly designed interrupter elements mounted within their own high-pressure air-storage tank.

Last year the 2 largest power transformers ever built in the 161-kv class were shipped to Memphis, with a third unit still to go. Rated 315,000 kva, the units required special construction to permit upright shipment on standard drop-frame cars.

Completed during 1957 were the 2 largest 3-phase autotransformers ever to be equipped with high-voltage bushing-mounted load-tap changers. Built to facilitate high-voltage system interconnection, the units are now serving Niagara Mohawk Power Corporation's Gardenville Station. Forced-air and oil-cooled, each unit is rated 125,000 kva at voltages of 230, 120, and 13.2 kv.

Two mobile substations were shipped for use in open-pit coal mines. Except that they are mounted on huge steel skids rather than on highway-type trailers, the units contain most of the standard components of a mobile substation. Used to supply power to giant stripping shovels, the units—one rated 5000 and the other 3750 kva—can be readily towed over rugged terrain.

Continued advances in mobile unit substations culminated in the shipment during 1957 of the highest capacity units yet built. In June a 9000-kva unit went to the Puget Sound Power & Light Company; scheduled for shipment early this year is a 9500-kva unit for the New Jersey Power & Light Co.

To supply power to a furnace for the Central Farmers Fertilizer Co., a record capacity high-current transformer was

constructed. It has a capacity of 37,500 kva and a rated line current of 45,600 amp.

Built in 1957 were the largest industrial voltage regulators to date. Six of the units, 3-phase and rated 1278 kva, were shipped to the Diamond Alkali Company of Cleveland. They will regulate d-c output from germanium rectifiers supplying power to produce chlorine gas and caustic soda.

Also developed was an oil test gap for measuring the dielectric strength of transformer oil. Using spherical electrodes, circulated oil, and a lower rate of voltage rise, the new device more accurately simulates actual transformer conditions. Adopted by General Electric, it is being evaluated by the American Society of Testing Materials as a national standard.

Test facilities were established for determining corona and radio-noise characteristics of transmission-line conductors—especially bundle conductors used primarily for very-high-voltage transmission. Outdoor-temperature and humidity-variation tests are performed in a climate-controlled room.

Sealed dry-type transformers from 300 to 2000 kva incorporate the most recent advances in materials, including the use of aluminum conductors and bus work throughout. In their insulation structures a unique inorganic material, called alpolite, is used. Because it is completely inorganic, alpolite offers high resistance to deterioration caused

by rigorous thermal duty. The new line of sealed dry-type transformers, inherently fire-and-explosion resistant, is capable of handling long extreme overloads with essentially no loss of insulation life.

Molded tank covers and molded bushings developed during 1957 may eventually replace steel covers and porcelain bushings. The new molding material is an outgrowth of molding materials resistant to arc tracking, first introduced by General Electric in the late 1940's for molded instrument transformers.

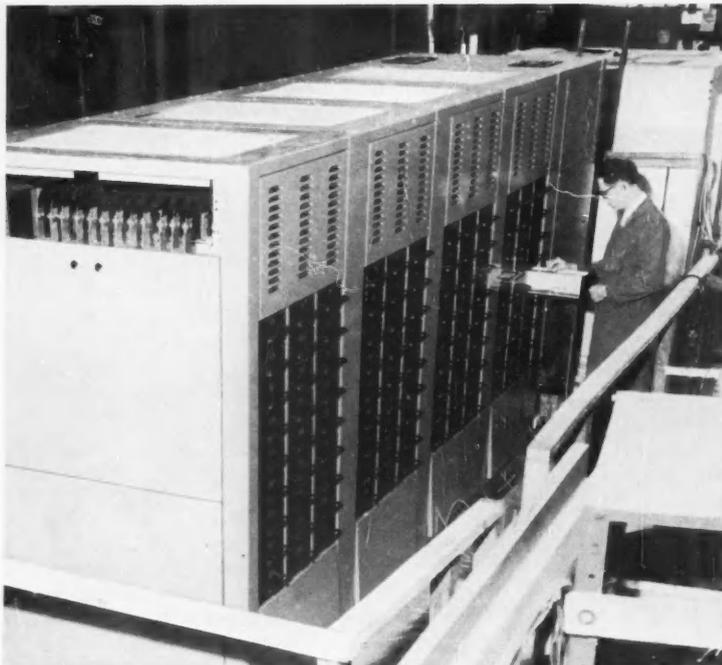
In instrument transformers, the butyl-molded construction was extended to a line of potential transformers for both indoor and outdoor service. Used extensively in switchgear and by electric utilities in conjunction with voltmeters and watt-hour meters for voltage and power measurements, the new transformers are considerably smaller and more rugged than their predecessors. They provide increased insulation strength and thermal capacity. Outdoor types utilize the new nontracking butyl insulation.

Inside a new acoustico-thermal laboratory, designed to aid in lowering sound levels and examining thermal characteristics, it's possible to test transformer sound characteristics down to 40 decibels. Research at this facility—one of 5 operated by General Electric—is directed toward improving sound and temperature characteristics of dry-type liquid-filled units up to 10,000 kva.

### Switchgear

No power system in the world has enough electric power to test to capacity General Electric's big 345-kv oil circuit breaker. This was proved last year when the American Gas and Electric Company arranged interconnection of the power networks of 13 utilities extending from Illinois to Florida for the first power field tests of a 345-kv breaker. The result: creation and interruption of short circuits believed to establish a new world's record—almost 14-million kva, or more than half the 25-million-kva breaker's rating.

The inherently lower maintenance cost and outage time of high-voltage airblast breakers has recently interested many power companies. This interest was reflected in a new and unusual design of airblast breaker where the interrupter elements are mounted within their own high-pressure air-storage tank to improve interruption efficiency and operating speed. Units rated 10,000 mva, 138 kv, and 5000 mva, 115 kv



**SEMICONDUCTOR POWER RECTIFIER SYSTEM**, world's largest, will power a chlorine generating process line. The first unit for this system was completed last year.



**MAGNETIC INSERT FINDER** locates concrete-buried steel-duct inserts in underfloor distribution systems.

were built for Consolidated Edison Co. of New York and Pacific Gas & Electric Co., respectively.

A major factor in the design of high-voltage airblast breakers has been proved to be the high rate of rise of transient voltages that may be present during breaker operation when faults occur on the first few miles of line adjacent to the breaker. These transient voltages can be duplicated on the section of transmission line recently installed at a Company development laboratory in Philadelphia and their effect on breaker performance accurately evaluated.

Several advances took place in 4.16-kv and 13.8-kv metal-clad switchgear.

Interrupting ratings of 4.16-kv equipment with air-magnetic type power circuit breakers were extended from 250 to 350 mva to fill growing demands on auxiliary power systems in large generating plants. The maximum continuous rating was increased from 2000 to 3000 amp and the momentary rating from 60,000 to 80,000 amp.

For urban substations, work began on 13.8-kv air-magnetic type power circuit-breaker equipment rated 1000 mva, 3000 amp, compared with a former maximum of 750 mva, 2000 amp.

Roll-out load-break switch and current-limiting fuse units for a-c power

circuits were introduced, as were single-breaker metal-clad distribution breaker units with entrance bushings for outdoor stations.

New nontracking flame-retardant arc-track resistant polyester glass insulation was introduced and flame-retardant polyvinyl-chloride plastisol bus-splice covers are now used on 4.16-kv equipments.

A new line of low-voltage—600 volts and below—current-limiting fuses was introduced that embraces ratings from 6 to 4000 amp having a laboratory-proved interrupting capacity of 200,000 symmetrical rms amp.

A new 2-step directional-distance subtransmission-line relay effectively coordinates with fuses and overcurrent relays. It will be applicable to lines where directional-overcurrent relays are inadequate and stepped-time distance relaying is not economically justified.

#### Capacitors

A new residential secondary capacitor design, available in ratings of 3, 5, and  $7\frac{1}{2}$  kvar, 240 volts, was put into production. The unit, 33 percent lighter than its predecessor, has a rectangular corrosion-resistant case design that permits complete impregnation of each unit, eliminating voids that might cause failures in the liquid dielectric.

The first large metal-enclosed equipment to utilize 50-kvar capacitor units was designed for easy shipment and assembly in the field. The design utilizes the principle of basic 1200-kvar module assembly to make any size equipment up to and including 6000 kvar.

Metal-enclosed submersible high-voltage capacitors for underground application in vaults or small sidewalk hand holes were developed. Available in ratings of 2400 and 4160 volts, 150 and 300 kvar, 60 cycles, for application on primary 5-kv distribution systems, it meets the needs of electric utility companies with limited space on overhead lines.

A new protective gap and series capacitor for application with distribution transformers up to 37.5 kva was developed. The gap prevents excessive voltages from appearing across the capacitor and makes series capacitor applications with distribution transformers highly practical.

Aluminum is gradually replacing galvanized steel as the structural material for stack-rack capacitor equipment, and plans were laid in 1957 to extend use of the material to some open pole-top auto-switch and open, fixed pole-top equipments.

A new low-inductance energy-storage capacitor, rated 100 kv, 0.25 micro-

farads, with a resonant frequency of 2.5 megacycles can be applied in atomic energy research projects, photographic equipment, discharge welders, and other energy-storage uses.

#### **Cable**

Exploration of aerial cable advanced significantly in 1957 with completion of studies to determine the effect of lightning. These studies, the subject of a symposium at the summer general meeting of the AIEE, indicated possible advantages of continuous metallic sheath. Aluminum was selected because it possesses conductivity, lightweight, and resistance to corrosion. Currently, a 15-kv butyl-insulated cable with aluminum sheath is on trial in service with a leading southern electric utility.

#### **Arresters and Cutouts**

For the first time, a new load-break feature on enclosed fuse cutouts enables electric utilities to provide for load switching at all cutout locations. A tiny, replaceable gas-filled cylinder mounted on the door of the 100-amp enclosed fuse cutout makes full-load switching possible.

Four major design improvements were made in a new heavy-duty open-dropout fuse cutout. Longer service life, greater operating economy, and higher interrupting ratings are assured by a new fuse tube, bronze fittings, new terminals, and an expendable fuse-tube cap. A sheath of fiberglass-reinforced polyester resin around the fuse tube is practically immune to weather and age. The interrupting rating of the extra heavy-duty cutout is now 10,000 amp at 7.8 kv.

Two new ratings, 3 and 6 kv, were added to the line of magne-valve distribution lightning arresters, available in either externally gapped or directly connected types with ground lead disconnect. The new smaller arresters extend the magne-valve distribution arrester line of ratings from 3 to 18 kv.

#### **Insulators and Bushings**

In 1957, a new line of extra-high-strength suspension insulators was developed that utilizes a special high-strength ceramic composition that is 70 percent stronger than electrical porcelain. Lighter in weight, the new insulators provide improved electrical characteristics and exceptional mechanical ruggedness. Included in the line are unit spacings of 4¾ and 5 inches, an exclusive feature within industry for 25,000-pound insulators.

Coordinated ceramic and product-engineering research made possible a new high-strength switch-and-bus insulator. Combining a time-proved shell arrangement with General Electric's new wet-process ceramic body results in economy stacking arrangements of high-and-standard strength insulators—with absolutely no reduction in electric rating. While weighing 25 percent less than predecessors, the new insulator's rugged strength eliminates special-handling requirements.

#### **Rectifiers**

The first unit for the world's largest semiconductor power-rectifier system was built, tested, and shipped last year. It will power a chlorine generating process line rated 35,000 kw, 250 volts at 140,000 amp d-c.

The equipment was placed on full-load test to prove out the design and application principles that were developed for this advanced semiconductor power rectifier. Control devices, auxiliary equipment, cooling-system design, and mechanical features either met or surpassed requirements during the tests.

This installation marks the opening of a new era, because semiconductor power rectifiers have previously been applied at lower voltages and smaller kilowatt sizes. The high efficiency and inherent reliability of a completely static system make the semiconductor rectifier extremely attractive to large chemical and aluminum producers.

A dramatic new type of silicon power rectifier was put in production in 2 sizes: 140 and 350 amp. Prior to the use of silicon, the largest size cell available was 100-amp germanium. The new silicon cell has a maximum voltage rating of 400 peak inverse voltage (piv) against a 200 piv for germanium.

#### **Distribution Systems and Busways**

The first major advance in plug-in busway design in 15 years was registered in 1957 with development of a system in the 225- to 1000-amp range. Designed exclusively and specifically for aluminum conductors, the new system is approximately 44 percent less costly to install and weighs up to 50 percent less than busways of comparable rating.

A thin steel underfloor power-distribution system for slab and fill or monolithic floors as shallow as 2½ inches was marketed for commercial, industrial, and institutional buildings. Distribution and feeding are accomplished on one level.

An extremely sensitive and accurate magnetic insert finder for steel under-floor distribution systems locates concrete-buried steel-duct inserts in existing underfloor distribution systems, when additional floor outlets are to be installed.

The development of a single-unit integral distribution center reflected a new concept in load centers. Eighty inches high, it can pass through standard factory doors in an upright position. The centers come in standard ratings of 75, 112.5, 150, and 225 kva at standard voltage ratings from 208 to 15,000 volts.

A new twin plug-in circuit breaker, combining 2 circuit breakers in a 1-inch case, was designed to give additional flexibility in circuit arrangements when combined with other top-quality General Electric breakers. It will fit a new group of load centers with main ratings from 40 to 200 amp.

A high interrupting-capacity fused switch was developed for panelboard and switchboard use. Metal grid-plate arc quenchers provide unexcelled interrupting ability.

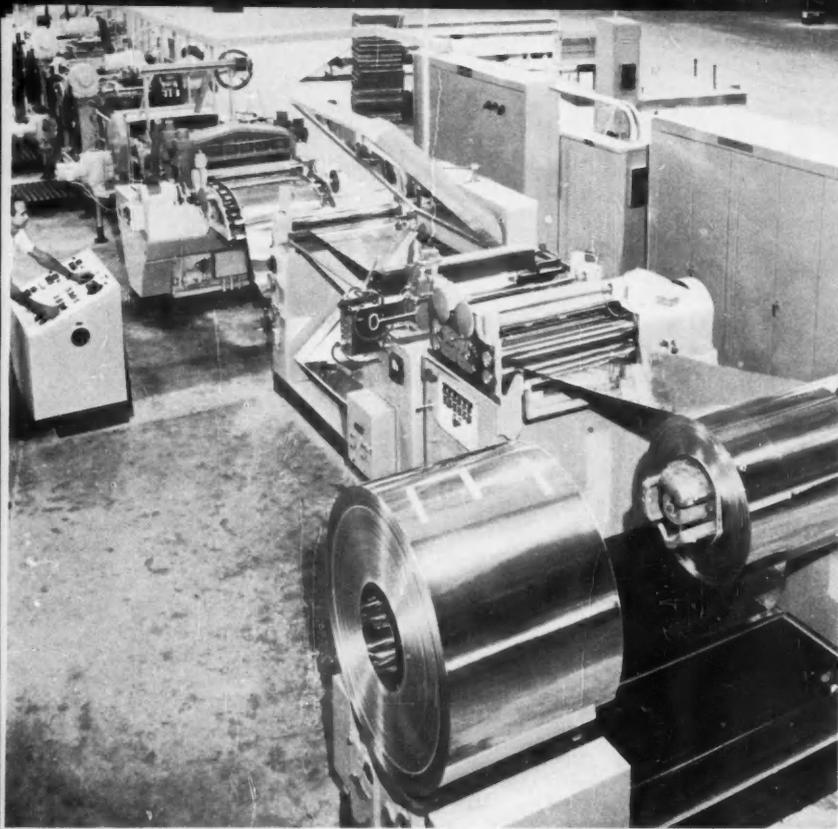
Remote-controlled motor-driven operating mechanisms were provided for 2 types of 800-amp molded-case circuit breakers, extending their industrial power applications. Automatic or manual resetting is available.

New 2- and 3-pole plug-in common trip circuit breakers rated 15 to 50 amp at 240 volts a-c were introduced for lighting and industrial applications in both separate enclosures and in panelboards.

#### **Meters**

A major change in the design of electric watt-hour meters simultaneously improved accuracy and reduced the cost. In the current-measuring coils, the new single-phase meters utilize 2 conductors, each having a simple single loop; conventional coils consist of 2 conductors, each split into 2 loops. The improved construction eliminates the problem of balancing the 2 loops of each of the conventional coils and greatly reduces material usage. In addition, the single-loop coil, not being a closed turn, cannot be a source of losses that affect meter accuracy.

A simpler low-cost residential network meter, also recently introduced, is based upon certain features of single-phase meters. In this device a single stator or driving element replaced the 2-stator meter conventionally used for residential network service.



**NEW EQUIPMENT** automatically processes tin plate from coils, improving quality control and reducing manufacturing costs—an ex-

ample of advanced mechanization methods that influences the steady rise in production per man-hour and use of electric power.

## Industry

Electric systems for industry in 1957 continued their trend toward greater complexity, requiring more and more engineering knowledge to satisfy user requirements.

The total amount of kilowatt-hours of electric energy consumed, with increased production, rose steadily. In terms of kilowatt-hours per unit of production, the electric energy required also increased. Thirty-five percent more kilowatt-hours were used per unit of production in 1956 than in 1946.

Man-hours of wage earners—excluding engineers and other professional and salaried personnel—remained constant over a 10-year period (illustration, curve A) despite the population increase requiring more goods, while kilowatt-hours (curve B) has grown about 2½ times.

Production of real goods—Federal Reserve Board index (curve C)—increased 40 percent. And the consumption of power per unit of goods also increased 35 percent over the same 10-year period (curve F).

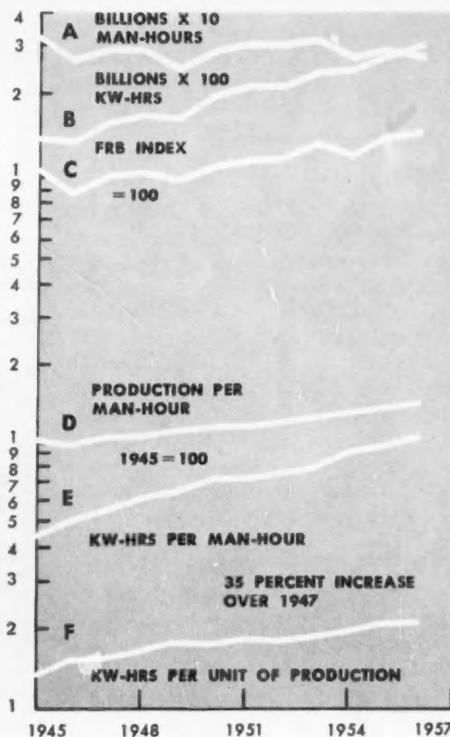
Individual industries, such as rubber, paper, steel, and textiles, show increases in power consumption per unit of production—a definite trend in nearly all industries, with a constant percentage increase each year. Among other things, it can no doubt be ascribed to the effects of automation and electrification.

Electric equipment and systems for industry are faster, more complex. Regulating and data-processing systems, positioning from punched cards, new sensing and inspection requirements—all demand more engineering content. Unfortunately, there are no “kilowatt-hour meters” to measure this kind of increase.

The year 1957 also marked the real entry of the gas turbine as a prime mover in the industrial field. Seven gas turbines were shipped for installation in the pulp and petrochemical industries.

### Motors

With the aid of a transient network analyzer, the effects of severe switching conditions on motors were investigated



during 1957. In fact, the whole subject of surge-voltage protection for rotating machines underwent—and continues to undergo—intensive study.

Gas-lubricated bearings were also subject to intensive investigation, particularly in 4 major areas of application: high-temperature devices, radioactive atmospheres where conventional lubricants break down, devices where freedom from contamination is essential, and high-speed machinery requiring low friction.

Introduced last fall was a new line of packaged adjustable-voltage d-c drives that incorporate a newly designed static regulator. Built around a silicon rectifier, a new static exciter requires no warm-up period but is ready to operate as soon as the motor-generator set is started. An average weight reduction of 25 percent was achieved in the new line of speed variators.

Designed to meet modern transmission needs for compact speed reduction, a shaft-mounted speed reducer was introduced last year in both single- and double-reduction ratios. Output speeds range from 370 to 10 rpm, in ratings from ½ to 40 hp.

Introduced last year was a new helical gear-motor line comprising 3 basic types:

an integral-type gear motor, an all-motor gear motor, and a separate helical speed reducer. The integral-type unit is offered in single, double, and triple reduction in an output speed range from 780 to 13.5 rpm. The all-motor unit and helical speed reducer have an output speed range from 350 to 13.5 rpm in both double and triple reduction.

Especially designed for applications where operating conditions are abnormal was a new line of Form-G severe-duty single-phase 60-cycle and 3-phase 60/50 cycle motors. Applications include the powering of dairy- and food-processing machinery and motor installations in the plating and mining industries that do not require explosion-proof features.

A small but powerful d-c motor, gaining up to 63 percent of its rated speed of 5500 rpm in 0.015 seconds from a standstill, was developed for automatic machines requiring rapid acceleration. Blower cooled, the 200-volt motor produces 2.2 hp in a frame 5.16 inches in diameter and 15.25 inches long.

For such applications as blowers, cooling fans, evaporative coolers, and air conditioners, a new slim shaded-pole motor weighs only 5.5 pounds and is less than 3 inches long. It is available in ratings from 35 mhp to 0.10 hp, in both 4 and 6 pole.

Now available in ratings from 1/6 through 3/4 hp is a complete line of Form-G door-operator motors. They accommodate applications ranging from light-duty residential garage doors to heavy-duty commercial and industrial doors.

The stator insulation system of a new textile motor was specifically designed for operation in the 75 C rise temperature range, obtaining maximum horsepower from the smallest practical frame size. Designed for use on spinning, roving, and drawing frames, the enclosed nonventilated motor provides maintenance-free operation in lint-laden atmospheres.

A completely redesigned NEMA Type II a-c weather-protected motor in ratings from 250 hp and up was introduced in 1957. Its features: high-up air intakes help guard against flooding or entry of ground-level dirt; light-weight removable bearing cap simplifies bearing maintenance; and new endshield offers more than 300-degree accessibility for inspecting and cleaning windings.

Also introduced last year was a new line of a-c induction motors from 40 through 125 hp—the first major redesign for motors of these sizes in almost 20 years. Built to standards suggested by NEMA, the new motors are 20 percent lighter than formerly. Actual weight savings per motor vary between 100 and 500 pounds.

For domestic sump-pump application, a new submersible pump motor can operate completely immersed under water. Its ball bearings are lubricated with a special grease to provide quiet, more dependable performance. With a special carrying handle on top, the motor is also highly suitable for building-and-construction contractors.

Designed for mobile lighting and heating, a new self-contained a-c power-

supply package comprises an alternator, a regulator, and a rectifier. Operating independently of any other source of electric power, the new power-supply package can be applied wherever an accessible rotating shaft exists for a lighting, heating, or other nonfrequency responsive load.

A new 5-inch diameter shaded-pole motor with a 40 percent lower sound level was designed for home, hotel, and hospital appliances such as vertical and horizontal unit heaters, console heating and cooling units, blowers, and similar applications. The new motor runs cooler than earlier designs and has all-angle bearings that require no reoilng.

In the field of acoustics, a correlator was developed for analysis of noises on the basis of their variation in time. As an example of its usefulness, the correlator might evaluate the relative importance of fan and bearing noise in an appliance motor and determine the paths by which the noise reaches the listener.

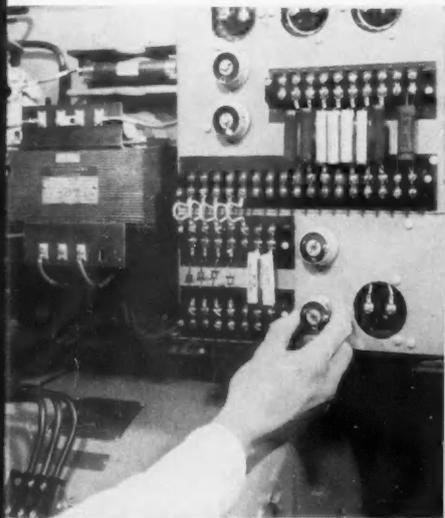
Manufacturers of room and central air-conditioning units now have a choice of either permanent-split-capacitor or shaded-pole fan motors in one frame design. Both motors utilize the compact 39-frame mechanical design. Reduced in size and weight without sacrifice of power, the new shaded-pole motor now offers many new and improved features.

Another development was the introduction in 1957 of a new line of smaller, more compact, totally enclosed nonventilated shaft-mounted Form-G fractional-horsepower fan and blower motors, for continuous-duty air-over applications. Their rugged construction, superior insulation, and highly efficient lubricating systems give quiet longer-life performance with a minimum of maintenance.

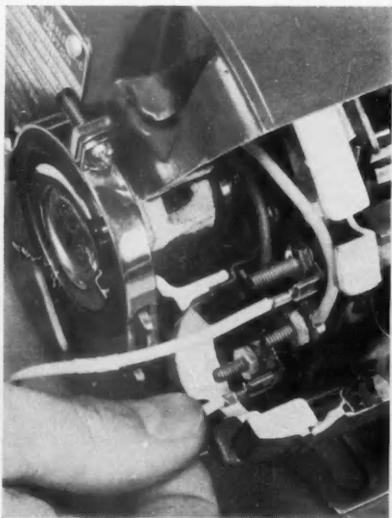
Quick-connect wiring tabs are now included as a feature on the Form-G fractional-horsepower line of belted-fan and blower motors. Designed for simple, economical wiring, these 3/8-inch wiring tabs reduce factory-assembly or field-installation time. They supplement present terminal studs.

To provide technical students with experience in building standard Form-G units from production-line parts, fractional-horsepower motor construction kits were made available in 1957. A laboratory-type instruction book accompanies each kit. With only nominal supervision, a good student should be able to successfully build a motor.

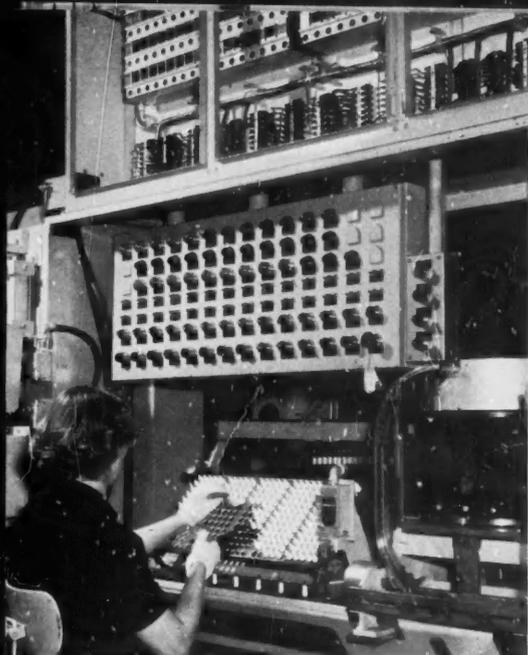
In 1957 the portable-tool industry was the recipient of a much needed



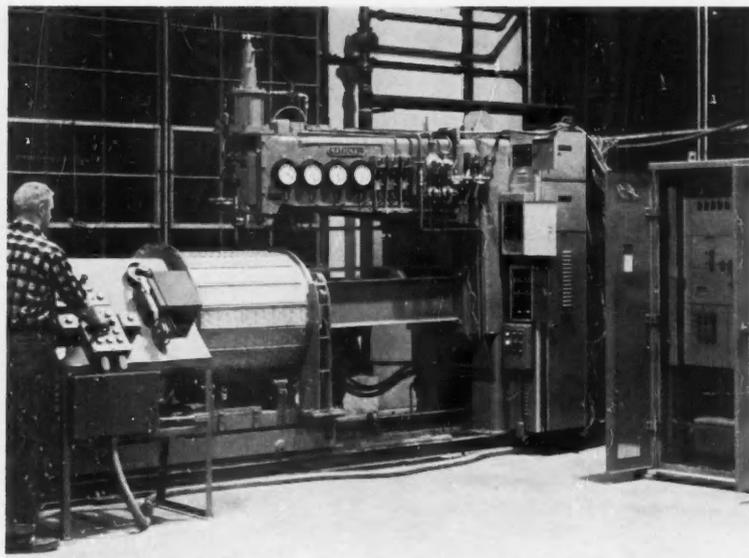
**SPEED VARIATORS** for d-c drives incorporate a newly designed static regulator.



**QUICK-CONNECT** wiring tabs on fractional-horsepower motors are economical to apply.



**STATIC CONTROL** applied to spark-plug assembly machine may effect substantially higher production.



**WORLD'S FIRST** automatically programmed resistance-welding machine realizes new degree of automation with numerical-positioning and resistance-welding controls.

piece of equipment: a new bayonet-release grounding connector and receptacle. Because the cord can be detached, storage of tools is easier. The grounding receptacle and connector will find use on such portable tools as drills, saws, sanders, hedge trimmers, grass clippers, and the like.

### Control

Static-control techniques gained wide acceptance in the automotive and machine-tool industries during 1957. The static-control system provided a much higher degree of reliability and much longer life on controlling machine functions than was possible with conventional industrial relays in those industries.

One of the most interesting applications of static control in the auto industry is on a crankcase-breather-machine device that assembles, loads, and crimps 2 sizes of crankcase breathers. The equipment used includes amplifiers, power supply, logic unit, monitoring light, amplifier bias relay, logic power supply, control transformer, master relay, and motor starters. The equipment combined in a panel conveniently performs the control functions.

Static control was also applied to a spark-plug assembly machine made by General Motor's A-C Spark Plug Division. A substantial increase in production is predicted by A-C engineers because of reduced downtime with static control, compared with their conventional magnetically controlled assembly

machines. A 48-unit static-control panel is also in production, printing the A-C monogram on oil-filter casings by silk-screen process.

Another application of the relatively new control concept of static switching was made on a digester system for a paper mill. Mechanical wear in multiple permissive and prohibitive interlocking switching, as well as costly maintenance and replacement time, is eliminated.

An unusual static-control application last year involved iron lungs for polio patients. When a lung patient breathes normally, his chest actuates a limit switch that cycles intake and exhaust air in the iron lung. Should a patient have difficulty in breathing naturally, the lung automatically takes over and cycles the intake and exhaust air for the patient. When the patient can and wants to take back control of the lung, he merely breathes out of phase with the automatic cycling and the lung then reverts back to the control by the patient. The entire process is handled on the static-control principle.

The world's first automatically programmed resistance-welding machine went into production early last year. This machine realizes a new degree of automation made possible by the application of 2 General Electric products—numerical-positioning and resistance-welding controls. The combination provides automatic positioning and welding operations from numerical data punched on paper tape. The result: an 85 percent reduction in assembly and weld time—

from 9½ hours to 1½ hours on each part produced.

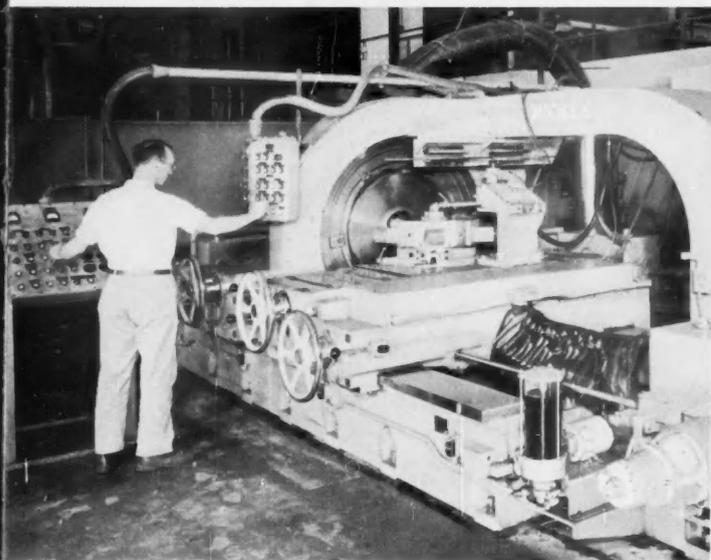
At present the machine welds tabs on cylindrical liners for jet engines. The punched tape contains numerical information to position the liner, select 3 values of weld current and 2 values of weld time, indicate when it is time to clean electrodes, make sample welds, and to inspect welds.

A series of tabs is welded along the surface of the liner and parallel to its axis. A series of spot welds is required for a single movement along the length of the liner. After one such motion is completed, the liner rotates to the next series and the cycle repeats longitudinally.

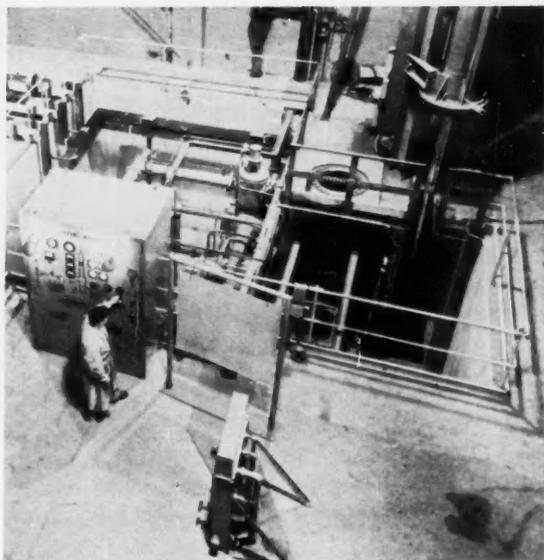
Weld spots vary from 1 to 3 per tab, depending on tab length, with a total of 1600 welds. The entire process is repeated for 360 degrees around the liner to complete the job. On completion of the final tab weld, a signal indicates the end of the run by energizing a light at the operator's control station.

Approximately 3½ seconds are required for each weld, including time for positioning between welds. With these 2 products, one assembly can be completed in ¼ of the time previously required, including setup operations.

The first in a series of numerically controlled drilling installations was announced last year. It is a drilling, spot facing, and chamfering machine controlled by a General Electric numerical-positioning control for 2 motions, rotary and vertical.



**SYNCHRONIZED PAIR** of 2-dimensional tracer systems on center-drive lathe simultaneously controls cutting of both sides of jet-engine turbine wheel.



**VACUUM-ARC FURNACE** of new design concept aims at high production; minimum downtime; quick, easy installation.

Cycle of in-and-out movement of the vertical drill head and column includes rapid approach, 2 rates of feed, 3 depths of penetration, and rapid return. The system controls the actuation of the cycle, selection of feed rate and depth of penetration, and inclusion or omission of the dwell. Vertical motion of the drill is programmed over a maximum length of 30 inches and is positioned at a rate of 60 inches per minute.

The first automatic center-drive lathe installation went into operation last year to machine jet-engine turbine wheels. Equipped with 2-dimensional electric trace controls, the lathe will machine both sides of a turbine wheel simultaneously while cutting web thicknesses as low as 0.030 inch in production runs. Formerly, wheels were machined with lathes capable of cutting only one side at a time, necessitating repeated operations resulting in cumulative errors.

A punched-card programming control for reversing hot mills in the steel industry makes possible the rolling of bloom, slab, plate, I-beam, and other shapes automatically from data recorded in the form of punched holes on a standard business-machine card. By depressing a push button, the operator can initiate rolling of a specific shape, with as many as 23 passes through the mill being made automatically before the piece is delivered to the runout tables and carried away.

A new pinhole detector that searches strip steel for holes smaller than the diameter of a human hair was developed.

The device operates at full sensitivity while strip steel rushes by at speeds up to 22½ mph. To spot any tiny defects, the detector relies on a mercury-vapor lamp that generates light equal to 2½ times the brilliance of reflected summer sunlight.

A hot-metal detector was developed to aid in automating hot-metal rolling processes. This new sensing device exercises supervisory control of the mill and permits broader use of card-program rolling schedules. It provides an On or Off signal in response to the presence or absence of hot metal at a given location.

A new line of small millivoltmeter pyrometers was developed to keep pace with the trend toward smaller size in process instrumentation. These pyrometers employ printed circuits, miniature tubes, and relays to save costly panel space. Utilizing a self-contained plug-in instrument and having different types of plug-in control units, with provisions for making electric connections from either front or rear, these pyrometers are easier to install and maintain than present models.

A low-cost variable-speed drive for use on metalworking or textile machines, white printers, and other equipment requiring speed selection and regulation was developed for small integral and fractional-horsepower requirements. Design engineers report that the instantly reversible drive has speed regulation characteristics superior to other magnetic and compatible systems now on

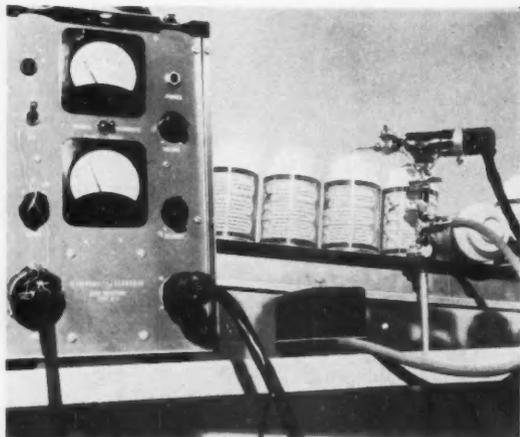
the market. Because of the absence of tubes, the new drive eliminates warm-up time and greatly reduces maintenance.

A modified approach to the principle of constant-current motor control made possible, for the first time, simplified circuitry and competitive prices for a new general industrial adjustable-speed drive in the range of 50 to 300 hp. Six of the new drives are already in use on aircraft test stands. The drives incorporate such features as wide speed range, high dynamic response, contactorless reversing, and regeneration.

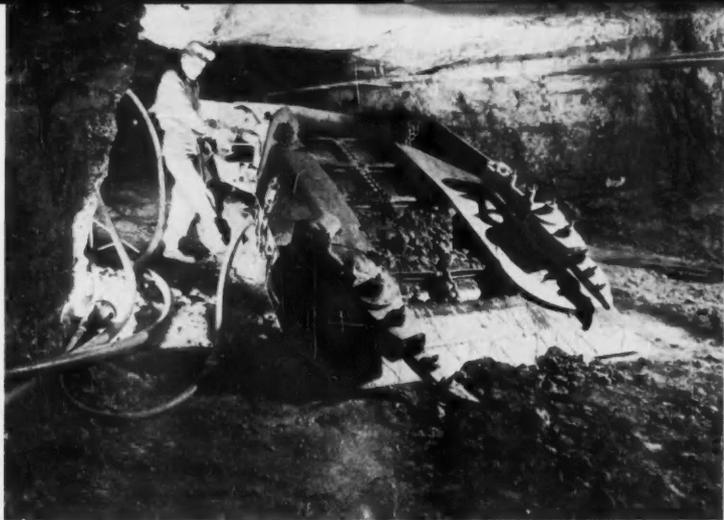
The test stands are used for development production and system component testing of aircraft voltage regulators, static exciters, and protective panels.

A new method of one-step increment starting for induction motors, which provides reduced light flicker and quieter motor operation during acceleration, was developed. Its major application is expected to be in large commercial buildings and other locations where power companies require that large induction motors be started with reduced kva inrush. Typical uses are air-conditioning and refrigeration compressors, fans, pumps, and blowers. The new system, a ⅔ part-winding starter, will accelerate most loads to full speed on the part winding. This eliminates the second increment of current inrush characteristic of conventional part-winding starting.

A new manual motor starter with plug-in heater was developed for grinders, conveyors, hydraulic presses, blowers,



**FIXED-HEAD HALOGEN DETECTOR** facilitates automatic high-production leak testing at low cost.



**PORTABLE CABLE** with Y-shaped ground conductor augments today's 3-phase a-c mining equipment, has long life in rugged service.

and mixers. It is designed for single-phase motors. Another motor starter, in NEMA size 0 to 1, was developed for machine tools, pumps, hoists, blowers, saws, compressors, and packaging machinery. Radically different in design, it is 42 percent smaller than previous open-form magnetic starters.

A new, electrohydraulic, selsyn tracer-control system was developed for application on various types of machine tools. In a typical application, a 2-carriage spar milling machine has 5 feed motions controlled by the new system. In addition, this complex machine uses 9 amplidyne-generator d-c motor-type selsyn tracer systems of an earlier design. The electrohydraulic system can provide equivalent accuracy at higher operating speeds for certain selected machine motions; using hydraulic cylinders as power elements simplifies the mechanical design of the machine.

#### Industrial Heating

A universal enameling oven, capable of operating by fuel gas or electric heat, was developed simultaneously with a universal preannealer for continuous annealing of wire and strip materials. Designed for the continuous baking and curing of film-type insulating coatings on wire, the universal oven also bakes or dries coatings applied to metallic strip or wire and impregnated cloth-type material.

Temperature controllers and the interchange of heat inserts change the oven heat pattern and insure adjustment of coating bake and cure to optimum values. Headroom requirements for the oven were lowered substantially, elimi-

nating the need for special high-bay enamel rooms.

A new continuous annealer unit, designed to operate separately or in conjunction with the universal oven, adapts to either electric or gas-heat sources. It is suitable for both round and rectangular wire tubing and strip materials. Integration of the continuous annealer with the new oven provides continuous combined annealing and enameling of most types of wire and strip materials, eliminating intermediate materials handling. The annealer can be operated either horizontally or in positions from 0 to 60 degrees from the perpendicular.

A new 16-inch capacity vacuum-arc-melting furnace was placed in operation at the Bridgeville, Penn., plant of the Universal-Cyclops Steel Corp., which uses it for production melting of molybdenum and molybdenum alloys. Removing gaseous impurities, reducing segregation, and producing a superior grain structure, the furnace casts an extremely pure ingot.

Ten selenium rectifiers deliver a power supply of 15,400 amp. At the operator station are the flow-type control panel, viewing screen on which an image of the arc is projected, and visual flow meters for cooling water. A vertical cylinder houses the electrode in its melting position.

The furnace has an ingot capacity of 16 inches in diameter and 66 inches in length—approximately 3500 pounds of steel or 5000 pounds of molybdenum. Although initially used for development and production of molybdenum, the furnace can also be used for iron- or nickel-base alloys, titanium, and zirconium. A completely new concept in

vacuum-arc-furnace design, the development is aimed at high production, minimum downtime between melts, and quick, easy installation.

#### Paper and Textile Industry

The first completely static switching control for use in reducing wood chips to pulp for papermaking was installed last year in a Texas plant. The over-all electric and mechanical system will reduce the normal cook time of 3 to 4 hours to approximately 10 to 15 minutes. In addition, conventional relays were eliminated because a corrosive atmosphere and frequent operation resulted in attendant maintenance problems.

A panel containing 56 static switching units acting through 14 magnetic amplifiers opens and closes various pilot-valve solenoids on a completely automatic sequenced schedule. The pilot valve operates larger air-operated valves that actually open and close the lines to supply steam, air, chips, liquor, and so on to either or both of the two digesters, as well as to blow out and exhaust the tanks.

#### Steel and Other Metals

Punched-card and tape controls and records became more prevalent in the steel industry last year. They were applied to automatically position roll-opening and side guides, set speeds of mill and table rolls, and direct reversals; they perform other control functions on large reversing roughing and slabbing mills.

In the complex steel business, the rapid collection and evaluation of useful data have always been a problem of

some magnitude. Equipment to collect data from a tandem cold-strip mill and automatically type it on an electric typewriter illustrates the latest approach to the problem. The system prints out footage of off- and on-gage material for each coil rolled, as sensed by an x-ray gage, together with other pertinent data useful in accounting.

Another trend toward automation in the steel industry appeared in the automatic inspection and data collection on tin-plate processing lines. Tin plate is inspected for pinholes, total thickness, thickness of tin coating, and the length of prime and off-prime material in each coil. New equipment makes automatic records on an electric typewriter at high speed, immediately available after the completion of each roll.

The tin-plate operation also was improved by the addition of automatic inspectors, or photoelectric scanners. Simple high-volume products are usually turned out on highly mechanized machines but nearly always inspected by human labor.

Frequently, in one part of a factory a fully automatic high-volume machine is tended only by a few maintenance personnel, while in another part of the same factory 100 or more people are continuously engaged in visual surface inspection of the product. To meet this situation, prototype automatic surface-inspection equipment for tin-plated steel was developed and met with a limited degree of success.

A data-logging system was developed for application as part of the over-all control system of a 4-stand tandem cold-rolled steel mill. It performs 2 major functions automatically: presetting for x-ray gage thickness control on the first and fourth stands and collection of data on the operation of the mill and the order and processing history of the steel.

The system produces a punched paper-tape record of the mill operation for each coil of steel processed. This in turn yields immediate typewritten records of the mill performance and later information for generating IBM punched cards for payroll and warehousing. The system is expected to reduce operator error in presetting the thickness controls and, at the same time, to improve mill-record quality through greater accuracy of data.

#### Manufacturing Industries

Several large can manufacturing companies made a major change in manufacturing practices in 1957 by purchasing their own tin-plate coil-processing lines. These companies previously obtained tin plate from primary metal producers in the form of cut sheets suitable for entry into presses and can body-making machines.

Each line includes uncoiler, leveler, electronic pinhole detector, visual surface inspection, shear, and sorting and classifying section. General Electric has supplied 16 packaged adjustable-

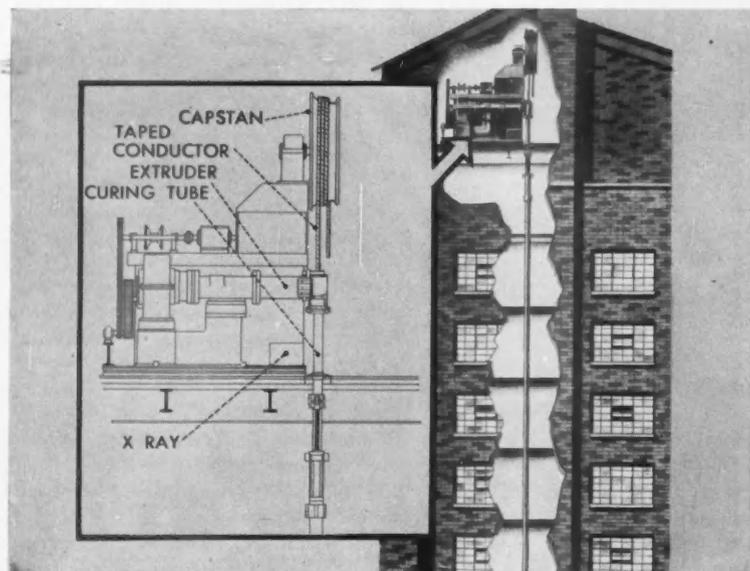
voltage speed-variator drives, and 39 electronic pinhole-detection gages for these lines. The can companies expect to obtain substantial reductions in manufacturing costs and improved quality control with these new lines.

The newest member of the halogen-leak-detector family is a fixed-head detector, specifically designed to facilitate automatic high-production leak testing at low cost. It will detect leaks from an opening through which only 1/100 ounce of standard refrigerating gas will pass in one year. Sensitivity is varied by selector switch. It is expected that this product will prove especially useful to manufacturers of products packaged in pressurized cans.

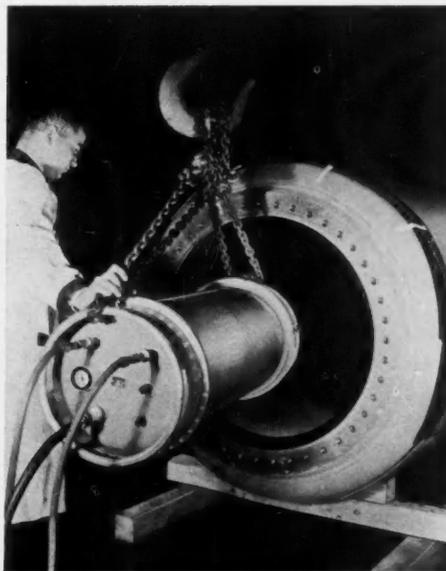
A vacuum-head detector unit was developed to extend application of the halogen leak detector to dynamic vacuum systems and vessels operating at pressures of 1 to 500 microns. The vacuum head is installed in the vacuum system and connected by cable to the controlled unit. Signaling a leak actuates the audible signal device and milliammeter.

#### Mining

An extra-flexible portable cable with Y-shaped ground conductor was developed for modern 3-phase a-c mining equipment. Use of a special copper braid construction reduces the possibility of phase-to-phase faults in the event of cable damage. Additionally, sufficient conductivity allows the cir-



**VERTICAL DOWNWARD EXTRUSION** of high-voltage butyl-insulated cables overcomes danger of eccentricity present in horizontal manufacturing methods.



**X-RAY BEAM** penetrates steel for "inside-out" radiography of circumferential welds.



**DIESEL-ELECTRIC POWERED** oil-well drilling-rig drives have the advantage of excellent portability, speeding preparation cycle.

cuit breaker on the machine to trip without interrupting the main power supply.

Specific applications of the new portable cable: a-c shuttle cars, loaders, cutting machines, roof bolters, and similar equipment. The cable has exceptionally long life under the rugged conditions encountered in these services.

#### Wire and Cable

A new gasoline-resistant appliance wire was developed for The Tokheim Tank & Pump Co., a pump manufacturer. It is suitable for use at 90 C in air, 60 C where exposed to gasoline vapors, and nominal ambient temperatures where exposed to liquid gasoline. To overcome automobile engine-stall that results from vapor lock, the pump manufacturer conceived the idea of locating the fuel pump in the automobile's gasoline tank. And General Electric developed the gasoline-resistant appliance wire, now listed by the Underwriters' Laboratories, Inc. (UL) for this application.

For machine tools, a polyvinyl chloride wire has a new improved lubricating surface and a silicone base that won't flake or scrape off or even drip at the wire's highest temperature rating. Actual pull tests in a conduit proved that the new silicone-treated wire pulls up to 3 times easier than the old-style wire with wax surface.

In manufacturing, vertical downward extrusion and curing of heavier-wall butyl-base insulation—the type required for high-voltage solid dielectric cables—were put into operation in General Electric's plant at Bridgeport, Conn. The equipment overcomes the danger of insulation eccentricity present in horizontal manufacturing methods.

In 1957, silicone-insulated wire and cable were available for the first time as power cable. They may be installed where the National Electrical Code has jurisdiction. The silicone wire and cable were also listed by UL as type RHH wire for 600-volt, 90 C service in sizes No. 14 Awg to 6 Awg, inclusive.

#### Industrial X-Ray

During 1957 a high kilovolt yet highly mobile industrial x-ray unit was introduced. It possesses a tube warranty of 10,000 hours and an extremely short warm-up time. Of special importance, its 360-degree rotation permits large savings in inspection time by making possible "inside-out" radiographs for examining circumferential welds. The new unit is widely adaptable to all types of examination, from light alloys to steel. Inherent lead shielding markedly reduces the need for costlier external shielding or wide evacuation of the inspection area.

Baker Laboratories, Inc., producers of canned modified milk for infants, reported a new advantage in the use of level-checking x-ray equipment. Detection of lowered level in the cans, through the use of x-ray, has eliminated their dependence on costly and time-consuming flotation tests to spot and remove leakers. The firm reported that this x-ray unit paid for itself within 5½ months of operation.

Mobile fluoroscopy at 250,000 volts was achieved in 2 new subsistence x-ray inspection units built for the U.S. Army Quartermaster Research and Development Command. It comprises a special 250-kv inspection x-ray source, mounted in a truck trailer. Purpose: to help the quartermaster evaluate damage to the contents of loads of rations air-dropped to the ground and to periodically inspect

stored canned foods for corrosion and spoilage.

Introduced in 1957, a unique high-powered electron-beam generator operates at 3½-million volts and at an unprecedented 26-kw beam-output power. Principal uses: the treatment of chemicals to improve their properties and behavior and the sterilization and preservation of foods with less—or no—refrigeration.

Earlier model electron-beam generators, operating at 1 and 2 Mev, had their power output lifted considerably by the application of 2 new principles. A 360-cycle scanning supplier prevents loss of phase synchronization with changes in current output, and d-c bias coils at the tube's window keep the beam centered at all energy levels.

#### Gas and Petroleum Industries

Diesel-electric power transmissions consisting of motors, generators, and control went into service in a variety of locations during the past year. These included land rigs drilling in New Mexico and Texas; inland barges working in the Louisiana bayous; offshore barges drilling in the Gulf of Mexico; and platform-tender rigs working on Lake Maracaibo, Venezuela. Under these widely varying conditions, electric drive equipment demonstrated its many advantages.

A recent demonstration in Texas emphasizes the inherent portability of electric drive equipment. A heavy-duty drilling rig was loaded onto 17 trailer trucks, hauled 125 miles, unloaded, all components positioned, and the rig prepared for drilling—all within 1½ days. This represents a fraction of the time normally required for the same cycle with a mechanical rig.

# Lighting

A major breakthrough of the "sight barrier" with an installation of fluorescent lamps that produces the highest level of comfortable lighting in the world was unveiled last year at General Electric's Lighting Institute, Nela Park, Cleveland, Ohio. This pioneering installation attains a lighting level of more than 1000 footcandles with new power-groove fluorescent tubes at high frequency in specially designed fixtures that are available commercially. The experimental installation is being used as working light for a workshop and as a demonstration of commercial and industrial lighting. In such establishments general lighting levels from 100 to 200 footcandles are considered to be well above average.

## Outdoor Lighting

A blanket installation of floodlighting equipment, believed to be the world's largest, was put in by New York International Airport during 1957. Part of a \$120,000,000 expansion and modernization program, the unique installation provides never-ending "daylight" for about 6-million square feet of the airport's Terminal City. This 655-acre area will include airline terminals, restaurants, hotel, shops, extensive parking area, and a botanical garden.

A new 1500-watt mercury lamp and floodlight were developed for this project. The powerful lamp is housed in a special 54-pound luminaire that measures 22 inches in diameter. For Terminal City, 338 of the floodlights are mounted in clusters atop 43 specially designed 75-foot pylons. The level of illumination varies from a minimum of about 1.5 to a maximum of 5 footcandles.

## Streetlighting

A demonstration roadway lighting facility where more than 30 different lighting combinations can be observed was unveiled last year. Called *Crossroads of Light* the demonstration streets offer opportunities for showing the effects of virtually every combination of modern lighting that can currently be applied to America's roadways. General Electric engineers will use this facility to conduct extensive investigations on how well the night driver actually sees under various roadway lighting systems.

The area will also serve as a proving



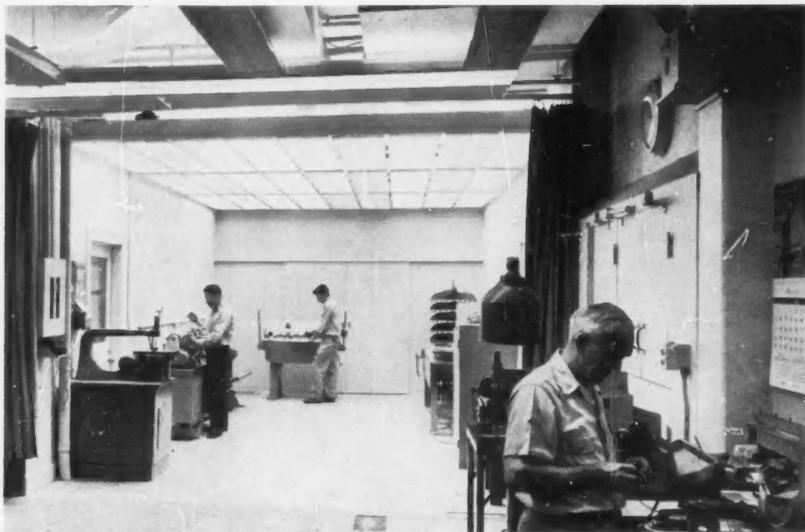
**NEVER-ENDING DAYLIGHT** provided by a blanket installation of floodlight equipment was set up for 6-million square feet of New York International Airport's Terminal City.



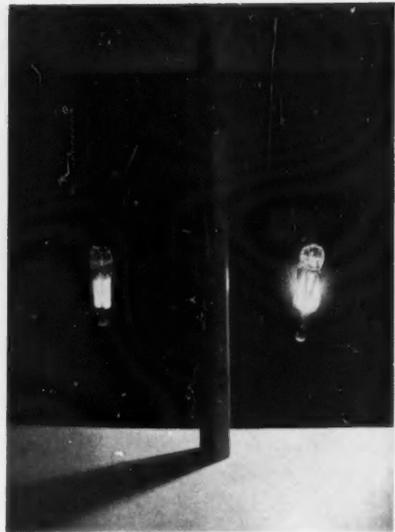
**DEMONSTRATION ROADWAY** lighting facility offers opportunities for showing the effects of virtually every combination of modern lighting that can be applied to American roadways.



**PARALLEL-TO-ROADWAY** fluorescent luminaires in a continuous row at a distance of about 25 feet above the pavement give almost perfect uniformity of light on the road.



**PIONEERING INSTALLATION** of lighting at General Electric's Lighting Institute attains the world's highest comfortable lighting level with new power-groove fluorescent tubes.



**HIGH-BRIGHTNESS** glow lamp now gives 8 times the light output of previous models.

ground similar to those used by automobile manufacturers to aid the Company in developing improved equipment to help reduce night hazards for motorists and pedestrians. A master control panel permits rapid changes of lighting setups so viewers can compare effects of all 3 major light sources—filament, mercury, and fluorescent—on streets similar to those found in any community. More than 130 luminaires of 15 different types are mounted on steel, aluminum, concrete, and wood poles. These luminaires are available in a variety of brackets.

Streetlighting luminaires equipped with the new power-groove fluorescent lamps make possible a 60 to 65 percent increase in light output over high-output lamps.

Parallel-to-roadway fluorescent lighting, a completely new and experimental system of street and highway illumination, has already been demonstrated at the roadway facility. A continuous row of fluorescent luminaires—mounted parallel to the curb and 25 feet above the pavement—give almost perfect uniformity of light on the road. The advantages: more driving comfort and greater safety.

Another test installation operates conventional fluorescent street lights from high-frequency power, resulting in higher operating efficiencies, reduced ballast weight, less internal heating, and greater light output per luminaire. Ballast weight was reduced as much as 75 percent and light output increased from 10 to 20 percent.

#### Bulbs and Lamps

New mercury sources for streetlighting, airports, and industrial applications were introduced during 1957. A 1500-watt quartz mercury lamp, rated at 81,000 lumens and operating at an efficiency of 54 lumens per watt, has the highest light output of any mercury lamp of this length ever produced for general lighting. Although designed specifically for use in lighting parking areas at the New York International Airport, it's expected to meet with wide acceptance in lighting other large outdoor areas.

Two new white mercury lamps offer 3 major advantages: as much as 63 percent more light just by changing from old-type lamps, as much as 33 percent lower light cost, and better white color than from any clear mercury lamps. The improved performance of the white mercury lamp results from a new specially designed strontium-magnesium orthophosphate phosphor. This material converts ultraviolet radiation into more white light than ever before possible.

Another line of 400-watt mercury lamps uses a special weather-resistant glass in the outer bulb to make it possible for the lamps to survive greater thermal shock without breaking. These new lamps are expected to be especially useful for gas-station, parking-lot, and a variety of other yard-area lighting where they are subjected to cold water and snow.

A lifeline of light for jet-aircraft pilots, produced by a powerful airport

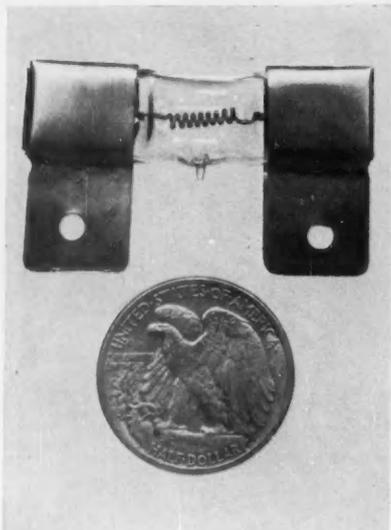
beacon lamp, will go into operation at U.S. Air Force bases. The new lamp, which provides positive location and identification of landing fields from greater altitudes than ever before, can be seen from a height of 30,000 feet and from 30 miles away in clear weather—even daylight. Under restricted visibility conditions, the lamp's beam can be seen from 5000 feet at distances of 5 miles.

The illusion of "lighted ice" was created for Christmas and decorative lighting during 1957. The new lamp is a colored sphere covered with tiny plastic crystals that simulate nature's gems.

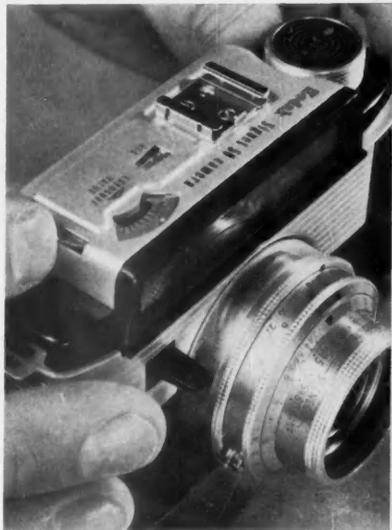
The brightest glow lamp, which has been in use for the past 2 years, operates at approximately 1 ma with 5000 hours of life to 60 percent of initial brightness. By modifying the design, a new high-brightness lamp operates at about 4 ma, giving 8 times the light output for the same life.

During 1957, a quartz lamp, pencil slim and only 2¼ inches long, was introduced for jet-aircraft wing tips and markers. Designed to operate at 150 watts, this high-intensity source maintains virtually 100 percent light output until near the end of life.

The twinkle lamp, introduced as a Christmas lamp in 1956, was expanded to a variety of applications last year. The basic design was adapted to lamps for both indoor and outdoor applications, including automotive, highway marking, hand lantern, toy, novelty, and decorative.



**QUARTZ LAMP** for jet aircraft has 100 percent light output until near end of its life.



**EXPOSURE METER** was designed to be integrally mounted on a new Kodak camera.



**POWER GROOVE** fluorescent lamps give a 60 to 65 percent increase in light output.

### Photography

An exposure meter, the smallest yet built by General Electric, was designed to be integrally mounted on a new Kodak camera. The meter ranges cover film speeds of ASA 100 to 400 and directly indicates exposure values (LVS numbers) of 5 to 18 that correspond to the camera lens number. One design feature—a steel case—serves not only as an enclosure for the meter but also as a flux return path for the magnet.

Another new exposure meter is the first American-produced meter to operate well within ASA accuracy standards and to be designed for the budget-minded. Because of the dial and pointer arrangement, the meter can be read directly for all common exposure-index numbers and shutter settings in any combination. This feature also makes the meter simple to use even though the scale includes both f-stops and the new LVS numbers.

A new concept in flash-tube design was introduced last year. It is a small linear source—pin terminals and a precision sealing technique produce a tiny lamp, requiring a remarkably small mounting space. The third, or starter, electrode is a conducting film on the arc chamber where the equipment designer can lead the ionizing pulse in a manner suited to his space limitations.

The promise of higher-speed color films for movies has made smaller diameter reflector photoflood lamps practical. Four of the new lamps—each rated at 300 watts—can be used on a 15-amp home circuit without blowing

the fuse. Even with existing color films and the usual f2.8 lens, pictures can be taken up to 10 feet from the subject.

New 300- and 500-watt projection lamps for use in amateur photographic slide projectors are shorter in length than their predecessors. This factor allows equipment designs to be lower, smaller, more compact, and less costly.

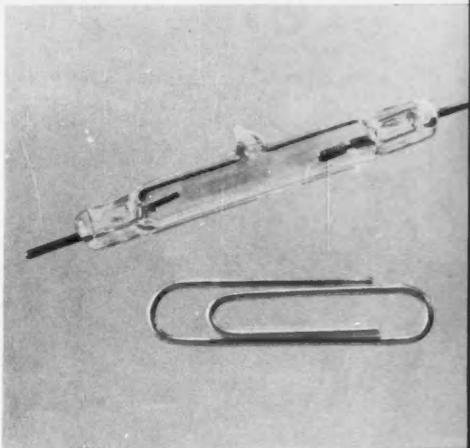
### Fluorescent Ballasts

A new shallow-height ballast introduced during 1957 for slimline 2-lamp applications is smaller, lighter, more efficient, and better insulated than its predecessor. Electrical and magnetic circuit innovations, a solution of heat-transfer problems, and more efficient use of materials and improved manufacturing technology helped make this new design possible.

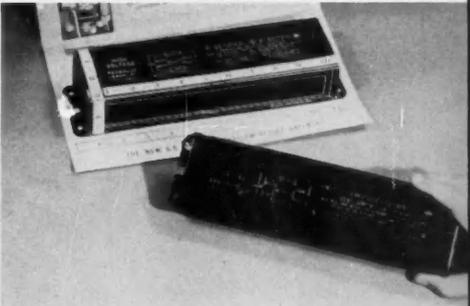
By means of a new sound-rating calculator, architects and consulting engineers can now predetermine whether they will encounter a ballast-noise problem in an installation. By setting the ballast's sound rating on the calculator along with the number of ballasts to be used, the proper room constant, and the ambient sound level of the room, the user can determine typical listener reaction by reading the calculator dial.

### Lampholders

A new and improved line of 2- and 3-lamp plastic-turret lampholders possesses a molded base of greater strength and rigidity and less weight than metal turret lampholders. A slanted front

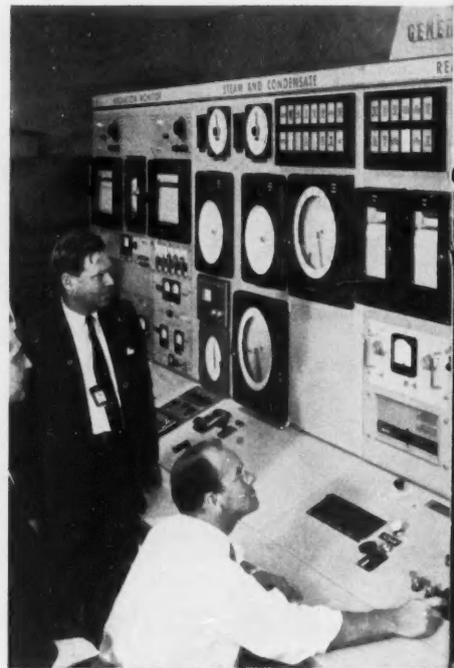
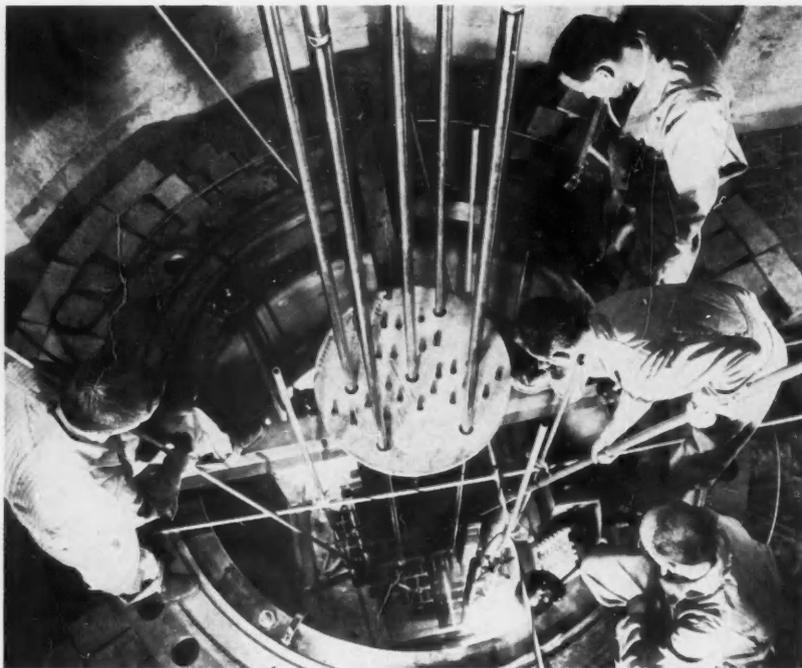


**SMALL LINEAR SOURCE**, minimizing space, introduces a new concept in flashbulb design.



**NEW BALLAST** for slimline 2-lamp applications is smaller and lighter than predecessor.

minimizes the dark area between fixtures, giving maximum light diffusion at the lamp ends. Segregation of lampholder leads makes identification positive in handling and wiring fixtures.



**DEVELOPMENTAL BOILING-WATER POWER REACTOR** at Vallecitos Laboratory sustained its first chain reaction in August 1957; instruments

## Nucleonics

On October 24, General Electric and the Pacific Gas & Electric Co. turned on the world's first all-privately financed, atomic electric plant at the \$10-million General Electric Vallecitos Atomic Laboratory (Cover) located near Pleasanton, California.

Only 1 year and 5 months after the decision was made to construct the Vallecitos boiling-water power reactor, 5000 kw of electricity were sent to homes, farms, and industries in northern and central California over PG & E Co. lines.

Actual power production was the culmination of tests that started August 5 when the reactor sustained its first chain reaction. The General Electric reactor is operating under license No. 1, issued August 31 by the Atomic Energy Commission (AEC).

The Vallecitos reactor will be used primarily to develop operational data for the 180,000-kw boiling-water reactor being built near Chicago by General Electric for the Commonwealth Edison Company and the Nuclear Power Group, Inc. The Dresden Nuclear Power Station is the largest all-nuclear power plant yet begun in the United States, was privately financed, and plant engi-

neering for this station is 92 percent complete at this time. Construction will be complete by 1960.

In addition to the boiling-water reactor, other facilities at the laboratory include . . .

- A radioactive materials laboratory equipped to carry out intensive studies of materials that have undergone nuclear radiation—studies already aiding in selection of improved material for reactors and improved reactor fuels.

- An experimental physics laboratory that houses a critical assembly for testing various types of reactor cores, nuclear test reactors for measurement of nuclear properties and calibrations, a core-assembly room, arc electronic computer, and other laboratories.

Work at General Electric's San Jose plant is also progressing on 2 small 12,500-kw single-cycle boiling-water reactor power plants for the American & Foreign Power Co., Inc. These two plants will be installed at a site in Latin America.

### Research and Test Reactors

The Lockheed Aircraft Corp. will be furnished 2 special research reactors and a critical assembly for use in the

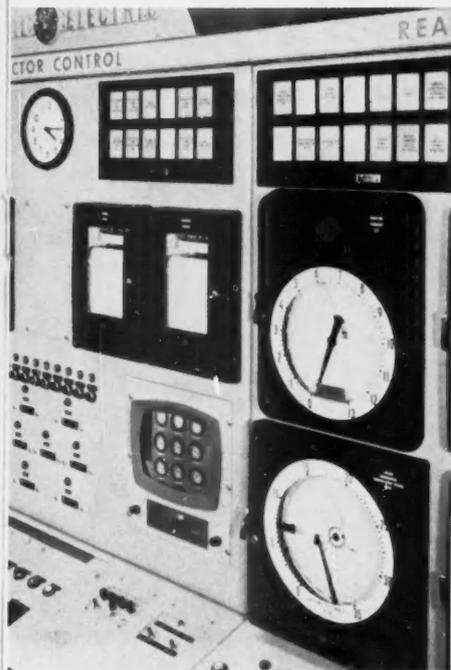
U.S. Air Force program for development of a nuclear powered aircraft. One of the reactors is a shielding development reactor (SDR), which will be suspended 200 feet above ground on cables to aid in studies of shielding materials. The other reactor is a radiation effects reactor (RER).

During 1957 the 7500-thermal-megawatt (tmw) engineering test reactor (ETR) for Kaiser Engineers, Div. of Henry J. Kaiser Co., and the AEC for use at the National Reactor Testing Station at Idaho Falls, Idaho, was completed. This reactor provides radiation facilities larger than any previously available.

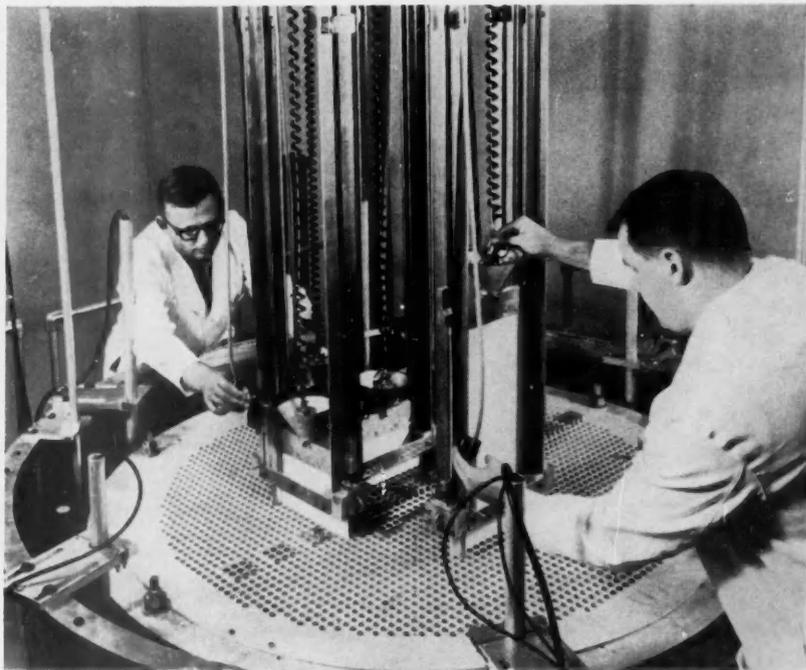
Two open-pool research reactors for Spain and Venezuela are also currently being worked on. Each will furnish 3 tmw. These reactors will be used for research in agriculture, medicine, and training of personnel in reactor operation and nuclear research procedures.

Successful tests of a Spanish reactor were completed and the reactor shipped to the Moncloa area near Madrid. The reactor will be assembled early this year in Spain and is expected to begin operation in March.

Other major advances were made in design and development of the \$4-million 30-tmw General Electric test reactor (GETR), designed primarily as a material testing reactor. It combines the advan-



in the control room recorded the historic event.



**CRITICAL ASSEMBLY** is used to mock up reactor cores at the Vallecitos Atomic Laboratory.

tages of high specific power found in tank-type reactors with the large, easily accessible, experimental space of pool-type reactors. The reactor is light-water cooled and moderated with a high-flux core contained in a 2-foot-diameter aluminum pressure vessel. The pressure vessel and core are submerged in a pool of light water that serves as a reflector and provides a large, flexible high-flux irradiation facility. This arrangement permits freedom in location; size; and configuration of loops, capsules, beam ports, and experimental chambers. Completion of the reactor installation is scheduled for this year.

#### Hanford Atomic Products

Noteworthy atomic progress was realized during 1957 at the Hanford Atomic Products Operation (HAPO) in all phases of research, engineering, and plutonium production. General Electric has operated the vast AEC installation near Richland, Washington, since 1946.

The use of plutonium-239 as an enrichment material instead of uranium-235 would permit the operation of enriched-fuel reactors without dependence on expensive uranium-isotope facilities. It would increase several-fold the amount of energy recovered from a given amount of raw uranium.

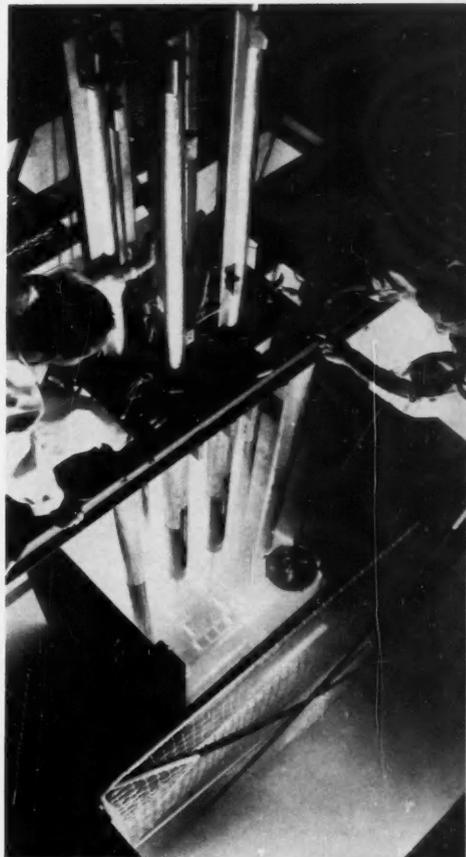
During 1957 Hanford undertook an extensive program to explore the utili-

zation of plutonium as a fuel in thermal, heterogeneous power reactors. This program embraces the use of the plutonium natural-uranium feed cycle. Therein the reactivity of natural uranium is supplemented by added plutonium, in either a self-sustaining cycle in which plutonium requirements are fully satisfied by repeated use of plutonium recovered from spent uranium-fuel elements or in a cycle requiring additional plutonium from an outside source.

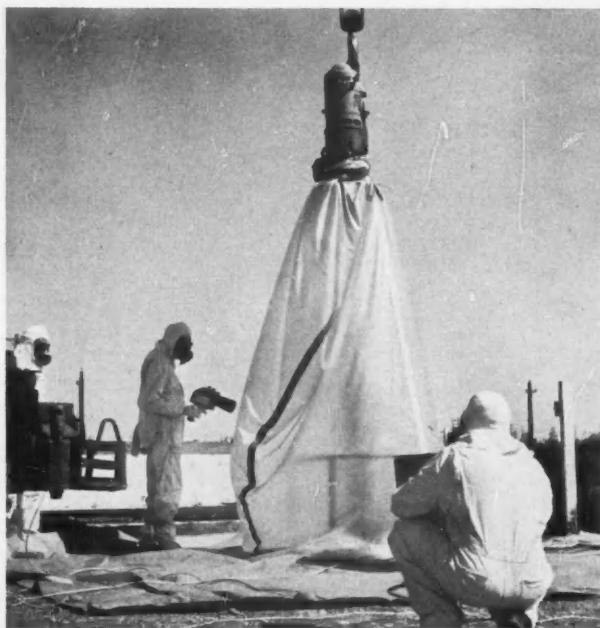
According to present plans, the plutonium recycle program reactor (PRPR) would provide an experimental facility for the determination of a plutonium-fueled reactor's physics characteristics, the evaluation of fuel-element designs, the study of reactor engineering concepts, and the operating techniques associated with the use of plutonium-containing fuels in power reactors.

The design of the PRPR is characterized by a high degree of flexibility, low neutron temperature, independent accessibility of the fuel elements, and comprehensive instrumentation for experimental purposes.

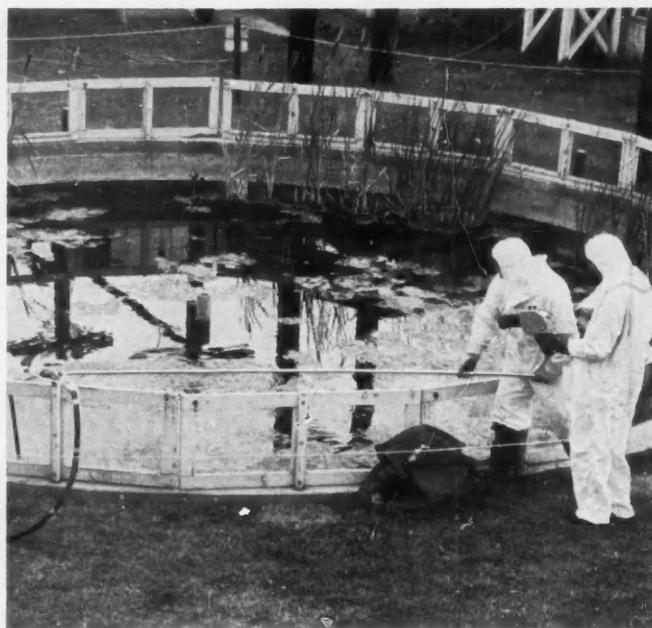
The PRPR will be moderated by unpressurized heavy water, cooled by pressurized heavy water—with the alternative of other coolants—and will have a heat rating of 70 megawatts. Electric power recovery facilities will



**OPEN-POOL** reactor will be shipped to Spain.



**PLASTIC SHEATH** seals off radioactive equipment when removed from waste storage tanks, prevents spread of radioactive contamination.



**HANFORD BIOLOGISTS** introduced cesium-137 into pond simulating natural conditions, recovered 95 percent of the isotope 5 days later.

be provided to supply the needs of the plant. The reactor, a pressure-tube type, will employ the gas-balance method, or manometric principle, of regulating the liquid-moderator height. This gas-balanced moderator will serve in reactor control and shutdown. Supplementary control will be obtained from replaceable mechanical shim rods. The reactor will be housed in a welded-steel containment building, with office and service space located in an adjoining wing.

Plutonium-containing fuel elements were fabricated experimentally and tested in support of the PRPR. For physics tests, 60 feet of 1/2-inch diameter plutonium-aluminum-silicon alloy capsules were fabricated. Plutonium-aluminum alloy and plutonium-aluminum-silicon alloy capsules have been irradiated to high burn-up without difficulty. Plutonium-containing ceramic fuel materials are also being prepared for evaluation.

#### Fuels

In May 1957 a fuel-element pilot plant went into operation at Hanford. Its completion provided Hanford with the first facility devoted exclusively to developing and piloting better reactor fuels. This facility is comparable in size and scope to one complete manufacturing "line" of Hanford's regular fuel-element manufacturing plant. As

such, it includes complete facilities for fuel container and uranium preparation, canning, finishing, and inspection.

Chemists at Hanford scored a major breakthrough in the reprocessing of reactor fuels during the past year. They recently demonstrated that zircaloy jackets—one of the materials most favored by reactor designers for fuel-element fabrication—can be dissolved off fuel materials by aqueous ammonium fluoride solutions, which are not corrosive to stainless steel. Thus most zircaloy-clad fuels can be processed in existing separations plants with minor modification of present equipment.

#### Disposal and Recovery

Looking into the future for possible ways to process high-level radioactive wastes, Hanford engineers studied the fixation of radioisotopes in solid media. One promising process consists of adding certain low-cost chemicals to aluminum-bearing wastes. A gel formed in a matter of minutes retains most of the radioisotopes. This gel may be discharged into prepared excavations without further treatment; alternatively, if desired, the water can be evaporated off, the mass heated, and the material disposed of in a sintered porcelain-like or glassy form.

The potentialities of self-calcination are also being investigated. By careful control of the gelled waste composition

and fission-product concentration, the heat generated by the fission products themselves would calcine the gel.

A long-range research program to recover fission products from Hanford waste streams began to bear fruit. With the realization of inexpensive recovery of radioisotopes, the waste-storage problem is being simplified. But, more importantly, radiation sources will be made available for industrial use.

Major interest centered on the recovery of cesium-137. This fission product has a long half life (30 years) and is a powerful gamma emitter, making it competitive with reactor-produced cobalt-60. The recovery process developed utilizes the unique cesium scavenging characteristics of the metal ferrocyanides. The acidic waste is neutralized to precipitate iron and the cesium then selectively precipitated as cesium zinc ferrocyanide. Further processing yields pure, stable cesium chloride suitable for packaging as a radiation source.

Other fission products are recovered from the precipitated iron and from the solution that remains after the cesium removal.

The process has been tested successfully with full-level plant waste on a laboratory scale, and pilot-plant development is under way. Megacurie amounts of low-cost radioactive cesium could be made available by 1960.

### Biological Studies

The first experiment of a series designed to determine the movement of individual fission elements through aquatic food chains was initiated during 1957. Cesium-137, an important long-life fission product, was introduced into a laboratory pond containing a large variety of plants and animals. More than 95 percent of the isotope was removed from the water 5 days after its introduction. The cesium-137 was accumulated in varying degrees by all the organisms in the pond, and a large amount was accumulated in the mud at the bottom of the pond.

The hazards of inhaling insoluble radioactive particles were investigated by exposing mice and also large animals to aerosols of ruthenium-106, plutonium-239, and strontium-90 particles. Whole-body monitors capable of detecting low levels of these isotopes in the live animal facilitated studying the deposition and retention of the inhaled insoluble particles. The metabolism of the particles and the pathologic changes caused by the radiation from the particles were also studied.

Experiments revealed that only 25 percent of the insoluble ruthenium-106 particles inhaled by mice appears in the lungs, and only half is expelled in 24 hours. The other 75 percent is either exhaled or excreted via the alimentary tract. After a period of time the particles in the lung were slowly removed; some appeared in other organs such as lymph nodes, spleen, kidney, and ovaries. The objective: to know whether ir-

radiation of pulmonary tissues by discrete sources—such as particles, which were shown to produce tumors—is more carcinogenic than homogeneously administered radiation and to give a firm basis for permissible exposure limits for man for insoluble radioactive particles.

Extensive tests were performed to determine the uptake of strontium-90 into plants grown in a nutrient solution and in soils fortified with various chemical forms of calcium. When fully available, calcium and strontium were concentrated in the plant in proportion to their concentration in solution. Contrary to predictions that competition would occur between calcium and strontium, little or no reduction occurred in the concentration of strontium-90 in the plants as calcium concentration was increased in the root environment. Other laboratories have shown that a reduction in plant uptake of strontium-90 occurs when they are grown in soils rich in calcium. This discrepancy suggests that the factors responsible exist in the soil rather than in the plant. Experiments under way are expected to clarify important parts of this complex problem.

Results from chronic studies in lambs show a decreased radiostromium uptake with increased calcium in the diet. A threefold increase in calcium resulted in about a twofold decrease in radiostromium uptake. This observed decrease in uptake, however, is less than one would predict if the body did not distinguish between calcium and strontium. Also indications suggest that some of the

effect ascribed to calcium may be, in reality, caused by adding gluconate to the calcium.

### Water Studies Semiworks

Hanford's Water Studies Semiworks, a pilot irradiation facility, was placed in full operation. It serves as a proving ground for fuel elements, materials, corrosion tests, performance testing of reactor-cooling-system components, and study of radiation problems involved in the use of pressurized pure water as a reactor coolant. Significant technical data were accumulated for both single- and 2-phase water-cooling systems at high pressures and temperatures.

This vital testing facility utilizes zirconium pressure tubes extending through a Hanford reactor. It provides a similar environment to those expected for advanced plutonium producing reactors.

### Pulse Column Developments

The efficient separation of plutonium, uranium, and fission products in a Hanford chemical processing plant was pushed nearer to the theoretically obtainable process limit by redesign of the solvent extraction equipment. Although laboratory data indicated that essentially complete separation from fission products could be obtained in a single multistage solvent extraction unit, such results were never obtained in production plants; several units in series were required.

As originally designed, stainless-steel perforated plates were used as the internals of the solvent extraction pulse columns. Difficulty with fission product removal was attributed to the accumulation of foreign impurities and absorbed fission products at the top, or product end, of the column. The periodic break-up of the agglomerated solids permitted a fraction of them to be carried overhead with the organic product stream. Because a separation of 1 part in 10 million is sought, even the slightest solid carry-over would undo the separation.

While the solution—the design of equipment to permit the accumulation of solids at the bottom, or waste end, of the column—appeared obvious, efficiency and capacity requirements also had to be met. Application of knowledge from many laboratory and semiworks studies made it possible, through the redesign of and incorporation of new materials of construction into the pulse column internals, to meet all the criteria.



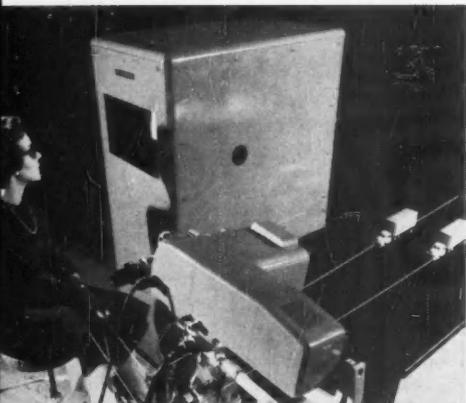
**CLOSED CIRCUIT TV** is becoming valuable in decontamination work at HAPO.



**GELLING** of atomic wastes being explored at HAPO may have promising possibilities.



**O'MAN** manipulator in the hot shop can handle from 500 to 3000 pounds.



**COLOR STEREO TV** permits an operator to observe screen and direct manipulator.

#### Titanium Heat Exchanger

Chemical researchers put titanium to work in Hanford's chemical-plant equipment. This represents the first application of the material for chemical process equipment in the atomic energy industry.

The superior corrosion-resistant qualities of titanium in nitric acid and nitrate salt caused it to be selected for use in a tube heat exchanger. Stainless steel was used previous to titanium application. Under conditions where stainless steel corrodes appreciably, titanium may outlast stainless steel by a factor of 20 or more. Therefore, although titanium costs more, its use is justified. Prior to fabrication of the heat exchanger, development of satisfactory testing methods to establish tube quality and develop a technique for preparing sound welds proved necessary. The exchanger operates with steam on the outside of the tubes and with an acid solution on the inside.

#### Aircraft Nuclear Propulsion

Mechanical "hands" that can disassemble an aircraft jet engine bolt by bolt are part of the remote-handling equipment in one of the world's largest shops for handling radioactive equipment.

The huge hot shop—160 feet long, 50 feet wide, and 63 feet high—is part of the AEC's test facilities utilized at Idaho Falls.

Remote-handling tools in the shop range from a 100-ton crane down through O'Man, a huge mechanical "arm" designed and built by General Electric, to a much smaller master-slave manipulator for making intricate mechanical adjustments.

The O'Man manipulator can handle from 500 to 3000 pounds, depending on the arm length and position used. This giant manipulator is suspended from a crane bridge and can cover the entire working area of the shop.

Operators of these manipulators and four other electrically controlled wall-mounted manipulators are protected by concrete walls some 7 feet thick and by 9 windows of lead glass and zinc bromide, 6 feet thick. Each window contains 500 gallons of zinc bromide to protect operators from stray nuclear radiation.

Enough controls are located at each window to operate any piece of servicing equipment in the entire shop. Radio contact can be maintained by operators in the control galleries with other oper-

ating sites and with a lead-shielded locomotive used to haul equipment to be maintained in and out of the huge shop.

The shop is serviced by a track system that enters through large remote-controlled double doors at the west end. Smaller entrances are provided for personnel who must enter the hot shop.

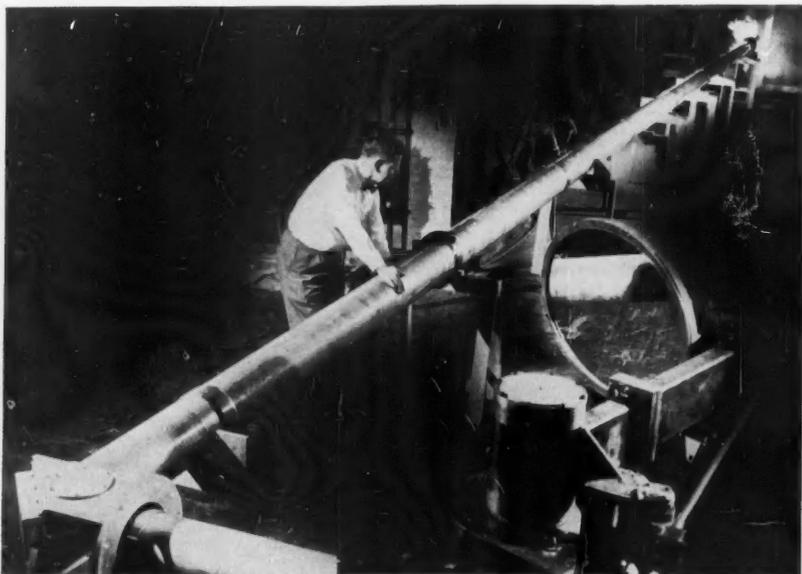
On the floor of the shop are 2 large-capacity turntables for rotating heavy equipment that must be serviced. Rotation of these nuclear aircraft-propulsion equipment components provides easier access by tool and better view from any of the 9 observation windows.

Connecting with the hot shop by water canal is a water-filled storage pool for fuel elements and other radioactive units. The pool, 120 feet long, 60 feet across and 24 feet deep, is filled with water that is much purer than ordinary distilled water.

Visual observation of work in the hot shop is difficult because distances involved between observer and equipment often exceed 50 feet.

Unique in the shop's viewing system is the world's first closed-circuit 3-dimensional color-TV system, developed last July. The system remotely services the reactors of a nuclear-propulsion test system. A color stereo system, its design permits the use of color-coded parts in reactor components and provides the precise depth perception needed for correctly positioning these parts.

In use, the TV camera is positioned inside the radioactive area. The viewing



**PERISCOPE**, believed to be the world's longest, has a 90-foot aluminum tube equipped with intricate mirror-and-lens system for safe viewing of a reactor undergoing test.

screen is located behind thick shielding walls and near the controls of a mechanical manipulator some distance away. By observing the 3-D color picture on the screen, an operator directs the movements of the manipulator inside the radioactive area. Special polarized glasses are required to view the picture.

Also installed at the test site is a periscope believed to be the longest in the world. Its 90-foot aluminum tube possesses an intricate mirror-and-lens system that permits a technologist to safely view—from behind heavy shielding—the performance of an atomic reactor undergoing test in the aircraft nuclear-propulsion program.

A "little brother" periscope only 60 feet long—yet longer than most submarine periscopes—operates along with the 90-foot periscope. The combination of these 2 allows observers to watch opposite sides of a "hot" reactor.

A new force-reflecting servo manipulator developed for AEC's Idaho Falls test station has a total of 20 independently controlled motions on 2 arms and a mobile mount for the master station. Dexterity of the hands was achieved by several unique gearing arrangements, efficiently packaged in small housings. Fingertip force rating is 20 pounds, and a force of 175 pounds is available at the crotch of the hand. Force ratio of the master hand and arm to the corresponding slave hand and arm is adjustable.

### Naval Propulsion

Last March the USS *Seawolf* officially joined the Navy's submarine fleet, following sea trials. Commissioning took place in Groton, Conn., bringing to a successful conclusion more than 3 years of development and test work. The *Seawolf's* power plant, designed and developed at the Knolls Atomic Power Laboratory (KAPL), near Schenectady, NY, will be able to operate for more than 100,000 miles without needing a new fuel charge.

The hull section that will house the prototype high-pressure water nuclear power plant for the world's largest submarine has been completed at KAPL's West Milton test site.

This is the first 2-reactor power plant ever developed for submarine propulsion. The *Triton* is a radar picket ship designed to operate in conjunction with a fast carrier task force furnishing it with radar information.

When completed, the over-all test facility for the submarine advanced reactor (SAR) will include fuel and equipment service buildings, warehouse, and office area.

Design of the SAR was completed in 1957, and manufacture of the reactor and power plant has greatly advanced. The pressure vessel for the prototype reactor was delivered to the West Milton, NY, testing site in October.

First public announcement of KAPL's new destroyer project was made last

March. KAPL will design a high-pressure-water plant for the destroyer, and prototype equipment for this project will be tested at the West Milton site.

The project is designated DIG, for destroyer I General Electric.

### Nuclear Reactors

New facilities costing more than \$1 million were completed at KAPL for use in a 2-pronged attack on the increasing technical complexities of nuclear reactor design.

The new 2-story building will house 2 nuclear reactors for experimentation and an IBM 704 computer for analysis of problems. The facility is being installed to help meet reactor requirements with less margin for error than has ever been possible.

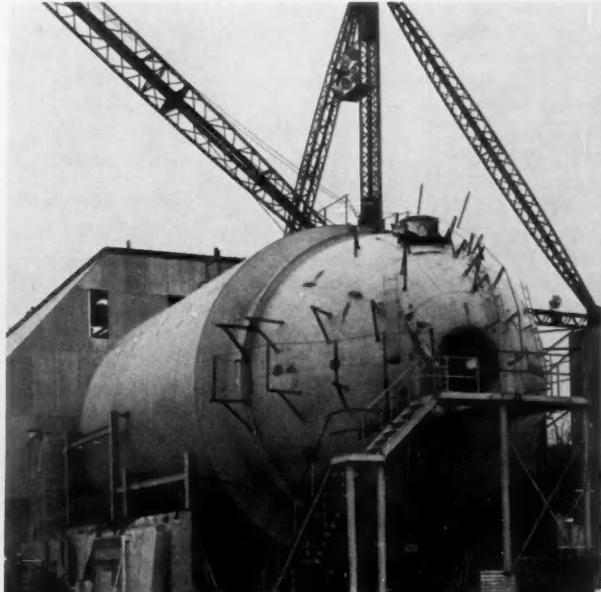
The new computer facilities will necessitate doubling the previous laboratory staff for mathematical analysis. It will be used for solution of atomic power-plant design problems in nuclear physics, heat transfer, stress analysis reactor control, and systems transient response.

Experimental reactors in the building will produce no power or heat but will be used to obtain physics and nuclear design information connected with the development of nuclear power plants.

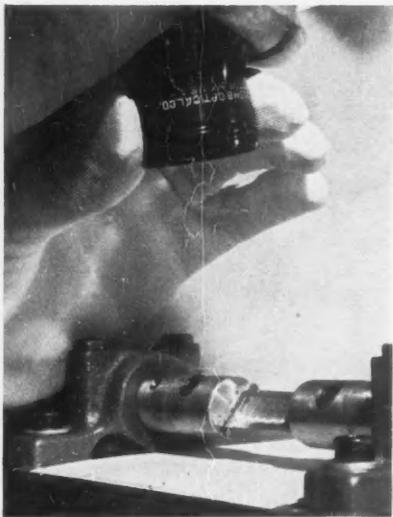
An electronic computing device for measuring, counting, and classifying time of flight of neutrons now accomplishes in an hour what previously



**NEW FUEL CHARGE** is needed only after USS *Seawolf*—now in Navy's submarine fleet—operates for more than 100,000 miles.



**SUBMARINE HULL SECTION** at the KAPL West Milton site will house the prototype atomic power plant for the submarine *Triton*.



**NEW DETECTOR** of temperature resistance utilizes tungsten wire as sensing element, withstands nuclear radiation from reactor.

required several months to accomplish with common computing equipment. The device has 256 channels, each storing up to 65,536 neutron counts.

Development of new reactors at KAPL involves mock-up of various fuel arrangements and accurate measurement of resulting neutron energy spectrum.

This is accomplished in a large part by measuring the time of flight of neutrons over a given distance and recording the number of these neutrons that fall into 256 different velocity ranges. Through various calculations, scientists can convert the velocity of these neutrons into corresponding energy ranges.

To accumulate this vital information, a neutron beam coming out of the thermal test reactor is chopped by a rotating shutter so that velocity can be measured. At the end of a flight path of established length, the neutrons are detected by a counter and the information relayed to the analyzer.

Information on each neutron counted is directed into one of 256 channels, each representing a velocity range. Up to 65,536 neutron counts is stored in each of these channels.

After the experiment this information is transmitted over cables to electronic calculating equipment that punches information from each channel of the analyzer onto a separate card.

This information is then fed into a digital computer for analysis of the data from the cards, and the result is then automatically plotted on a graph that shows the reactor energy characteristics.

The entire operation from neutron count to production of a graph that reveals the energy spectra of the reactor requires only about an hour, compared with a month's work had a single scientist recorded the data manually.

A system for handling hot atomic fuels at KAPL permits the reinsertion of radioactive fuel into the loop facility of a material test reactor for the first time. The loop facility simulates conditions under which fuel will burn in the power-producing plant for which it's designed. The equipment is now in use at the AEC's National Reactor Testing Station in Idaho Falls.

KAPL's preliminary pile assembly (PPA) reactor has been started and shut down more than 10,000 times in the 9 years of its operation. The ability of PPA to be shut down and restarted in 15 minutes facilitates the rearrangements of fuel elements, making possible the simulation of a large variety of reactors. Performing jobs of this sort, PPA predetermined the heat distribution in the core of the *Seawolf* prototype reactor and a number of other reactors studies.

#### Square Bubbles

A unique phenomenon, square bubbles, was observed at KAPL during the year. They appear in irradiated lithium fluoride during annealing and are typical bubbles in every respect except shape. Characterized by brilliant interference colors, they are probably no more than 0.002 millimeters thick. Unirradiated lithium fluoride has produced no bubbles—square or round—under any conditions to date. Studies are under way to find the reasons for this unusual phenomenon of square bubbles in irradiated lithium fluoride.

#### Other Developments

A 12,500-kw nuclear-powered turbine-generator set is being built for the American & Foreign Power Co., Inc., as part of a packaged nuclear power plant, for installation in Cuba. Presently, a plant of this size is economically feasible *only* where high fuel costs exist. Critical areas of the turbine require the use of erosion- and corrosion-resistant materials, plus the elimination of undrained pockets where radioactive particles may lodge. An integrated control system between the turbine and reactor is also being developed.

A new resistance-temperature detector withstands nuclear radiation and other environmental conditions encountered

in reactor service. Tungsten wire, wound on mica cards and protected by layers of mica slip in sandwich form, provides the temperature-sensing resistance element. Use of tungsten as the resistance material makes possible precise calibration and good stability.

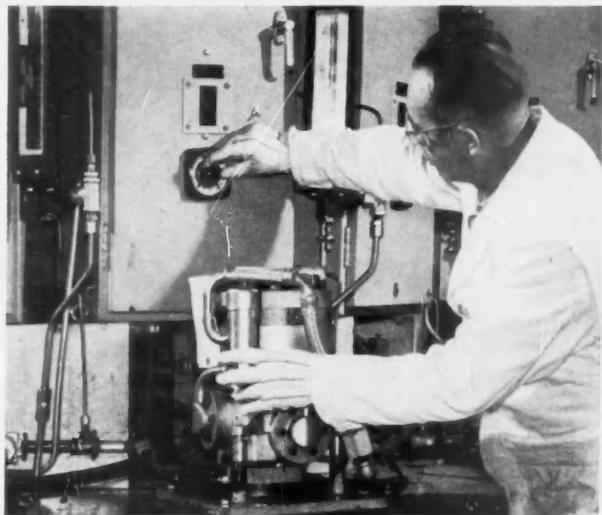
Completed during 1957, a commercial line of nuclear detectors provides complete coverage of reactor-control conditions from start-up, through intermediate control, to power level operation. The detectors vary in size from about 24 inches long by 3 inches in diameter to a 1¼-inch-long by less than ½-inch-diameter ionization chamber used in flux plotting of power reactors.

Intended for use on atomic submarines, an electric and electromechanical system for measuring and controlling steam-plant variables was developed in 1957. Replacing the usual pneumatic-mechanical systems, the new instrumentation improves reliability and reduces noise levels—both extremely important during combat maneuvers. A variation of the system was applied to measurement and control of the level of hotwell condensate collected from submarine propulsion-turbine condensers.

Designed for use in nuclear reactor control, a stable micro-microammeter detects and measures extremely small electric currents. Its fast response and freedom from drift are not found in other available instruments. Additionally, the device readily adapts to many nonnuclear applications where accurate and fast reading of small currents is necessary.

Control and power cables were designed and tested to meet the rigid requirement of containment vessels for nuclear power plants. By utilizing proper materials to fill the strand and cable interstices, gas leakage through the cable's cross section is prevented. In conjunction with stuffing gland seals in the vessel wall, tests showed that the cables remain gas tight inside the vessel up to 32 psig and 350 C.

Construction started on a radiation laboratory that will house a 10,000-curie cobalt source, a 1-million-volt ion accelerator, and a 1-million-volt electron accelerator. The gamma rays, fast neutrons, and high-speed electrons produced will be used in a broad program of investigation. This program will cover the effects of radiation on materials and systems, new techniques using thermal and fast neutrons, and focused high-power density electron beams.



**HERMETIC SEALING** of compressors for new air-conditioners is carefully checked to provide air-tight operation throughout the life of the units.

## Air Conditioning

Advances in heating and cooling equipment were made during 1957 against a background of expanded manufacturing facilities, laying heavy stress on unusual quality-control measures. Among these were development of pressurized-atmosphere manufacturing rooms, underwater-submersion leak testing of heat exchangers, impact and vibration testing of shipping containers, and test equipment for checking compressor hermetic sealing.

### New Cooling Units

A packaged cooling unit was developed for cooling in homes having no central duct system—homes heated by boilers or radiant heat. Adaptable also to the commercial field, the unit proved useful where budget prevented installation of a deluxe system and where installation of a number of room coolers proved uneconomical or unsightly. The unit is finding wide acceptance in stores, factories, and offices throughout the country.

An air handling unit was developed consisting of a blower, cooling coil, and filter combination for use with remote condensing units. This versatile package permits the placement of an attractive unit at convenient locations both in commercial establishments and homes.

A new line of self-contained air conditioners was developed to extend

the size range of commercial and industrial units to 30 tons, greatly expanding the opportunities for application of packaged air conditioners. Industrial air conditioning represents a vast and virtually untapped market. The new units have 3600-rpm fully hermetic 10- and 15-ton compressors with the larger models employing dual compressors. Additional features include a new attractive appearance design, accessory heating coils for steam and hot water, sealed ball bearings for fan shafts, and replaceable hermetic-refrigeration systems.

### Year-Round Units

Any consideration of year-round air conditioning involves the basic member of the team—the furnace; thus 2 new furnaces were developed during the year. One, a gas furnace, has appliance-type styling with a square-cornered functional look. A new 10-year warranty on the heat exchanger is being offered without additional charge. It has non-linting self-cleaning burners and a combination gas valve now being widely copied.

The other, an oil furnace, anticipates market demand for an oil furnace that can be converted to gas. Designed for compact minimum-space installation, cooling equipment can be easily added. Simplification and standardization of all

components make this furnace unusually easy to install and service.

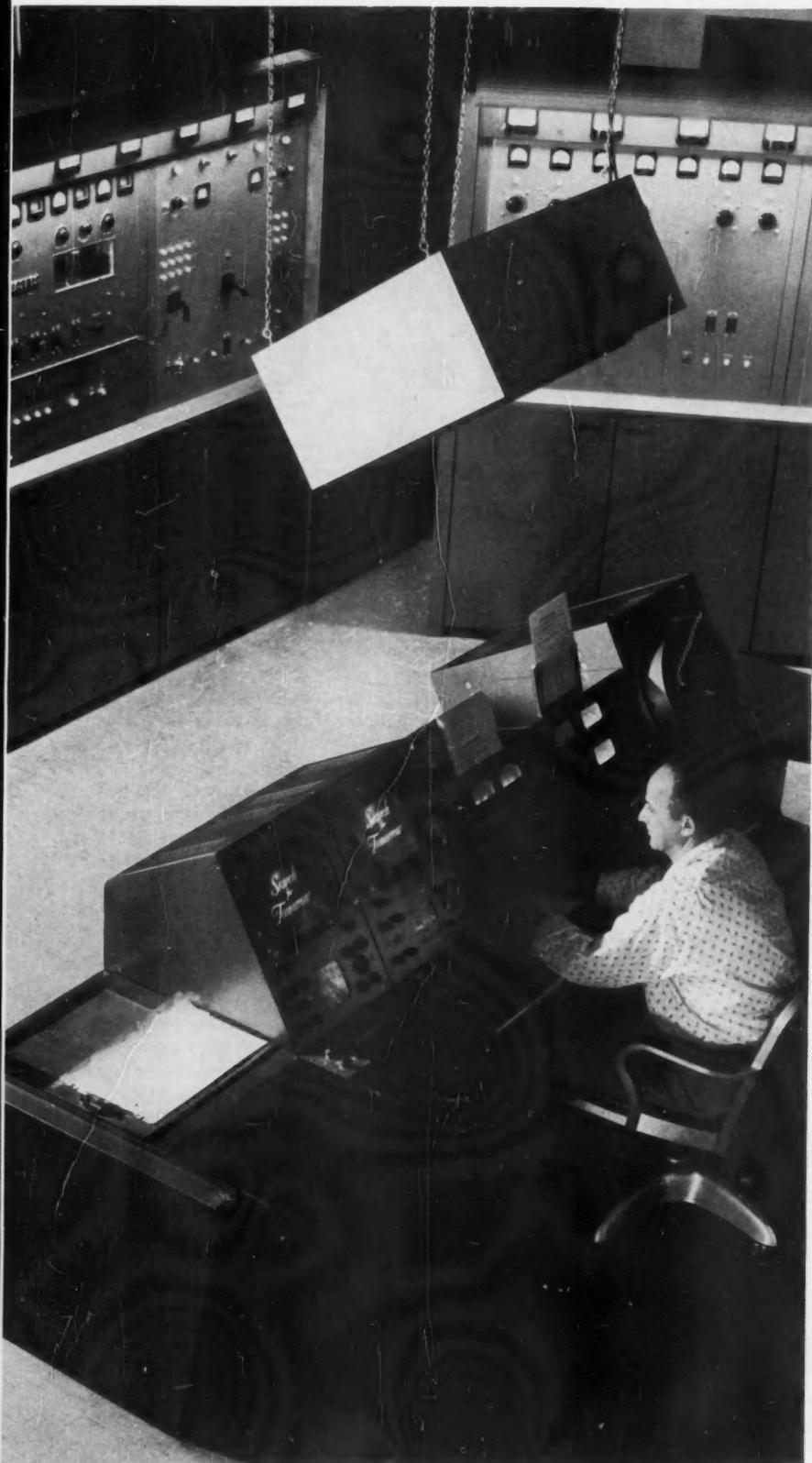
A family of compact high-efficiency heat pumps was developed for 2½ and 3 tons of cooling respectively. They will operate self-protected throughout a temperature range of -20 to +120 F.

Because of their small size for the capacity delivered, a substantially greater opportunity exists for entry into the high-volume builder market. The new 3-ton unit is 40 percent smaller than the previous model; the 2½-ton unit extends the line down into smaller house sizes.

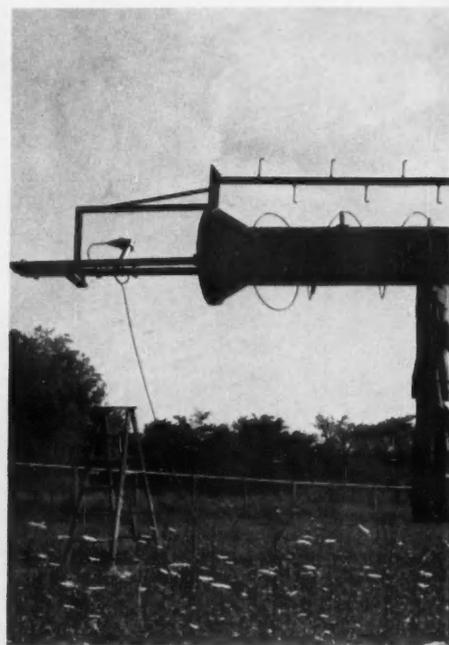
The new line of units is not only smaller than previous models but also more efficient. Heating and cooling operating costs are reduced approximately 18 percent over previous designs; the selling price is approximately 15 percent lower. This line of packaged air-source heat pumps is believed to be the most efficient on the present market.

A new method for selecting capillary tubes for refrigeration applications was developed through correlation of experimental data with an analytical solution representing physical-flow conditions. The correlation allows for delay in vaporization that exists in the tube prior to the transition from liquid flow to a 2-phase mixture of liquid and gas.

A new fan and limit switch 50 percent smaller than previous models was developed for gas- or oil-fired domestic heating systems. One enclosure combines the necessary components to control the fan or blower operation and also acts as a safety-limit control.



**WDAU**, world's most powerful TV broadcast station, is now in operation in Scranton, Penn.



**FIRST HELICAL ANTENNA** modified

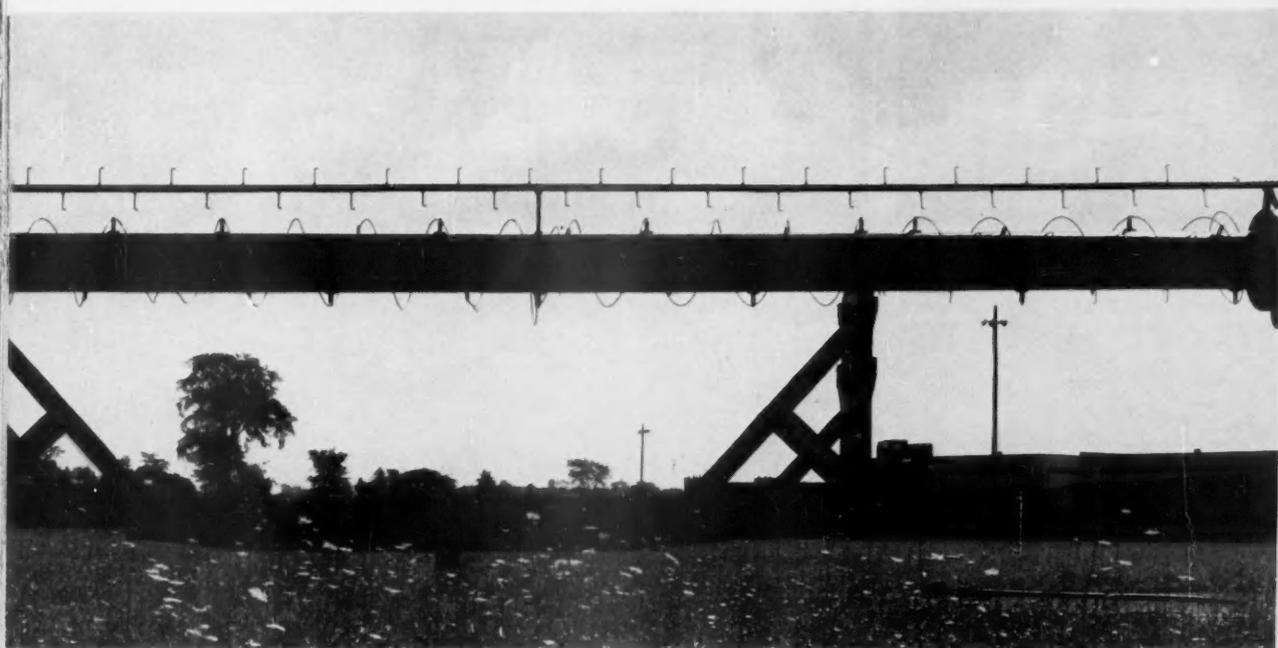
Many advances took place during 1957 in increasingly complex electronics technology. General Electric's broad interests in this field range from communications and components through industrial and defense electronics.

#### **Broadcasting**

Last year, installation of the world's most powerful TV broadcast station was completed at WDAU, Scranton, Penn. Now in operation, the system produces 2-million watts of effective radiated power in the ultrahigh-frequency (UHF) band. Both transmitter and antenna are arranged in dual sections, and a new wave-guide switcher achieves a new high in flexibility and reliability.

Shipped in 1957 to WJMR in New Orleans was the first helical antenna modified to produce a directionalized horizontal field pattern for TV broadcasting. Station WJMR was authorized by the Federal Communications Commission (FCC) to simulcast on their present UHF Channel 20 and on VHF Channel 12, using the directional helical antenna to limit radiation toward a co-channel station in Jackson, Miss.

A major contribution to very-high-frequency (VHF) TV transmission is a new low-channel 11-kw transmitter. De-



to produce a horizontal field pattern for TV broadcasting undergoes pattern tests prior to shipment to WJMR-TV in New Orleans.

## Electronics

signed to meet all existing and anticipated requirements for monochrome and color broadcasting, it is a companion unit to the high-channel 10-kw transmitter.

### Closed-Circuit TV

Two important additions to closed-circuit TV are a remotely operated 4-lens turret and a remote iris control for use with the turret. At a location some distance from the camera, the turret permits selection of any one of 4 high-speed high-quality lenses. Equipment users can change from a wide angle to an extreme telephoto lens by pushing a button. Iris control allows for independent adjustment of each lens's opening to accommodate variations in light intensity of the scene's illumination.

Inserting a Vidicon camera chain into a newly developed viewfinder converts it to a studio-type camera chain. The viewfinder is used for broadcast TV as well as closed-circuit applications.

### Cathode-Ray Tubes

During the year cathode-ray tubes were developed utilizing a new screening technique for deposition of phosphors of extremely thin layers. Where standard phosphor screens have thicknesses in

the order of 25 microns, transparent phosphor techniques allow thicknesses of about 1 micron.

With this new development, it's practical to produce cathode-ray tubes with resolution capabilities in the order of 1000 to 3000 lines per inch.

### Receiving Tubes

It would appear that the year 1957 set an all-time record for electronic tube reliability—7329 receiving tubes operated in the Semi-Automatic Ground Environment (SAGE) air-defense computer for 3000 hours with no shorts, opens, or mechanical defects. Credit for this outstanding performance goes to a new, sturdier computer tube used in some applications interchangeably with an older computer twin-triode.

Currently being developed are a number of ceramic-metal tubes, remarkable for their resistance to high temperatures and excellent dielectric properties at high frequencies. At present, these tubes are scheduled for military equipments or other applications where extreme environmental conditions preclude the use of normal glass tubes.

One of the significant accomplishments in development of receiving tubes last year was a new test method that may

greatly step up reliability. An impulse test was devised that evaluates the vibration output of tubes over a wide frequency-range and promises to permit even higher production-quality standards in electronic tubes for military, aviation, and other critical applications.

Receiving tubes now under development for 110-degree TV picture tubes operate with lower heater power than formerly employed in tubes of high cathode-current capabilities, thus reducing total heat produced. The 110-degree picture tubes allow more compact receivers that require heat dissipation within the cabinet to be held to a minimum. High perveance, high plate dissipation, and large plate-current capability are designed in the new receiving tubes.

Two new high-gain automobile receiving tubes for operation with 12-volt plate and heater supply voltages make possible more economical radios in 1958 automobiles. The increased gain permitted elimination of a tube, socket, and associated circuitry, giving the consumer, in effect, a more sensitive reception with no vibrator hum.

### Power Tubes

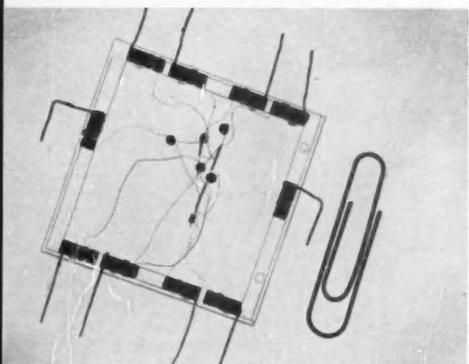
A hydrogen thyratron for switching service in radar modulators and other



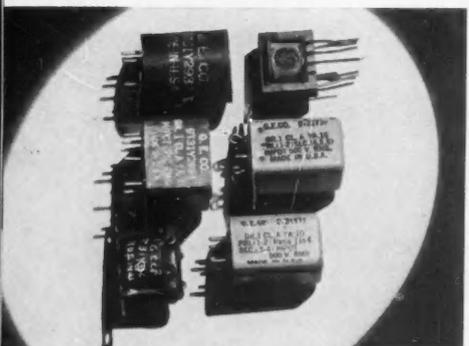
**MIDGET** double-diode selenium rectifier offers sizable savings to TV set manufacturers.



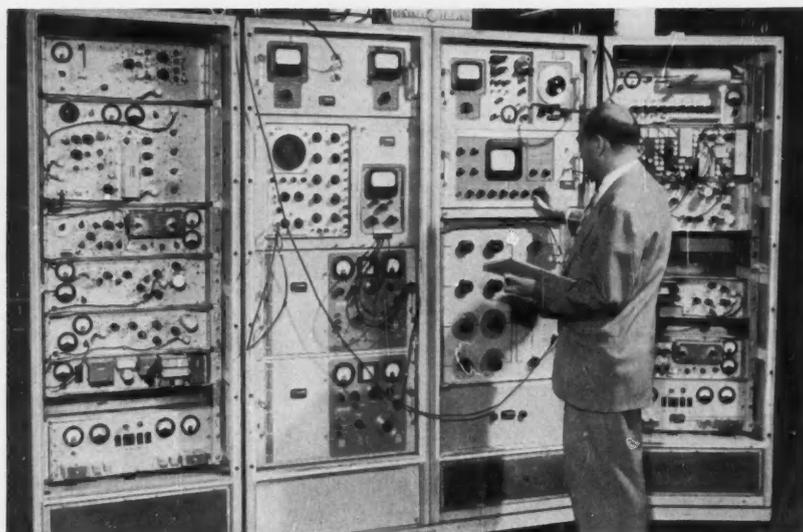
**HIGH-POWER** silicon transistor has a grounded emitter cutoff frequency of 400 kc.



**TINY CRYOTRONS** may replace vacuum tubes and transistors in certain applications.



**TRANSFORMERS**, subminiature and low cost, speed production and sample delivery.



**RACKS OF EQUIPMENT**, developed with Lincoln Laboratory of MIT for U.S. Air Force's new tropospheric scatter UHF communications system, have a 700-mile range.

pulsing service carries high-peak currents and withstands extremely high voltages. The tube has a short-deionization time and is suitable for operation without negative bias. The ratings make it especially suitable for pulsing magnetron and other high-frequency tubes with power inputs up to 33-megawatts peak and 60-kw average.

With very little available light, a new image orthicon TV tube permits portrayal of scenes where illumination is in the red and near-infrared portion of the electromagnetic spectrum.

Designed for 1-megawatt peak power in x-band radar applications was a new tunable high-gain 3-cavity liquid-cooled klystron. Of metal and ceramic construction, the tube operates under severe mechanical and environmental conditions.

Designed for operation in the 2500- to 4000-megacycle range, a hard-solder continuous-wave interdigital voltage-tunable magnetron has a power output to 10 watts in the narrow-band circuit. In an external r-f circuit it may be voltage-tuned over all or a portion of the frequency range for which it's designed.

A newly developed low-noise broadband traveling-wave tube operates over the frequency range of 7.5 to 11.3 thousand megacycles (kmc). With it, a noise figure of less than 10.7 decibels with a minimum of gain variation can be obtained across the entire band at a power output in excess of 1 mw. The tube was designed primarily for use in military systems where broad bandwidth, low noise, high gain, and freedom from

tuning adjustments are important considerations.

### Transistors

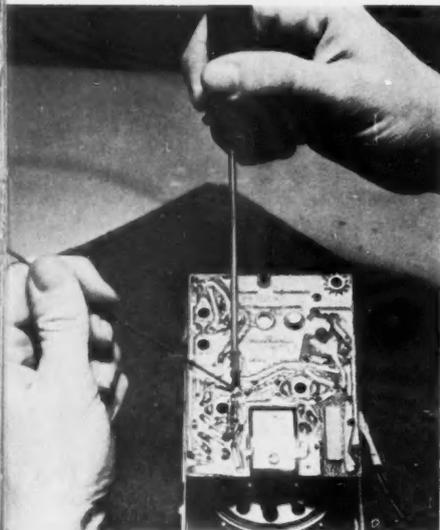
Considerable success was achieved during 1957 with lightweight single-phase magnetically regulated d-c power supplies operating from a 60-cycle source. Tested was a bench layout in which an unregulated d-c source is regulated with switching transistors used as series regulation elements.

Also developed was a line of transistorized general-purpose analog computer modules for use in both general- and special-purpose analog computer systems. All of these components offer completely transistorized or magnetic circuit techniques for ruggedness, high reliability, and extremely low d-c drift. A size saving of approximately 5 to 1 over conventional tube-circuit types for comparable performance was achieved.

During 1957, a new double-diode selenium rectifier was accepted on a large scale by the TV industry. Though designed for a variety of uses, it's ideally suited for application in the TV horizontal-phase-detector circuit. It replaces the larger, more expensive vacuum tube and socket, with considerable savings to the manufacturer.

### Semiconductors

A silicon high-frequency triode, made by the diffused meltback process, was designed for use in both amplifier and direct-coupled transistor-logic switching circuits. With a nominal alpha cutoff frequency of 25 megacycles, it has a



**TINY SOLDERING IRON** develops 750 to 850 F tip temperatures, rapidly recovers heat.

power gain of 15 decibels at 5 megacycles.

Tailored to customer specifications, a 3-terminal negative-resistance device called a silicon unijunction transistor has closer tolerances than any other transistor available commercially. The closer tolerances increased its versatility in general detection and switching circuits and facilitated its use in bistable, monostable, and astable circuits.

Both the foregoing transistors operate reliably in ambient temperatures ranging from  $-65$  to  $+150$  C; they can be stored indefinitely at temperatures to 200 C.

Portable radios will be the initial application of a new pnp germanium transistor utilizing the diffused-base meltback technique. Full-scale production of this device is scheduled for the third quarter of this year.

Progress in the high-frequency transistor field brought about the introduction of a new germanium tetrode. This tetrode was successfully applied to a wide range of prototype equipments: video amplifiers and high-frequency communication equipments, to name a few.

A newly developed high-power silicon transistor has excellent heat transfer from the junctions in the silicon to the mounting base. Allowable power dissipation is 85 watts at a mounting-base temperature of 25 C, and 35 watts at 85 C. Maximum storage and maximum junction-operating temperature is 150 C.

Developed also was a high-speed germanium computer photodiode with a rise-response time of less than 0.01

microseconds when irradiated by light in the wavelength range of 300 millimicrons to 2 microns. Experimental devices, the diodes are fabricated using surface-diffusion techniques.

Accurate wide-range test equipment was developed for use in evaluation and quality control applied to measuring d-c and small signal audio and r-f transistor characteristics. Also, a program began in 1957 to develop performance standards for accurately measuring such semiconductor characteristics as power gain and cutoff frequency.

#### **Cryotrons**

Analogous to an extremely fast relay, the cryotron may supplement vacuum tubes and transistors in a variety of applications. Utilizing them, a large digital computer may eventually be constructed to occupy only 1 cubic foot of space, exclusive of refrigeration and terminal equipment. Such a computer would have a variety of applications—missile-guidance systems, airborne navigational computers, or ordinary data-processing and storage systems, to name a few.

In 1957 a cryotron flip-flop made of tin and lead was developed with a time constant of 10 microseconds—10 times faster than any previously reported.

#### **Communications**

Maritime services can now have reliable VHF and frequency-modulated (FM) communications in the face of storm and man-made noise, with up to 5 channels, in full compliance with FCC requirements. General Electric's standard line of mobile equipment—now packaged into a compact, weatherproof marine VHF cabinet—houses a 25-watt transmitter and a VSI selector for use in Bell System service.

Mobile and microwave equipments are now integrated into extensive systems permitting communication between several fixed and mobile stations. Such systems were placed in operation last year on Florida's Sunshine State Parkway and the Massachusetts Turnpike for intertoll-station and toll-station-to-vehicle service.

Transistors incorporated in new circuit designs are providing products of greater reliability and versatility, coupled with reduced power-input requirements. For example, transistorized receivers and transmitters for power-line telemetering and supervisory control are being shipped as major parts of power-line carrier-current systems. Vibrators in many mobile-receiver power supplies

are being replaced by transistor circuits for reduced maintenance and greater reliability.

With ceramic tubes and new design techniques, a new 450-megacycle amplifier is capable of 250-watt output for mobile-base station service.

#### **Tropospheric Communication**

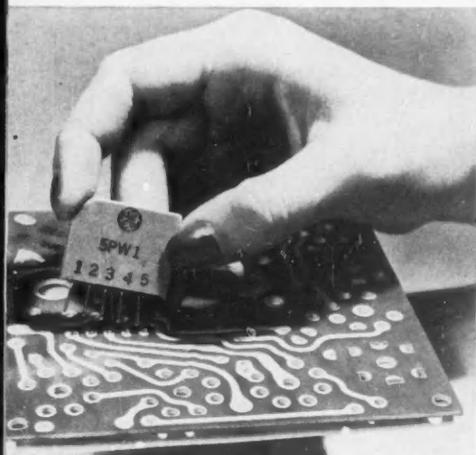
To provide reliable long-distance Arctic communication, Lincoln Laboratory of the Massachusetts Institute of Technology chose a radio system utilizing tropospheric scatter propagation. This system provides UHF communications far beyond the horizon by scattering the radio signal from the troposphere, or air blanket, that surrounds the earth. General Electric contributed to the project its extensive background of experience in the design, development, and production of civil and military communication systems. The special techniques proposed to extend the range 700 miles included the use of a high-power klystron amplifier, single-sideband modulation, and a quadruple diversity receiving system with receivers of improved signal-to-noise ratio.

#### **Radar**

Search and height-finding surveillance radar for the Army's new Missile-Master System were delivered last year. The system coordinates the fire of Nike batteries. To meet the stringent requirements for this application, major modifications were incorporated in 2 General Electric radars of proved design—the AN/FPS8 search and AN/FPS6 height finder.

The new AN/FPS37 search radar, a result of major engineering developments incorporated in the AN/FPS8 search radar, typifies the continued improvement in existing ground-radar systems. A new high-gain antenna provides a 50 percent increase in range. Addition of a second channel to the basic system also makes available a complete standby unit should the operating system go off the air for any reason. Dual channels are practically essential for reliable 24-hour-a-day operation. Some improvements have already been made by the Civil Aeronautics Administration in AN/FPS8 systems at Chicago's Midway and New York's Idlewild Airports, where traffic-handling capability during inclement weather has doubled since these systems were first installed.

Developed and implemented for continuous hour-by-hour accumulation of data was an electronic accounting-



**ENCAPSULATED** resistor-capacitor network adapts to placement, resists humidity.

machine card system capable of effecting future product improvement of radar and missile-guidance systems. With these data, the design, development, and field-testing stages can be efficiently evaluated.

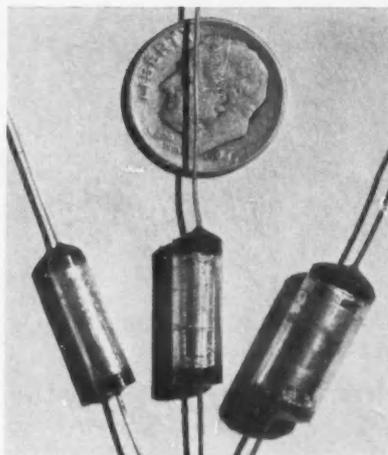
Utilizing the Doppler effect, a system was developed for the Army that increased the accuracy of predicted artillery fire by determining the average muzzle velocity of a specific weapon using a given lot of ammunition.

#### Computers

A technique for driving magnetic-core memories was developed that's inherently compatible with transistors. It utilizes magnetic regulation and isolation to allow drive-line potentials to vary in accordance with utilization circuit requirements. Major advantages of this system of current control are the ability to maintain absolute current values to within  $\pm 1$  percent and relative currents between drive lines to within  $\pm 0.25$  percent.

An analog-to-digital converter was built last year to measure simultaneously 3 separate input voltages in the range of 0 to  $\pm 100$  volts with an accuracy of 0.01 percent of full scale. Each of the 3 voltages is sampled and measured 60 times per second and recorded digitally on magnetic tape running at 60 inches per second.

Developed for airborne digital computers, a set of 6 transistorized building blocks represents 90 percent of all required hardware for data-processing equipment. A library of several hundred of these building blocks was constructed, permitting assembly of experimental



**CAPACITORS**, uncased and low in cost, have microfarad ratings of 0.001 to 0.1.

data-processing equipment quickly and at low cost.

A unique packaged power supply for computers meets specification demands not heretofore encountered. Combined in this new package are 19 separate pull-out chassis made up of 2 static exciter regulators, a meter panel, selector panel, voltage-protection panel, as well as 14 units containing 2 power supplies each.

#### Electronic Transformers

Machine calculation of electronic transformer designs is now possible with a new computer program. It performs essentially the same calculations and selects automatically the same parts as the human design engineer. Plate-filament transformers with outputs up to 1000 watts and of hermetically sealed construction can be designed with the program to the smallest possible physical size. Trial runs indicate that a typical design requires about 1 minute of computer time.

Added to the subminiature line of transformers during the year were 24 standard-case sizes and 4 new standard-construction types.

Development of temperature and radiation-tolerant electronic transformers passed 2 milestones in 1957. One involved adaption of a ceramic encapsulant to give transformers protection from adverse environments. The other gave experimental evidence of the transformer's ability to withstand a 500 C temperature combined with intense radiation existing in the test reactor at Brookhaven National Laboratory, Upton, Long Island, NY.

#### High-Precision Antennas

In April a \$1½-million Air Force test facility was completed for assembling and testing high-precision radar antennas. Built on top of a remote Berkshire mountain in Massachusetts, the system stability and location away from railroads and other heavy traffic protect the delicate instruments from vibrations.

A prototype of a new direction finder operating on the Doppler principle senses and indicates the direction of arrival of radio signals in the frequency range of 1.5 to 30 megacycles.

#### Magnetics

A program for determining the dynamic resistance and midcharacteristic value of turns per centimeter of magnetic-core length was initiated during the year. The purpose: to better predict performance of magnetic amplifiers. A simple half-wave magnetic amplifier using measured cores was constructed and tested.

#### Miniature Circuitry

Developed for use with miniaturized and printed circuitry, a miniature soldering iron weighs less than 1½ ounces. It is designed for production-line soldering of subminiature equipment, printed circuits, and instruments. Tiny connections can be soldered inside equipment with a minimum heat loss or damage to adjacent wiring, insulation, and terminals.

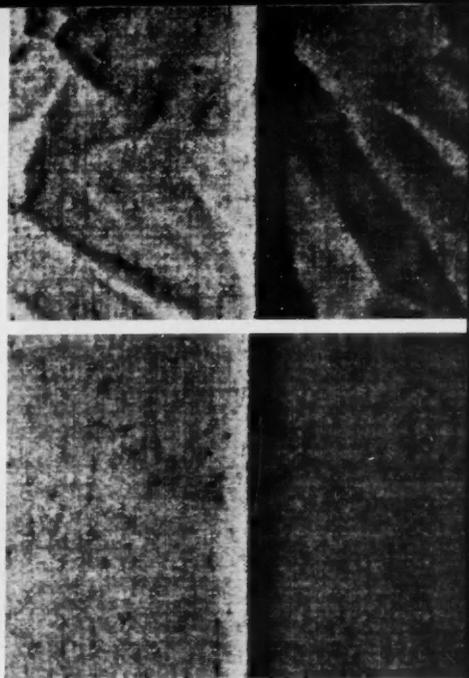
In 1957 pilot production began on a new, subminiature solid-electrolyte battery with a projected shelf-life of 20 years. It's designed to withstand temperatures from  $-100$  to  $+165$  F during storage or operation.

Also introduced was a new line of encapsulated resistor-capacitor networks, for resistance to high humidity and adaptability to automatic placement.

#### Capacitors

A significant product development in 1957 was the rectangular capacitor. By unique packaging arrangement, this capacitor not only fulfills critical application requirements but also permits circuitry formerly impossible because of excessive filtering demands. Three case sizes are available in polar and nonpolar construction.

Another important contribution made during 1957 is the limited production of uncased capacitors. These tiny capacitors have a standard length of 0.75 inches, with diameters ranging from 0.175 to 0.312 inches at microfarad ratings from 0.001 to 0.1.



**AUTOMATICITY IN APPLIANCES** increased during 1957. A new automatic clothes washer was equipped with 5 push buttons to produce a combination of variables covering any conceivable clothes load.

And a special control installed on automatic dryers eliminates wrinkles from a variety of synthetic fabrics: samples dried without using control (top); samples dried using control (lower).

## Appliances

A substantially expanded line of small houseware appliances was introduced during 1957. A 12-pound floor polisher now has a polishing head that swivels down for easy storing. Automatic electric saucepans in 4- and 2-quart sizes were introduced, with accurate silicone thermostats for temperature control. A new spray steam-and-dry iron eliminates the need for predampening through a new spray control. An infrared space heater with a nonglowing heating element was also developed. And a more flexible rug tool was offered to housewives for vacuum cleaning.

### Automatic Washer

In keeping with the trend toward more automaticity in appliances, a new automatic clothes washer was equipped with 5 push buttons to produce 5 combinations of wash temperature, rinse temperature, agitation speed, and spin speed. An extensive study revealed that these combinations of the variables would cover all conceivable types of clothes loads. The user's discretion determines wash time.

The washer's selector switch consists of a push-button switch mounted on a plate and operated by a series of wide plastic keys. This arrangement not

only allows freedom of styling but also retains all the features of push-button switching. By depressing a single key, the switch initiates the right combination of temperature and speed for a specific fabric, insuring proper washing results.

As an added feature, a rinse-agent dispenser automatically flushes a pre-loaded quantity of fabric softener into the rinse water.

### Automatic Dryer

A special control installed on a new automatic dryer maintains temperature conditions that eliminate wrinkles from a variety of synthetic fabrics. Synthetic suits dried in this machine maintain their creases but dry without wrinkles.

Fabrics containing sufficient thermoplastic fiber content enable the suits to do this. For wrinkles induced at low temperature during the course of wearing relax at a certain critical temperature. But creases pressed in at high temperature resist the thermal relaxation of the dewrinkling cycle.

### Television Receivers

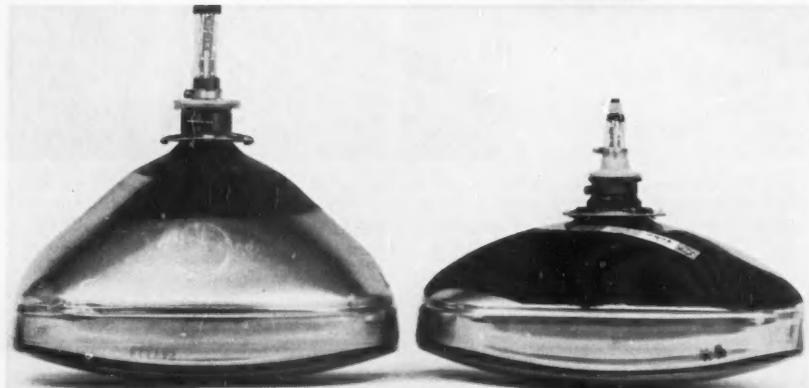
A fundamental improvement in picture-tube design enabled table and console television receiver designers to

reduce total cabinet depth to 15 inches. The 110-degree-deflection picture tube also enables a proportionate reduction in depth of portable receivers.

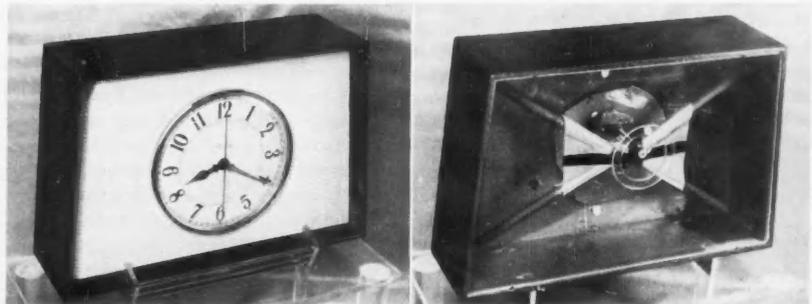
Abandoning the 70- and 90-degree picture tubes and the bulky cabinet required to house their long funnel and neck was considered a major contribution toward making television sets harmonize with modern furniture.

Development of the wide-angle tube overcame such problems as cost, power requirements, picture quality, and allowable temperature rise within the cabinet. The most difficult problem involved development of a deflection yoke capable of scanning the tube face and maintaining focus. The solution: a special winding on a tapered ferrite core, producing a magnetic field varying with focal distance to control the electron beam. Shaping the glass funnel and yoke to conform to the maximum deflection electron-beam path, thus minimizing the magnetic field energy, solved the power consumption problem.

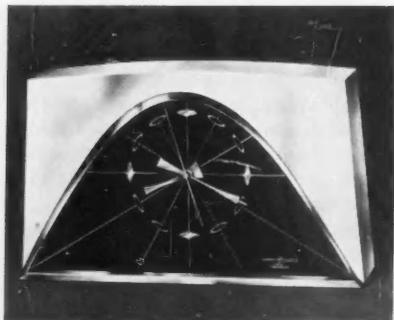
A new power tuning system utilized 13 push rods to perform 2 functions: selecting channels, and "remembering" the customer's preferences in adjusting the automatic fine tuning to local variations in signal conditions. The system



**IMPROVED DESIGN** of picture tubes enabled designers to reduce total TV cabinet depth to 15 inches. Result: TV sets now harmonize better with modern furnishings.



**PERMANENT-MAGNET MOTOR** obtains power from 4 ferrite rods. Flux is picked up from a 60-cycle coil concealed about a foot away. Thus this clock has no visible power supply.



**LIGHT ENERGY** operates new clock that needs no plugs, winding, or batteries.

was adapted to remote control through a single push-button plug-in in the rear of the set.

#### Room Air Conditioners

New room air conditioners recently introduced offer a major reduction in physical size while maintaining high cooling capacities. The 20 percent reduction in the unit's volume resulted from the use of newly developed compressors and heat-transfer surfaces.

The customer's choice of capacity, noise level, air throw and circulation, dehumidification, and degree of venti-

lation and exhaust is widened considerably. Three speeds are available with and without cooling for maximum flexibility of performance. And an extremely low noise level can be obtained when quiet operation is most desired.

Another new model is only 13 inches deep, 13 inches high. Simple to install, this small 115-volt unit, rated 7.5 amp, should appeal to do-it-yourself installers.

#### Hi-Fi Radio Receivers

During the year FM broadcasting brought better musical programming to many areas of the country, increasing the public's desire for good-quality sound reproduction. With this in mind, General Electric added an AM-FM receiver to its product line. Offering automatic frequency control on the FM band, the receiver is equipped with two 6½-inch speakers, high-quality sound, and both phonograph-input and tape-recorder-output jacks.

The portable radio line, greatly expanding its use of transistors, offers 4 transistor models: 2 pocket models of plastic and extruded aluminum with 4 and 6 transistors, respectively, and 2 standard size portables in leather and plastic, each with 6 transistors.

A deluxe 3-way portable radio made of impact polystyrene plastic, unbreakable in normal use, gives an acoustically better performance. Combined vernier and direct tuning affords easy station selection. Other features include printed circuit chassis, 4-inch speaker, built-in ferrite-rod antenna, and easily accessible power-cord compartment.

#### Clocks

A clock that operates entirely on light energy and requires no plugs or winding was developed, using advanced semiconductor techniques to generate sufficient power to run the clock. Light falling on crystals of highly refined silicon generates the power while minute amounts of 60-cycle power radiated by power lines and electric wiring serve to control the light-generated current. Although not plugged into a power outlet, the clock runs synchronously with the master clock-controlled generators in the central power station. This clock is now in advanced development stages.

Another clock also in development stages is without visible power source. It has no electronic circuits, batteries, or cord. It picks up flux from a 60-cycle coil concealed about a foot away from the clock. Magnetic rods pick up and

transfer the power to a synchronous motor.

Several new trends in clocks appeared during 1957. A lucite sunburst model 16 inches in diameter—with gold, clear lucite and gold, and ebony with gold color combinations—exemplifies the decorative wall clock trend. A clock appropriate for children has a puppy juggling a ball. An incandescent lighted alarm clock provides the user with a control knob to vary the dial's brightness, while a lighted clock with an ON-OFF switch proves an important first in the kitchen-and-bathroom clock field.

#### Housewares

A new 12-pound permanently lubricated floor polisher introduced last year has buffing pads, polishing brushes, and scrubbing brushes for wood, tile, or linoleum floors. The contoured sides allow easy reaching into low spaces, while a vinyl bumper protects walls and furniture. The polishing head swivels down for storage.

Two new automatic electric sauce pans offer accurate thermostatic temperature control, heat-resistant plastic handles and feet, and polished drawn-aluminum bodies. In 2- and 4-quart sizes, the pans are conveniently stored and completely water immersible for easy cleaning.

Controlled by a push button, a new spray steam-and-dry iron eliminates predampening. The iron, weighing only 3¼ pounds, has a visualizer fabric dial for selecting correct ironing temperatures.

An infrared heater that doesn't glow red was developed during the year. Special hidden vanes behind the stainless-steel grill reduce air turbulence and insure an even pattern of air circulation.

A double-action-rug and bare-floor cleaning tool was also introduced. The tool contains opposing litter-getting brushes designed to catch litter on both forward and back strokes and to be self-cleaning.

A cord take-up reel that may be positioned anywhere on the cord increases safety and improves appearance by winding up to 9 feet of standard houseware appliance cord within 2 plastic circular-reel shells. The cord is wound by holding the reel cover in one hand and turning the spindle with the other hand.

#### Timers

A miniature timer for radio and TV sets requiring 30 percent less space and having a 2-hour sleep switch, matches the trend toward small-scale transistor



**PERMANENTLY LUBRICATED** new floor polisher weighs only 12 pounds.



**EASY-TO-CLEAN** automatic electric sauce pan can be completely immersed in water.

radios. The same trend toward the long, low, compact, modern line was evident in a new line of range timers that includes a clock with signal for up to 1-hour intervals, another clock with signal for up to 3½-hour intervals, and a combination timer for use with automatic oven. The combination timer also has an up to 1-hour signal.

#### Other Developments

During 1957 an analytical and experimental investigation of the stress on corrugated fiberboard containers caused by warehouse stacking was conducted. Formulas were derived that explain the mechanics of container failures with top-to-bottom loading. The formulas were checked by compression testing 3 different sizes of home-range containers with a loading similar to that received in warehouse stacking.

Small size, total enclosure, pressure-lock termination, and circuit flexibility are the features of a new rotary switch designed for the control of electrically reversible window fans. The 7-position switch—less than one half the size of its predecessor—will control both shaded-pole and capacitor-type single-phase motors up to 6 amp, 120 volts, a-c.

A new room thermostat with contemporary straight-line styling was developed for domestic-heating and air-conditioning systems. The thermostat's square lines harmonize with the design requirements of today's homes. Bold-faced temperature readings are visible from across an average-size room. A companion control regulates the cooling, heating, and fan units in the home air-conditioning system.

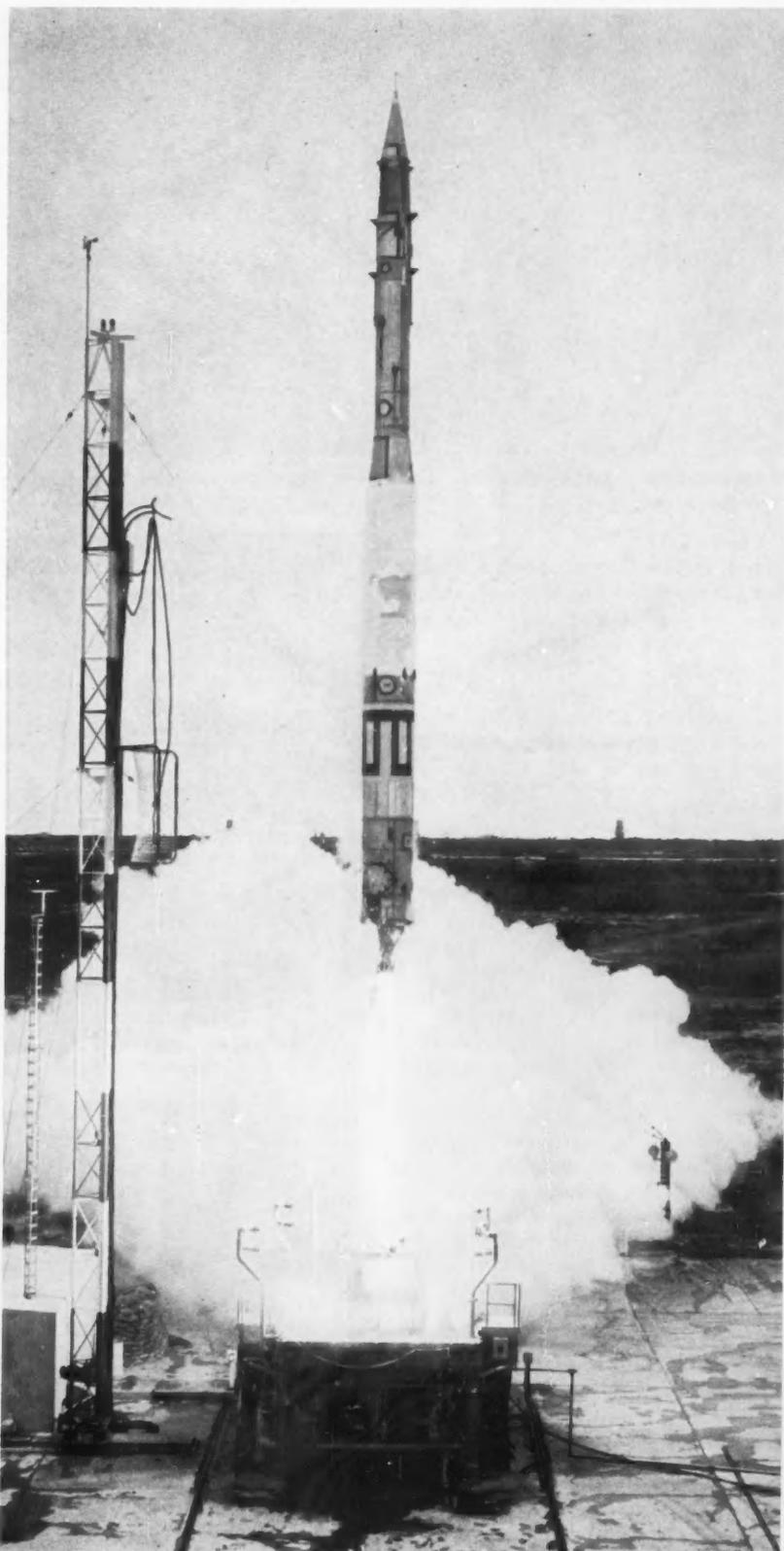


**SPRAY STEAM-AND-DRY** iron, weighing only 3¼ pounds, eliminates predampening.



**SQUARE LINES** of new thermostat harmonize with modern home-design requirements.

# Aeronautics



**FIRST-STAGE ROCKET ENGINE** powered Project *Vanguard* missile to an altitude of 109 miles and a top speed of 4250 mph, from Air Force Missile Test Center, Cape Canaveral, Fla.

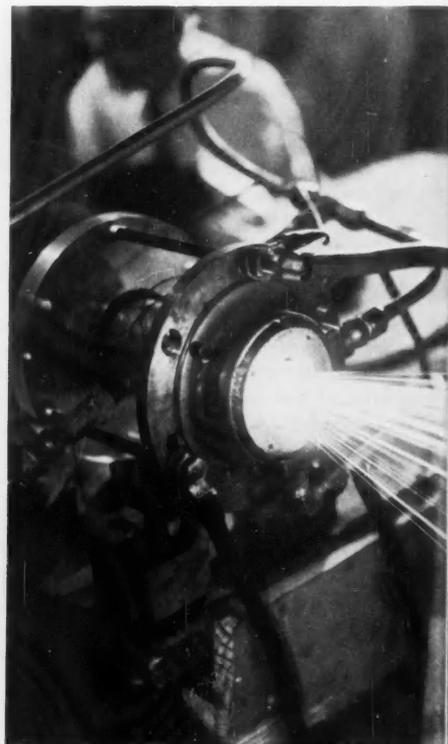
Early in 1957 General Electric delivered several first-stage X405 rocket engines for the Project *Vanguard* earth-satellite program. During subsequent static firing tests in the field, the motors performed highly satisfactorily.

On October 23, 1957, one of these first-stage motors powered the Vanguard 3-stage missile to an altitude of 109 miles and a velocity of 4250 mph during a test launching at Cape Canaveral, Fla. So far as is known, the X405 is the first large liquid-fueled rocket engine to be *completely* successful in its first flight.

The X405 underwent hundreds of tests at General Electric's Malta Test Station in Schenectady during its development. Prior to delivery, the rocket engine consumed more than 2-million pounds of liquid oxygen in static test runs.

Many departments of the Company and scores of subcontractors contributed in development and construction of the exacting components needed to make the X405 successful.

General Electric itself is a subcon-



**PLASMA GENERATOR** for specialized wind-tunnel and materials studies required arc stabilization.

# and Missiles

tractor to the Martin Company, Baltimore, which in turn is prime contractor to the U.S. Naval Research Laboratory. Over-all responsibility for Project *Vanguard* belongs to the Laboratory.

The first-stage X405 rocket engines, rated 27,000 pounds of thrust, power the 3-stage 11-ton Project *Vanguard* missiles on the first leg of their journeys into space. Operating for about 150 seconds, they burn liquid oxygen and kerosene (RP-1). Their gimbal mountings permit changing thrust direction as much as 5 degrees.

What may be the largest research and development contract ever awarded General Electric was formally let in June of last year by the U.S. Air Force. A \$158-million contract for the nation's top-priority ballistic-missile program, it calls for research leading to development of nose cones for the *Atlas*, an intercontinental ballistic missile (ICBM) and the *Thor*, an intermediate-range ballistic missile (IRBM). Headquarters for this work is situated in Philadelphia.

Farther north, in Pittsfield, Mass., scientists and engineers are busily at work on 2 of the U.S. Navy's ballistic missiles—the *Polaris*, with a 1500-mile range, and the *Talos*, the Navy's new long-range surface-to-air guided missile.

Regarded as the most challenging problem since the application of atomic propulsion to naval vessels, the development involves fire-control equipment to launch *Polaris* from a submerged submarine. In conjunction with the Lockheed Aircraft Corporation, work also progresses on the missile's guidance system. Combined with the Navy's mobility, the *Polaris* should have ICBM capabilities.

*Talos* will be installed in converted naval cruisers. Automatically selecting the missile from a storage area, its fire-control system will weigh more than 350 tons and take up space enough to house 10 freight cars.

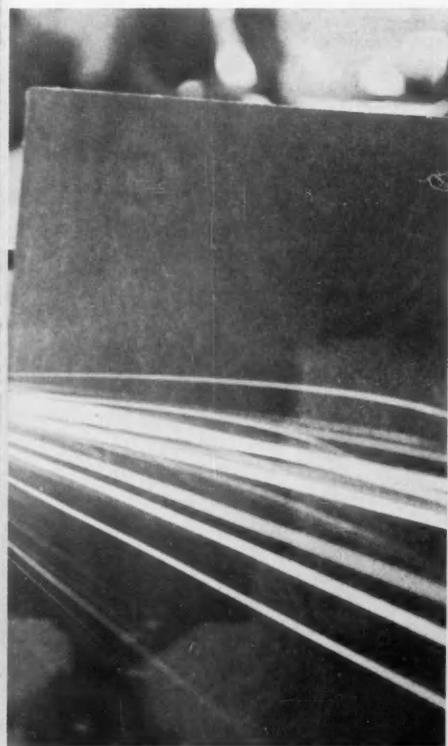
## Aerodynamics

Developed in 1957 was a high-pressure gas-stabilized arc-driven plasma generator for specialized wind tunnels and materials studies. Some of the problems solved in its development were stabilization of the arc in the gaseous

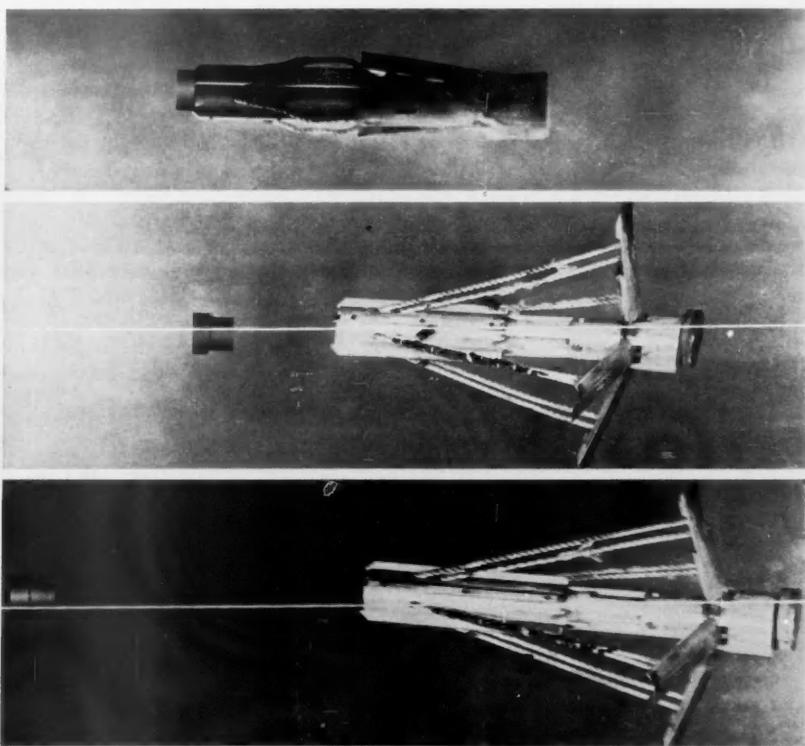
environment, development of nonconsumable electrodes, plus fabrication of an arc chamber to withstand high pressures and extremely high heat fluxes. The unit is similar in concept to the water-stabilized arc.

Fluid-vortex confined arcs were made with power gradients of about 50 kw per inch of arc length—or more than 6000 kw per cubic inch of space occupied by the arc. Most recent studies were made in structures so arranged that the vapor formed by the arc could be expelled through a nozzle in the form of a jet.

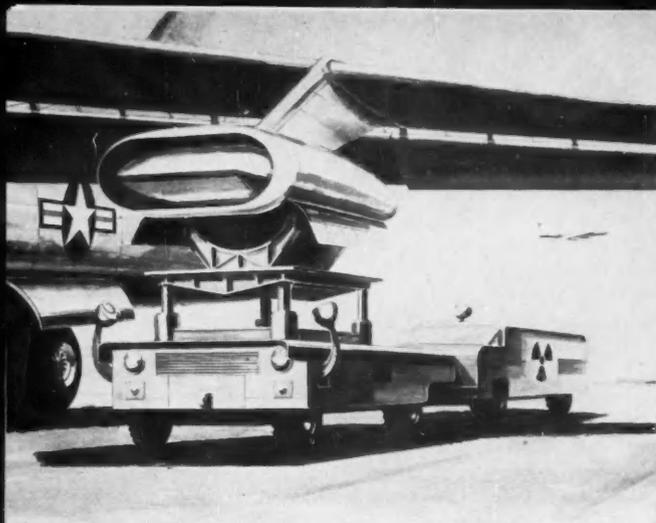
Temperatures more than twice as hot as the surface of the sun were achieved in the Aerosciences Laboratory on a continuous basis by a team of men working in close cooperation with an able scientific subcontractor. This model—an advanced version of the fluid-stabilized electric arc so recently of widespread scientific interest—uses water as the external "blanketing" agent and reaches approximately 25,000 F. Future designs will use gases for the stabilization agent, allowing for simulation of atmospheric conditions. The blast of hot plasma emanating from the arc chamber is being used for nose-cone research on



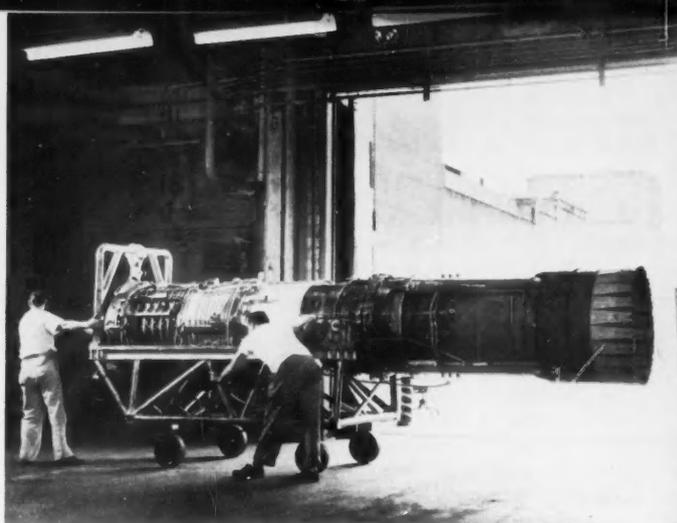
tion in gaseous environment and development of nonconsumable electrodes.



**BOOSTER UNIT** (top) for testing missile nose cone—fired from a 5-inch gun—rips through air, right to left, at Mach 2, then releases nose-cone model as air drag slows its flight.



**NUCLEAR PROPULSION PLANT** depicted by artist indicates that ground crew would work from a specially shielded vehicle.



**J79 JET ENGINE** produces the highest thrust-to-weight ratio ever achieved by any American power plant in present-day production.

the Air Force's ballistic-missile program (Cover).

One of the present limiting factors in rocket design is the extreme heating rates encountered, particularly when the missile re-enters the earth's atmosphere on its downward journey. A considerable portion of heat transfer is the result of radiation from extremely high-temperature air in the region occupied by the shock wave preceding the missile. To measure the intensity and distribution of this radiation under actual circumstances, a photoelectric rocket spectrometer was designed and built last year. It will be situated in the missile nose cone, operating only during re-entry into the atmosphere.

A booster unit used in the free-flight testing of missile nose-cone models, designed to simulate separation of a nose cone from the missile airframe, can be fired from a 5-inch gun. After separation, the nose-cone model gives free-flight data on nose-cone afterbodies. The 3½-inch model can be scaled up to provide data on larger models.

#### Nuclear Propulsion

Information on how a nuclear propulsion plant for aircraft might be installed was released last March at the International Atomic Exposition. Tests of a turbojet engine powered by a nuclear reactor were conducted on the ground at the Atomic Energy Commission's test site in Idaho Falls, Idaho.

#### High-Temperature Advances

Electronic equipment operated at 752 F without the use of a refrigerant or cooling system during 1957. Accomplishments to date are the direct result of 2 major high-temperature programs.

The initial program revealed that airborne electronic equipment could be designed and packaged to operate over a wide temperature range, -65 to +450 F, and in other severe environmental conditions with a performance comparable to that of existing 250 F equipments. Additionally, size and weight penalties were relatively small, ranging from 0 to 10 percent. The second program, aimed at advancing the state of the art to 752 F, was an extensive investigation of temperature and nuclear radiation-tolerant parts, materials, and manufacturing processes for application in airborne electronic equipment. To prove feasibility, a demonstration-model amplifier, designed to drive a standard servo-motor, was successfully operated at ambient temperatures up to 752 F.

A new silicone-bonded reconstituted-mica-mat dielectric capacitor, developed in 1957, promises continuous high-temperature operation up to 300 C and short-time operation to 350 C. This development supplements the 500 C mica capacitor now commercially available on a development-order basis. In the presence of nuclear radiation, the 500 C capacitor exhibits a satisfactory quality of operation.

Developed for aircraft application were 2 new aircraft wires. First of these is a 600-volt fire-resistant wire for fire detection, related circuits that must operate without failure for short-time emergencies, and other critical circuits that may be subjected to a total temperature of 750 F. The second development is a 600-volt single-conductor silicone-insulated nonflammable wire. This new wire can be used for ambient temperatures ranging from -75 to +200 C total.

#### Jet Engines

In Paris last May, at the 22nd Salon International de l'Aeronautique, General Electric introduced its CJ-805 commercial jet engine, designed to power the world's fastest jet liners. The evolutionary engine is designed to give high performance at low cost per mile and is the ideal power plant for medium-range transports. A powerful engine, it's also light and efficient.

The CJ-805's variable compressor stator blades make possible a high-pressure ratio necessary for fuel economy, cutting down engine weight and overhaul costs. At the same time, it also permits a single-rotor design with only 3 main bearings. Dependable, positive control is provided, requiring no pilot attention.

Earlier in May the commercial engine's military counterpart, the General Electric J79, was publicly displayed in Washington, DC, for the first time. This engine has the highest thrust-to-weight ratio of any American power plant in production today. Its design is one of the most efficient ever achieved.

Powering 3 of the world's fastest aircraft—Convair B58, Lockheed F104A, and Grumman F11F-1F—the J79 jet engine was developed in less than 4 years—1 year less than normally considered feasible for bringing an engine to full-production status.

The engine reached its production stage after undergoing more than 12,000 hours of testing—factory, simulated-altitude, and flight testing—most of which was accumulated in 1 year. One of the major factors enabling engineers to keep the J79's weight to a minimum is the use of variable stators.

Production started during the year on



**TWO-IN-ONE** aircraft gas-turbine engine is both turboshaft and turboprop power plant.

the magnetic-temperature-control amplifier for General Electric J79 jet engines. Weighing approximately 6 pounds, the unit mounts directly to the airframe. It is part of the nozzle-area control servo that maintains a preset turbine discharge temperature.

Circuits incorporating magnetic amplifiers and temperature sensors were applied to J47-17 and -33 engines to provide a signal warning of excessive temperature in critical engine areas. Both pilot signaling and direct-exhaust nozzle-control bias were provided by the type of circuits developed to increase the safety and contribute to the combat effectiveness of the F86D interceptor.

Developed during 1957 also was a new form of presentation of aircraft gas-turbine performance data on punched cards for digital computer operation. It allows comprehensive performance data to be transmitted to airframe manufacturers at a much earlier date and in a form more easily incorporated in installed-engine aircraft-performance studies.

A major gain was made in improving fatigue strength of cast jet-engine turbine buckets. By controlling grain size during the casting process, buckets are produced with fatigue strength comparable to that obtained from forged buckets while still retaining the high-stress rupture strength of the cast products.

Replaceable captive nuts and bolts now make possible remote assembly and dismantling of jet engines. Retained in their respective flanges, the captive nuts and bolts are aligned so that they can be assembled without cross-threading.

Designed last year was a special 40,000-hp mechanical-drive turbine and gear to power a jet-engine compressor test stand for the Pratt & Whitney Air-



**T58 TURBOSHAFT ENGINE** powered the Vertol H21D (shown) and a modified Sikorsky S58—the first twin-engine helicopters in U.S. to be propelled by aircraft gas turbines.

craft Division. Requirements of this unit are unusual. For example, it must develop 40,000 hp at any output speed between 5000 and 8000 rpm.

#### **Two-In-One Gas Turbine**

Work began on a \$58-million Navy contract for development of what will virtually be 2 small gas-turbine engines in 1—both a turboshaft and a turboprop power plant. Designated the T64, the new engine will employ a basic power section common to both engines. In the 2600-hp class, it will have more than a 3-to-1 power-weight ratio plus outstanding fuel consumption. Its low weight and high power promise greater payloads, range, and operating efficiency for short-haul transports, large convertiplanes, cargo helicopters and other support aircraft. The T64's advanced control system will need little pilot attention.

#### **Helicopter Power Plant**

In October of last year the U.S. Navy's Bureau of Aeronautics announced that the T58 turboshaft engine officially passed the 150-hour qualification test. Results of the qualification test show the engine exceeded performance guarantees on both horsepower and specific fuel consumption (SFC). The T58 produced 1065 military horsepower, compared to the 1024 guarantee. The military performance guarantee of 0.66 SFC was bettered. In addition to confirming the engine's durability, test results also indicate the T58 bettered guarantees on such items as engine acceleration rates and oil consumption.

At the Sikorsky plant in Bridgeport, Conn., the T58 made its first flight in January 1957 in a modified S58 heli-

copter. In September at the Vertol plant in Morton, Penn., it powered the Vertol H21D. These flights represent the first twin-engine helicopters in this country to be powered by modern aircraft gas turbines.

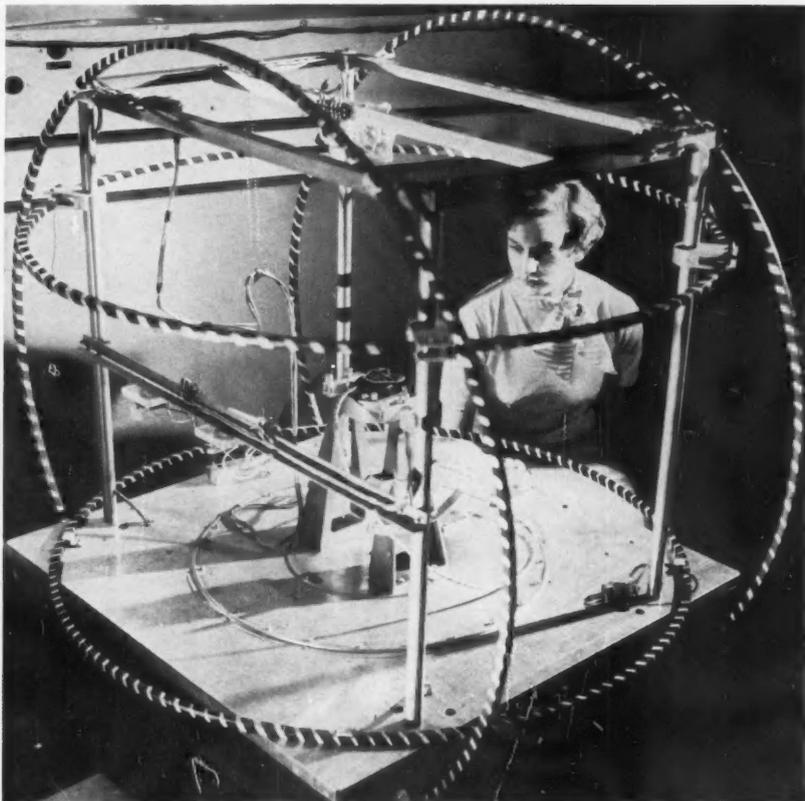
Prototype T58's delivered to Sikorsky and Vertol bettered performance guarantees; average shipment engines delivered 1067 military shaft horsepower and 0.659 military specific fuel consumption. Work continues on the J85—a small, lightweight turbojet developed by the U.S. Air Force for use in piloted and pilotless aircraft.

#### **Systems and Components**

Development of the first static excitation systems for aircraft generators was completed. Static excitation systems were designed for the generators utilized in 5 new military aircraft and 1 large commercial aircraft; generator ratings range between 20 kva and 90 kva at 400 cycles, 120/208 volts a-c. The new systems employ magnetic amplifiers and silicon rectifiers instead of rotating exciters, vacuum tubes, or variable resistance devices.

Completely new controls were developed for the protection of aircraft electric generating systems. These controls employ magnetic amplifiers in place of sensitive relays to achieve greater reliability and to obtain more accurate performance. Overvoltage protection, undervoltage protection, and underfrequency protection are accomplished by standard subassemblies. These designs represent the first application of magnetic amplifiers in the protection of aircraft generating systems.

A revolutionary brushless d-c generating system was developed for use in



**INTRICATE EQUIPMENT** provides a stable magnetic field for testing the compass transmitter of new lightweight low-priced compass system intended for business aircraft.

aircraft. The generator is an inductor-type 800-cycle a-c machine; silicon rectifiers are used in place of a commutator to convert its output to direct current. It is equipped with a 600-cycle a-c permanent-magnet exciter. This completely brushless generating system with its static regulator and advanced protective control provides greater reliability, better voltage regulation, and faster response than can be provided by conventional d-c generating systems.

A compact, rugged magnetic-amplifier voltage regulator that weighs only 3 pounds was developed for missile generating systems. It can be used to control 400-cycle generators with ratings up to 10 kva. This regulator maintains generator excitation under all generator operating conditions, including short circuits at the generator terminals. Generator voltage is held within  $\pm 1$  percent for all generator loads between 0 and rated value and all temperatures between  $-55$  and  $+100$  C.

#### Instrumentation

A new aircraft flowmeter system in the 0 to 15,000 pounds per hour flow range

is being made available for military and commercial jet transports. Incorporating many new design features, the system operates directly from the aircraft's 400-cycle supply without the use of separate special equipment. First application will take place in the DC8 jet transport of the Douglas Aircraft Co.

For small jet engines needing a miniaturized flowmeter system with a range to approximately 5000 pounds per hour, a transmitter was developed. The miniaturized transmitter has a 400-cycle motor, magnetically coupled to an impeller. Its indicator includes integral lighting and a self-synchronous receiver.

The smallest electric tachometer in existence, so far as is known, was developed in 1957 for jet-engine aircraft. Weighing only 5 ounces, it is useful as a supplementary instrument for indicating engine speeds below or above the range of the speed indicator incorporated in an engine-performance indicator.

Last year 4 large eddy-current dynamometers were furnished an aircraft engine manufacturer. Water-cooled, they

are rated at 7000 hp for the speed range of 1005 to 3015 rpm. Each pair will be connected in tandem with a 1000-hp d-c dynamometer and a reduction gear to form a 15,000-hp system.

Introduced last year also was the first lightweight low-priced compass system for business aircraft, providing an electrically driven panel-mounted gyroscope of improved performance. Based on a combination of the magnetic compass and electric gyroscope, the system provides a stabilized heading reference accurate to 2 degrees or better.

A new-type fast-response thermocouple was developed in which conventional 2-wire elements are replaced by 1 element in the form of a tube encasing the other element, a wire. This assembly is encased in a tube sheath. Both elements and sheath are insulated electrically with aluminum-oxide powder. This results in extremely small thermocouples with greater mechanical and thermoelectric stability. With its small size, this thermocouple is particularly attractive for applications where large devices might cause disturbances in the system being measured.

#### Navigation

A new 4-gimbal 3-single-axis gyro, an all-attitude reference for aircraft application, will go into production this year. Known as type SR1, the device produces roll, elevation, and heading references at all plane attitudes for navigation, control, and bombing functions. This new gyro reference is designed to include not only compensation for the earth's rotation but also the aircraft's east-west ground speed.

#### Computers

One of the most modern, efficient, automatic data-processing and computation centers in the missile industry was installed last summer at a General Electric plant in Philadelphia. The center was installed to reduce data from missile flight tests and environment and component tests and for scientific computations to aid advanced studies. Complex missile weapons-system development made the center necessary.

In machine computational techniques, a significant advance opened the way to economical and rapid development of data required for much improved analysis of airframe-engine combinations capable of high supersonic flight speeds. Both analog and digital computing machinery are utilized. One example of its use: the machine runs at a scale time of

one tenth the actual mission time and plots results in the form of a flight profile of distance versus altitude. Digital techniques were also developed for the same type of computational problem because they lend themselves better to the larger number of similar calculations that will have to be made on later weapon systems.

Made during the past year was a basic decision to use germanium junction transistors for reliable digital modules. Two factors influenced the decision: size and power consumption of vacuum tubes in computer applications make them highly undesirable; and quantity production of silicon transistors wasn't deemed satisfactory.

### Communications

Four synchronous detection receivers were delivered to the Air Force last year. Additionally, a synchronous detection adapter was designed to convert standard receivers to suppressed-carrier double-sideband operation. Synchronous receivers eliminate image problems because no intermediate frequency is employed. Interference and fading that result from multipath effects are also absent.

A new re-entrant cavity offers higher efficiencies over ridged or line-over-plane cavities presently used in microwave equipment. Currently being evaluated in airborne equipment, the new cavity is one fourth the size and weight of present ridged units operating over the frequency range of 2000 to 4000 megacycles. Under consideration are proposed evaluations for the cavity's use in sweep generators and r-f sources for other applications.

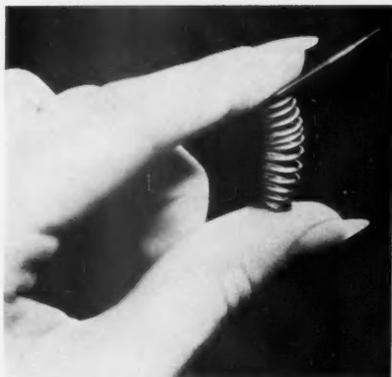
Placed in production during 1957 for an airborne digital communications system was subminiature packaging utilizing subminiature relays.

### Infrared

Developed in 1957 was a simplified procedure for predicting the absorption of infrared by the atmosphere between a target and an observer. The estimation process previously used was replaced by a systematic solution of the problem. Through this procedure, a person inexperienced in atmospheric physics can calculate atmospheric absorption.

### Armament

A new type of armament, designed to give helicopters defensive protection in battle, was introduced last May. It comprises 2 kits of 0.308-caliber machine



**THERMOCOUPLE'S** small size eliminates disturbances in systems under measurement.

guns and small rockets, attachable to any type of helicopter. Primary purpose of the armament in support missions is to lessen the helicopter's vulnerability to ground fire.

### Gearing

Developed for the main reduction of the T58 turboshaft engine was a small lightweight gear box. Weighing 75 pounds, it's capable of transmitting full engine power at 19,500 rpm and delivering this power at 6000 rpm. Self-contained, the gear box has a built-in lubrication system.

For aircraft application, a power transmission shaft operates at 3-degree misalignment between input and output ends and also allows for axial shrinkage or growth. The unit is capable of transmitting more than 60 hp continuously between a jet-engine-mounted gear box and an airframe-accessory gear box. Total weight of the design, including the unit's protective cover, is only 7½ pounds.

As a whole, the aircraft industry is one of the first groups to become deeply involved in high-temperature gear operation. Several years ago, the first meetings were held to determine how to solve the many environmental problems associated with high-temperature gear operation. As a result, last year a full-scale high-temperature gear test stand not only was built but also was put in operation at General Electric's plant in Lynn, Mass.

### Accessory Power

A completely self-contained accessory power system for missiles, utilizing modular components for versatility and flexibility of outputs, generates electric or hydraulic power—or both—in ratings of 1.5 to more than 10 hp. Fuel accumula-



**AIRBORNE** hydraulic power system is 60 percent lighter than current production models.

tors are sized for duty cycles as short as a few seconds or for extended periods of many minutes. Fine frequency control within  $\pm 1$  percent is obtained in this manner.

An answer to the heat problems of high-speed aircraft comes in the form of a new product development called a turbonator, an air turbine and an a-c generator on a single shaft. Turbine exhaust air is used to cool the generator, permitting its operation in high ambients independent of aircraft cooling systems. A complete 60-kva system weighs only 135 pounds.

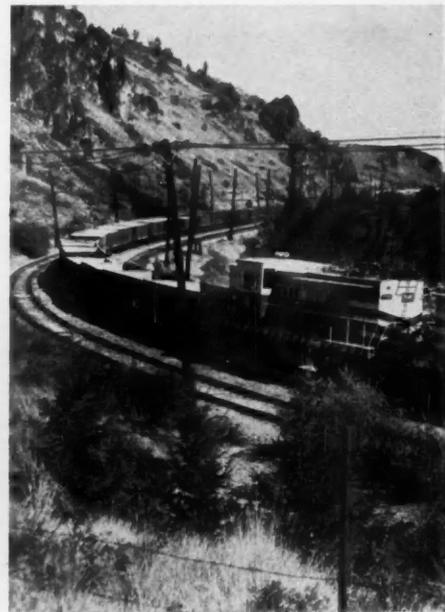
The result of a demonstrator program, an airborne hydraulic power system is 60 percent lighter and contains only one third as many parts as current production models. Unique design features include a finned reservoir housing that eliminates special cooling equipment, a high-speed ball-piston pump, and a fail-safe turbine wheel.

Flight safety programs produced 2 design approaches to fail-safe turbine wheels, eliminating the potential hazards of high-speed rotation. In one method, turbine buckets are fastened to the wheel disc, with pins stressed to shear at above-normal operating speeds but below the burst speed of the heavier wheel disc. The second method employs drilled holes of a carefully calculated diameter in the roots of welded turbine buckets.

Designed to handle low-viscosity lubricity but highly corrosive fuels, a new pump weighs only 1.15 pounds and is less than 3 inches long. Intended for the high-temperature applications such as missiles, it can be used for fuel or low-flow hydraulic pumping. When used to pump corrosive monofuels, such as normal propyl nitrate, a great saving is possible in system weight.



**HIGHER FREIGHT-TRAIN SPEEDS** in the mountainous terrain of the West will be met by 30 new 8500-hp gas-turbine electric locomotives being constructed for the Union Pacific.



**TWO ELECTRIC LOCOMOTIVES**, 125-ton 2400-volt d-c, were purchased by the Butte, Anaconda

## Rail

During 1957, Union Pacific ordered 15 more of the 8500-hp gas-turbine electric locomotives. This brings to 30 the total number of these giants now under construction for this customer. Believed to be the largest internally powered locomotive in the world, this new motive power is intended primarily to meet the need for higher freight-train speeds in the mountainous terrain of the West. The 4500-hp gas-turbine electric locomotives now in service can haul a 100-car freight train up a ruling grade at 13.5 mph, but the new locomotives are capable of handling a 150-car train on the same grade at 18 mph. Another yardstick for measuring the design progress represented by these locomotives is that they develop 20 hp per ton of locomotive weight compared with 16 hp per ton for the 4500-hp locomotive.

Because of their size, the new locomotives are built in 2 units. Powered by 12 motored axles, they are geared for a top speed of 66 mph. The leading cab contains the engineman's station; the diesel engine that supplies power for cranking the turbine, operating the auxiliaries, and moving the light locomotive; the cooling system; and the train air-brake compressors. The trailing cab houses the gas turbine and electric generating equipment. A 24,000-gallon

fuel tender completes the locomotive, giving it an over-all length of 179 feet.

Fuel is pumped into the tender at approximately 180 F. The 4-inch-thick glass-wool insulation surrounding the tank is chiefly responsible for keeping the fuel warm. Supplementary heat is supplied by electric heaters that receive power from the diesel-driven auxiliary generator and by recirculating fuel heated from the atomizing air supply.

The fuel capacity of the tender will permit these locomotives to haul 5000-ton trains between Los Angeles and Omaha, a distance of 1811 miles, with only 2 intermediate stops for fueling. Because of their high-horsepower capabilities, they can maintain higher speed on the mountain grades, making them especially suited to the western divisions of the railroad.

### Electric Locomotives

Two 125-ton 2400-volt d-c electric locomotives furnished to the Butte, Anaconda and Pacific Railway last July have already established a record of successful performance.

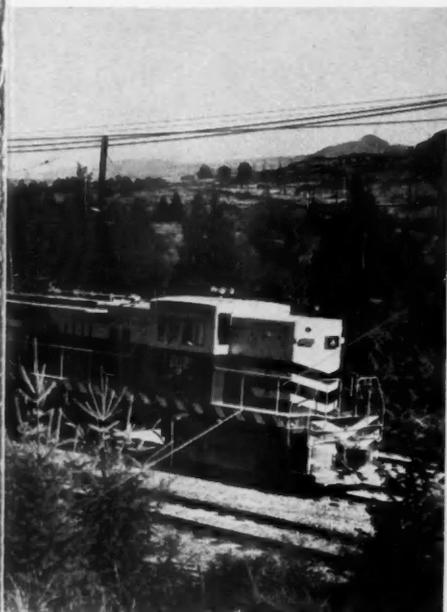
Powered by four 1200-volt axle-hung d-c motors, the locomotive has a continuous rating of 2480 hp. It is capable, however, of developing approximately twice this power for short periods when

accelerating a train or ascending a short grade. Regenerative braking, which has provided economical and smooth handling of trains on descending grades since the Railway's electrification in 1913, is also furnished.

Placed in service beside the 80-ton electric locomotives built when the railroad was electrified, the new units will help handle the growing ore traffic between mine and smelter. Significant of the advances made during the intervening 44 years, the new locomotives have a 46 percent better power-weight ratio, enabling them to economically meet the demand for increased haulage capacity. While the 2 units can easily handle the present trains, provision was made for operating as many as 3 units in multiple under the control of 1 engineman. This forms a 7440-hp locomotive capable of handling a train containing 7500 tons of ore.

### Export Locomotives

Production began during 1957 on 3 sizes of the new standard export line of diesel-electric locomotives for operation on foreign railroads. The first shipment consisted of eleven 990-hp meter-gage locomotives for the Chilean State Railways. Geared for a top speed of 60 mph, these units are being used in passenger



and Pacific Railway to help handle growing ore traffic between mine and smelter.



**PRODUCTION BEGAN** in 1957 on 3 sizes of the new standard export line of diesel-electric locomotives. The Chilean State Railways received the first shipment.

and freight service on the meter-gage lines in the northern part of Chile. Four locomotives of the same model were also shipped to the Santa Fe mines in the same locality.

The first order for the most powerful locomotive of the export line—rated at 1980 hp—was placed by the Argentine State Railways; 25 were purchased for main-line service on the General San Martin Railway. These operate on 66-inch-gage track and have the unusual feature of a 70-kw alternator to supply power for heating passenger trains electrically. They are geared for a top speed of 77 mph in passenger service.

Brazil was the first customer for the 1320-hp locomotive. The Sorocabana Railway, already an extensive operator of General Electric electric and diesel-electric locomotives, ordered 22 of these units for general service.

Additional orders from the following customers were filled during 1957: Leopoldina Railway, Brazil, eighteen 1320-hp meter-gage units; Anglo Lautaro, Chile, three 1320-hp units; Rede Mineraria de Viacao, Brazil, three 990-hp meter-gage units; and Turkish State Railways, five 1980-hp standard-gage units. Special modifications, together with gage variations and the use of 2- or 3-axle trucks, can be made without basic design or manufacturing changes.

Bearing out conclusions drawn from thorough surveys of the export market, this universal design of locomotive is

proving highly popular. Since this export line was introduced last April, orders were received for a total of 250 units for operation on track gages ranging from 36 to 66 inches. These are going into service in both hemispheres. In South Africa and Turkey they will be the first diesel-electric locomotives to be placed in operation on the railway systems. The eighteen 1320-hp units for the Colombian National Railways are the most powerful 36-inch-gage diesel-electric locomotives in the world.

#### Special Locomotive

A compact, universal 76-ton 975-hp prototype diesel-electric locomotive for world-wide service on narrow-gage railroads was furnished to the Transportation Corps of the U.S. Army.

To meet the rigid weight limits imposed, aluminum was widely used in the superstructure, and high-tensile steel in the main platform and trucks. Assuming equal distribution of the load over all 6 driving axles, the individual axle loading is only 25,330 pounds—less than half the value allowed on U.S. railroads. This permits safe operation on the light bridges and track found on many narrow-gage lines.

Trucks are designed to accommodate various narrow-gage tracks. The wheels can be relocated on the axle, and the brake rigging adjusted for operation on 36-inch, 39 $\frac{3}{8}$ -inch (meter), and 42-inch-gage track. The traction motor was

developed to provide maximum power in the extremely limited space between wheels on 36-inch-gage track.

The locomotive is designed to operate in ambient temperatures as low as -65 F and be stored in temperatures as low as -80 F. To overcome the problem of metallic brittleness encountered at such reduced temperatures, the truck frames, main platform, and draft gear housings are made from special alloy steels that retain high impact characteristics at low temperatures. Oil-fired heaters supply hot water to the air compressor, diesel engine, battery, and fuel tank to heat these components before starting. At the other end of the temperature scale, the engine cooling system has sufficient capacity to maintain safe operating temperatures with ambient air at 125 F.

Restricted operating clearances were met by an extremely compact design. The low over-all height required was achieved by cradling the power plant between 2 longitudinal box sections running the length of the locomotive platform.

Railroads in various parts of the world use different types of couplers and draft gear. This locomotive is prepared to accommodate 17 varieties, with coupler heights ranging from 22 $\frac{1}{2}$  to 36 inches above the rail.

If additional power is needed, 2 of these locomotives can be coupled and operated by a single engineman.



**ATOMIC POWERED GUIDED-MISSILE CRUISER**, the first nuclear propelled surface ship, will utilize steam supplied by cross-compound turbines from a pressurized water reactor.



**SUPERTANKER SS Universe Leader** is world's largest commercial cargo vessel.

## Marine

Engineering design work is well under way on an order received early in 1957 for the main propulsion turbines and gears for an atomic powered guided-missile cruiser. This will be the first nuclear-powered surface ship. Its twin screws will be driven by cross-compound turbines through locked train gears. For the turbines, a pressurized water reactor will supply saturated steam.

Sea trials of the atomic-powered submarine USS *Seawolf* were completed in early 1957. (See *Nucleonics*, page 30.) Based on the highly acceptable performance of the *Seawolf's* propulsion equipment, orders were received for sim-

ilar equipment for 5 additional atomic-powered submarines.

Reactor control equipment for the atomic submarine USS *Triton* (Nucleonics) utilizes an amplidyne-generator voltage-regulating system. This plus a static switching system provide control and protection for the reactor.

The plant operator aboard the *Triton* can thus adjust the power developed by the reactor through movement of its control rods. An automatic control system regulates reactor power according to load.

Protective equipment for the *Triton's* reactor uses static switching modified to fit the requirements of nuclear submarines. Signals giving information on plant-operating conditions are combined to cause a "scram" or "drivedown" of the reactor control rods if an unsafe condition develops. Memory units record the cause of the abnormal condition.

Navy acceptance trials of the USS *Ranger*—the second of 5 aircraft carriers with duplicate propulsion equipment—were completed in July of last year. Trials ran the gamut from full-power ahead to crash-back astern, extended astern operation, and locked-and-drag shaft tests. Throughout the entire series of tests, the *Ranger's* 4 main-propulsion turbines and gear—with a total rating exceeding 200,000 hp—performed excellently.

### Merchant Shipping

The 83,000-deadweight-ton supertanker SS *Universe Leader*, larger than any commercial cargo vessel now afloat,

successfully completed her sea trials at Kure, Japan.

Now in regular service, the supertanker has a length of 854 feet and a beam of 125 feet; she transports Far East oil to United States Pacific Coast ports. The *Universe Leader* was constructed in Japan by the Kure Shipyard Division, National Bulk Carriers, Inc., New York.

Capable of carrying more than 700,000 barrels of crude oil, the supertanker is powered by a 21,175-hp cross-compound propulsion turbine and a double-reduction gear.

The current world-wide activity in building cargo and passenger ships brought orders for main-propulsion turbines and reduction gears from many foreign shipyards. During 1956 and 1957, the orders included 1 set for Norway; 5, Sweden; 9, Denmark; 2, Canada; and 31 for Japan.

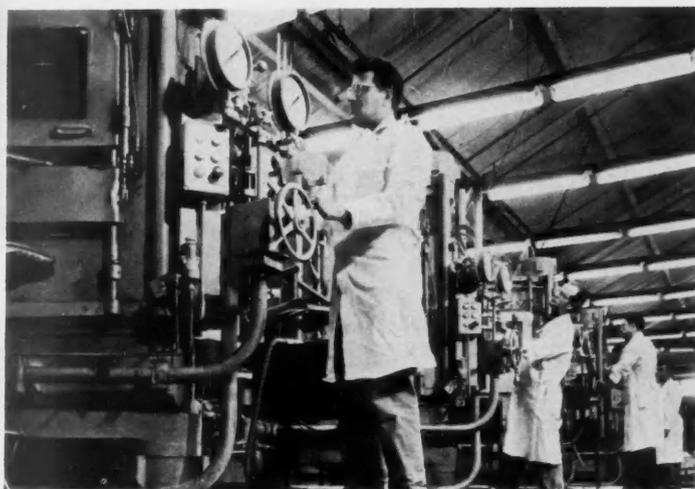
### Other Developments

Newly developed Navy Service C and marine Form G fractional-horsepower motors underwent an exhaustive series of tests to meet rigid military specifications. To insure maximum moisture and corrosion protection against the severe environmental conditions of marine application, the motors are given a special finish, and their stators are triple over-all coated with baked-on protective varnish. The motors are supplied in either dripproof or spray-tight enclosures.

Prototype static excitation systems for ship's service generators were built for the DD828, an experimental Navy destroyer utilizing a revolutionary 400-cycle electric system, and the DD445 destroyer, a new type ship widely used by the Navy. So well have the static systems performed that present orders for static excitation exceed by several times the total of all such systems ordered by the Navy in the past decade.

Last year design was also completed on a static excitation system for a 750-kw 60-cycle ship's service generator on the DLG-9-class missile-launching ships. Similar systems for the 1800-kw generators on the SSN588-class nuclear submarines were designed and will be built in early 1958.

A new type of hydraulic torque applier was developed for applying torque to test gear boxes. Basic principle of the new device is similar to a water wheel. With it, engineers can apply a wide range of torque.



**MAN-MADE INDUSTRIAL DIAMONDS**, produced in high-temperature high-pressure machines (above), resulted from the application and combined skills of engineering, manufacturing, and management specialists.

## Chemical and Metallurgical

Pilot production of man-made industrial diamonds—identical in properties to natural diamonds—was arranged in October 1957. Substantial quantities are now being produced, marking another milestone in man's scientific and industrial progress.

The announcement that diamonds had been made in the General Electric Research Laboratory was released in February 1955 (see January 1956 REVIEW, page 8). Slightly more than 2½ years later, the Metallurgical Products Department bridged the gap from research to pilot-plant production. To advance a scientific project from research laboratory to commercial realization normally takes 5 to 10 years.

This enormous accomplishment—from basic research, through equipment and process development, to the present pilot-plant facility—represents a \$2½-million investment of share owners' money by General Electric. America's future growth and security are closely linked to maintaining a high level of research and development to sustain continuous product innovations and improvements.

The nation's dependence on the diamond supply from the Belgian Congo and South Africa is now partially less-

ened. Hopes persist that complete independence can be gained in a few years.

Indispensable to many industrial operations, diamond grinding wheels are used in the sharpening of cemented-carbide cutting tools. In turn these are used extensively for machining operations on aircraft, guns, shells, tanks, trucks, and automobiles.

Current price of the man-made ungraded diamonds is slightly above that of ungraded natural diamonds. Improved production techniques, however, will gradually bring their price down.

For their production, a pressure chamber was built to maintain for the first time temperatures up to 5000 F at pressures exceeding 1½-million psi for long periods. With this equipment plus other more recently developed apparatus, diamonds are now produced in a matter of minutes.

Development of chambers to withstand such extremely high pressures and temperatures—as well as methods for measuring conditions within the chambers—has launched research of great potential importance. Such efforts have already produced a new substance called *borazon* (Cover and Research section, page 8) that rivals diamond in hardness but isn't found in nature.



**TOUGH AS NAILS** characterizes a new polycarbonate resin with unusual dimensional stability, heat resistance, and impact strength.

### Metals X-Ray

A newly built shadow-projection x-ray microscope with electrostatic optics allows observation of many interesting metallurgical structures of practical value, previously unrevealed by optical metallography. Specimen preparation, though critical, is not extremely difficult. The greatest success came from examining light metals, while ferro-

magnetic specimens showed structures of special interest.

In another development, an area smaller than the point of a small metal probe can now be analyzed using a new and highly specialized instrument. Called the microemission x-ray spectrograph, parts of a metal sample 0.1 mil in diameter can be accurately analyzed and identified.

#### Analytical Techniques

A new radioactive tracer technique now extends the application of autoradiography to metal and ceramic systems. When necessary to know the distribution of an element across a metal or ceramic surface, samples are exposed to a radioactive gas such as hydrogen or tritium and sulfur dioxide or carbon monoxide. After a photographic emulsion is placed on the sample, the radioactive areas become black, readily locating the elements of interest.

Differential thermal analysis was used increasingly during the year to observe the transitions and reactions that a substance undergoes in heating. The method is useful in evaluating polymers and the compatibility of materials, detecting new phases in materials, estimating heats of reaction, and in reaction kinetics.

#### Silicones

Tough enough to replace organic rubbers in many applications, a new double-strength silicone-rubber compound was introduced commercially in 1957. Having low moisture absorption and good oil resistance, the compound can be fabricated by all conventional methods of handling silicone rubber.

Another silicone-rubber compound was developed for use in industrial and domestic oven-door seals and in other "hot" applications. Tintable to any color, this low compression-set material withstands intermittent temperatures as high as 600 F.

An electrical grade silicone-rubber compound was specifically designed and manufactured for wire insulation. Among its applications are aircraft, motor, and apparatus lead wire, defroster and hook-up wire, and naval atomic cable.

General-purpose room-temperature vulcanizing silicone-rubber compounds were also introduced commercially last year. They have low shrinkage in cure, a high temperature stability, and smooth, glossy, detailed surfaces from cured impressions.

To further expand design and oper-

ating possibilities of equipment demanding high-temperature lubricants and fluids, 2 new members of the silicone fluid family were marketed. They offer better oxidative stability and lubricity. Both are designed for use in aircraft and other turbine-engine oils; in hydraulic fluids, as fluids and lubricants for high-temperature pumps; and as base materials for high-temperature greases.

Ready for immediate use when received, a new dielectric silicone fluid was designed for use in capacitors, pulse transformers, specialty transformers, all types of radar equipment, oil-filled power cable, and TV circuit components.

#### Resins

Market development of a new plastic material, tough enough to replace metals in many applications, was stepped up in 1957 through pilot-plant production.

The new polycarbonate resins aroused considerable interest from plastics molders and potential customers alike. Its unusual dimensional stability, heat resistance, and impact strength suggest applications not previously handled by conventional thermoplastics. Used as a molding compound, the new polymer is also being evaluated as an extrusion compound, varnish, coatings, and as a film.

Another silicone resin withstands intermittent temperatures in the 550 to 600 F range. Offering exceptional toughness additional to the usual silicone resin characteristics of good color and gloss retention, it can be used as a clear coating or as a vehicle for high-grade heat-resistant coatings.

Improved during the past year, a silicone-resin dipping and impregnating varnish—the only one of its kind commercially available—combines blister-free coverage with excellent thermal stability, resistance to low-temperature crazing, excellent penetration, low viscosity, high gloss, and smooth continuous films after multiple dips.

#### Molding Materials

Achieved in 1957 was an electric insulation advance through development of a family of electrical grade, polyester molding materials. An important feature: their resistance to electrical creepage and tracking.

These new materials have an indicated life 10 to 15 times that of ordinary polyesters, and up to 3 times that of premium grades costing up to 10 times more. Physical and electrical character-

istics are equivalent to those of commercial materials presently available.

Two new heat-resistant phenolic molding compounds were also introduced last year. They resist heat of 400 and 500 F respectively and mold to a specific gravity of about 1.53, compared to 1.60 to 1.65 for other powders. Rapid cure, fast preheat cycles, and good dimensional stability as well as excellent finish contribute to molding economies demonstrated in field acceptance at the present time.

#### Laminates

The need for a higher degree of reliability in printed circuits for critical electronic equipment led in 1957 to introduction of versatile new types of laminate.

For example, an epoxy paper laminate combines many of the features formerly available only in a number of separate grades. Its properties include self-extinguishing characteristics, cold punching, high insulation resistance, and mechanical properties 50 percent higher than the best phenolic-paper electronic grades. As a substitute for epoxy glass, this epoxy paper laminate offers fire retardancy, lower cost, reduced weight, and greater ease of fabrication.

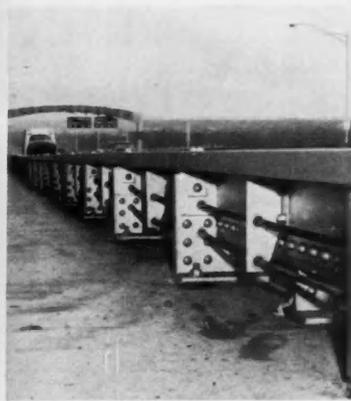
Also, limited glass-fabric reinforcement increases mechanical strength of paper-base material as much as 5 times. Application of the high-impact laminates in printed circuits and fabricated component parts gives more rugged performance under mechanical shock and permits use of thinner laminates and larger unsupported areas.

#### Ceramics and Alloys

A recently marketed high-purity fused magnesium oxide that replaces older, less pure materials exhibits substantial improvements in electrical properties. Three years of laboratory and field testing have produced evidence of higher insulation resistance with life in actual heating units. Additionally, the magnesium oxide's high purity of 99 percent allows its use in specialized ceramic and insulation applications.

Through use of special metallographic etching, dislocations and subgrain boundaries in tungsten were visually observed. Dislocations were also observed along slip lines in swaged tungsten rod at theoretically predicted angles.

Zone-melted single-crystal tungsten rod of high purity was also produced. It is expected to be useful for a variety of applications.



**SIXTY MILES OF CABLE** was installed in the new \$84-million Walt Whitman Bridge across Delaware River for power, control, and lighting.

## ... For Construction

More than 60 miles of General Electric cable was used in the new \$84-million Walt Whitman Bridge, opened in May 1957. Spanning the Delaware River from South Philadelphia to Gloucester, NJ, the bridge, including its approaches, is 6¼ miles long—the eighth longest single-suspension bridge in the world. Cable was installed in ducts and trays, suspended on messengers, and buried in concrete to complete the complex installation required for the necessary lighting, control, and power.

### Low-Voltage Switchboard

Designed for any incoming service of 600 volts or less, a new low-voltage switchboard was built in standardized modules for application versatility. Its main bus is rated 800 through 4000 amp. The structure and vertical bus bars are drilled to accommodate virtually any combination of 7 different low-voltage protective devices. Because the switchboard is pre-engineered to predetermined standards and constructed in unitized modules, it is possible to completely lay out, price, and dimension the switchboard from published information. It also allows protective devices to be added, replaced, or rearranged in the field with minimum labor.

### Panelboard

Combinations of single-, 2-, and 3-pole circuit breakers up to 54 poles can be accommodated on a new plug-in combination lighting- and power-dis-

tribution panelboard. It has a maximum rating of 240 volts a-c; the main feeders are rated to 600 amp. The plug-in feature, which allows the single-, 2-, and 3-pole breakers to be arranged in various combinations, means the branch circuits can be altered to meet changing applications.

### Busways and Wireways

Designed for use where plug-in outlets over a wide area are necessary, a new 100-amp plug-in busway can be hung on 10-foot centers in an edgewise

position. Suited for industrial plants, commercial establishments, manual training shops, and laboratories, it can be used both as a plug-in system and as a feeder for lighting systems and as a feeder or branch circuit from a switchboard or other power-consuming device.

A new hinged-cover wireway, completely open for lay-in wiring, becomes particularly useful when dealing with limited space and complicated building contours. Available in various sizes and lengths, the wireway utilizes a hinged cover that opens over the entire length



**LOW-VOLTAGE SWITCHBOARD** designed for incoming service to 600 volts was built in standardized modules for application versatility; main feeders are rated 800 to 4000 amp.

of the run. This permits lay-in wiring through every length and fitting and eliminates the customary method of threading the conductor through collars.

#### Wiring Devices

Easy installation distinguishes a new line of interchangeable wiring devices. Instead of bending a part of the mounting bracket to hold each device in place, a screwdriver is used to twist a double-hook on the device. The line includes outlets, a-c switches, a-c or d-c T-rated switches, and pilot lights. All have pressure-lock terminals.

A new selector switch for use on General Electric remote-control wiring systems makes an important contribution to living better electrically. Each of the 12 circuits controlled is identified on a window provided on the switch wall plate. A small light, adjustable from dim to bright, illuminates the circuit identification tabs and makes the switch easy to locate and operate in the dark.

#### Transformer

To meet low noise-level requirements in commercial buildings such as hospitals, motels, shopping centers, libraries, and offices, a transformer with ratings through 50 kva, single phase, and 150 kva, 3 phase, was introduced. Having a noise level of 45 decibels or below, the transformer represents the first time the exposed type of core construction was offered in these higher ratings for commercial buildings. Lacking a metal enclosure, the case is eliminated.



**WIRING DEVICES** in a line can be easily interchanged by the twist of a screwdriver.



**HIGH-ENERGY COBALT-60 UNIT** treats cancer patients in Deaconess Hospital, Milwaukee.

## Medical

Operating at an unprecedented 1-million volts, or about 8 times the conventional maximum, a new diagnostic medical x-ray machine ignores such unwanted images as ribs and spinal column, plunging deep within the chest and other body parts for more detail. Some radiologists believe that the device may help early discovery of lung cancer.

Prior to this development, high-potential tubes were limited to therapy and industrial inspection. Gradual tube loading in those applications contrasts sharply with the sudden loads demanded in diagnostic work. The new unit will maintain rated potential in exposures as rapid as 1/20 second.

#### Cancer-Treatment Machines

A high-energy cobalt-60 cancer-treatment machine, as mechanically flexible as an x-ray unit, provides an easy transition from conventional voltage x-ray to high-energy radiation therapy. Simpler and less costly, the new unit offers 10 roentgens per minute at 1 meter, or 40 roentgens at 50 cm—ideal for the hospital of moderate patient load. The safety-head shutter is spring-loaded to close on power or compressor failure and also on expiration of preset treatment time.

According to radiologists, cobalt-60 and other high-energy radiation sources offer potential benefits in treatment of

deep-seated cancers: delivery of more radiation through surface tissues, less skin reaction, and less system reaction to side-scattering of rays into surrounding tissues.

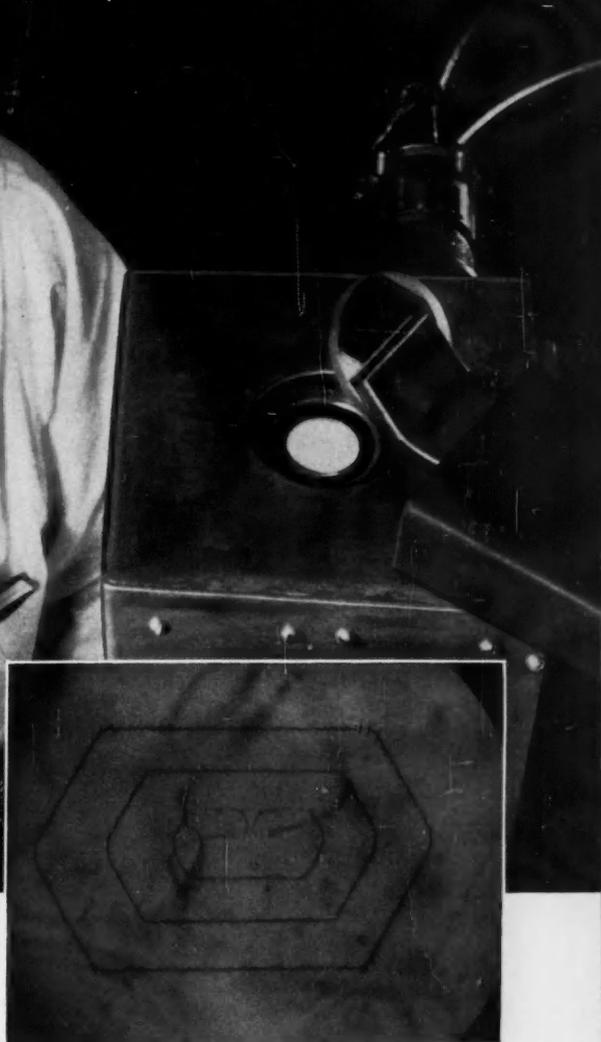
A recently developed x-ray therapy machine with a "throttle" can be adjusted to treat the skin with low-penetrating "soft" rays or to penetrate to deep-seated malignancies with 300,000 volts. The soft rays of the spectrum produced by this unit are 50 percent absorbed by a sheet of aluminum only 1/256 inch thick. An end-grounded multisection tube permits bringing the nose of the unit close to the body in critical areas—armpit, head, crotch, and neck. The unit can be adapted to rotational therapy through 360 degrees at speeds up to 12 degrees per second.

#### New Diagnostic X-Ray Equipment

A wheel-mounted mobile diagnostic x-ray unit operates up to 200 ma at 100 kv peak. It rolls easily along hospital corridors and over doorsills or into elevators. Offering more than double the power of conventional mobile equipment, the unit saves the bedfast patient trips to the x-ray department. Shorter exposure prevents blurred images.

Compactness, lower cost, and high output are combined in a new diagnostic medical x-ray generator that operates up to 300 ma and 125 kv.  $\Omega$

Dr. William C. Dash, B. S., Lehigh University (1946), Ph.D., Cornell University (1952), has been a member of the *Semiconductor Studies Section* at the General Electric Research Laboratory for five years, investigating optical absorption and perfection of semiconductor crystals.



## Looking into silicon

**Dr. William C. Dash of General Electric develops a new technique for studying dislocations in silicon crystals**

Silvery wafers of silicon used in semiconductor research — and in the manufacture of transistors — are as opaque as a brick wall to visible light, but highly transparent to infrared. Dr. William C. Dash of the General Electric Research Laboratory has adapted the "snooperscope," an infrared-sensitive device developed during World War II, as a convenient means of looking into silicon crystals.

Recently Dr. Dash and his associates devised a method of precipitating copper along the rows of out-of-line atoms inside silicon crystals so that these flaws — called *dislocations* — can be seen by the snooperscope. Since physicists now explain many aspects of crystal behavior — how they grow and why they bend

— in terms of dislocations, the Dash technique is an important new tool for learning more about the solid state. Dislocation patterns predicted by theory have actually been seen for the first time on the screen of Dr. Dash's snooperscope.

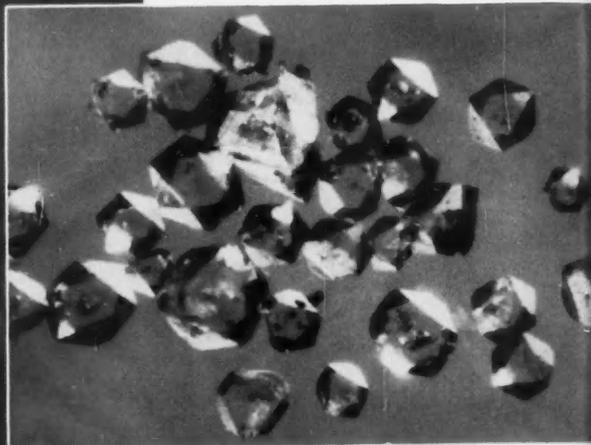
At General Electric, such research is motivated by a belief that providing scientists with the tools, the incentives, and the freedom to seek out new knowledge is the first step toward progress for everyone.

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

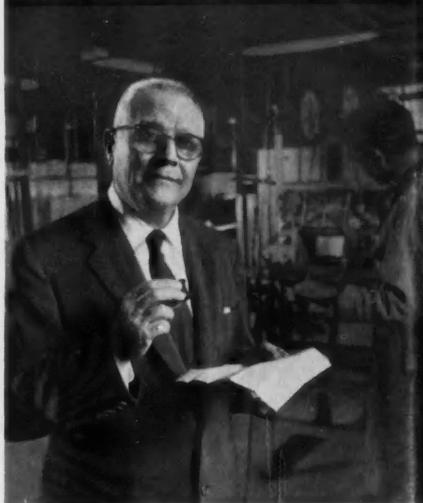
Infrared light passes through silicon and reveals pattern of dislocations on the screen of the "snooperscope."

# MAN-MADE INDUSTRIAL DIAMONDS:



**Tiny man-made industrial diamonds** were a laboratory achievement two years ago. Today, General Electric is producing diamonds in quantity at a pilot plant in Detroit. The above photograph was taken through a microscope and enlarged 60 times.

## WHO BENEFITS FROM NEW



*Charles Koebel is president of the Koebel Diamond Tool Co., one of many firms assured of a continuous supply of diamond abrasive products.*

**Customers** get new values from research and development. More than one-third of all General Electric products now being made for home and industry did not even exist 15 years ago.

## The making of diamonds by General Electric is one example of how research and development accelerate the nation's progress

Two years ago, General Electric unveiled tiny man-made diamonds—identical with nature's—as a "laboratory achievement." Today a pilot plant is producing these diamonds in significant quantity for industrial use.

Industrial diamonds are critical to America's productive strength, for they are needed to cut, grind, polish, and machine metals used in defense equipment and civilian goods. Now, the United States can look forward to the time when it will not have to rely entirely upon a closely controlled foreign supply.

### A result of basic research

This breakthrough was made in the General Electric Research Laboratory, where scientists were searching for fundamental knowledge about heat and

super-pressures. After four years of research and experimentation—and duplication of the "squeeze" 240 miles inside the earth—these scientists produced diamonds identical in every way with those dug from the earth.

This discovery was taken up by development engineers at our Metallurgical Products Department in Detroit; in two years they translated the laboratory achievement into a useful product, produced in quantity and at a cost low enough for commercial application.

### Importance of profits to research

At General Electric today, one out of every 13 people is a scientist or engineer, and the work of research and development is carried on in 93 laboratories. In fact, we are currently investing

over three times as much, per sales dollar, in research and development as the average for all industry.

Such investments in research and development can, of course, be warranted only when there is opportunity for adequate profit. Probing the scientific unknown is a risky and uncertain venture that can achieve a great deal—or nothing. One of the important functions of profit is to stimulate those ventures which, if they turn out to be successful, lead to the swiftest progress.

The American people, by encouraging local and national policies which provide a chance for earned rewards, can stimulate continued high levels of research and development . . . and thus assure national security and further progress for all citizens.

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**

*For a copy of an address by Dr. Guy Suits, Vice President and Director of Research at General Electric, before the President's Conference on Research for the Benefit of Small Business, write Dept. 2B-119, Schenectady, N.Y.*

### PRODUCTS LIKE MAN-MADE DIAMONDS?



*Jack Mays, an employee and a share owner, has a better job—newly created at General Electric's new diamond-producing pilot plant.*



*Fred Robinson heads the English & Miller Machinery Co., which supplies General Electric with equipment used in diamond production.*



*In national defense, the machining of metals like those needed in jet aircraft will no longer depend solely on diamonds available from abroad.*

**Employees and share owners.** The common interests of share owners and employees are served when research and development create profitable new businesses and lead to new jobs.

**Small businesses.** New and improved products have increased the number of General Electric suppliers to over 42,000, and opened business opportunities for 400,000 independent retailers.

**All citizens.** The results of research not only help keep the nation strong but, like Edison's discovery of the electric light 78 years ago, live on and continue to benefit people for generations.



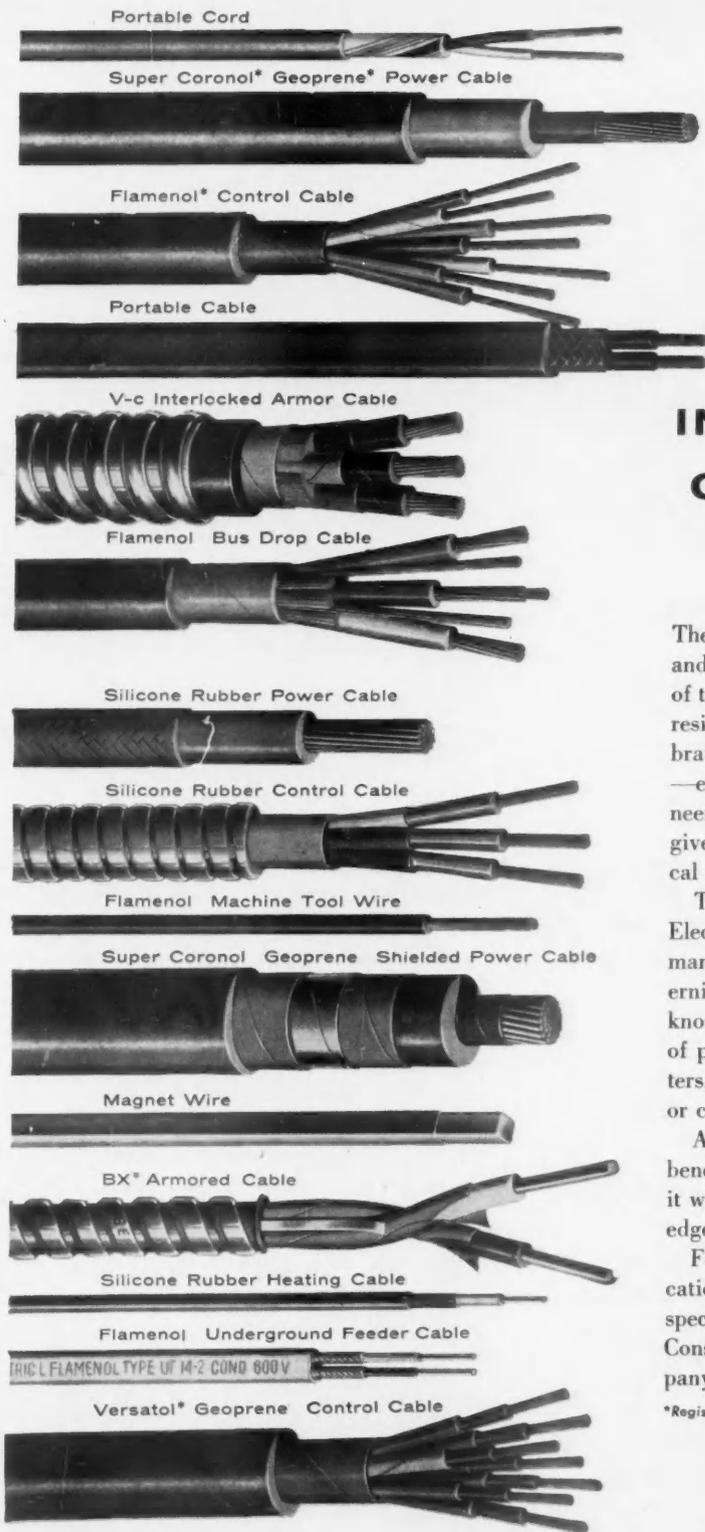
## Since 1919 the International Division of the General Electric Company has...

worked with and helped peoples throughout the world. The I. G. E. network of distribution is vast. It is made up of eighteen affiliated companies, four offices, and over 200 distributors located outside of the U. S. A., Canada and Hawaii. This world-wide organization is actively engaged in the sale of all General Electric products. It is also continuing to contribute to improving the economic and industrial position of all countries in the free world which is one more reason why at General Electric we say . . . *PROGRESS IS OUR MOST IMPORTANT PRODUCT.*

C-58-1

INTERNATIONAL  
GENERAL  ELECTRIC  
COMPANY

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



## More scope for selection

### IN THE FULL LINE OF GENERAL ELECTRIC CABLES

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

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.

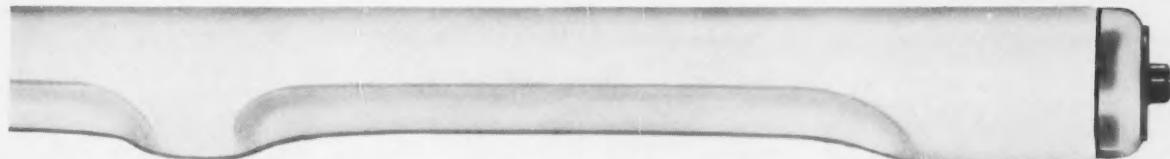
All this adds up to experience . . . the kind that can benefit you. Next time you have a cable selection problem it will pay to take advantage of General Electric's knowledge and experience.

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**



# The Powerful Power-Groove!

*General Electric's radical new fluorescent lamp design can give you higher, more economical light levels*



**AT ERICKSON TOOL COMPANY** (above), 450 G-E Power-Grooves, eight feet long, mounted 10 feet high, with 10 feet between rows, maintain a lighting level of 160 footcandles economically. This means there is plenty of light right at the machines (see footcandle reading at right)—where extra light means extra safety, extra accuracy for workers. No supplementary lighting is needed. Powerful Power-Grooves do it all!

While plans for their new building were still in the early stages, officers from Erickson Tool Company of Cleveland, Ohio, visited the Lighting Institute—General Electric's lamp headquarters at Nela Park. There they saw the whole array of lighting methods and discussed the powerful new G-E Power-Groove Lamps.

They were shown how these revolutionary lamps provide outstanding general lighting, making it unnecessary to use supplemental lighting on individual machines (like that used by Erickson toolmakers in their old plant). They saw how powerful Power-Grooves would fill a plant with pleasant light that's easy on the eyes . . . as well as the pocketbook. The decision was made: Erickson's new plant would have G-E Power-Groove Lamps throughout!

Because G-E Power-Groove Lamps give nearly twice as much light per tube as High-Outputs— $2\frac{1}{2}$  times as much as 8-foot slim-lines—you can get more light per fixture—with fewer parts to maintain. And compared to other fluorescent systems, you can save 5-20% on your initial investment.

*Get the whole exciting Power-Groove story.* Write General Electric Co., Large Lamp Dept. GER-18, Nela Park, Cleveland 12, Ohio. Better still, visit Nela Park and let us show you on-the-spot demonstrations of how the powerful Power-Grooves can work for you . . . economically.



**WORLD'S BRIGHTEST WORKSHOP**—Now you can see powerful Power-Grooves in action . . . lighting the world's brightest workshop. It's at the G-E Lighting Institute at Nela Park. Plan to visit it and see for yourself.

*Progress Is Our Most Important Product*

**GENERAL  ELECTRIC**