WESTINGHOUSE

Engineer

Annual Engineering Review

JANUARY 1956

Traditionally, during the past several decades, Westinghouse has presented an annual review of its engineering and scientific achievements. The engineering subjects in each review have, of course, been different; likewise the format of the magazine has changed with the times. Nevertheless there is a pattern of all of them—one that is perhaps common to engineering. As the stories indicate, each year produces a few major accomplishments, and many, many less dramatic, but important developments. More often than not, the major accomplishments are the culmination of many smaller developments—for such is the course of engineering.

But there is something else on these pages, something that may not be too evident from the written words. Today, at Westinghouse, there is more emphasis on the technical future than perhaps at any time in the Company's history. Developments on a day-by-day and a year-to-year basis are vital to progress, and will always have at least a full measure of attention; but the fast-changing, complex nature of technology necessitates probing the long-range future as well—and with considerable effort.

The increased emphasis starts, of course, at the Research Laboratories, where in a completely new facility more and more effort is being devoted to fundamental research —aimed at developing new scientific knowledge rather than specific products or devices. Work in the high-vacuum field, for example, is not merely an attempt to produce a better vacuum than ever before; this is but a means to an end—the study of the actions and interactions of atoms. Similarly, metallurgists are working—not by the old cut-and-try method of developing new metals and alloys—but toward the day when metals can be designed, their characteristics predicted accurately. And this day is not far off.

Just as research must look to the future, so must engineering. Each operating division of the company has—in addition to its normal complement of engineers—a separate group, whose primary task is to conceive and execute the product designs of the long-range future, i.e. five, ten years or more hence. These men are encouraged to exercise their imagination and ingenuity to the fullest in their look toward the future.

A nearly completed metals facility will explore the possibilities of new metals, and develop techniques of producing them. The tremendously promising field of semiconductors now has a completely separate department devoted exclusively to their development; it will soon have new plant facilities as well. There are others, many others, who are also devoting all or a major proportion of their time to the future, but this sampling at least suggests the latitude of the effort.

Most of the pages of this magazine are devoted to the more important and interesting engineering and scientific developments that reached fruition during the past year, and rightfully so. These year-to-year developments represent the major technical effort of Westinghouse, in this or any other year. But in reading these stories, it is well to reflect that many of the new concepts and designs are possible only because of long years of research and advanced development work. The Cypak control system, for example, exists today only because much effort was devoted in previous years to development of magnetic and semiconductor materials.

For obvious reasons, not much of the work being done toward the future can be described here. But we hope that in reading this issue you will find in it not only information of immediate interest and value, but also a suggestion of things to come.

J. A. HUTCHESON
Vice President, Engineering

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THE COVER

Many new devices are resulting from investigations of semiconductors. On this month's cover, artist Dick Marsh shows symbolically the production of a semiconductor rectifier; "slices" of the single crystal are combined with other materials to form the wafer that is the heart of a rectifier.

Editor . . . RICHARD W. DODGE
Assistant Editor MATT MATTHEWS *Art and Production* JAMES G. WESCOTT
Editorial Advisors J. A. HUTCHESON, J. H. JEWELL, DALE MCFEATTERS

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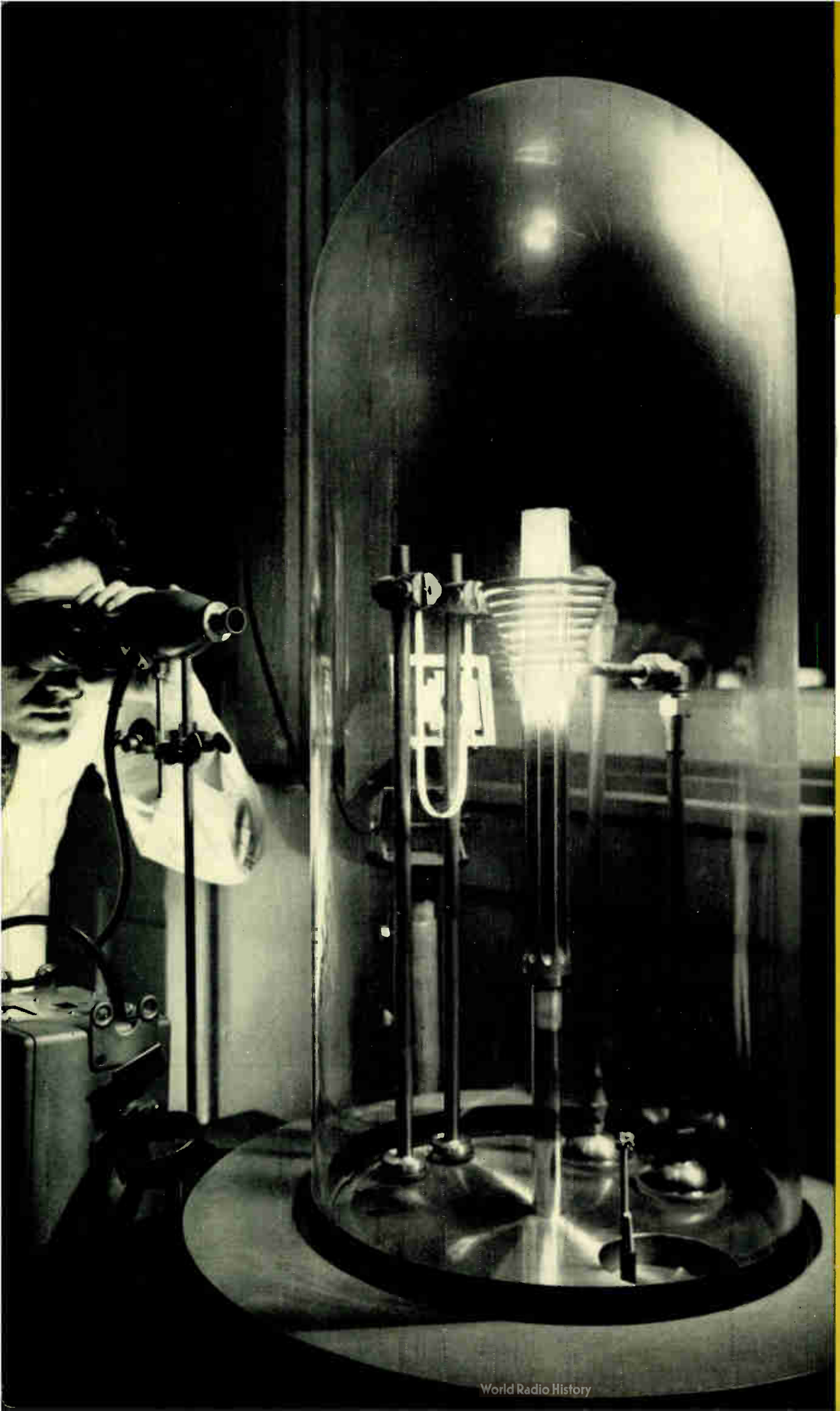
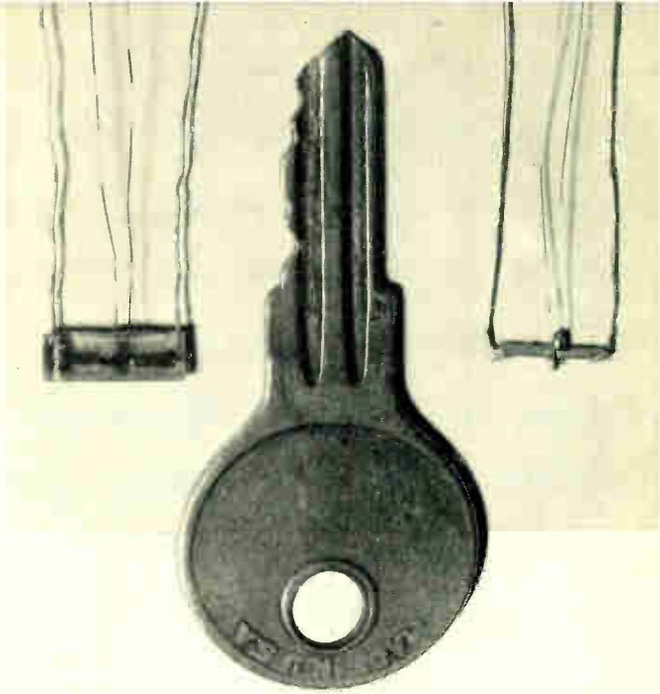


The metal being melted acts as its own crucible in this new technique, called cage-zone refining. The bar is melted progressively from end to end, thus drawing impurities to one end.

HALL MULTIPLIER—
COMPUTER POSSIBILITY

THE VOLTAGE resulting from the deflection of charged particles when passing through a magnetic field soon may be put to a new use. This phenomenon, called the Hall effect, has been used in semiconductors to determine whether current carriers are electrons (negative charges) or positively charged "holes" (the absence of electrons, similar to the absence of water in a bubble rising in water). By applying a magnetic field at right angles to the direction of current, the moving charges are deflected; this results in a charging of the conductor surfaces. This charge accumulation can be measured as a voltage, ordinarily in microvolts. A recently developed device utilizing the Hall effect produces many volts, making the device a realistic possibility for computing service since the output is a measure of the product of magnetic field and current. The watthour meter, for example, might use such a device. The useful voltage output has been obtained by locating rectifying contacts on the measuring surfaces. The Hall effect changes the rectifier characteristics and the output becomes a variable current, which can be fed through high impedances giving power and voltage in a useful range.



A key to the size of the Hall multiplier unit. The unit is shown both before and after encapsulation.

RESEARCH AND MATERIALS DEVELOPMENT

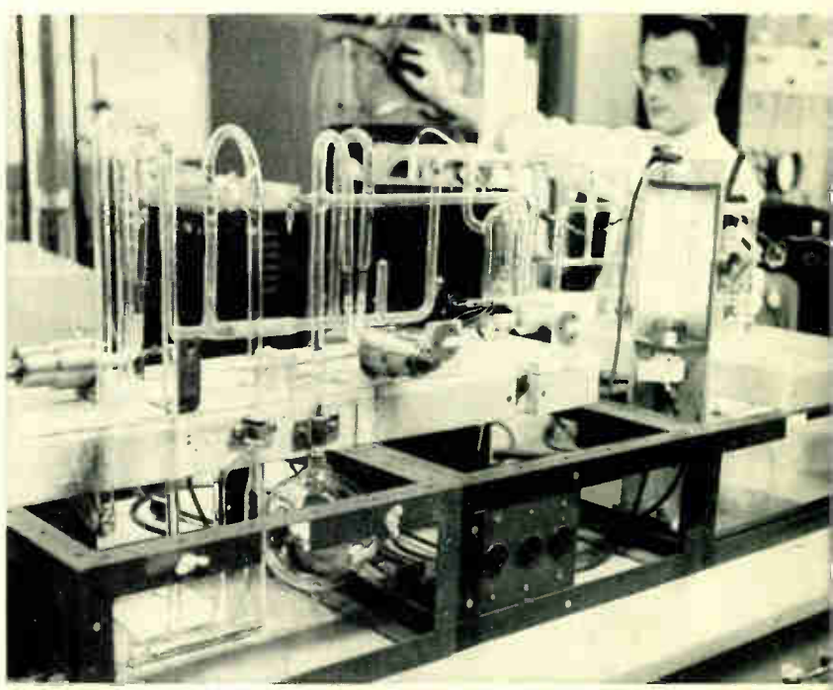
Because research seeks knowledge, it has no end. Similarly the development of materials is a progression of steps that have no foreseeable ending. Thus the information on these pages actually is in the nature of a progress report, and represents a sampling of work now underway in these fields.

WHAT GOES ON IN A GAS DISCHARGE?

SCIENTISTS have decided to find out more about what goes on in a gas discharge. As a starting step, they are studying helium, the simplest of the gases, to gain a complete understanding of the mechanism of current flow through the gas. It is known, for example, that ionization can occur in the helium positive column (the major portion of the arc length) by two means—direct ionization, where an electron hits an atom with sufficient energy to ionize it, and by a two-stage process where an electron excites an atom to an excited level (metastable state) of relatively long lifetime. The metastable atom can then be completely ionized by a collision with another excited atom or a relatively slow electron. As a result of this two-stage process, the voltage gradient necessary to maintain the gas discharge is less than would normally be necessary if all ionization was direct. The study now underway will determine the balance between production of ions and metastable atoms, rates of these processes, loss of excited atoms, and other fundamental information about the process.

New and sensitive techniques had to be developed before the study could proceed. For example, an accurate method was necessary for detecting metastable atoms. This is now done by measuring the absorption of light by the excited atoms. Time-sampling techniques, where an average of many samples is

Laboratory setup for investigating mechanism of gas discharge includes ultra-high vacuum apparatus.



taken, has resulted in high sensitivity and accuracy of the measurements.

Another problem was the preparation of very pure helium. The best gas available contained two parts in 10^5 of neon. Researchers have had to prepare quantities with less than two parts in 10^7 to give them proper test accuracy.

From such fundamental study will come information that will lead to the improved devices of the future.

SUPERCONDUCTIVITY—A SUPER PROBLEM FOR SCIENTISTS

ONE OF THE LEAST understood phenomena in physics is superconductivity. Scientists have long been attempting to establish a theoretical representation for the superconducting state. Materials such as lead, tin, aluminum, and vanadium, have two common characteristics at temperatures near absolute zero (—273 degrees C). First, they have essentially no resistance within the limits of measurement, and second, the superconductor is a perfect diamagnet, i.e., it will completely exclude magnetic flux when placed in a magnetic field. Scientists are searching for an explanation of these unusual properties. One approach that has made a real contribution to the understanding of the fundamental properties of superconductors is the study of the specific heat (i.e., the amount of energy required to raise the temperature of a given amount of material one degree).

The way in which energy is absorbed by any form of matter and distributed among the various possible energy levels is basic to the understanding of any of its properties. In the case of metals, energy is absorbed separately and, to a first approximation, independently by the atomic nuclei forming the crystal lattice and by the conduction electrons, which behave as a fluid more or less free of the lattice. At room temperature the energy absorbed by a metal is distributed about 99 percent to the lattice and one percent to the electrons. There is a temperature for each metal, within a few degrees of the absolute zero for most metals, at which the energy absorbed is divided equally between the electrons and the lattice, which is to say, the electronic and lattice specific heats are equal. Below this temperature the electronic specific heat predominates. Therefore, it is necessary to go to very low temperatures to measure the electronic specific heat without having it entirely masked by that of the lattice.

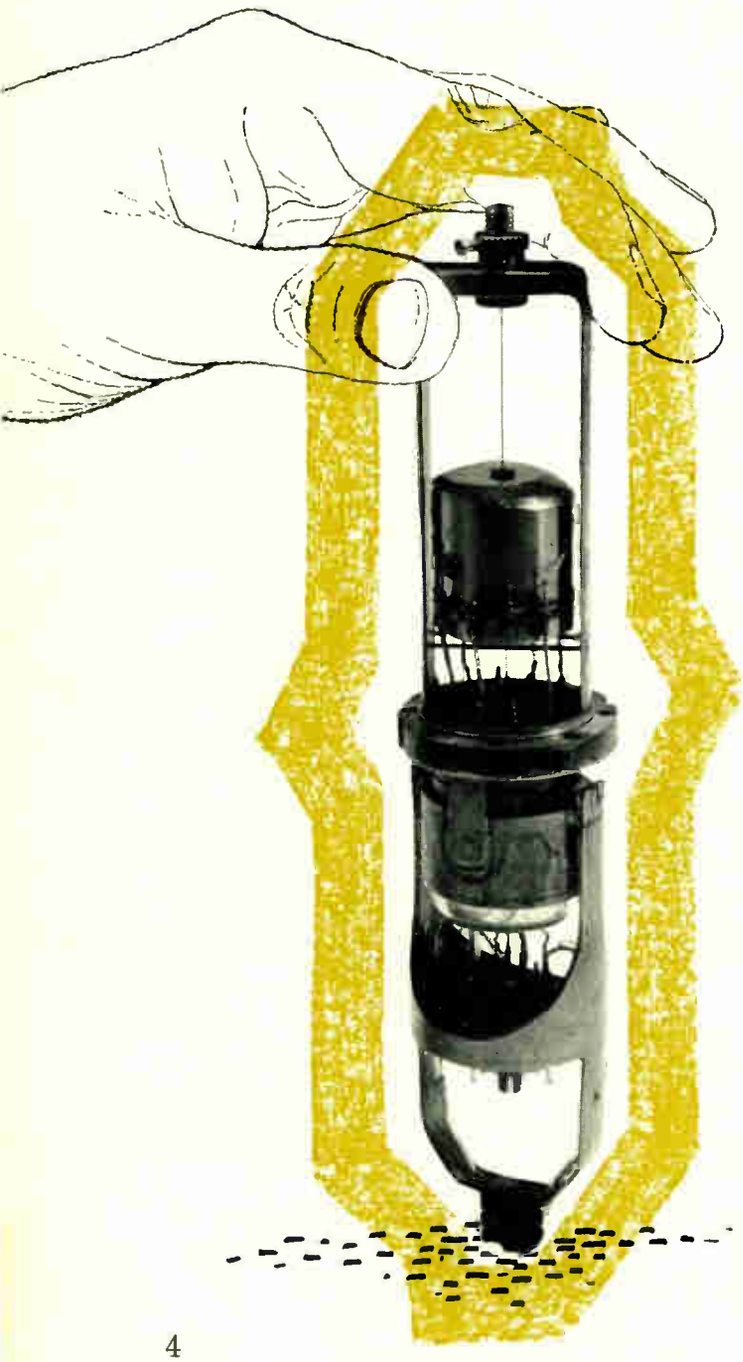
Since the phenomena of superconductivity arise from unique behavior of the electrons, a study of the electronic specific heat is of particular interest.

The men who are making these very low temperature measurements (they work in the range between one and five degrees above the absolute zero, that is, minus 268 to minus 272 degrees C) say that although their experiments are simple in principle, they are quite difficult and require extreme precautions in practice. Specific-heat determinations require the addition of a known amount of energy and measurement of the rise in temperature for a sample of known mass.

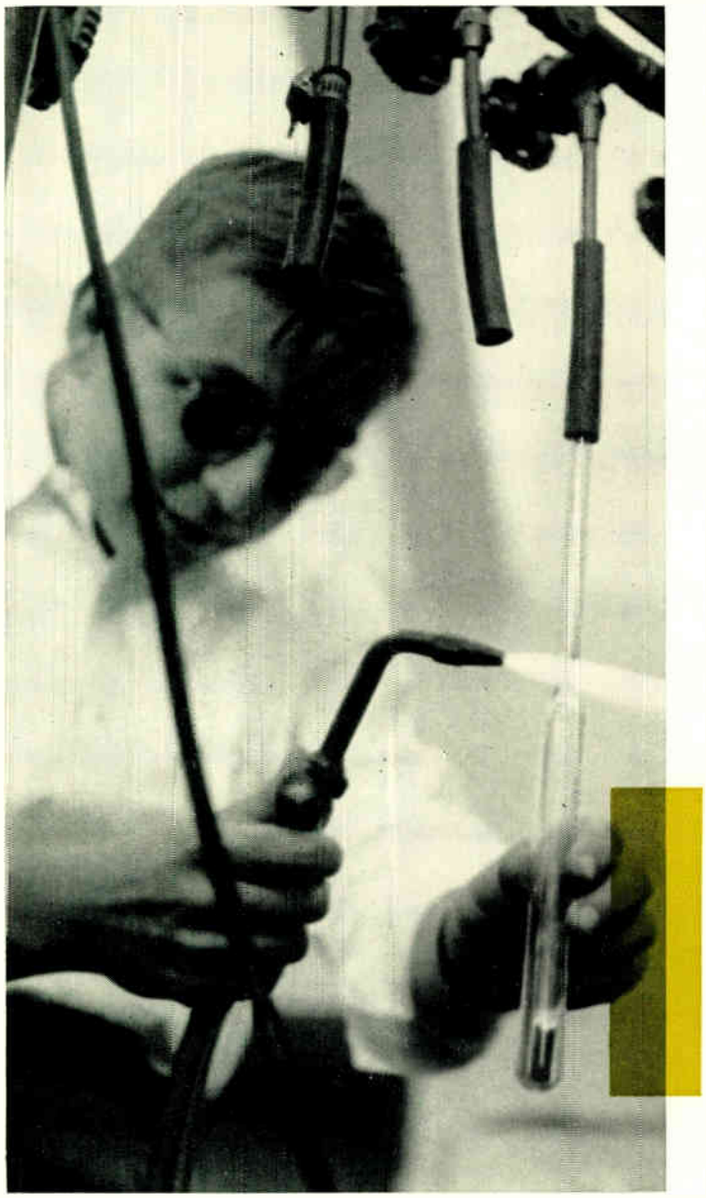
The specimens used are cylinders about one inch in diameter and two inches long. They are suspended from fine nylon threads inside a chamber maintained at a vacuum of 10^{-10} millimeters of mercury. This ultra-high vacuum is necessary to prevent excessive heat conduction between the sample and the walls of the chamber by gas molecules. This chamber is immersed in a bath of liquid helium, which is the refrigerating liquid used in obtaining the requisite low temperatures.

The major difficulties arise from the fact that the quantities being measured are fantastically small. For most materials the specific heats at these low temperatures are one thousandth of their room-temperature values or less. For making measurements, heat is supplied equivalent to five microwatts for about 30 seconds. This is enough to raise the temperature of the sample about five hundredths of a degree.

Before these determinations could be made with the desired precision, it was necessary to eliminate the flow of extraneous heat into the sample. The total input of extraneous heat must be kept below five hundredths of a microwatt. Energy could



Mounting for the sample is vital to specific-heat measurements at near-absolute-zero temperatures. The upper portion of the assembly, containing the sample suspended by a nylon thread, is immersed in liquid helium under vacuum. Leads from measuring devices are brought out through a seal.



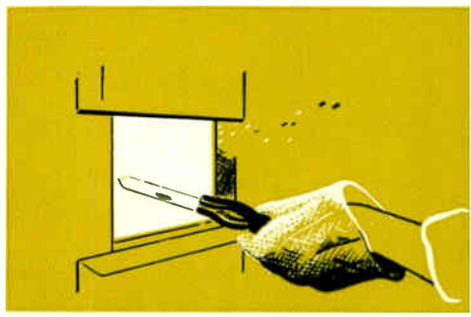
$$\left(\frac{X}{2}\right) Li_2O_2 + (1-X)\ MnO \longrightarrow Li_xMn_{(1-x)}O$$

This chemist's shorthand symbolizes a new method for making resistive elements that have predictable temperature coefficients of resistance. The device that results is similar to the thermistor, as typified by the "electronic eye" used in electric-range temperature-control circuits. The resistance of the element varies inversely with temperature, i.e., as temperature increases, resistance decreases. The new process makes it possible to control the temperature-dependence of the material much more accurately than has previously been possible. The discovery is actually a by-product of a fundamental study of atomic interactions. Scientists were investigating a prediction that ferromagnetism could be produced in certain metal oxides by altering the electronic structure of a fraction of the metal atoms. This alteration was also expected to affect the electrical properties of the oxide. In this case, the electronic structure was modified by the introduction of the element lithium into the metal-oxide crystal lattice. Although the expected ferromagnetism did not materialize, an investigation of the electrical properties proved to be of both fundamental and practical interest.

Lithium is added to the metallic oxide by "baking" lithium peroxide (Li_2O_2) with the metal oxide. The resulting reaction is self-contained so that the sintering can be done in a sealed container (shown at left), with accurate control of the process.

Tests with manganese have yielded material with resistivities from 10^5 to 10^{10} ohm-cm. Nickel and copper have also yielded satisfactory results, extending the resistivity range to one ohm-cm. Iron and cobalt should likewise be successful.

Thus, a "detail" of a fundamental atomic study becomes a discovery in itself.



Material to be "baked" is sealed inside a container under vacuum.

easily reach the sample at this rate from stray electromagnetic fields or from eddy currents induced in the sample by its vibration in the earth's magnetic field. Consequently the sample and electrical measuring equipment must be shielded and vibration eliminated. Furthermore, the actual measurements are made at night when building vibrations and electromagnetic disturbances are at a minimum.

Having developed new techniques ensuring the observance of these principles, scientists at the Research Laboratories have been measuring electronic specific heats with an accuracy of about one percent. Furthermore these measurements can now be made quickly and in a comparatively routine fashion. The new techniques have set new standards of accuracy and speed in this difficult field. The data obtained are of great value in improving existing theories of electrical and thermal conduction, magnetism, crystal dynamics, etc. or proposing new ones applicable at any temperature.

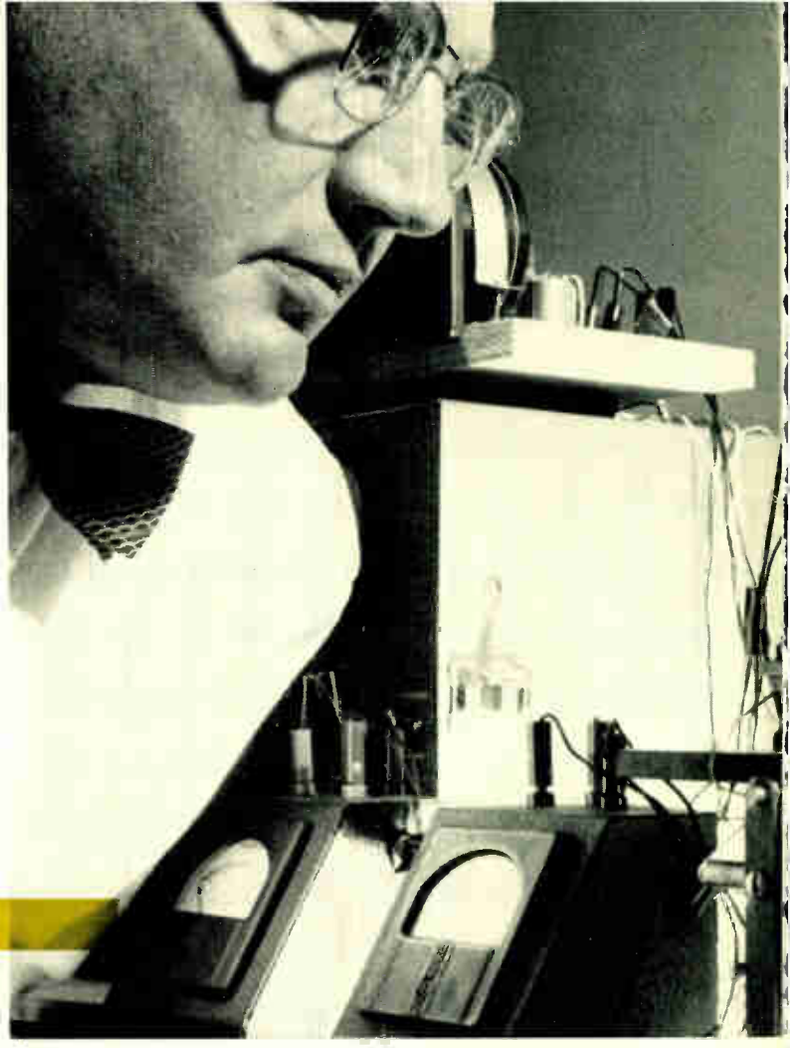
The most spectacular contribution of this work has been in the field of superconductivity. For a normal metal near absolute zero, the lattice specific heat is approximately proportional to the third power of the absolute temperature, and the electronic term is directly proportional to the absolute temperature. This result follows from the theory of metals, and its most convincing experimental demonstration was provided by the work of a group in the Laboratories on the noble metals, copper, silver, and gold, which do not become superconducting. However, for a superconductor, although the lattice specific heat is still proportional to T^3, the electronic specific heat assumes a temperature dependence quite different from that of normal metals. In fact, recent work at the Laboratories on vanadium, tin, and aluminum has shown that it varies exponentially with temperature and can be represented by an expression of the form $ae^{-b/T}$ where a and b are constants characteristic of the material and T is the absolute temperature. The studies on aluminum involved further elaborations of technique since it was necessary to work at temperatures down to within 0.2 degrees of absolute zero and with power inputs only 1/15 of that quoted above.

Although the new property of superconductors discovered at the Research Laboratories isn't the complete solution to the riddle, it is an important clue to a theoretical understanding of superconductivity.

DOUBLE-DUTY GYROSCOPE

Gyroscopes that supply guiding information to control systems are of two basic types, usually referred to as position and rate gyros. A position gyro, in effect an "odometer", measures total angular change, while a rate gyro, the "speedometer" version, measures angular velocity. Both types operate on familiar gyroscopic principles; the position gyro supported on a multi-gimbal mount utilizes the rigidity in space characteristic of gyros, while the rate gyro restrained to a single axis of freedom, relies on the proportionality of gyro precession torque to input velocity for its operation. In today's control systems, restrained rate-responsive gyros are more generally preferred because of their relative simplicity and non-tumbling characteristics. They can be made to serve as position indicators by providing a time integral of their velocity response, which is angle.

A new gyroscope makes use of a novel mounting arrangement to provide in one unit both rate and integrated-rate response, both of which are required for high-performance control systems. This gyroscope consists of a "canned" gyro wheel in an enclosed, fluid-filled case. The gyro wheel is supported from a concentric sleeve by cross springs, which provide rate-calibrating restraint about the precession axis. The sleeve in turn is supported on ball bearings in close proximity to the case; the viscous shear of the thin section of fluid between the two provides the damping restraint about the precession axis required for integrated-rate response. By these means, displacement of the gyro wheel about its precession axis is a measure of the sum of input angle and angular rate in a ratio fixed by the relative magnitude of the viscous and compliant components of restraint.



Performance of integrating-rate gyro is checked in developmental tests.

LUMINESCENCE AT HIGH TEMPERATURES

FINDING PHOSPHORS that retain their luminescent qualities at high temperatures is a tough proposition. In the first place there apparently aren't many. And secondly, it's difficult to measure their properties accurately at high temperature. To alleviate this situation a new test arrangement has been devised.

In most investigations of this type, the phosphor is placed in a vacuum, in which case the temperature of the fluorescing phosphor surface is difficult to determine. Usually the temperature of the metal base on which the phosphor is coated is measured, and assumed to be the same as that of the phosphor surface. In the new arrangement, the phosphor is coated on the end of a quartz rod to which is attached a thermocouple. This is placed in a helium-filled quartz chamber. Surrounding this chamber is a quartz jacket that can be filled with liquid nitrogen for low-temperatures or heated air for high temperatures, to give a range from minus 196 degrees C to plus 600 degrees C. A radiation baffle and a vacuum jacket surround this chamber, thus making a four-walled vessel.

Flat polished end windows of quartz permit excitation of the phosphor sample with a wide range of ultraviolet wavelengths. Luminescence of the sample is transmitted through the quartz rod on which the specimen is coated to an electron-multiplier phototube, the output of which is measured or recorded.

Although knowledge of the high-temperature behavior of phosphors has already enabled the production of fluorescent-mercury lamps, much remains to be learned about the behavior of these peculiar materials at high temperatures. This new test arrangement should contribute much new information.

TOWARD A "PERFECT" INSULATION

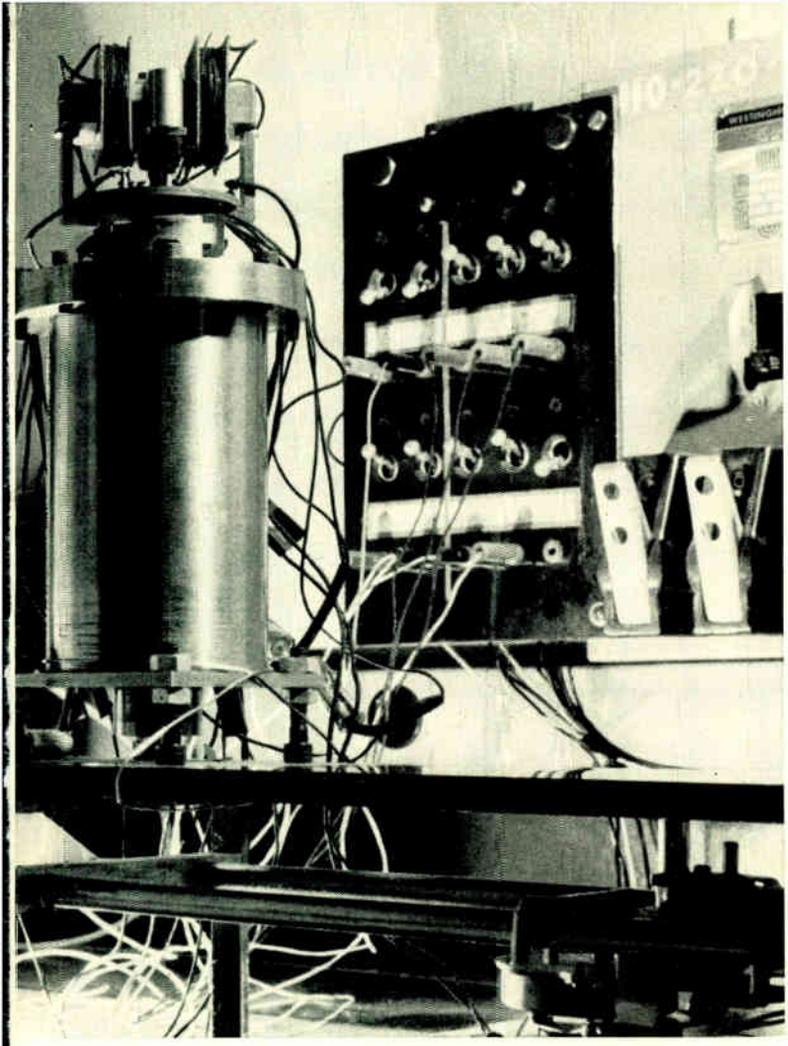
INSULATION CHEMISTS never give up in their search for "perfect" insulating materials. Although they are still a long way from that goal, each year produces significant improvements. Basically, what they are looking for is an insulating material that would have the toughness, ductility, heat-transfer characteristics, thermal stability, fire resistance, and impermeability to moisture of a metal—plus the electrical properties of a good, low-viscosity mineral oil.

A new solventless silicone resin, developed jointly by Westinghouse and Dow Corning, is a long step closer to that "perfect" insulation.

These resins can be formulated in any viscosity from that of water to that of a heavy tar. In electrical insulation viscosity is extremely important, inasmuch as many applications depend upon the ability of the insulation to penetrate and completely fill all voids, as well as being void-free itself. The new resins can operate at 200 degrees C for at least ten years, and for short periods at over 250 degrees C; they have excellent electrical properties, comparable to or better than the best synthetic resins.

Silicone resins have been available for some time, but have been limited in application by their high viscosity. The low viscosity possible with the new resins makes feasible many new applications.

The new resins have the properties needed for an impregnant for electronic components for aircraft and guided missiles; also, they have possibilities for use in high-voltage generator insulation and motor insulation of greater thermal endurance and reliability.

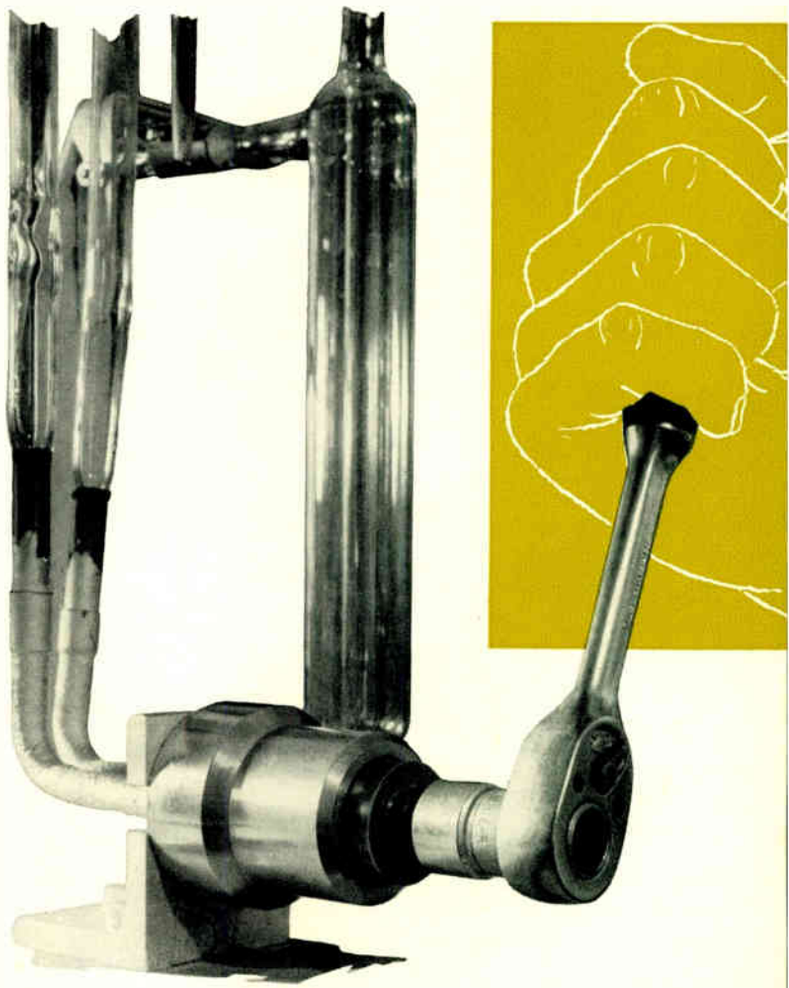


valve, when separating a typical vacuum system from atmospheric pressure, allowed pressure in the system to rise at a rate of 10^{-3} mm of mercury per minute, and thereby required continuous pumping of the system. The new valve permits pressure to rise at a rate of only 10^{-7} to 10^{-9}, an improvement that means the system can operate over a relatively long period of time with no pumping required.

The redesign has also resulted in a unit that is easier to manufacture. By the use of Monel in place of copper and Kovar, the life of the valve has been increased significantly.

The ionization gauge, the tube commonly used for measuring high vacuum, "consumes" some of the gas particles it is measuring. While undesirable from a measurement standpoint, this characteristic can serve a useful purpose. After the high-vacuum system is sealed off, the device serves as an ionic pump to remove helium, which diffuses through the glass from atmosphere. The mechanism of ionic pumping has not been understood until recently, when it was discovered that the ions formed in the ionization gauge are driven into the glass walls of the tube; a metal film, 20 or 30 angstrons thick, "traps" the ions in the wall, making it difficult for them to escape back into the tube. The layer of metal on the inside tube surface comes about during the outgassing of the tube, when metal evaporates from the tube elements during the high heating. Further studies of the ionic pumping process into metal surfaces are now in progress.

This valve permits high-vacuum systems to operate for longer periods without pumping.



SULPHUR HEXAFLUORIDE— AN ELECTRON "SPONGE"

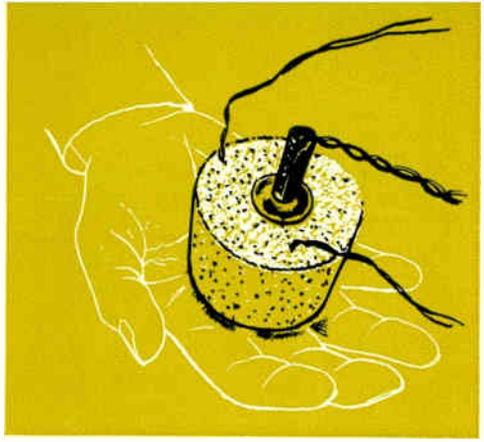
WHY IS SULPHUR HEXAFLUORIDE such a good insulating gas? Present studies of this and other gases to determine their insulating properties are finding the answer.

Sulphur hexafluoride is much like a "sponge" for low-energy electrons, soaking them up by forming negative ions of low mobility and velocity, so that no further ionization can result. This electron attachment process has been studied by means of a mass spectrometer. Mono-energetic electrons, or electrons of a single energy, are projected into the gas and the resulting negative ions measured. This method yields much more exact information than could be obtained in the previous studies where the incident electrons possessed a wide range of energies.

From the studies, the cross section (probability of the atom being hit) of sulphur hexafluoride was found to be much greater than that previously measured. This large cross section of the sulphur hexafluoride molecule makes it at least 10 times more efficient than any other attachment process yet discovered.

NOTHING! THAT'S GOOD IN HIGH-VACUUM RESEARCH!

HIGH-VACUUM RESEARCH scientists are continually developing devices to improve on the "nothingness" of ultra-high vacua. For example, the Alpert high-vacuum valve has been redesigned to improve its performance. The previous



The steel tube in the plastic measures stresses.

MEASURING THE SQUEEZE OF SHRINKING RESINS

DOCTORS ADVISE HUMANS to release pent-up emotions and stresses by "blowing their tops" occasionally, or perhaps through physical exercise. The important thing is to get rid of the tension before it does harm. Materials are a little bit like humans in this respect, too. For example, when plastics are poured into a mold, certain stresses and strains are imprisoned as the material hardens. These "residual stresses" can sometimes damage a delicate component embedded in the plastic. Of greater danger is the possibility that when the casting is cooled, these stresses, plus those induced by a difference in thermal contraction between the plastic and the component, would exceed the breaking strength of the plastic, thereby destroying the molding.

To measure these residual stresses a stainless-steel tube about as long as a cigarette and about an inch in diameter is embedded in the plastic during the pouring operation. Attached to the inside walls of this tube are cobweb-like grid strain gages with wires leading to the outside of the mold. Since the walls of the tube itself are only about 20 mils thick, practically all of the longitudinal and circumferential stresses are transferred to the strain gage as a change in the resistance of the wire; from this the amount and direction of residual stresses can be calculated.

While humans will probably always be bothered by internal stresses, plastics of the future may be developed with low or non-existent residual stresses.

This guillotine tests shock resistance of metals.

IMPACT GUILLOTINE FOR TESTING SHOCK RESISTANCE

TO A METALLURGIST, the Charpy notch impact test is as familiar as the chemical symbols Fe, C, and O. Although long used as a method for determining the transition point between ductile and brittle zones of metals, the method has some major disadvantages. For example, sample preparation takes considerable time and a V-shaped notch must be accurately machined 79 mils deep into one side of the small sample. A pendulum-type apparatus breaks the sample by swinging a weight against it.

Final data is in the form of a graph with impact energy for rupture plotted against the temperature of the sample. Even after elaborate preparations and careful technique, the exact temperature of the transition is not clearly defined.

A new method utilizing an impact guillotine uses a much larger sample, 14 inches long by 3½ inches wide, by 1 inch thick. Instead of the notch, a weld bead is put on the bottom side of the sample and an artificial crack put into this weld by means of an abrasive cutting wheel. A standard weight is dropped on samples at various temperatures and the transition temperature readily bracketed within a narrow range. For example, if trials at minus 20 degrees F show breakage each time, and trials at plus 20 degrees F produce no breakage, the transition point is clearly defined within useful limits.

Results are reproducible by the guillotine method and sample preparation has been cut to one third that of the Charpy method. Another laboratory step that's making the metallurgist's job a little easier.

What is it? A tangled mass of metal shavings? Or of textile fibers? Wrong on both counts. This is a microscopic view, magnified 20 000 times, of a thickening agent in grease. The ropelike structure is one of the metallic soaps, which give grease many of its desirable properties. The photo is no ordinary one either—it's produced by electron microscopy, a technique that is coming into more and more prominence as scientists delve deeper into the nature of things. Magnification of 100 000 times is possible with the electron microscope, compared to about 1000 times for the best optical microscope. The electron microscope is being used for many investigations—to study the effect of detergents on cloth, to examine pure-iron crystals and stainless steel welds, and many others. The results are yielding useful information about properties of materials.

MOLYBDENUM FOR JET ENGINES

HIGHER OPERATING TEMPERATURES offer one route to improved performance of jet engines. The big problem is to find blading materials that will stand up under higher temperatures. Potentially, molybdenum has tremendous possibilities—it has excellent high-temperature strength, good ductility, and high fatigue strength. But there's one large limiting factor that has thus far prevented its use in jet-engine design—its oxidation resistance is unusually poor.

One way to circumvent this weakness is to coat the blades with a metal whose oxidation resistance is high. But finding a material with the necessary oxidation characteristics that can be somehow coated on molybdenum, and that will withstand the environmental conditions in a gas turbine, is not easy. Since the creep resistance of molybdenum alloys is markedly superior to conventional high-temperature alloys only above 1600 degrees F, any coating must protect the moly above this temperature. The coating must also be able to withstand the thermal shock of heating and cooling rapidly as the engine starts up or stops. And it must be able to withstand the impact of small objects that invariably find their way into gas turbines. Any coating applied to the blading must not only be ductile, but must be capable of perfect coating every time. Even a small pinhole in the coating that exposed only a tiny surface of the molybdenum would eventually result in complete oxidation of the molybdenum. Tests show that the entire moly core could disappear, leaving only the coating.

Results of laboratory tests thus far have been encouraging, although a final solution has not yet been found. However, the results have been sufficiently promising to warrant a program of engine testing. Toward that end forged molybdenum blades will be engine tested with different coatings.

NEW TECHNIQUES FOR X-RAY DIFFRACTION

THE TECHNIQUE of x-ray diffraction is finding some new uses, especially in the study of semiconductors and grain-oriented steels. The first step in many semiconductor devices is to produce a perfect single crystal of, say, silicon, from which thin wafers can be cut, much as so many slices of bread, for use in rectifiers and other equipment. To produce a large single crystal, a small but perfect "seed" crystal is touched to the surface of pure molten silicon, then gradually withdrawn and a large single crystal is thus built up. However the success of the crystal-pulling operation is dependent upon the initial proper placement of the seed crystal with respect to the molten surface of the silicon. A silicon crystal has many planes; a good crystal can be drawn only if the correct plane is placed parallel to the surface. This requires a close "look" at the planes to determine the right one. X-ray diffraction devices are making possible this critical decision, by furnishing an accurate picture of the crystal structure.

Magnetic, workability, and strength properties of metals are strongly influenced by the arrangement and orientation of crystals in the material. The ability to measure the crystal arrangement or orientation texture is an essential element for developing improved metals and alloys. A new x-ray diffraction device, developed by materials engineers, enables the three-dimensional study of crystals. Use of this device permits a closer plot of the crystal orientation in a metal and thus a better determination of its effect on metal properties.

Shooting tiny bb's at a jet engine sounds like a David and Goliath type of operation. The analogy, in fact, is quite close. As a jet plane roars down the runway, stones and other foreign objects are sometimes sucked into the front end of the engine. Screens across the opening keep out the large objects, but even small particles at high speeds can damage the compressor and turbine blades.

Molybdenum, which is being considered as a possible turbine blade material, has one weakness—above 1500 degrees F it oxidizes rapidly. Thus for jet-engine parts it is coated with a thin layer of non-oxidizing material such as Inconel. However, if a small stone whizzing through the engine should strike a blade and crack the coating, the blade would be exposed to oxidation.

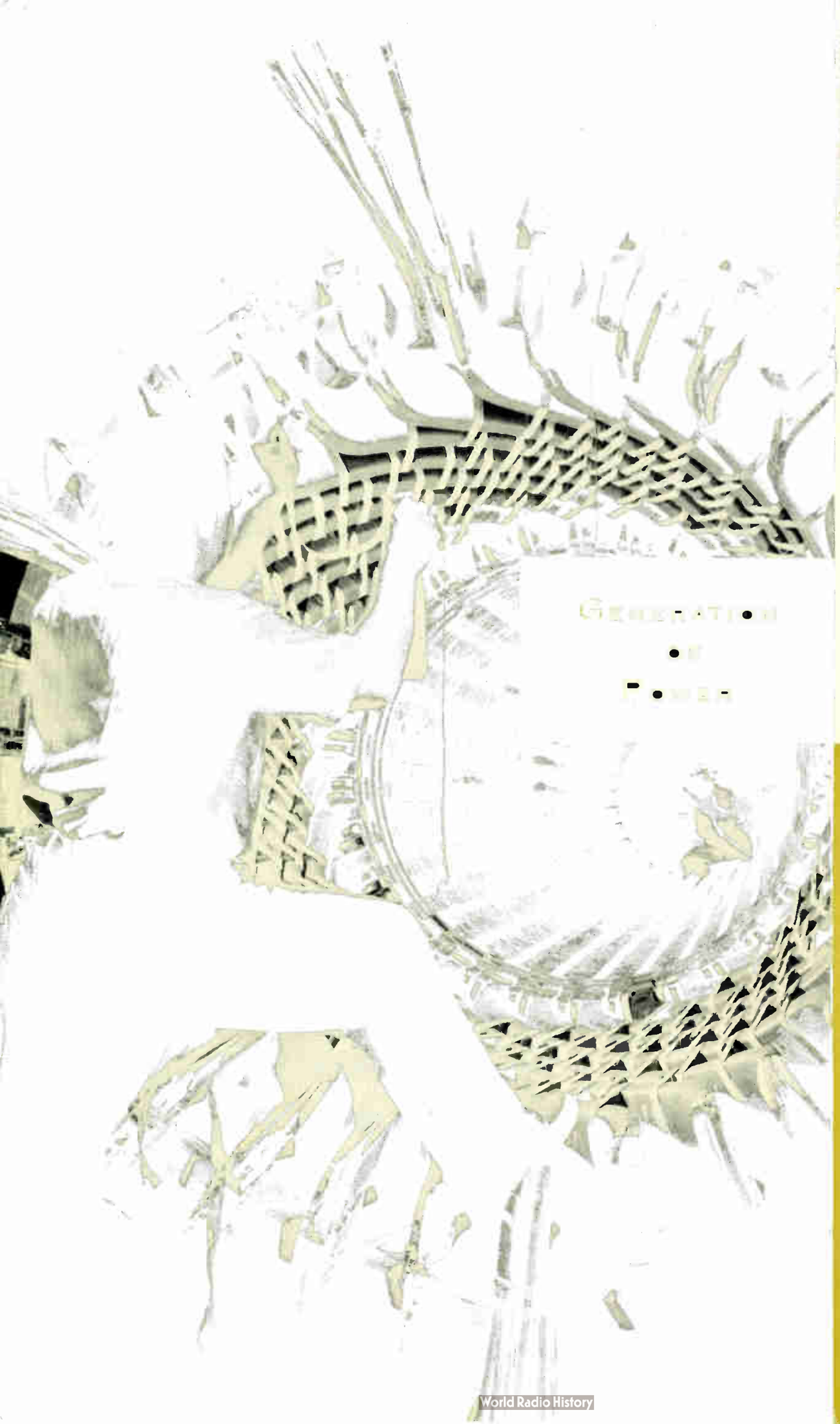
To test for this possibility, materials engineers are using a conventional air-operated bb gun, which fires at a blade sample at operating temperature, thus simulating the effect of small stones. Thus far, the Inconel-coated blades are proving tough enough to withstand the simulated stone-throwing, thereby departing from the David and Goliath analogy. Results are so promising that the Inconel-coated moly is also being investigated as a possible material for afterburner parts, which might lead to significant weight reduction and an increase in the jet engine's efficiency.

MEASURING THE "NECKING" NATURE OF MATERIALS

THE STANDARD METALLURGICAL elongation test consists of taking a metal sample about a half inch in diameter and roughly five inches long, placing it in strong mechanical jaws and pulling the sample to the breaking point, at the same time measuring the force exerted before breaking. Two pieces of information are gained—the force exerted at the breaking point, and the total elongation before breaking.

A much more realistic picture of the behavior of materials can be obtained by plotting true stress—true strain curves for the material in tension, basing the stress and strain measurements on the changing dimensions. The information thus obtained can be used not only to determine the effects of heat treatment, chemical composition, and mechanical working, but can also be used to predict the behavior of the material under other more complex states of stress, such as those found in combined stress tests and forming operations.

Investigation by metallurgists shows that the standard tension test would provide the needed information for the complex stress conditions mentioned if the diameter of the specimen could be measured constantly during the test. This sounds good, but no tension test would be accurate if it were stopped at various points to measure the diameter with a conventional micrometer. A special new device clamps around the half-inch-thick specimen and accurately and automatically follows the "necking down" of the specimen to the point of breakage. Thus investigation time is reduced and more valuable data is obtained.



These windings will generate 250 000 kilowatts at 24 000 volts—both record highs in this country. The high power is made possible by inner-cooling of the windings. These high-voltage stator coils are insulated with Thermalastic insulation. This is one of two 250 000-kw, 3600-rpm generating units, to be installed at TVA's Gallatin Station, Tennessee.

NEW CONCEPT FOR CLASSIFYING INSULATION

MAN-MADE SYNTHETIC RESINS, although not too different chemically from nature's original versions, are coming with better and better electrical characteristics. Chemical structures can be tailor-made to obtain a wide variety of electrical properties. This is playing hob with the present methods of classifying an insulation by its chemical composition. For example, new wire enamels that by old definition could only be used as class A (organic compound) are actually suitable for class B service, or a rise in operating temperature from 105 to 130 degrees C. Some enamels are even approaching class H, or 180-degree operation. As a result, a new concept of insulation classification has evolved. This consists of a combination of testing and a mathematical evaluation of the insulation, not as isolated materials (organic or inorganic), but as insulating systems. Out of this has grown a whole new concept of classification, testing, and application. The new standards being worked out by industry will have a great influence on future motors and generators. This will allow designers a great deal of latitude, by making available thinner insulations for operation at higher temperatures. Thermalastic, for example, when evaluated under these new tests, appears to be 25 degrees C better than the class B service for which it was originally designed.

The most revolutionary news in the field of power generation is the introduction of the nuclear reactor as a heat source. Not to be overlooked, however, are the many other improvements that accrue in generating equipment each year. Although usually less dramatic, they represent a continuous improvement process.

44-INCH TURBINE BLADES

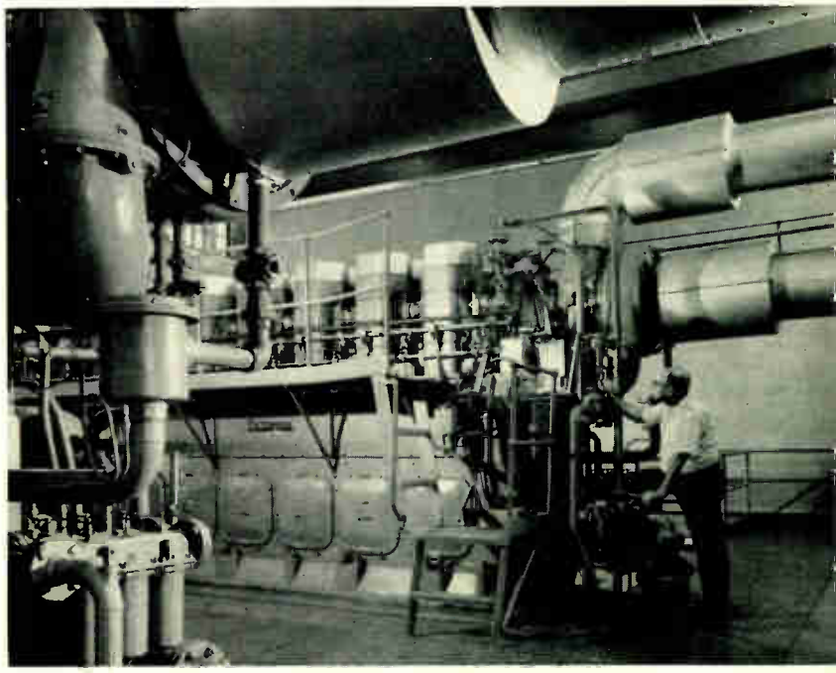
THE RECORD-BREAKING front-end steam pressure for the turbine being built for the Philadelphia Electric Company—5000 pounds, 1200 degrees F—has made it necessary to break records at the other end of the turbine also. After passing through the super-critical and high-pressure 3600-rpm turbines, the steam will be exhausted through an 1800-rpm double-flow low-pressure unit. The 1800-rpm turbine must pass 1 200 000 pounds of steam per hour. Multiply this figure by the 625 cubic feet that will be occupied by each pound of steam at exhaust pressure—that's a lot of steam! Hence, the need for the new 44-inch exhaust blades—the largest steam-turbine blades yet designed.

New methods of calculating natural frequencies utilizing computer techniques have reduced the design time for the 44-inch blade by more than half. Furthermore, a much more thorough search of the various possible combinations of lashing (to increase natural vibration frequencies and prevent harmful resonant vibration) assures designers that the resulting blade will have the best possible combination of the various parameters involved. Using an IBM card-programmed calculator, one engineer has done more design work in four months than two could previously do in nine months using former design techniques.

ELECTRIC GOVERNOR TAKES CHARGE

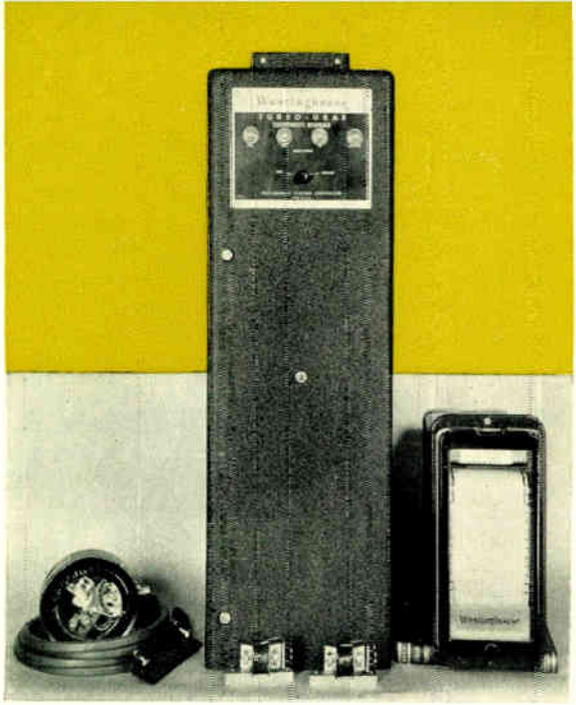
SUDDEN LOAD CHANGES on an engine-generator set would play havoc with the frequency of its output if some form of engine governor were not used. Conventional governors, usually mechanical or hydraulic, have been used for many years to sense speed changes and then readjust engine speed to produce the correct frequency output. For the most part, however, the response time is such that the engine has already changed speed before the correction can be made. A new electric governor, applied commercially this year, has a load-sensing circuit that acts so quickly that it begins moving the throttle before the engine has essentially changed speed due to the load changes. In effect, as far as the engine is concerned, the governor anticipates the speed change and does something about it immediately. As a result, the new governor can hold frequency deviation to 1½ percent and can recover fully in less than one second under the extreme conditions of full load pick-up (no load to full load).

In addition to the load-sensing circuit, the electric governor contains a frequency-sensing circuit designed to correct for speed drift at any particular load. The entire electrical control is static; magnetic amplifiers, transformers, rectifiers, resistors, and capacitors are the principal components. Utilizing this regulator, engine-generator sets can be paralleled on an isochronous basis without the usual frequency droop.



This is the first commercial installation of the electric governor.

The new electric governor has thus far been applied on sets from 30 kw to 1250 kw. However, there is no limit to the size of the set to which it can be applied, since the output to the electric control unit is from the secondary of the potential and current transformers of the generator. The only change required for larger sets is a larger current transformer; otherwise the control is identical regardless of the size of the engine generator. The larger the engine, the more force required to move the throttle; thus the hydraulic actuating systems used with the governor are made in three sizes that give torques of 75, 110, and 500 inch-pounds.



Of special interest is the spindle eccentricity instrument, which measures the maximum travel of the spindle from a reference point and remembers it, measures the minimum travel of the spindle and remembers it, subtracts the two values and displays the results as a line on a chart. Then it slowly forgets so that it can entertain a new thought.

KEEPING TABS ON STEAM TURBINES

STEAM TURBINES won't be able to get away with "nothin' no more." A newly developed line of Turbograf turbine supervisory instruments will indicate and record the actions and reactions, bendings and expansions, and vibrations and eccentricities of a steam turbine during its entire lifetime. The instruments will measure and record (and in some cases alarm when limits are exceeded) the turbine conditions of shaft vibration, position of spindle to thrust bearing, expansion of spindle with respect to cylinder, expansion of cylinder, straightness of spindle upon starting, axial thrust, position of the throttle valve, and temperature differences between parts. The complete line of supervisory instruments, consisting of eight units, replaces five older instruments. The devices for measuring thrust, differential temperature, and throttle valve position are new. The others have been ruggedized, styled, improved, and made easier to service. Each instrument is identical in appearance, and is easy to install since it is a single piece plus the pickup device and recorder.

STEAM MAKES SINGLE PASS THROUGH THIS TURBINE

THE FIRST SINGLE-CYLINDER, 25-inch exhaust-end-blade turbine is being built for Commonwealth Edison's Northwest Station in Chicago. The machine marks several other firsts; it is the first 3600-rpm machine to use a 25-inch exhaust row of blades (the largest turbine blading used on 3600-rpm machines) without a reheat cycle. Previous machines have been of the tandem-compound, double-flow type—that is, a high-pressure turbine in tandem with a double-flow, low-pressure turbine having 25-inch exhaust blades. This machine employs one single-flow turbine exhausting through 25-inch blades into the condenser. Need for the new turbine design was created by low steam-inlet conditions—230 psig at 560 degrees F—which meant high volumetric flow to produce the 35 000 kw desired. From a physical standpoint, the single-flow machine is shorter, and adapts itself better to the existing foundation of the unit that is being replaced.

ATOMIC POWER—ON THE MOVE

ATOMIC POWER shifted into higher gear this year. Not only were government-sponsored projects progressing rapidly, but also plans for privately financed nuclear-power plants began to assume more concrete form.

On the defense side of the picture, the first atomic-powered submarine, the USS *Nautilus*, got underway early in 1955 powered by a nuclear-power plant built by Westinghouse for the Atomic Energy Commission; after successful sea trials, the vessel was given preliminary acceptance by the Navy in April, and has since participated in fleet maneuvers.

Meanwhile work is progressing on nuclear-power plants for the smaller fleet-type submarines. This project, called SFR, got underway shortly after the prototype power plant for the *Nautilus* first operated in the Idaho desert in 1953. Intensive development work on the design of the SFR was followed, in January, 1955, by award of a Navy contract to Westinghouse to construct reactor plants for two fleet-type submarines, the SSN 578 and the SSN 579. The Submarine Fleet Reactor will be water-cooled; it will be designed to fit into a considerably smaller hull than the *Nautilus*, and will have somewhat different operating characteristics than the STR plant. Experience gained in the development and subsequent operation of the land-based prototype and the *Nautilus* power plants will enable a number of simplifications and improvements in the new SFR plant.

The Large Ship Reactor (LSR) project was likewise in full swing. The reactor is now in the advanced design stage. Site construction is to be started in March, 1956.

Paralleling the military developments, plans for electric-utility power plants were also moving forward. The nation's first civilian nuclear-power plant—the pressurized-water unit for the Shippingport plant of the Atomic Energy Commission and the Duquesne Light Company—was on schedule. The design of the nuclear portion of the plant, being built by Westinghouse under contract to the Atomic Energy Commission, was essentially completed. Construction of major components was started. Design of the turbine-generator portion of the plant was also well advanced. At the Geneva Conference in August, many design details of the PWR plant were made public*, including the fact that this reactor vessel will be some 33 feet high, 10 feet in diameter, and weigh about 250 tons. Also, the fuel will consist of enriched uranium seed surrounded by a natural-uranium blanket.

By the end of October, six other proposals had been submitted to the Atomic Energy Commission by electric-utility groups, indicating a desire to construct large commercial atomic-power plants. These six proposals included five different reactor types; one was a boiling, water reactor, another a fast breeder, the third a sodium-graphite reactor, the fourth a homogeneous reactor, and the remaining two were water cooled and moderated plants. All of these proposed units had ratings of 75 mw or greater.

Of the three reactors whose builders had been announced by the end of September, Westinghouse will participate in the one—the homogeneous plant. This will be a 150-mw unit; the Pennsylvania Power & Light Company and Westinghouse

*See "PWR Power Plant" by Simpson, Shaw, Lyman, and Donworth, *Westinghouse* ENGINEER, Nov. 1955, P. 179.

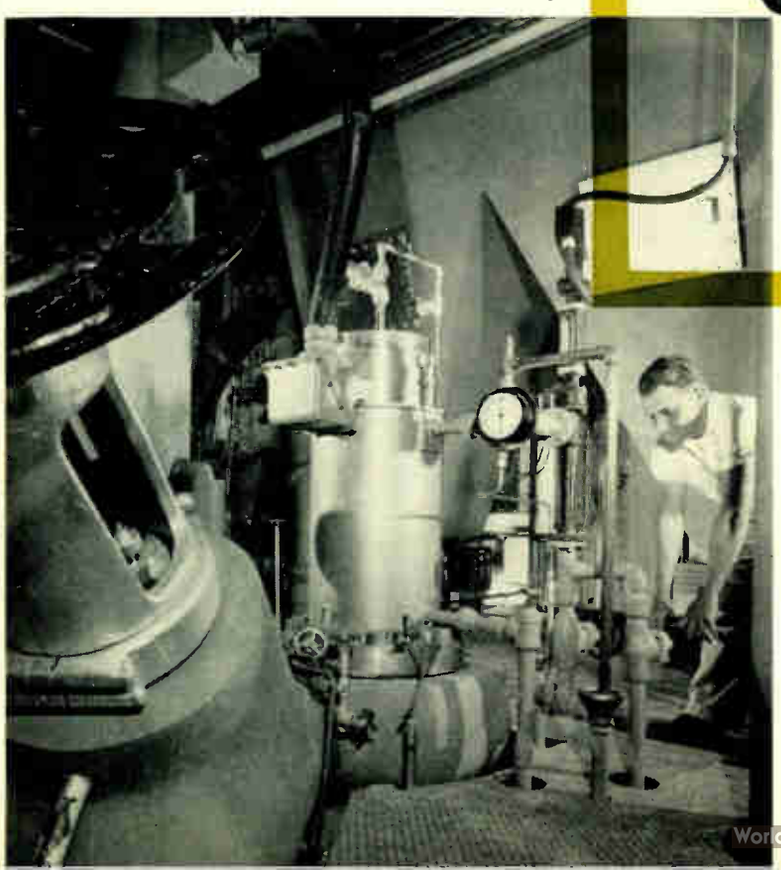
will be co-developers in the design, and Westinghouse will construct the pioneering reactor—designated the Pennsylvania Advanced Reactor (PAR)—and related generating equipment.

Two things are especially significant about this reactor. It is the first large-scale homogeneous reactor proposed. In this type of reactor, the fuel is in liquid form; coolant and moderator are also a part of this liquid. Among the expected benefits for this type of reactor is the fact that fuel can be added without shutting down the reactor. Also significant about this power plant is that it is being built on the basis that it will be commercially competitive with generating stations using conventional fuels.

Sometimes overlooked is the fact that a reactor, while the key part of an atomic power plant, is but one of many components that must be designed specifically for atomic power-plant use. Many entirely new conditions, such as ability to withstand radiation, are imposed upon some components. As a result, a new "family" of components has come into being for atomic-power plants.

Canned motor-pumps, developed initially for the *Nautilus*, are now in production in sizes from ½ hp to 1600 hp. This pump is designed primarily to circulate fluids in hermetically sealed systems. It is used, for example, to circulate coolant fluid in the primary loop of the *Nautilus*. The unique "canning" of the rotor and the stator of an induction motor, permits the radioactive fluid to flow directly through the air gap of the motor. Of prime importance, of course is that the whole pump be leak tight; even though the unit may pump thousands of gallons a minute, not one radioactive drop can be permitted to leak from the unit. Add to this the fact that the system may be under a pressure of 2500 psi and temperature of 650 degrees F and the design difficulties in producing such a motor pump become obvious. Interestingly, this canned motor-pump has proved to be valuable outside the nuclear-power field. In the Possum Point Station of the Virginia Electric Power Company a 4700-gpm unit is being used to circulate boiler-feed water in a closed-loop system. By elimination of the high-pressure, high-temperature seal necessary between a conventional pump and motor for this type of operation, a principal source of maintenance problems has been eliminated.

The first canned motor-pump used to circulate boiler feed water in a closed loop.

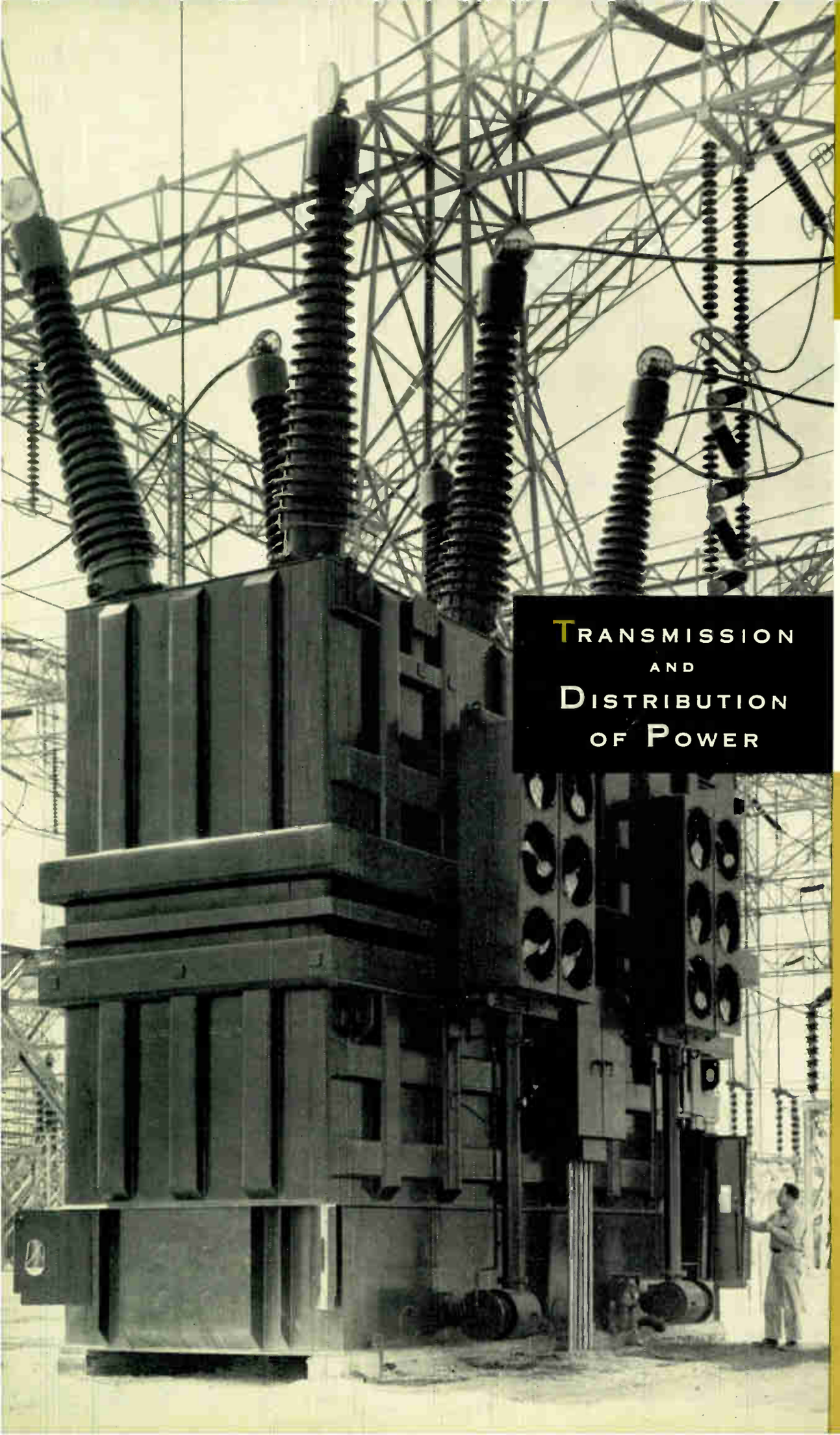


The magnetic amplifier has also moved in on reactor power plants, bringing to reactor control the advantages of an all-static system. A new Magamp control system accomplishes the various indication, alarm, and control functions associated with the loop between atomic reactor and heat exchanger. Signals from the primary loop are amplified to the level necessary for indicating and trip devices; other signals alter the control-rod position of the reactor, as necessary. This Magamp control replaces electro-mechanical devices, thus providing a more reliable and maintenance-free system.

While present reactors are being designed and built the search for new and better materials goes on. Toward this end, Westinghouse will build a new reactor for testing materials of all kinds under intensive nuclear radiation. This will be the world's first industry-owned materials testing reactor, and will be the first element of a reactor center to be built by Westinghouse. The new reactor, known as the WTR, will utilize enriched uranium and will be water cooled and moderated; it will operate in the range of 20 000 kw. The large test thimbles that will pierce the core will afford greater test capacity and flexibility than those of any reactor in the United States. The new testing reactor will be constructed on a site near Blairsville, Pa.

This scale model of the nation's first full-scale atomic power plant for the generation of electricity was an AEC exhibit at Geneva.

As this issue went to press, it was announced that Belgian private enterprise will install an atomic power plant to provide electrical energy during the Brussels World's Fair in 1958. Design of the new plant is based on the use of a pressurized-water reactor; generator output will be 11 500 kw. Westinghouse will manufacture all equipment for the primary system; apparatus for the secondary system and various auxiliary equipment will be produced by Westinghouse and by Belgian manufacturers.



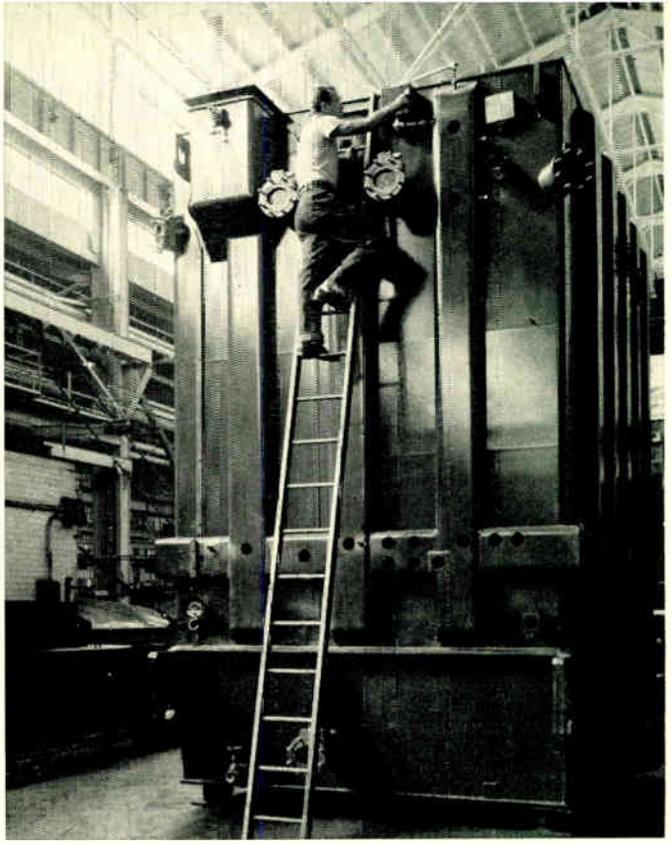
Transmission and Distribution of Power

This 400 000-kva autotransformer is installed and operating at the Tanners Creek Plant of the Indiana & Michigan Electric Co. This, and another identical unit built by Westinghouse, are the largest autotransformers ever installed.

POWER TRANSFORMERS— STILL GROWING!

THE UPPER LIMIT for ratings of power transformers is still nowhere in sight. This year power transformers continued their steady increase in rating. The largest generating station transformer—to be built for the Detroit Edison Company—now stands at 360 mva. This unit, scheduled for completion in late 1956, is three-phase, forced-oil-to-air cooled, and will step up voltage from 17.3 to 129 kv at the River Rouge Plant. This 360-mva unit will be only slightly larger than the 315-mva units built for the Detroit Edison Company in 1955, which were previously the most powerful transformers yet ordered. Both the 315- and the 360-mva units will be shipped upright in one piece, less coolers and bushings.

A 400 000-kva autotransformer is installed and operating at the Tanners Creek Plant of the Indiana & Michigan Electric Co., at Lawrenceburg, Ind. It and another identical unit built by Westinghouse are the largest autotransformers ever installed. The transformer has a voltage rating of 341 kv to 327 kv with taps for 318, 309, and 300 kv. There is a 13.9-kv tertiary winding for third harmonics and neutral stabilization. It is forced-cooled with power for pumps and fans supplied by integrally-mounted transformers connected to the 13.9-kv winding. Although close-ratio autotransformers have been used for many years, this is the first such application on a 330-kv system. Weight of the transformer filled with oil is 574 000 pounds. It is approximately 33 feet high from base to bushing tips, 30 feet long, and 16 feet wide.



This is a 315-mva generating-station transformer under construction. Both this transformer and a larger 360-mva unit will be shipped upright in a single piece, minus coolers and bushings.

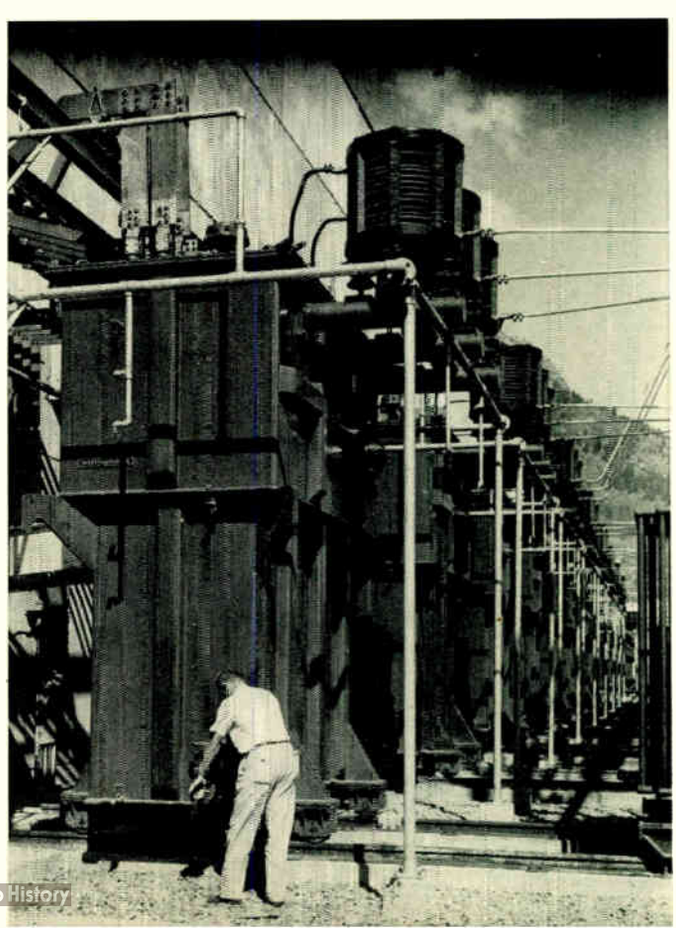
In its path from generator to point of application power must often be transformed, interrupted, switched, controlled, and measured—among other things. The array of devices that perform these tasks are constantly being improved.

NETWORK TRANSFORMER "REDUCES"

NETWORK TRANSFORMERS installed in underground vaults usually find themselves in close quarters. Also, they are subjected to the severe corrosive effects caused by such things as tide water or street-cleaning solutions. Add to this the fact that the transformer tank has been of intricate design, with tubular coolers, and the task of maintenance cleaning and repainting obviously is difficult. Performing these operations in the vault has often been next to impossible, the result being that many utilities have found it simpler to yank out the unit, replace it with a new one, and do the necessary maintenance in their shop. A new 500-kva subway transformer, designed for a New York utility, makes it possible to do these operations in the vault, without removing the transformer. It is not only smaller and lighter, but also has coolers constructed for easier cleaning and painting.

For the 500-kva rating, the total volume has been reduced by about 15 percent, total weight by about 20 percent, and the height by about 15 percent. The height reduction means that in a vault built for the old design the new transformer can be either supported from the floor or suspended, in order to raise the unit off the vault floor where the most severe corrosion occurs.

These transformers are the first water-cooled rectifier transformers ever used on an aluminum pot line. They are serving the Anaconda Aluminum Company's two new pot lines at Columbia Falls, Montana. Using water-cooled units instead of the previous self-cooled ones, several operating advantages are gained: transformer floor area is reduced to less than half, weight is decreased by 35 percent, and first cost is less. Sixteen rectifier transformers are used in this installation, eight for each of two 100 000-ampere, 700-volt pot lines. Each 10 200-kva transformer takes power at 13.8 kv and feeds it into a 12 500-ampere ignitron-rectifier unit at 700 volts. The eight rectifiers in parallel supply the 100 000-ampere pot line.



Higher temperature insulation (group 3), including silicone-varnish impregnation, enabled a 30-percent reduction in weight and a 40-percent reduction in volume of this dry-type distribution transformer as compared to the previous design. Designed for installation in offices, schools, and similar installations where low sound level is required, the inherent sound level has been kept as low as possible; a resilient mounting between core-and-coil assembly and the case reduces sound transmission into the conduit, bus duct, or building structures. The new group of transformers is made in single-phase ratings from 15 to 167 kva, and in three-phase ratings from 45 to 300 kva.

OVERLOAD INDICATION FOR DISTRIBUTION TRANSFORMERS

MOST OVERLOAD INDICATORS for distribution transformers merely tell the operator—usually by an indicating light—when an overload exists. While this is better than no indication, it doesn't give the operator all the information he needs. To maintain an accurate picture of load growth on his system the operator should know what portion of the time a transformer has been overloaded. A new overload indicator gives him this type of knowledge. It records the number of overload hours of the transformer, thus providing information as to the relative growth of an overload condition and its effect on the life of the transformer.

The new indicator, the type **TD** (thermal duty), utilizes a thermostat located inside the transformer; instead of sensing oil or tank temperature this thermostat is positioned to indicate winding temperature. When temperature of the windings reaches a predetermined overload value the thermostat closes a circuit to a timing motor in the indicator, which records the length of time that the overload is present. A warning light also operates in conjunction with this motor as a secondary warning device.

The TD indicator requires virtually no maintenance and only periodic reading. It never needs to be reset, as sufficient room is provided on the dial for recording all the overload time that will be encountered in the life of an average transformer. Provision for resetting has been made in case the operator wishes to start a new record on a transformer that has been relocated due to a previous overload condition.

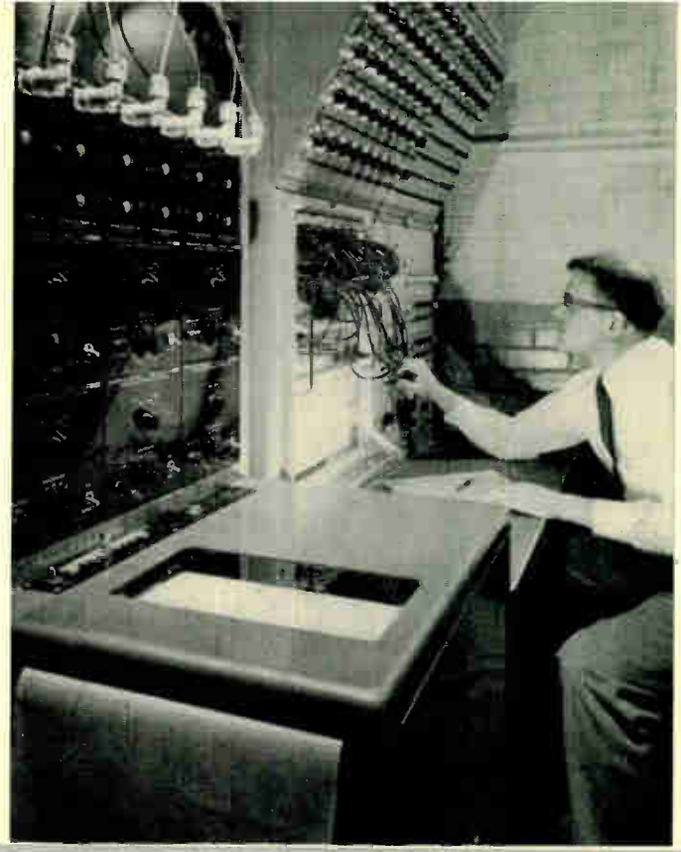
Voids or defects in plastic-filled instrument transformers no longer have a place to hide. Each unit on the production line is given a nondestructive ionization test, as shown at left, which immediately detects any imperfections in the plastic filling. In the new test procedure an a-c test voltage is applied to the transformer. Any corona discharge present in the transformer produces current pulses, which are fed into circuits that amplify them to produce a signal on a cathode-ray tube screen. The test is more effective in checking for defects than power-factor, 60-cycle disruptive, overpotential, or impulse tests. It virtually assures that each instrument transformer is free of any imperfections that could cause radio or television interference or eventual insulation breakdown. The new testing method is currently being used on all plastic-filled current and potential transformers.

Two small transformers have been fitted for new "jackets." One is an open-type high-temperature transformer used in military electronic and radar circuits. Earlier class H-transformers of this type were merely dipped in varnish; the new method is to provide a coating of silicone rubber (see photo at far right) which gives better resistance to moisture and to thermal cycling effects. Coils are first impregnated with high-temperature silicone varnish, then the entire core-and-coil assembly dipped in the silicone rubber. The new transformer is capable of operation at average winding temperatures of 200 to 225 degrees C for 2000 hours or more. The second new jacket has more of a tailored appearance. Many military transformers have been encapsulated in Fosterite, a phenolic resin, for insulation and moisture-proofing purposes. The new construction (see photo at right) is of a cast resin formulated for this purpose. Greater uniformity of impregnation, dimensions, and thickness of coating are made possible by the new casting technique.

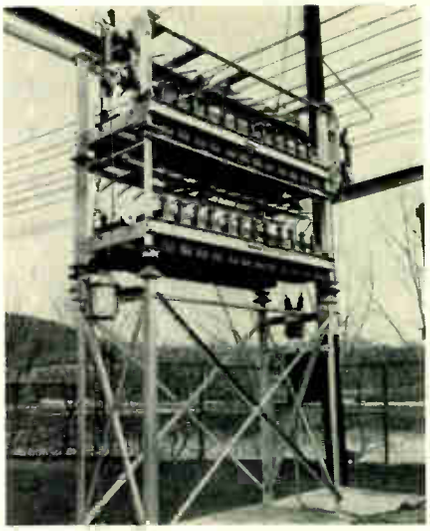
DISTRIBUTION-TRANSFORMER IMPROVEMENTS

IN ADDITION to the development of the new TD thermal indicator, several other refinements have been made in distribution transformers. The single-bolt cover now has a lifting eye, which means the transformer can be hoisted into place without lifting slings. The nameplate has been made larger, with bigger stamped numbers for better legibility.

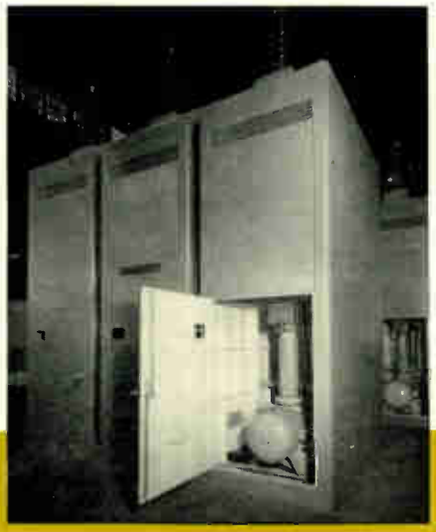
The 7200- and 7620-volt distribution transformers in ratings from 25 through 50 kva have been made shorter. The 25-kva unit has been made seven inches, or over 20 percent, shorter and other ratings have been reduced by about two inches. Similarly the 75-, 100-, and 167-kva distribution transformers have also been reduced in height, and in weight as well. Height reductions of as much as 10 inches and weight reductions of up to 700 pounds (or 49 percent) have been effected. The reduction means that space required on the pole is less; in most cases an old unit can be replaced by a larger unit of the new design, without changing to a larger pole. These reductions of size and weight have been made possible by more efficient design and by better cooling means.



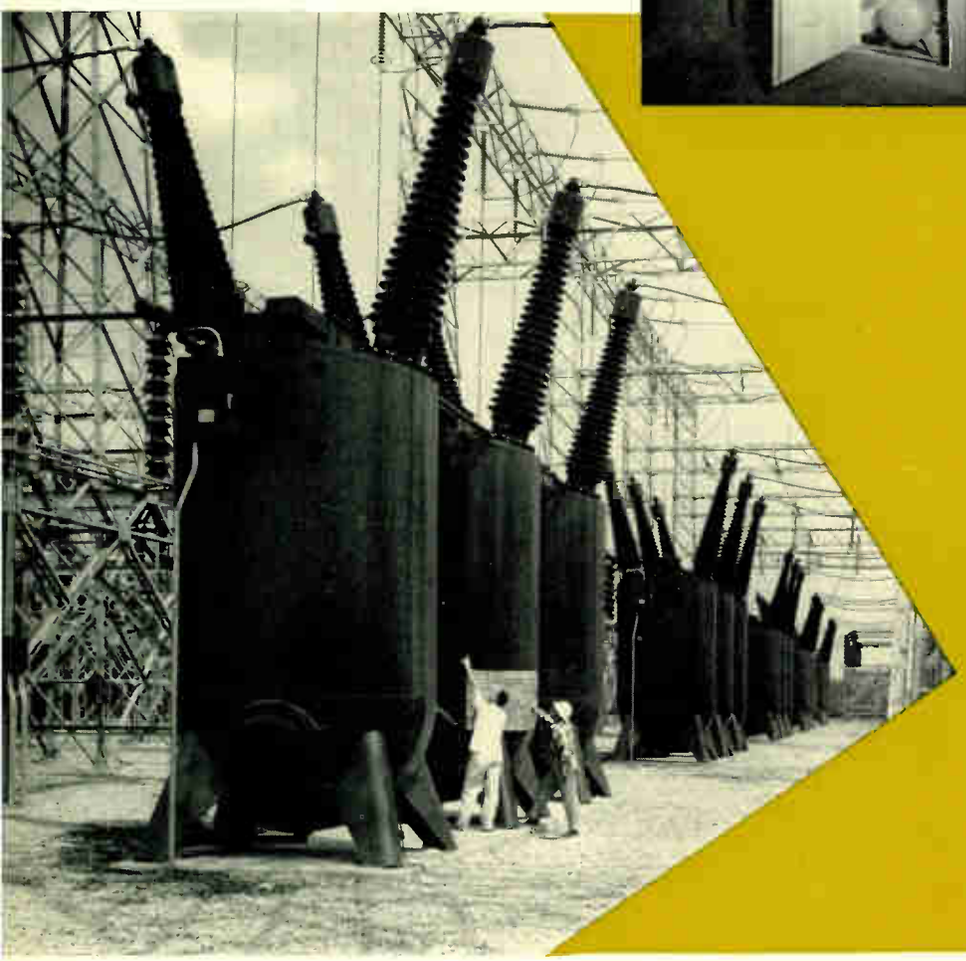
Transformer design problems can be solved with ease on this analog computer (see photo above). For example, finding the distribution through the transformer windings of transient voltages caused by lightning strokes is one of its major uses. This information could well lead to smaller transformers, inasmuch as the necessary spacing between windings can be more accurately determined. Problems or portions of problems more suitable to a digital computer are presently transmitted by a device (below) over telephone wires to the computer center at East Pittsburgh. Information on punched cards is fed into this device, which transmits pulses corresponding to the punched information. As the receiver in East Pittsburgh obtains this information it produces a duplicate set of cards, which can be fed into the digital computer. Results from this computer are returned to the problem source over the same transmission device, and used there as input information for the analog computer. The versatility of this combination of analog and digital computers enables the complete solution of many heretofore impractical transformer design problems.



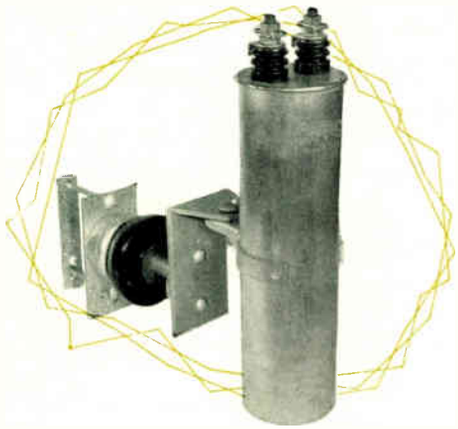
Automatically switched kilovars in preassembled packages are ready for use in small substations where 300 to 1200 kvar is required at voltages from 2.4 up to 13.8 kv. Utilizing the standard outdoor stack-type capacitor assembly, the units can be one or two stacks high, with busing arranged for three-phase wye or delta connection. Oil switches and a control device are a part of the assembly. The switch utilizes a "plug-in" arrangement, providing easy disconnection during servicing. The structure keeps live parts elevated to prevent accidental contact. All the user need do is put in a foundation for the unit, bring control power in to the control cabinet, and connect to the overhead power line.

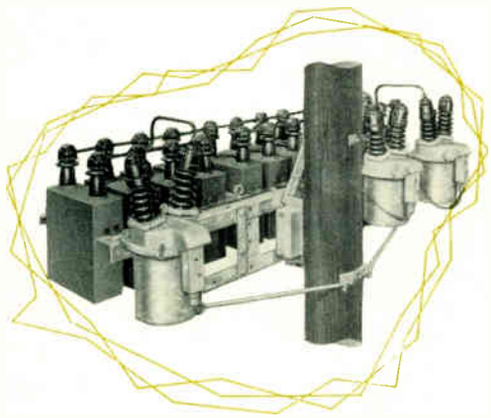


The interrupting capacity of the 69-kv compressed-air circuit breaker has been extended from 3½-million kva to 5-million kva. The breaker was redesigned to meet the demands of Consolidated Edison of New York, whose circuit capacity is reflecting the growing electrical load in this country.

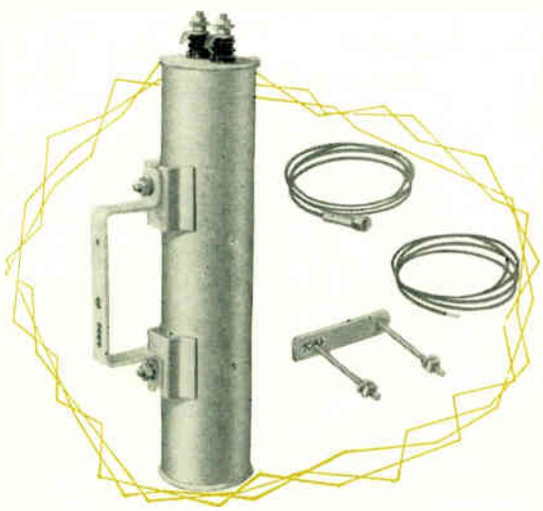


The 330-kv circuit breaker has passed its first series of graduate exams with flying colors. Tests given by Ohio Valley Electric Corporation were on the subject of line-dropping operation, or more specifically, the interruption of leading (capacitive) currents. Capacitive-current interruption is important because of the voltage surges that can result if restriking occurs. Three different lengths of line were interrupted, from 34 to 185 miles. A total of 103 three-phase tests were given, and the breaker performed without restrikes, reignitions, and therefore no overvoltages in all cases. Give that breaker an A+!





"In line" Autotrol—a variation in the standard 300-kvar model—mounts capacitors in line, thereby getting weight closer to the pole. The design provides for direct mounting of the pre-assembled unit to pole by two through bolts, rather than conventional crossarm mounting.



A "king size" 7½-kvar, 240-volt capacitor is the answer to the increasing demand for capacitive reactance on secondary distribution circuits. The unit is particularly suitable for use with 37½- and 50-kva transformers. This new secondary capacitor rating supplements the present 3- and 5-kvar sizes.

To get the best "running mates" available, engineers have designed a line of capacitors especially for series installation with distribution transformers in the range of 10 to 75 kva. When placed in series with the primary of the transformer these low-voltage capacitors essentially cancel out transformer reactance, giving improved voltage regulation. The principal gain is the ability to fully utilize the transformer overload capacity for low-power-factor loads. Another important advantage is the reduction of serious voltage changes that would cause light flicker when loads of widely varying magnitude and low power factor are applied.

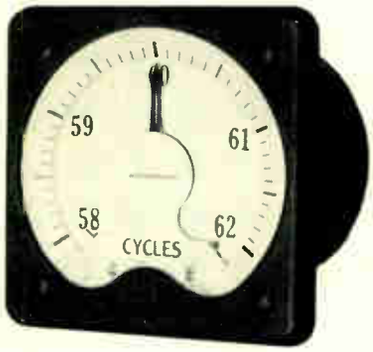
The new capacitors carry 240-, 480-, and 800-volt ratings, as they are generally selected to have a voltage rating equal to 10 percent of the transformer primary voltage. Three basic reactance values are available in each voltage class so that the capacitor selected will have a reactance of about 4 percent, based on the load-current rating of the transformer. These low-voltage capacitors are generally connected in the ground lead of the transformer primary on grounded systems. When used on ungrounded systems the capacitors are mounted on special insulating brackets.

NEW RECLOSER FILLS VACANCY

A HIGH-CAPACITY, three-phase automatic circuit recloser extends the usefulness of these devices by filling a vacancy between previous recloser and power-circuit-breaker ratings. The new unit provides 6000-ampere interrupting capacity with a load-current capability up to 400 amperes, as compared to previous ratings of 2500 and 100 amperes.

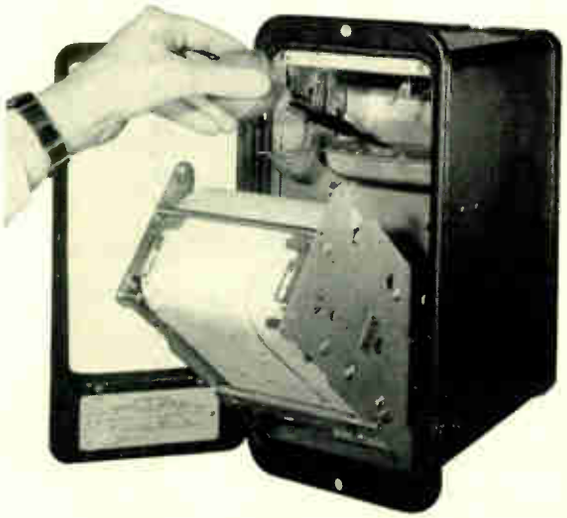
When used on 15- or 5-kv-class distribution systems, the recloser detects and operates to interrupt a fault on the system beyond the recloser. After a definite brief pause, the unit recloses to restore power. If the fault has been cleared by this momentary voltage interruption, the recloser remains closed and returns to normal readiness. If the fault remains on the system, the recloser trips once again and recloses until a predetermined cycle of operations is completed, when it locks in the open position. Coordination with other protective devices, such as fuses or other reclosers, is obtained with a preset sequence of instantaneous and delayed tripping operations. The first instantaneous operation usually clears temporary faults, and fuses between the recloser and the fault are not damaged. If the fault is not temporary, subsequent delayed openings give those intermediate fuses a chance to clear permanent trouble locally, thus preventing interruption of service to the entire circuit served by the recloser.

This is a new high capacity, three-phase recloser.



NEW CONCEPT IN FREQUENCY MEASUREMENT

Frequency has traditionally been measured by special cross-coil-type mechanisms, operating on a position principle without conventional torque springs. A newly developed transducer converts frequency to d-c voltage, allowing a standard d-c torque-type voltmeter to be used as the indicating or recording receiver. The transducer consists of two resonant-circuit networks in combination with a bridge-type rectifier circuit. Mid-scale frequency develops zero differential output from the two networks, while any frequency above or below develops a voltage, in one direction or the other, to the operating receiver. Frequency ranges of 58 to 62, 55 to 65, and 50 to 70 cycles are standard, and the receiver is calibrated in d-c volts with a dial marked in cycles. The torque-type receiving instrument is simpler, and develops higher torque with more reliable indication and greater accuracy stability than conventional-type instruments.



NEW RECORDING INSTRUMENTS

Completely new recording instruments, employing new concepts in design, have a high level of space economy, maximum ease of maintenance and servicing, and high level of performance and reliability. The new instruments have all operations accessible from the front, making the ratio of panel width to scale length a minimum, which saves on switchboard space, control-room size, and increases ease of readability and servicing. The new instruments are of the ASA standard one-percent accuracy class for measuring a-c and d-c volts and amperes, watts, vars or frequency, and utilize three completely new operating mechanisms, developing twice the operating torque of previous designs.

Arcs are extinguished with a "whoosh" in a new 10-million-kva compressed-air circuit breaker now on test. Compressed air does everything—provides electrical insulation, interrupts short-circuit currents, and closes the breaker. Externally, the new breaker resembles an oil circuit breaker. Each phase interrupter is contained in a steel tank containing air at 250 psi. The operating and linkage mechanism is much like that on an oil breaker. When the breaker is tripped, a crossarm inside the tank moves downward and triggers a pilot valve on the interrupter, which exhausts air across the contacts, and through the hollow bushings. This results in a pressure unbalance across a main actuating piston, and the piston drops, opening the contacts and drawing an arc in an orifice. The arc is interrupted by the blast of air from the tank through the orifice, and out through the hollow conductor of the condenser bushings. The crossarm stays open whether or not there is air in the tank, providing positive and permanent voltage isolation. Feature of this design over previous air breakers using porcelain structural members is that bushing-type current transformers and potential taps can be used. First application of the new breaker will be on the Consolidated Edison system of New York.

TRANSISTORS FOR POWER-LINE CARRIER

TRANSISTORIZED power-line carrier has served its apprenticeship, and has earned its journeyman status. The first experimental installation was made on the Potomac Edison system in December 1953. Models of the present design have been operating without interruption since August 1954. The equipment provides carrier relaying protection, working with distance relays over a section of power-transmission line. The carrier signal enables the relays to distinguish between faults internal and external to the section.

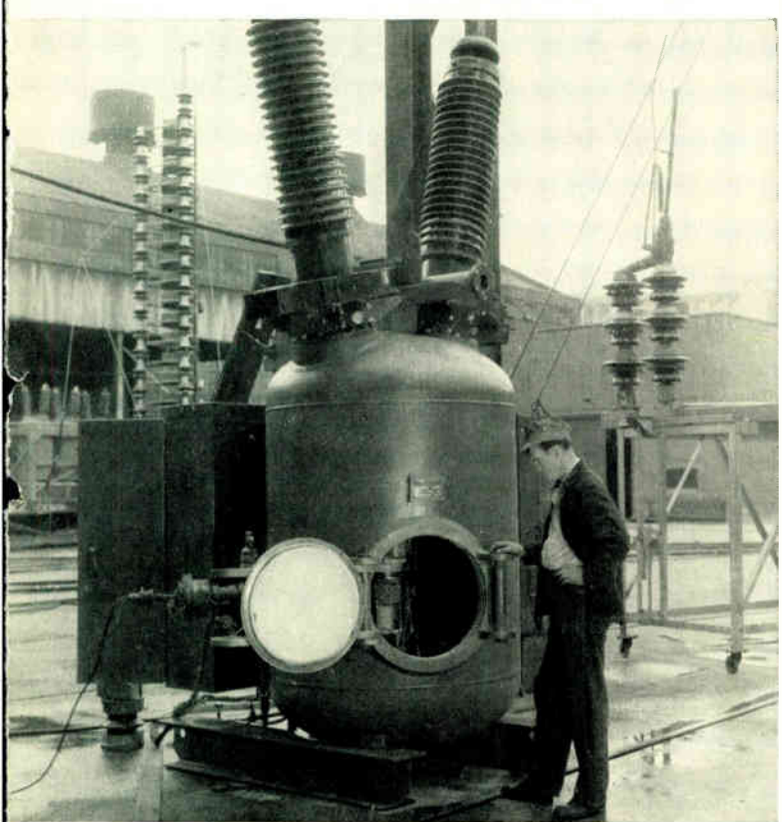
Transistorized carrier bids fair to take the work away from its predecessor, the vacuum-tube carrier equipment, for a number of reasons:

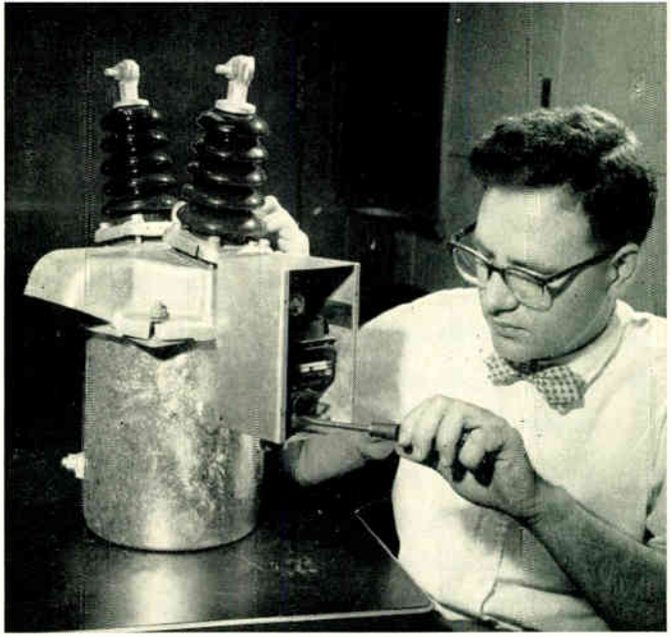
First, the equipment is smaller, thereby easier to handle and install. Vacuum-tube equipment is mounted in cabinets 72 inches high by 25 inches wide and 14 inches deep; transistor equipment, housed in a Flexitest case 22 inches high by 6 inches wide and 6 inches deep, can be mounted directly on the switchboard alongside the relays.

Second, transistorized equipment is much more saving on station battery power; standard vacuum-tube equipment requires about 250 watts continuously, while the transistorized version uses less than 10 watts.

Third, transistors promise greatly reduced maintenance cost, since no vacuum tubes are employed. As compared with a three months to a year life for the average vacuum tube, transistors can be expected to last indefinitely.

As for performance, transistorized equipment power output is approximately one watt, but sufficient sensitivity has been provided to operate through a channel attenuation of 40 decibels. Previous equipment on this installation was designed for a 33-db channel. Initially, voice communication and phase comparison relaying will not be provided, but both features are being developed.



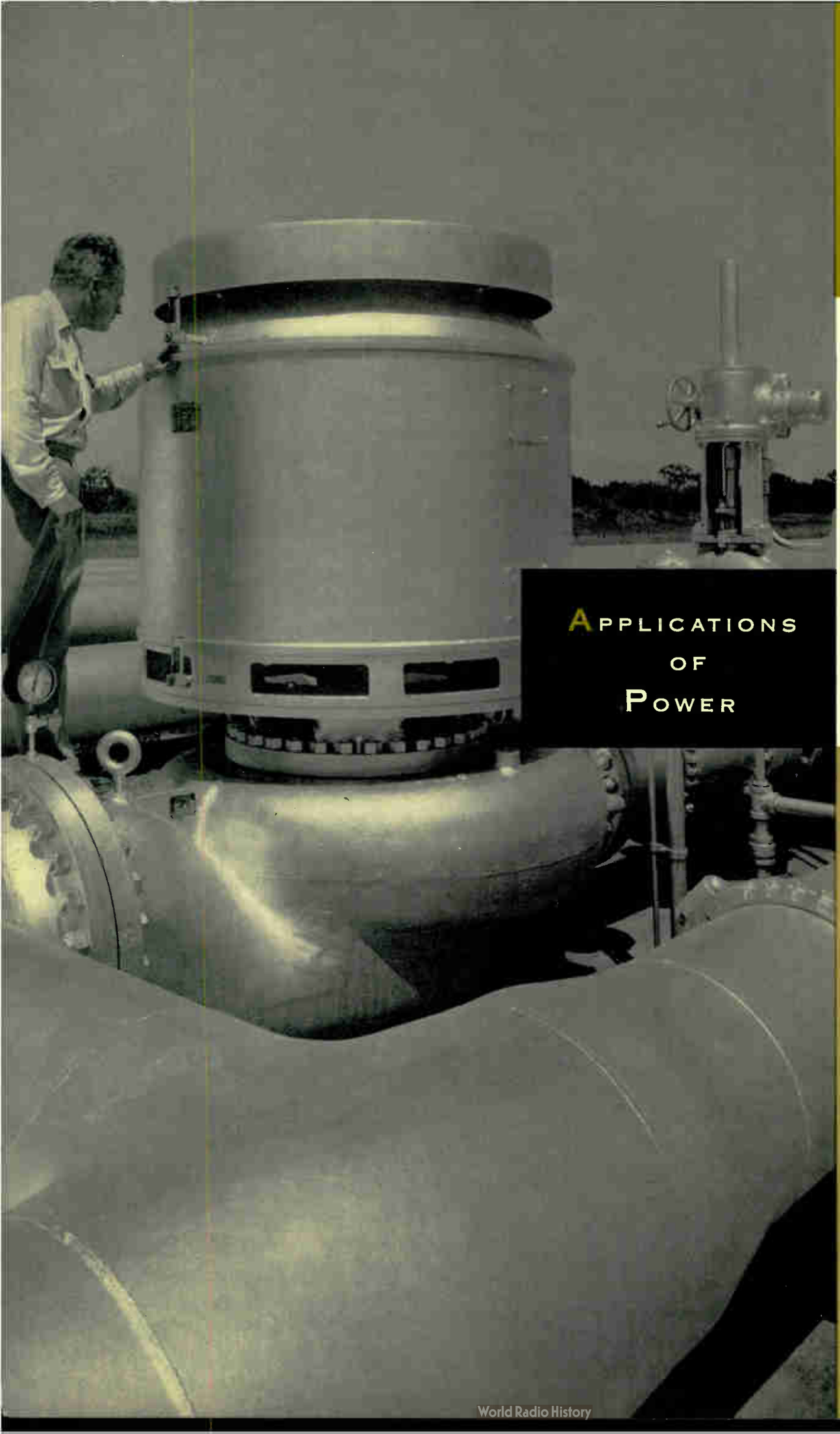


Load on distribution lines can now be disconnected or picked up in increments rather than all at once, thanks to a new switching device known as a load pick-up switch. This time-delayed switching operation will be of considerable help to utilities in easing system shock when picking up load after power outages. Upon loss of voltage, tripping can be delayed up to five minutes, so that the unit will ride out circuit-breaker operations. A stored-energy device, a holding coil restrained by a pneumatic timer, then trips the unit after the preset delay without need for auxiliary power. A sealed-in-glass thermal time-delay relay will pick up the load after voltage returns with a preset delay up to five minutes. The unit is rated at 200 amperes, 15 kv.

CARRIER CURRENT CARRIES ON

NEW ROUTES are being chartered for carrier current to navigate. By so doing, power-line carrier is picking up cargo ordinarily carried by other means. An example was a power-line section consisting of two links of overhead wire and an intermediate length of pipe-cable between Detroit Edison's Northeast and Northwest stations. Ordinarily, the carrier path is provided by a single-phase wire of an overhead power line. However, when part of the route is pipe cable, pilot-wire relaying (relaying by means of a separate pair of wires) is usually used, because of the limited knowledge of transmission characteristics at carrier frequencies of power lines consisting of both overhead wire and power cable. Digital computing techniques were used to obtain these characteristics for the Detroit Edison line, so that carrier could be used to provide directional-comparison and distance line relaying, and remote tripping for tap-transformer protection. Advantages of such carrier installations are primarily economic, depending upon the application under consideration. The limitations affecting the application lie in the accurate prediction of the transmission characteristics of the path at carrier frequencies. The knowledge obtained from this application can be used to establish a simplified procedure for calculating transmission characteristics of similar circuits in the future.

Another unusual route for carrier—the ground wire—was provided by the Louisiana Power and Light sytem. Using capacitive coupling, the ground wire, insulated with small, low-voltage insulators, actually carries the carrier current. Here again, the advantages are economic—reduced cost of coupling capacitors because of lower voltages, and less restriction of transmission bandwidths due to the broader tuning that is possible with the lower reactance coupling capacitors that are used.



Applications of Power

This vertical, totally enclosed, fan-cooled motor drives a centrifugal pump in a pipeline application.

Motors

MORE NEW FRACTIONALS

LATE IN 1954, a new design of fractional-horsepower motors began production in a few sizes. Last year (1955) production of general-purpose motors of the new 48-frame design had extended from 1/8-hp through 1/3-hp, 4-pole motors, both split phase and capacitor start. A new totally enclosed design was also developed, and production started.

The major design improvement in the new motor is in the ventilation system, which has a higher capacity and higher efficiency than the present 56-frame motor. This enabled the large reduction in size and weight effected with the 48-frame motor. In a typical case, the 1/3-hp motor was reduced in weight from 21.9 pounds to 17.4, or about 20 percent.

Conversion of the general-purpose motors to the new frame size has progressed to the point where new special-purpose designs are about to go into production. The first of these will be an oil-burner motor, which will eventually include 1/12-, 1/8-, and 1/6-, and 1/4-hp open motors; all but the 1/4-hp motors will also be available in a totally enclosed design.

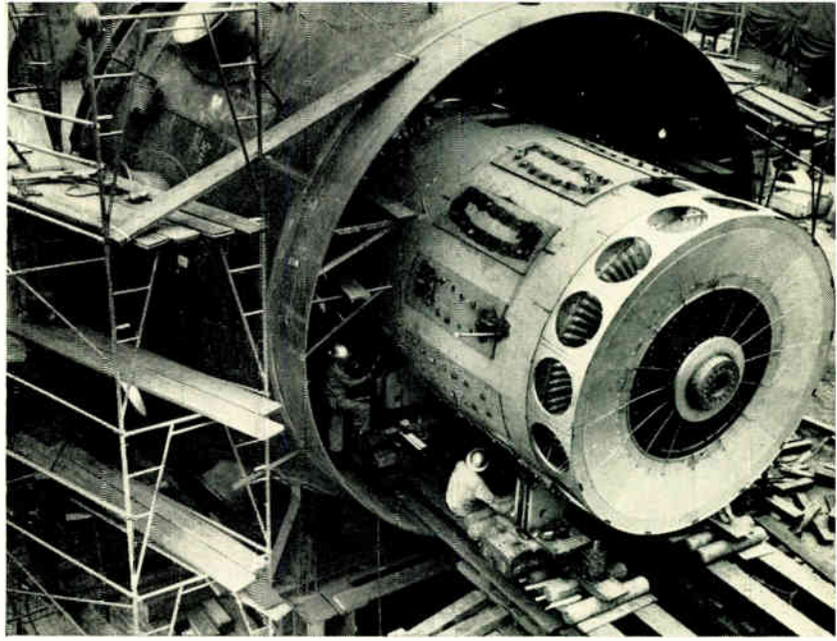
The end uses of electric power are many, varied, and constantly changing. A look at the advances in application of power, i.e., at new developments in devices and systems, bears ample evidence of this fact. Herewith a few of the many improvements.

LIFELINE MOTOR BRANCHES OUT

WHEN ENGINEERS tackled the job of designing a smaller a-c motor to fit the new NEMA standardized ratings, one object was to make the design as flexible as possible. Now that the new Lifeline A motor is in production in all sizes from one through thirty horsepower at 1800 rpm, they have turned their efforts to taking advantage of that flexibility. The result is a number of motors for special applications—identical in physical appearance and mechanically, but with electrical design tailored to fit unusual requirements. Four new motors are examples.

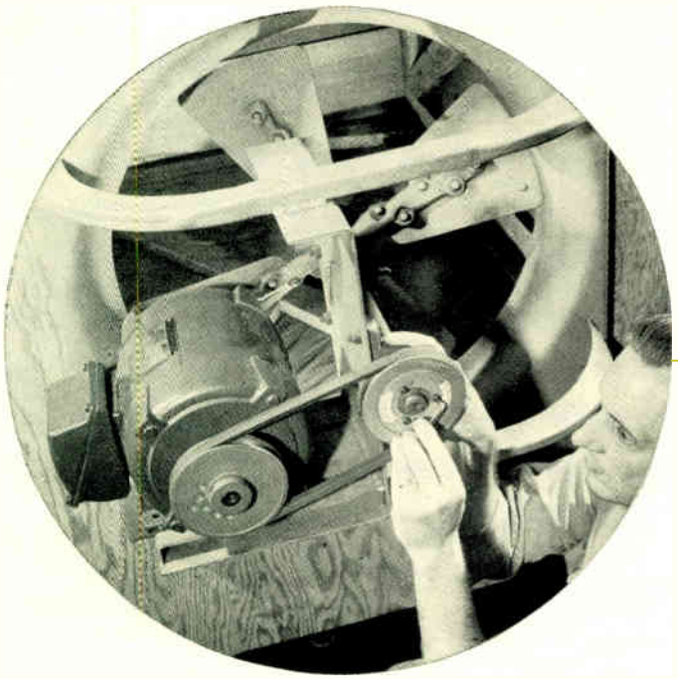
In the manufacture of glass fibers, the finished fiber is wound on spools driven by small a-c motors. Each time a spool is filled the winder is stopped, a new spool put in place, and the winder started again. This occurs about ten times per hour. The fiber produced during deceleration and acceleration periods is not of acceptable quality; therefore reduction of such non-productive time to a bare minimum is essential. A special drip-proof motor with starting and pull-out torques about twice as high as required for its three-horsepower rating cuts the time required to about half that required by ordinary motors of the same rating. Yet the motor is built on the standard frame size for a three-horsepower, 3600-rpm motor.

Motors that drive oil-well pumping rigs must be capable of positive starting and efficient operation despite wide variation in line voltage. The long transmission lines involved require an extremely high voltage at the transformer to allow for the large voltage drop at the end of the line. A special version of the new Lifeline A motor satisfies the voltage requirement, and in addition has low magnetizing current and de-



Both the wind tunnel and its capabilities were "stretched" when an old tunnel was cut in half, separated, and two 20 000-hp drive motors inserted inside the tunnel. The original 12 000-hp drive now serves as a starting power supply, and as a variable-frequency drive supply for the motors at low horsepower. The new 40 000-hp drive makes an air speed of mach 1.80 possible in the 8½- by 11¼-foot test section. The tunnel, the Southern California Cooperative wind tunnel, is operated for sponsoring companies by the California Institute of Technology.

Hermetic motors lead a tough life. They are located within the housing of hermetically sealed compressors for refrigeration and air-conditioning uses and their windings are subjected to the potentially damaging effect of the Freon-gas and oil mixture that cools them. This new hermetic motor is wound with a special refrigerator grade Bondar wire, which has superior resistance to the softening and blistering effect of the Freon-oil mixture. Improved electrical performance is also a characteristic.



This air-over motor, shown connected to a fan, has two ratings. One is the normal rating for the particular frame size, with the required air velocity; the other is the maximum continuous rating with a higher air velocity over the motor.

velops the required torque with high power factor, which lead to efficient operation. Mechanically, the motor is similar to the conventional motor. Protection against rodents and a conduit box suitable for outdoor service is provided.

The horsepower output of a motor is, within limits, dependent on how fast heat can be removed. Normally, totally enclosed motors for driving fans are given a horsepower rating for one specific velocity of air flow over the motor surface. After extensive testing to obtain the required data, engineers have now given these "air-over" motors two ratings. One is the nominal horsepower rating for the frame size, and the air velocity required to cool it; the second is the maximum continuous horsepower rating with a higher air velocity. Addition of this second rating often allows the use of a smaller motor for a given fan installation. For example, the motor rated at one horsepower, 1750 rpm with an air velocity of 200 feet per minute has a maximum continuous rating of 1.7 hp with an air velocity of 2500 fpm. (This percentage increase in horsepower, i.e. 70 percent, does not hold for all sizes, but decreases for larger motors.)

All modern motors are built to withstand temporary overloads without damage. A new silicone-insulated enclosed motor is built to carry an overload continuously. Sounds strange, but it has a purpose. In chemical and similar industries actual load often increases with time beyond that anticipated. With the new motor, loads of 115 to 125 percent of rated value (depending upon motor size) can be handled continuously. Thus it is not necessary to change to a physically and electrically larger motor if load increases beyond expectation.

Use of silicone insulation in the stator and heat-stabilized silicone grease in bearings accounts for the increased capacity of the motor over a standard motor of the same frame size.

An added benefit is the fact that protective control is more easily applied to the motor. Control that permits full utilization of the horsepower rating and yet gives adequate protection against overload is difficult to provide. The overload capacity of the new motor makes this less of a problem.

These motors illustrate the variations of the new Lifeline motor that can be achieved because of the design flexibility it incorporates.

SEAGOING MOTOR

CONSIDER the following partial requirements for a new device: Submersible in seawater of 32 to 85 degrees F at depths of from 15 to 50 feet for continuous periods up to 168 hours . . . Streamlined for a speed of 15 knots underwater . . . Designed for 75 pounds per square inch external pressure and momentary pressure of 10 000 psi due to shock wave . . . Construction largely of non-magnetic materials . . . Satisfactory operation at any angle from horizontal to 45 degrees from horizontal.

They sound like specifications for a submarine. But instead they're part of the requirements for a new submersible motor built for the Navy. This is an a-c motor designed especially to drive a sound-producing device towed underwater by a minesweeper to detonate sonic or acoustic mines.

Everything is unusual about this motor. It's nominal rating is 200 horsepower on 400 volts, 3 phase, 60 cycles, 3550 rpm. However it will operate on varying programmed frequencies from 10 to 60 cycles on power supplied by a variable-frequency, constant volt-per-cycle generator.

The interior of the motor is completely filled with a light lubricating and insulating oil for shock resistance; the oil is pressurized by a pressure-regulating device that maintains an internal pressure greater than external pressure regardless of water depth. Any leakage is from inside to outside and the regulator compensates for leakage as well as for expansion and contraction of the oil due to temperature change.

To produce minimum water resistance the motor is purposely made small in diameter and long in length. Its length to diameter ratio is 3.4 compared to the 1.3 ratio of a conventional motor of comparable rating.

Except for the portion of the shaft passing through the rotor core and the stator and rotor laminations, the whole motor and frame are non-magnetic. The frame, end bells, and pressure-regulator castings are all made of manganese bronze for high strength.

Sleeve bearings lubricated by oil immersion permit operation at any angle. Oil flows continuously through the bearing toward the motor center line.

Because of its liquid filling, the motor has a rather startling, but unavoidable, frictional loss of 12 000 watts at the highest speed. This necessitates a circulation system to ensure a flow of oil through the air gap.

Oil flows from the gap through four cooling passages between the stator core and frame, which is at the temperature of the external water.

Motor engineers may run into some tougher design requirements, but it's unlikely that they'll have any more unusual ones than for this seagoing motor.

Control

TRIPLE-THREAT INDUCTION HEATING CONTROL

A NEW CONTROL UNIT design for machine-frequency induction heating can be assembled as a generator-control station, an output-control station, or a combination of the two in a master station. The control covers the range of motor-generator sets from 50 to 250 kilowatts at 10 000 cycles and 50 to 300 kilowatts at 3000 or 960 cycles.

A generator-control station provides all of the necessary components for controlling the high-frequency generator, including excitation power supply, output voltage control, meters, overload relays, and ground detector. The output station provides all of the components required for efficient application and control of the high-frequency power; these include load-matching transformers, power-factor correction capacitors, process timer, contactors for controlling application of power, and quench-water control.

Prior to the new design, a packaged-type generator control was supplied, which was mounted on top of the motor-generator set. Since the output station is usually located at some distance from the generator, many components such as meters and line contactors had to be duplicated at the output control. By combining both generator and output control into one master station, the duplication is eliminated and manufacture, installation, and maintenance is simplified.

Flexibility of the design makes it possible to convert a station to another type, or change rating or frequency with a minimum of effort and component replacement.

NEW "BRAINS" FOR INDUSTRY

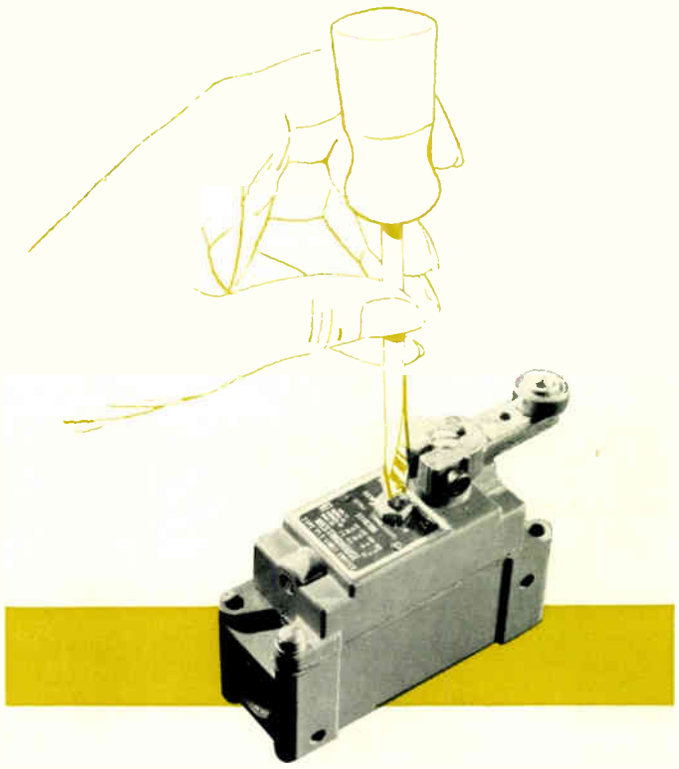
CONTROL SYSTEMS that "think" are eligible for a new set of brains now being passed out—Cypak Director Systems, first announced last April. Composed completely of static switching circuits, consisting of magnetic amplifiers and solid-state devices, such as transistors, Cypak systems think with all the dignity of a human brain—no clicking, snapping, latching, or sparking! As a result, there is nothing to wear out, erode, or get out of adjustment. The nerve center of Cypak systems are the switching elements, which perform the basic logic functions—*and*, *or*, *not*, and *time*. These functions, properly combined, can do all the thinking required by any type of digital control system with speed and accuracy.

Among the more important Cypak systems built and tested to date are (1) a control for a fully automatic six-story elevator, (2) a relatively simple punch-press control and a much more complicated spiral milling machine control, (3) a system for the selective removal and delivery of ingots from a soaking pit to a rolling mill, (4) a skip-hoist director that permits the automatic charging of a blast furnace in accordance with a program selected by the operator, and (5) a relay control for an automatic bus-duct welder.

A typical Cypak application is a turret lathe with automatic spindle control built by Warner and Swasey Company of Cleveland. Each of six turret faces is provided with five set-up functions. These functions include a choice of four spindle speeds, forward or reverse spindle rotation during the work stroke as well as during the return slide motion, idle spindle on any work face, and automatic braking throughout. The operator indexes the hexagon turret to each of its six tool faces so that six different machining operations are successively accomplished on any particular part. On a given production run, the lathe operator need merely select the proper motor speed, work- and return-stroke rotation of the spindle, and spindle gear ratio. From there on, Cypak takes over and performs all subsequent control of switching necessary to provide the correct intelligence to the controlling component. Cypak power amplifiers energize the motor starters and solenoids.

The lathe, with the help of Cypak, produces parts faster and more economically by greatly reducing machine handling time and operator effort.

A set of standardized amplifiers have been developed, which serve as a connecting link between Cypak logic and the muscles of a control system. These output amplifiers increase the power available to a level suitable for operating industrial solenoids, motor starters, and similar devices that require more power than the Cypak system will deliver. Amplification is accomplished by driving a doubler-type magnetic amplifier from the output of the logic elements. The ratings of output amplifiers are 50, 150, and 300 volt-amperes. These ratings are based upon the requirements of Westinghouse Life Line starters up to and including size four. Larger output amplifiers will be developed as required by future applications.



Loosening the locknut and turning the screw selector of this new limit switch (type PLS) is all that is needed to change its operation from clockwise to counterclockwise. Or, the screw can be adjusted to a "universal" position, in which case contacts are actuated by movement of the lever in either direction. A companion limit switch, the PRS, is a rod-operated, plunger type unit. They are intended for machine-tool and general-purpose applications where size must be kept to a minimum and accurate operation is essential.

CONTROL DEVICES

IMPROVEMENTS in control devices for low-voltage circuits and motors must be never ending if they are to keep pace with the company they keep. Herewith, a few from the preceding year:

Air-Conditioning Starter—A magnetic starter for air conditioning and refrigeration is specifically designed for the control of hermetic motors. The fast tripping time of the overload relay matches hermetic-motor operating characteristics, thereby giving close motor protection and preventing costly motor burnouts. The relays are factory calibrated to reduce variations in tripping time, and are factory sealed to prevent tampering. The new starter can be applied up to 230 volts a-c, at 20 and 30 amperes continuous current.

The boom in air-conditioning loads in recent years has made line regulation a problem in many localities and created a need for a suitable current-limiting device. An increment or reduced-voltage starter will limit inrush currents to approximately 50 percent of the normal locked-rotor currents. The device consists of the air-conditioning contactor, a timer, and one or three resistance units depending on whether the application is single or polyphase. Upon initial energizing of the air-conditioning equipment, the resistors are placed in series with the main starter contacts. After a delay of approximately one second, the timer energizes the contactor and shunts the resistors.

The device is rated for normal full-load current of 30 amperes maximum, and 180 amperes locked-rotor current.

Adjustable Bus Duct—Bus duct with "telescoping" bus bars can be varied in length plus or minus six inches. This new concept makes exact field measurements unnecessary. The adjustable lengths are made for all ratings of plug-in duct, 225 to 1500 amperes, and all rating of low-impedance bus duct using a maximum of two bars per phase.

Ambient-Compensating Breakers — Current ratings of standard Quicklag, Quicklag-P, and PL breakers no longer are greatly affected by ambient-temperature changes. These breakers are generally grouped in panel boards and load centers where the temperature due to the close proximity of a large number of small breakers is higher than that of the conductors they are protecting outside the panel boards. Thus, these thermal breakers have in the past derated themselves even in normal ambient locations, resulting in overprotection of conductors.

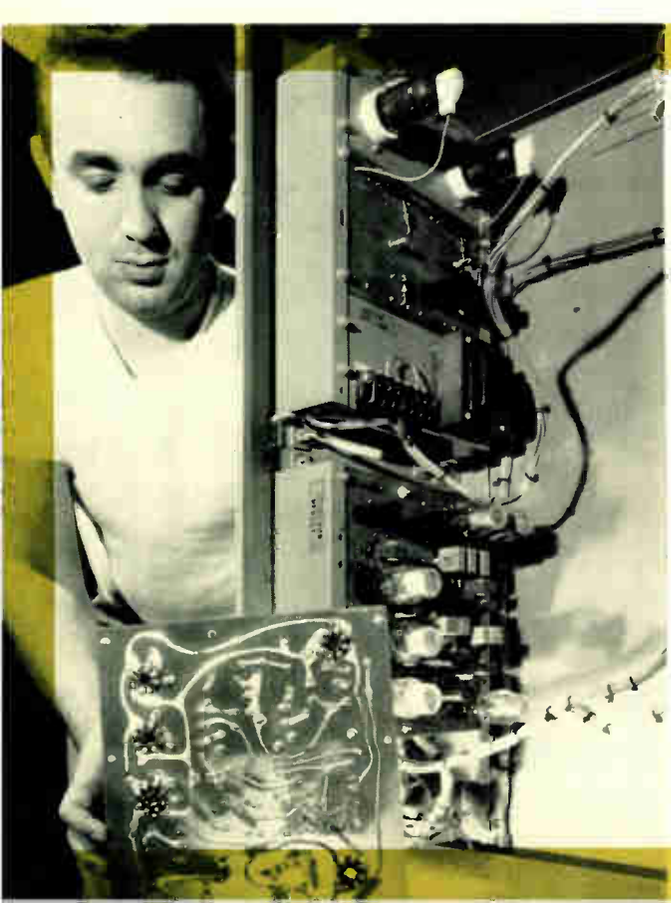
This unnecessary penalty imposed by higher enclosure temperatures has been overcome by the addition of an element responsive to ambient temperature, which counters the action of the main bimetal deflection. Complete compensation is undesirable since conductors should not be fully loaded in high-temperature locations.

Pendant Control Stations—The use of oil-tight components has extended the application for pendant control stations. These devices, suspended by an electric cable, operate starters that control the starting, stopping, and the reversing of electric motors.

The station may include indicating lights, selector switches, or other Oil-tite components. A unique component is the "stop" lever, which projects from the bottom of the station, is readily accessible, and stops operation when struck from any direction.

The unit may be made completely weatherproof for outdoor applications where rain and freezing is encountered by substituting a pushbutton in line with the other pushbuttons for the "stop" lever, and mounting a neoprene cap on each of the pushbuttons.

Perma Coil—This new molded line starter and contactor coil replaces the previous cotton-filled, varnish-impregnated coil. This coil is resin vacuum impregnated prior to injection molding with thermo-setting material. Advantages of the Perma Coil over its predecessors are better heat dissipation, which results in longer life, provides complete protection from mechanical injury, and greatly improves the moisture and fungus resistance. This coil is made for application on starters and contactors at voltages of 110, 220, and 440 volts, 60 cycles.



Printed circuits, such as the one shown at left, are now used in resistance-welding controls. Photo shows the printed wiring side of the panel; components are mounted on the reverse side. All components are clearly identified on the face of the panel; this, plus the elimination of the maze of wires on the wiring side, leads to simplified maintenance. The printed circuits also account for a weight reduction of up to 30 percent in some models.

Electronics and Solid State Devices

BETTER GETTER BEGETS BETTER TUBE

AN IMPROVED zirconium getter, the device that absorbs any gases that are left after evacuation or generated during operation, has made an improved radio broadcasting tube possible. The high vacuum maintained by the zirconium getter has made possible the replacement of the old, rugged pure tungsten filament by a more efficient thoriated filament. As a result, filament heating power has been reduced from 8 to 3 kilowatts per tube. Also, the thoriated tungsten cathode has an inherently longer life, and therefore longer tube life is anticipated compared to previous tungsten-filament types. The combination of longer life and lower cathode heating power will result in a $2500-per-year savings to radio stations using the new type tube (WL-5891), more than enough to offset the cost of the tubes involved.

SILICON—A FAST-RISING NEWCOMER

AN AMBITIOUS BOXER sometimes competes in more than one weight class. If he is outstanding he may even hold a world title in one, or more than one class. Silicon rectifiers, which made their debut in the low-power class about two years ago are now also campaigning in the heavyweight class, as power rectifiers. Silicon diodes capable of handling as much as 8 kilowatts of power were developed this year.

The theoretical possibilities of silicon as a power rectifier have been recognized for several years. One big limitation, however, has been the internal heat generated, which is a function of the forward voltage drop and the maximum current. Thus, in effect, the lower the forward drop the higher the current rating can be. Low-power silicon diodes built so far have mostly had voltage drops ranging from 1.5 volts upward. This year engineers, by a concentrated effort, were able to reduce the voltage drop for the new power rectifiers by more than 50 percent, to 0.8 volt at a current of 8 amperes and a cell temperature of 190 degrees C.

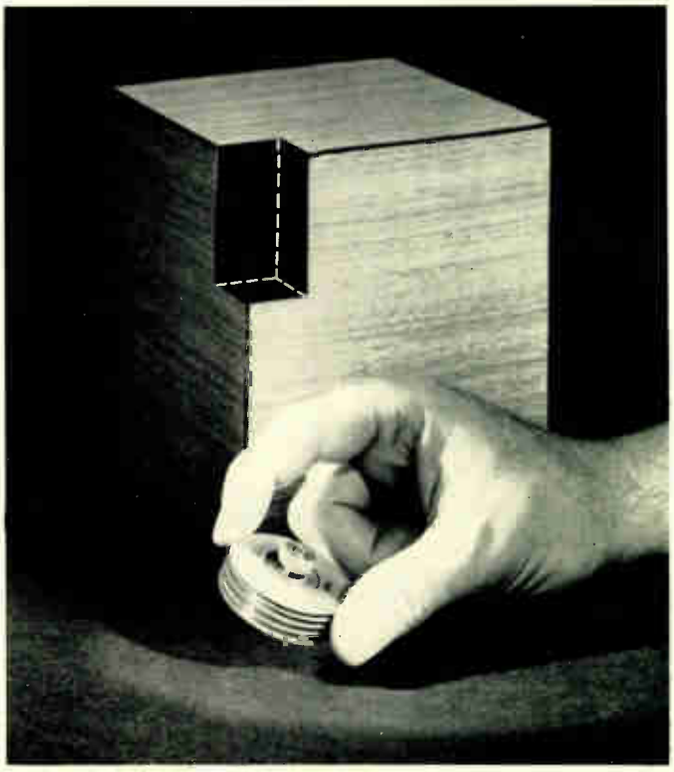
Presently, units have been made in four different voltage classifications—50, 100, 150, and 200 volts. All have a forward current rating of 8 amperes with natural convection cooling in ambient air at 25 degrees C. Higher current ratings—up to 40 amperes—can be achieved by force cooling these units.

An idea of the significance of this development can be gained by comparing the new silicon rectifier with a selenium stack of comparable current and voltage rating. The new rectifier—when mounted in a finned case one inch high and an inch and a half in diameter, cooled by convection, and with a 65 degree C ambient—has a rating of 15 amperes at 200 volts peak inverse. A selenium rectifier capable of carrying this current under the same ambient conditions would require plates of 45 square inches each. Since the commercial voltage rating per plate is only about 30 volts, seven such plates in series would be needed. The selenium stack thus would have a volume of about 150 cubic inches—compared to 2 cubic inches for the silicon unit.

Also, since each selenium plate has a forward drop of about 1.4 volts, the total drop for seven plates would be about 10 volts, compared to slightly less than one volt for the silicon unit. As a result, the efficiency of the silicon unit is over 99 percent, compared to 95 for the selenium unit.

The temperature characteristics of silicon—it will operate from −65 to 190 degrees C—has made it a natural for military applications, where it has already been applied on a brushless alternator for aircraft (see p. 30), and a number of other applications. However, its small size and high efficiency also make it a good bet for many industrial applications, such as in magnetic amplifiers, welders, plating lines, and many others. The development of silicon rectifiers with higher current ratings, which is expected in the near future, will broaden the possibilities considerably. Silicon will make a strong bid to replace all selenium rectifiers; conceivably it may even challenge the high-voltage electronic rectifiers.

Below, a new silicon rectifier. A selenium rectifier for the same current and ambient is approximately the size of the box shown at rear.



Welding

A NEW WEST-ING-ARC WELDING PROCESS

The West-ing-arc inert-gas arc-welding process developed in 1954 has a new relative. This is a spot welder that differs from the arc welder only in the addition of a timer and suitable nozzles for the welding gun. The new process will spot weld metals up to ⅛-inch thickness, and can be used to plug weld considerably thicker pieces. The new process works something like this: The special nozzles of the welding gun are placed against the metal. The trigger is pulled, which initiates a timed sequence. The nozzle is purged with inert gas, then the arc is initiated and timed out. At the end of the welding period the electrode stops feeding, but the current is not stopped immediately. This allows the electrode to burn back and free itself from the weld pool, thus setting it up for a succeeding weld. An important feature of the new process is the lightness and portability of the equipment involved. It is used in conjunction with the standard RCP welder, which is rated at 500 amperes. Weld times from 8 to 360 cycles are obtainable with the new spot-welding process.

This industrial r-f generator tube has been redesigned for more convenient installation (see story below).

VACUUM TUBE HARVEST

A NEW CROP of vacuum tubes appears each year. They may have any one or a combination of such attributes as higher ratings, smaller sizes, improved performance, or longer life. Let's consider a few:

A four-kilowatt high-vacuum triode, which has been used for several years in communications and radio-frequency heating applications, has been redesigned. The old tube (WL5736) uses copper thimbles for the filament and grid terminals, and is installed by means of a clamp-on connector. A new version (WL6623) uses flat-strip flexible leads, which are made part of the tube, so that connections to the circuit can be made more conveniently and at lower cost. The possibility of poor electrical connection is eliminated, and the relatively high circulating r-f currents can be carried more effectively. Also, the forced-air cooled radiator of the WL6623 is larger and offers less resistance to air flow. As a result, the cost of a suitable blower is lower.

A rectifier tube for automobile receivers has been developed with a higher rating, which allows more leeway to set designers and gives longer life. Specifically developed for the wide voltage variations that occur in an automobile receiver, the tube is a diode with a rating of 100 milliamperes rectified current (previous tube produced 70 ma.) It has two separate cathodes and plates so that the possibility of arc-over is reduced. In spite of the double system, the tube is built in a 7-pin miniature bulb without exceeding acceptable bulb temperatures.

The rating of a small high-voltage vacuum diode principally used in dust precipitators has been jacked up tenfold with no increase in size. The new tube (WL481B) is now rated sufficiently high to replace the next larger size of high-vacuum rectifier tube in many applications. The WL481B is rated at 30 milliamperes average and 150 milliamperes peak plate current, and 25 000 volts peak inverse voltage. Consequently, the new tube can be used to do the same jobs as its predecessor (WL481A), and in addition many jobs now done by the next higher rated tube, but at a much lower cost.

Industrial Applications

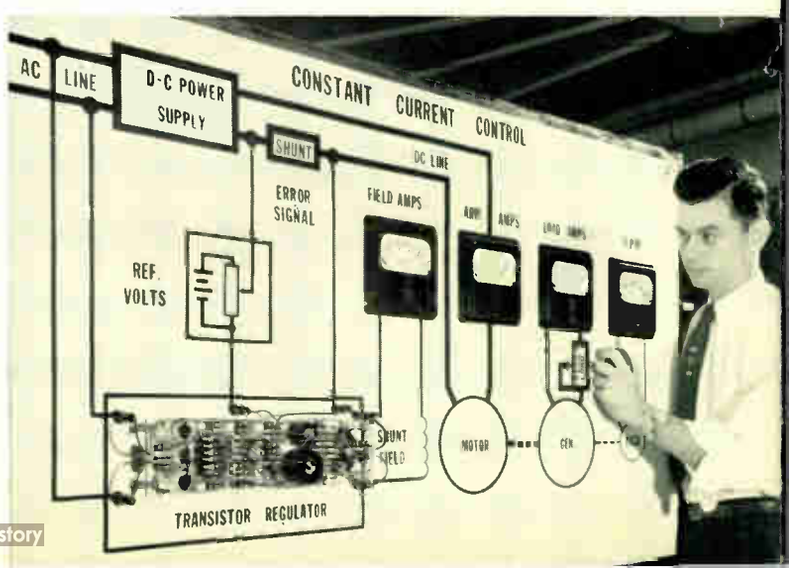
TRANSISTOR PROGRESS IN INDUSTRIAL APPLICATION

ALTHOUGH the development of transistors is not quite at the stage where widespread industrial application can be made, control engineers are not just sitting on the sidelines and watching. They are actively at work finding applications where the transistor's unique properties can be best utilized. Two examples of experimental designs give a small indication of the possibilities.

In the metal-working industry, many instances exist where a device is needed to sense the presence of hot metal. A new hot-metal detector utilizes a photo-transistor as an infra-red sensing device, and uses transistors in the amplifying circuit. It can be used in any application where a metal object at 700 degrees F or more must be detected and a signal transmitted indicating that presence. One example is in the rolling of steel tubing. With a specified volume of metal to start with, and a constant outside diameter, the thickness of the tube wall can be determined by the tube length. If the pipe is rolled with too thin a wall the pipe will be longer than average, and conversely, if the wall is too thick, the tube will be shorter. The accuracy of the wall thickness can thus be determined by the tube length. By placing several of these hot-metal detectors at specified measured distances apart, the length of the pipe can be measured and thus the wall thickness. Advantages of a transistorized hot-metal detector over the previous photo-electric equipment would be its increased sensitivity to infrared and its inherent ruggedness for such applications.

An experimental constant-current motor control uses all static, semiconductor elements, mainly transistors and silicon-diode rectifiers. Such a control might be used for maintaining constant horsepower on a reel drive. In an experimental model a ¾-horsepower, d-c shunt motor is used as a driving motor. The voltage drop across a shunt in the d-c armature circuit provides a signal proportional to the motor armature current. This signal is fed to the regulator, which automatically adjusts the shunt field of the d-c motor to maintain constant armature current and thus constant horsepower. In addition to the advantages that accrue because of the all-static nature of this control, the regulator is also extremely small and has very fast response. The experimental model, while it utilizes a ¾-hp motor, has sufficient capacity for motors up to 3 hp. The same basic regulator could also be used for speed control. While still in the development stage, this application indicates future possibilities.

A demonstration model of a transistorized constant-current control.



OLD PRINCIPLE GETS NEW IDEAS

SPEND A LITTLE engineering time on an old principle and the results are sometimes surprising. A case in point is a recent modification of the Kramer drive. In general, this system consists of a wound-rotor induction motor coupled to a shunt-wound d-c motor on the same shaft. The slip power from the rotor of the induction motor is converted to d-c and fed to the d-c motor. The speed of the system is controlled by adjusting the field of the d-c motor, i.e., strengthening the d-c field slows the drive by putting more load on the secondary of the induction motor. The d-c motor converts the power taken into torque, thereby maintaining high efficiency over the speed range of the drive.

The original Kramer system used a rotary converter to turn the alternating current from the wound-rotor motor to direct current for the d-c motor. The new modification utilizes selenium rectifiers, thereby greatly simplifying the maintenance problem by replacing a rotating element with a static unit.

Another modification applied to the drive was to provide extremely accurate speed regulation via a Magamp regulator. An a-c tachometer measures the speed of the drive, and feeds an a-c signal to a frequency-bridge error-detecting unit. If the speed is not correct, the error detector produces a signal that is amplified in a two-stage magnetic amplifier and fed to the field of the d-c motor, thereby correcting the drive speed. The drive is capable of powering a machine with a speed accuracy of plus or minus 0.1 percent for normal disturbances, with a speed range of about three to one. It is suitable for drives from 15 to 500 horsepower.

This new modification of the Kramer drive is designed for machines that spin synthetic fibers, where extremely close speed regulation is required, an application that has largely been the field of electronic regulators. The new drive system has the advantage of simplicity, high efficiency, and perhaps most important, greater reliability, because of the ruggedness and the static nature of the selenium rectifiers and the Magamp regulator.

MAGAMP QUARTERBACKS IMPROVED DRIVE

FIVE YEARS AGO the magnetic amplifier was in somewhat the same position as a rookie quarterback in professional football—it showed great promise, but lacked experience and had yet to prove itself in the tough industrial league. Since then the Magamp has fully lived up to all its advance notices; it is now a seasoned veteran.

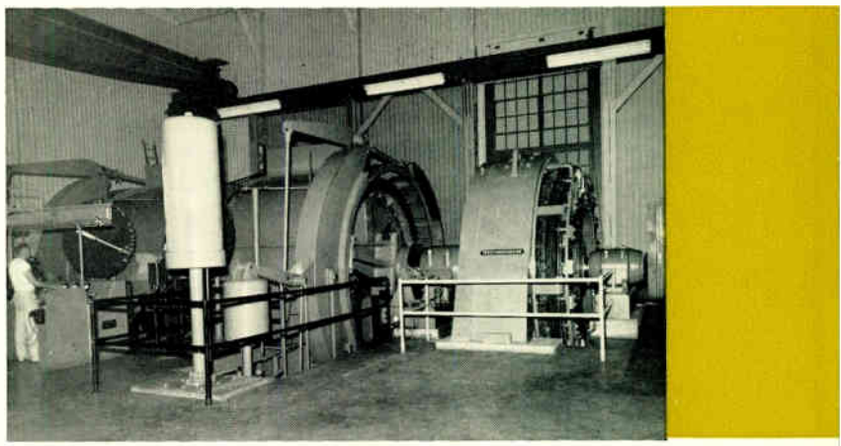
This year the Magamp learned some new plays. One important one was an improvement in the regulation of multiple-generator sectional paper-machine drives.

In this type of drive, each section is powered by its own generator and motor combination. In the new system, the speed of each individual section drive motor is matched to that of a master reference set. This is accomplished by a mechanical differential error-detecting unit, which compares the speed of the reference to that of the drive motor; any difference in speed produces a signal that is amplified in a two-stage magnetic amplifier and a correction fed to the field of the section generator to correct the drive-motor speed.

But, in the sectional paper-machine drive Magamps have other jobs as well. The constant-potential exciter, which supplies excitation for the section drive-motor shunt fields, the section-generator differential shunt fields, and the bias requirements of the Magamps, is held constant by a Magamp regulator. Also the speed of the master reference itself is held constant by a Magamp regulator, so that the speed of the paper machine can be held to a variation of one tenth of one percent or less.

Voltage variations of the 60-cycle power systems are eliminated by the use of a 400-cycle alternator to supply power for the Magamps. The use of 400-cycle power also makes possible smaller components and higher system gains.

This multiple-generator system can be used on all paper-machine drives, but is most advantageous where wide speed range is necessary. Speed ranges up to 10 to 1 are common with this scheme. The use of an all Magamp device provides a static regulator, thus reducing maintenance and improving the reliability of the system.



This first man-and-material hoist drive to have Magamp control is the installation at the Anaconda Company's Kelley Mine. A current-limit magnetic amplifier, working in conjunction with a Rototrol regulator, controls the operation of the hoist's 2250-hp d-c drive motor. The new control gives improved rates of acceleration and deceleration, and smoother operation. Mechanical stress on the hoist equipment is thus reduced. Above, from left to right are the control console, the two drums of the hoist, the d-c drive motor.

STEEL-MILL DEVELOPMENT

THE TWO LARGEST steelmaking arc furnaces in the world are in operation at the Trenton, Michigan plant of the McLouth Steel Corporation. These huge arc furnaces have a shell diameter of 24½ feet and a capacity of 200 tons. Power is fed to them by 24-inch diameter electrodes carrying current of 35 000 to 45 000 amperes at voltages up to 510, the highest ever applied on steel furnaces.

All electrical equipment is of heavy-duty construction to withstand the rugged operating conditions imposed by such large furnaces. Transformers are rated 25 000 kva, 24-kv primary, 3 phase, 60 cycle, with secondary coils formed entirely of bus bar. Compressed-air circuit breakers—rated at 34.5 kv and 1200 amperes—are used for both primary fault interruption and furnace switching duties; these circuit breakers have a fault interruption capacity of 500 000 kva.

Electrode speeds of 36 to 90 inches per minute are obtained through Rototrol-controlled 15-hp mill motors. Special Rototrol regulators and generators are designed to provide electrode positioning with a minimum change in furnace operating level.

TENSION CONTROL FOR SENDZIMIR MILLS

A SENDZIMIR REVERSING strip mill is first and foremost a precision device. Used primarily to produce uniform ultra-thin strip (often a small fraction of the thickness of the paper this is printed on), every component of the mill must be as accurate and precise as possible. A new Magamp tension regulator for Sendzimir mills provides more constant tension on the strip, enables faster acceleration and deceleration, and has a greater tension range, all of which contribute to a better end product.

A pattern field in the Magamp regulator is excited in proportion to the tension setting made by the operator. A second, or deflection winding receives a signal indicating the actual tension on the strip. These two windings are arranged to be in opposition; any difference in the strengths of the pattern and deflection windings results in a signal to the reel motor, to either increase or decrease the tension. When tension is correct, the two windings cancel each other, except for a small steady-state signal to maintain desired strip tension.

The deflection winding receives its intelligence as to tension through an electro-mechanical system. A roll on the mill is arranged such that it is deflected in proportion to the strip tension. This deflection is transmitted through a mechanical system to move a magnetic pick-up unit, whose output is fed to the deflection winding of the magnetic amplifier.

This new Magamp regulator has been applied on a 37-inch reversing strip mill at the Washington (Pa.) Steel Company. Here it replaces a system that was hydraulically and electrically controlled. In the old system steps of resistance were inserted in the regulating system to maintain strip tension by means of booster voltage. The new system uses a reactor-type unit with a linear output and essentially infinite steps for tension regulation by means of a booster voltage.

NEW ALUMINUM SHEET AND FOIL MILLS

THE DRIVE AND CONTROL for two new aluminum-foil mills are designed for an extremely wide range of possible operating tensions. These mills, for the Kaiser Aluminum and Chemical Corporation's new facilities near Ravenswood, West Virginia, will reduce aluminum sheet from a maximum thickness of 0.026 inch to a finished thickness of 0.0004 inch; strip widths from 27 to 56 inches will be processed. The 1000-hp main drive motor for each mill is supplied by its own 800-kw generator. Main drive motors and generators are excited by rotating exciters, which are controlled by magnetic amplifiers. Reels are driven through gear changers, with two different gear ratios available to the operator. Rewind reels are powered by either one or two 75-hp motors or by one 50-hp motor. Magamp regulators control the reel motors and generators. Compensation is made in the generator current regulation for windage and friction losses in the reels, gear-changers, and in the reel motors.

This selection of two possible gear ratios, the choice of the number of drive motors used, and the range of regulated current all add up to a wide range of possible tensions.

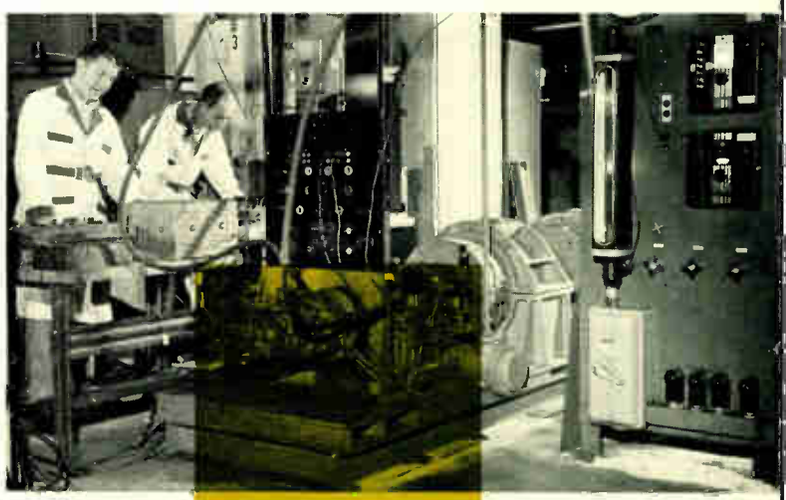
A new aluminum sheet mill for the same plant will employ a 2000-hp double-armature motor as the main drive. This mill will reduce sheet from a maximum of 0.102 inch to a finished thickness of about 0.0035; strip widths of 27 to 54 inches are produced. Maximum strip speed of the new mill will be about 3250 fpm.

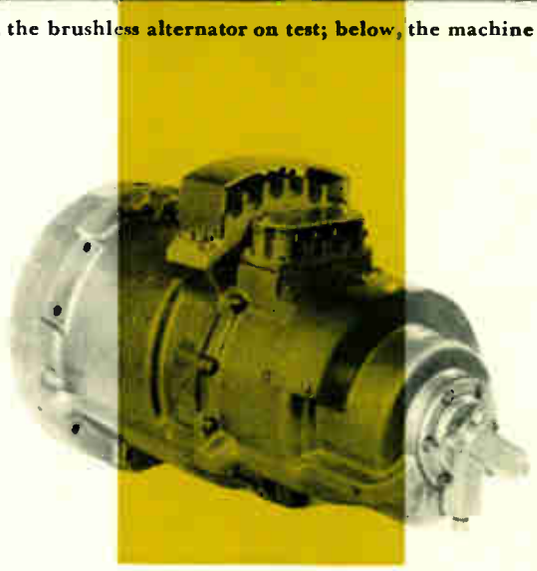
Aviation

AN ENVIRONMENT-FREE AIRCRAFT GENERATOR

CONSIDER THE AIRCRAFT generator in the photograph below. This is a 40-kva, 8000-rpm a-c machine. Looks pretty much like any other a-c aircraft generator, doesn't it? But there are some mighty significant differences. This is a *brushless* a-c machine; furthermore it is cooled by 300 degree F oil. The fact that it is brushless means it can operate at very high altitudes without difficulty. The oil cooling provides lower internal temperature drops, allowing a higher overall temperature rating.

Elimination of the brushes was made possible by the development of silicon rectifiers capable of operation mounted on an 8000-rpm rotor. D-c current from an external source is fed to the field of an integral exciter; the a-c output of the





Above, the brushless alternator on test; below, the machine itself.

exciter is generated on the rotor and is fed to a three-phase-bridge silicon rectifier mounted in the rotor shaft. The d-c output of the rectifier is fed into the alternator rotating field. The output of the alternator is on the stator in the conventional manner.

To reduce the exciter field requirements current feedback is used. An integral current transformer in the alternator output provides current to a second three-phase-bridge silicon

rectifier; the rectifier output is fed into a winding on the exciter field.

Included in this machine is a permanent-magnet generator. The a-c output of the generator is fed into a third integral three-phase-bridge silicon rectifier, and the output provides d-c power for the control and protective relaying (30 volts at 2 amperes).

Engine lubricating oil is used as the cooling medium for the new generator. The combination of oil cooling, plus the absence of brushes means that this machine is essentially environment-free.

Companion to the new brushless alternator is a new Magamp voltage regulator and protection panel combined in one unit. This unit not only regulates the output of the a-c generator, but also protects it against grounds, and feeder and bus faults. In addition, it protects equipment utilizing the a-c power from overvoltage and undervoltage faults.

Like its counterpart, the generator, the new regulator is extremely light in weight. A standard Magamp regulator plus protection panel weighs over 24 pounds; the new combination unit weighs but 13.5 pounds. Voltage regulation is also extremely close; guaranteed regulation is 115 ± 1 volt line to neutral compared to the usual 115 ± 3 volts.

The new regulator has three stages: a sensing stage that senses the output voltage of the generator, compares it with a reference voltage, and supplies the error signal; a first-stage magnetic amplifier, which amplifies this signal; a second-stage magnetic amplifier that controls the shunt-field current of the generator exciter to keep output voltage constant. The control panel has relays that sense the various faults and operate to remove the generator from the line.

The new regulator and protection panel makes use of printed circuits, and silicon power rectifiers, which are largely responsible for the decrease in weight over previous panels.

Lamps and Lighting

MERCURY—STILL ON THE MOVE

MERCURY LAMPS continue to enlarge their area of usefulness. A prime example is in street lighting. Although mercury lamps have long been popular for this use, because of their high efficiency and long life, each lighting fixture has required a separate current transformer to operate on the standard 6.6-ampere street-lighting circuits. A new mercury lamp can be used directly in sockets now using incandescent lamps, with the addition of voltage-sensitive and time-delay relays and special cutouts. The new lamp has a rated light output of 20 000 lumens, will require about 430 watts for its operation, and will be made in both conventional mercury and fluorescent-mercury form.

The operational advantages of large mercury lamps, i.e., high efficiency, long life, and high light output, are now extended downward to the smaller ratings. New, compact 100-, 175- and 250-watt lamps are applicable to residential and secondary streetlighting, and to industrial and some commercial lighting. Rated life of these new lamps is 6000 hours.

The use of several atmospheres of xenon in short-arc mercury lamps has added valuable characteristics for searchlight operation. Formerly, short-arc mercury lamps utilized a small standby electric heater outside the bulb to vaporize the mercury when a substantial amount of light was desired immediately. No special heaters are needed in the xenon-mercury lamp. The xenon is a gas at all ordinary temperatures, and serves as a path for the arc when the lamp is first turned on. This arc provides initially about 25 percent of the final light output of the lamp, and supplies the heat necessary to vaporize the mercury.

Some 2000 of these new lamps will be used to convert 12-inch marine signalling searchlights from incandescent to mercury-arc lamp operation. These searchlights serve a dual purpose—sending messages by Morse-code blinker system, and for general searchlight work. The lamps will be installed in such a way that a simple flick of a lever will throw their beams in or out of focus. When focused, the new 1000-watt searchlight produces about three million beam candlepower or more than 10 times that of the old lamp, which greatly increases the range of the searchlights, particularly for daylight signalling; when out of focus, the signalling beam is wider and can be seen more easily when the ship rolls.

Equipment designers are sometimes somewhat limited by having to design a product that has some or many parts interchangeable with similar devices. Not so with a new a-c aircraft generator, in which every component was designed with optimum performance in mind. The result is a new unit that is the lightest in its high-temperature class. The new generator is a 20-kva, 3-phase, 120/208-volt unit, and operates at 8000 rpm, 400 cycles. It weighs but 44 pounds and is primarily intended for high-speed, high-performance aircraft, such as fighters. The unit consists of a class-H insulated alternator portion that receives its excitation from a similarly insulated integral d-c exciter generator. Components of the new generator are made of the lightest materials and with the smallest cross sections possible. Castings are made of a new creep-resistant magnesium alloy. The mounting diameter has been reduced from the standard 10-inch arrangement to 8 inches; this new size will match that of a newly developed constant-speed drive. The new a-c generator is rated at 20 kva under military class-C conditions, which specify 120 degrees C cooling air at sea-level conditions and high air temperatures at altitude conditions.

ULTRAVIOLET GOES SWIMMING

CONTAMINATED WATER can be made safe for drinking merely by exposure to the proper amount of ultraviolet radiation. Lamp engineers have long recognized the fact that ultraviolet from mercury-arc lamps was effective in this respect, but the use of the technique has been greatly limited by its relatively high cost compared to chlorination. Now that high-efficiency, long-life lamps, such as the Sterilamp, are available, water sterilization has been receiving more attention. Exhaustive laboratory tests have been made to determine the amount of ultraviolet radiation needed to sterilize a given amount of water in a specified time. This, of course, depends to a large degree on the initial contamination of the water and how pure the final result must be. As an approximation, however, in the case of "average" water, up to 750 gallons an hour can be purified by a 40-watt Sterilamp.

Several factors influence the sterilizing effectiveness of ultraviolet radiation. Iron salts and organic matter both absorb ultraviolet; common alkali salts, on the other hand, do not. The relative amounts of these ingredients thus can have a pronounced effect on the amount of radiation and on the time required.

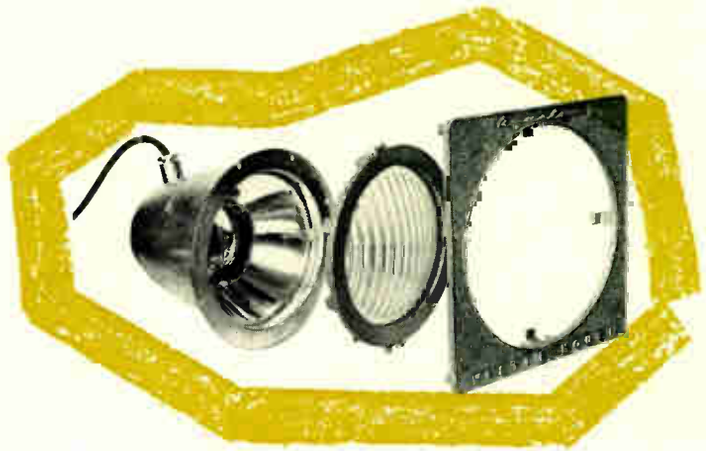
Temperature of the water is also a factor, because it affects the ultraviolet output of the Sterilamp. The warmer the lamp, the more ultraviolet it produces. For example, a lamp operating at 105 degrees F produces about four times as much radiation as one operating at 50 degrees. One solution to this is to encase the lamp in a quartz jacket, which gives a higher operating temperature.

Ultraviolet sterilization of water has many potentialities. Many industrial processes require pure water that has not been chlorinated—dairies, breweries, bottling plants, and pharmaceutical houses, for example. Home use is another possibility, since water sterilized by ultraviolet meets the requirements of the Public Health Service standards.

LIGHTING ENGINEERS KEEP UP WITH THE PACE

LIGHTING ENGINEERS have to keep their eyes peeled in two directions at once. On the one hand they must keep up with lamp engineers by designing fixtures that take full advantage of the characteristics of new lamps; and on the other side, they must stay abreast with changing needs in the application of light. This double-barreled requirement each year produces a number of new fixtures, some for new applications, some to improve present applications.

Underwater Floodlight—An increasing trend in residential swimming pools is underwater lighting, both for effect



and for night use of the pool. A new floodlight, designed with the residential pools in mind, is both simpler to install and easier to maintain. (See above.) The frame is permanently attached to the pool wall and supports the lens holder flush with the front of the mounting frame. No separate bronze receptacle is needed—the floodlight can be placed in a simple unfinished niche in the pool wall. The housing will accept several different bulb types, from 250 to 500 watts, and is suitable for pools of 50 feet width or less.

Street-Lighting Luminaire for the Fluorescent Mercury Lamp—Although several street-lighting luminaires accept the color-corrected fluorescent-mercury lamps, none were designed specifically for this application. A new luminaire, the OV-35, is designed around the new lamp, thus making most effective use of their light characteristics. With the 400-watt J-H1 lamp, the OV-35 provides a type III distribution with a peak candlepower of over 8000, high coefficient of utilization, and excellent uniformity of illumination.

In addition to its light characteristics the luminaire has several superior new mechanical features. The optical system is completely sealed against the entrance of moisture, dirt and insects. The reflector is held in place by a single spring, which simplifies maintenance of the unit.

Semi-Indirect Fluorescent Luminaire—Replacement of several separate pieces of plastic with one large extruded plastic shield is a feature of a new semi-indirect fluorescent luminaire. This luminaire bottom shield can be removed for cleaning by the simple expedient of pressing in on the sides of the plastic. For lamp replacement, the shield need not be removed, since lamps are accessible through the top of this hanger-mounted luminaire. This new lamp unit (type PB) is made in both two- and four-lamp sizes and utilizes either 40-watt four-foot fluorescent lamps or four- or eight-foot Slimline lamps.

Shutdown time in any high-production mill is an expensive proposition. Therefore the utmost speed in locating any source of trouble and correcting it is imperative. A new fault finder continuously monitors control circuits and indicates by lights a fault in any one of them. The basic unit monitors six circuits; several units can be combined where necessary. As long as each circuit is clear, its light on the panel remains lighted. If a fault occurs, even momentarily, the light goes out—and remains out until the fault finder is manually reset by the operator. This reset feature assures the detection of momentary faults, and also makes this a fail-safe device, since when a light goes out the operator knows that trouble exists somewhere, either in the control circuit or in the fault finder itself. If the device were arranged to flash a light on when a fault existed, even the failure of the light itself or any part of the fault finder circuit would prevent a warning of trouble in the mill's control circuit.

Gas will get a "lift" from three huge synchronous motors when it hitchhikes its way from Texas to the East Coast via Texas Eastern Transmission's pipeline highway. This is the largest motor yet applied to cross-country gas-transmission compressor stations. It will be the first instance of a single-unit compressor station of this size on a large pipeline. Ordinarily, several smaller compressors are used in series. The three compressor stations will be spaced out along the line, in Mississippi, Tennessee, and Kentucky.

Each synchronous motor is rated 15 000 hp, 900 rpm, 4160 volts, unity power factor. The motors and exciters are forced-ventilated with all spark-producing parts enclosed in housings maintained under pressure of safe air. The machines use a special flexible-type starting-winding connection, which will enable them to start the high inertia of the combined motor and compressor without overstressing the bars. The motors will be started directly across the line.

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Calculating the performance of a shaded-pole induction motor is no simple task. Computing its performance at only *one speed* requires 95 basic arithmetic operations—when the network includes only the fundamental rotor circuit. Then come the harmonics. Adding the third-harmonic rotor circuit increases the operations to 145; adding the fifth and seventh brings the total to nearly 400 separate operations.

A card-programmed calculator now reduces the time for simpler operations by as much as 30 to 1; in the more difficult computation of the fifth and seventh harmonics—an impractical task with a desk calculator—the CPC takes but five minutes.

With the use of the shaded-pole motor increasing, the digital computer has removed a tough roadblock; it not only speeds up calculations and makes difficult ones practical, but also reduces possibility of error.

• • •

Torturous treatment is taken in stride by a new aircraft lamp. As a matter of routine, the new lamp withstands centrifugal forces of up to 1000 g, i.e., each part of the lamp is subjected to 1000 times its own weight. The lamp fits in the tip of a helicopter blade,

and is designed to give a distinctive identification feature to this type of aircraft.

In a series of gradually improved designs, the lamp was made rugged enough for this service by rigidly supporting the filament wires. Two tightly coiled filaments are used in series to provide the required light intensity. The lamp produces about 35 candlepower, but reflectors in the blade tips increase the effective light output about nine times.

Because of the helicopter's unusual ability to maneuver easily and quickly in any direction, correct interpretation of its movements at night is vital to air safety. Experimental work has been done in automatically switching on and off green and red lights in the blade tips so that they present a green semi-circle on the right side of the helicopter and a red semi-circle on the left side. Thus any change in the helicopter's flight path could be readily observed.

This new lamp is a joint development of Westinghouse and the Kaman Aircraft Corporation, which developed the helicopter lighting system for the Navy.

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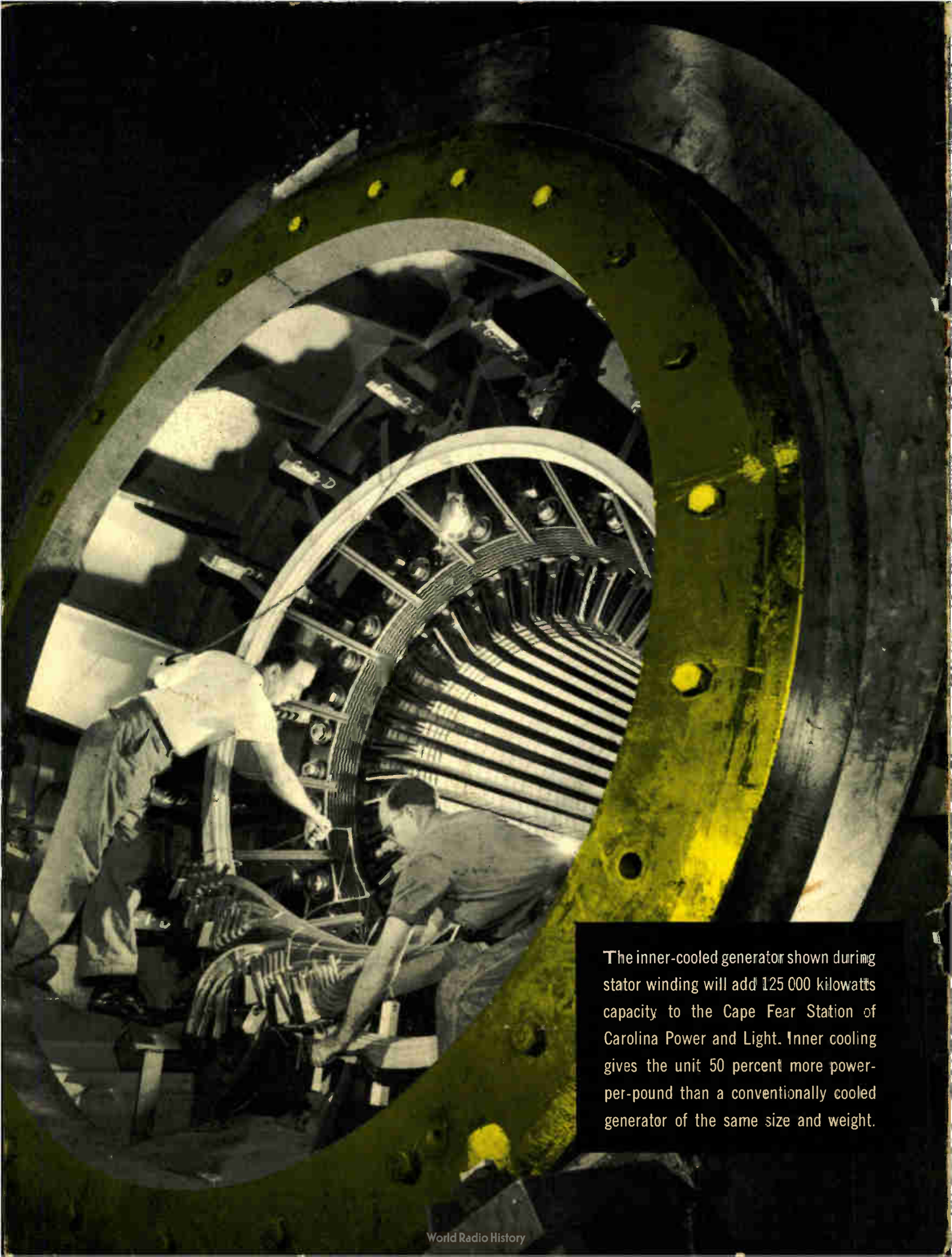
The color-correcting phosphor developed for the fluorescent-mercury lamp is proving that it is as versatile as it is talented. Originally used to convert some of the ultraviolet from the mercury arc to visible red and thus achieve a more balanced color from the lamp, the phosphor is now serving a dual role. In a new 400-watt mercury lamp, the phosphor serves as a partial reflector in addition to improving the color.

The phosphor is coated on the sides of the reflector-type bulb. The end of the bulb is not phosphor coated, but merely frosted inside. Light coming from the mercury discharge strikes the phosphor and is either reflected downward through the end of the bulb or passes through the sides, giving the lamp an upward component in addition to the downward light. The invisible ultraviolet from the arc creates red light on striking the phosphor, and this is reflected or transmitted in a similar way. The net effect is that about two thirds of the visible light output is downward, and one third is radiated upward to the ceiling, or can be redirected downward by a reflector. All of the light output is color-corrected.

A new 2400-kw tin-reflow line, one of the largest single-package installations to date, will process tin-plated steel strip at 2000 feet per minute. The steel strip will pass progressively through induction-heating coils rated at 400, 600, and 800 kw. The tinplate is brought up to melting temperature and flowed. Up to 500 kw can be applied per foot of strip length, this high density making possible a sharp flow line (melted zone). An automatic temperature-control system uses photoelectric cells to pick up light reflected from the bright flow line, which is held in position within ± one inch, regardless of strip speed, width, or thickness.



The inner-cooled generator shown during stator winding will add 125 000 kilowatts capacity to the Cape Fear Station of Carolina Power and Light. Inner cooling gives the unit 50 percent more power-per-pound than a conventionally cooled generator of the same size and weight.