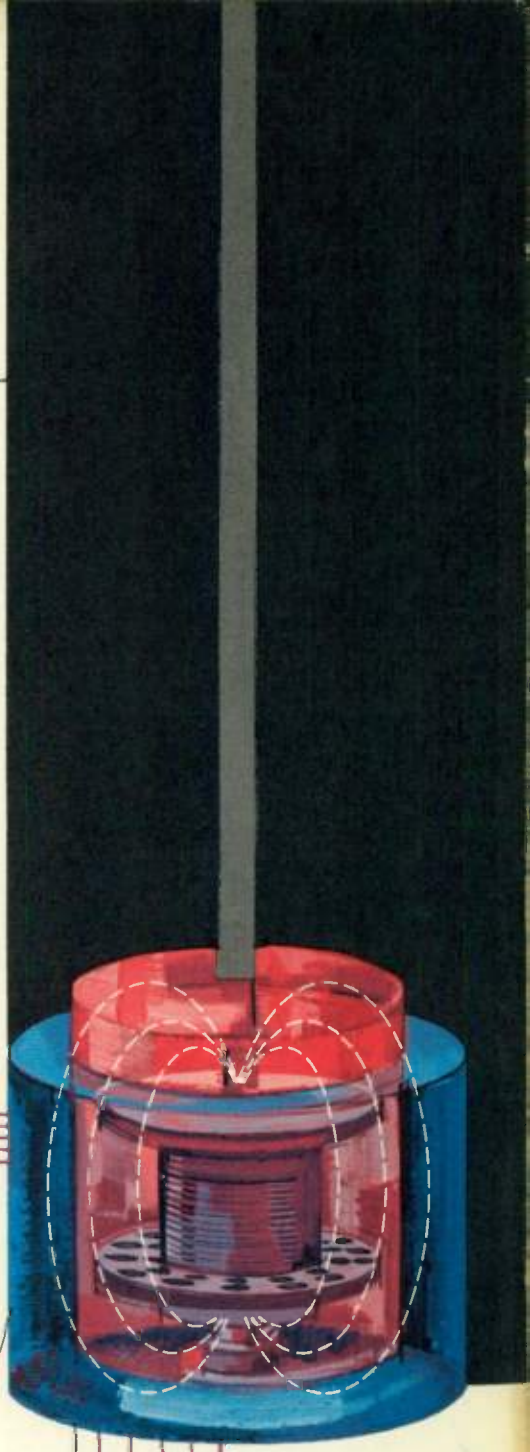
Westinghouse ENGINEER

JANUARY 1962

Annual Engineering Review



In this first month of 1962, few people would question the oft-repeated statement that the tempo of technological development has been—and still is—increasing rapidly. The spectacular feats in the field of rocketry are but one example.

But this is an example of considerable new knowledge being channeled toward a well-defined goal—a specific "product" for a specific purpose. A corollary effect is equally important. This is the case in which new knowledge leads to one product that is so versatile that it is useful in many diverse applications. The rapid growth in use of several semiconductor devices in products for the home, for industry, and for defense is ample proof of this effect.

Neither of these cases is clear cut, of course, and each contributes to the other. Any large single-purpose project inevitably spins off by-product information useful in completely different applications. And any multi-purpose product is invariably useful in single-purpose projects—as semiconductor devices are in missile systems.

All this points to the fact that if new knowledge is to be used to its fullest advantage, scientists and engineers must be alert to possibilities well beyond their immediate objectives.

So, too, must people in one technical area be alert to the possibilities raised by developments in other technical areas. This is part of the objective of this issue; namely, to present in brief form a wide variety of developments and applications, in the hope that they will not only help inform you of developments in your own area of special interest, but also to alert you to other developments that you may be able to adapt to your own needs. If the issue serves this purpose, it will have contributed in its own way to the most efficient use of new knowledge and the rapid advance of technology.

J. A. HUTCHESON
Vice President, Engineering

POWER
GENERATION
TRANSMISSION
AND DISTRIBUTION

APPLICATIONS
OF
POWER

MARINE
AVIATION
AND SPACE

RESEARCH
AND
ENGINEERING

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for the year 1961

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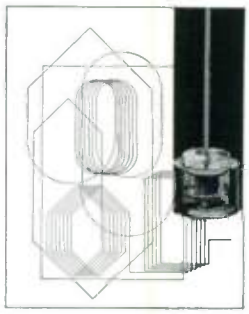

Volume 22 • Number 1

Cover Design: Various kinds of electrical equipment use windings in many shapes and forms to generate magnetic fields. Unfortunately, the current-carrying limitations of conventional electrical conductors restrict the field strengths that can be obtained. Hence, the development of the superconducting solenoid (p. 27) is a major breakthrough in magnetic field technology, and for Westinghouse, one of the year's most significant engineering highlights.

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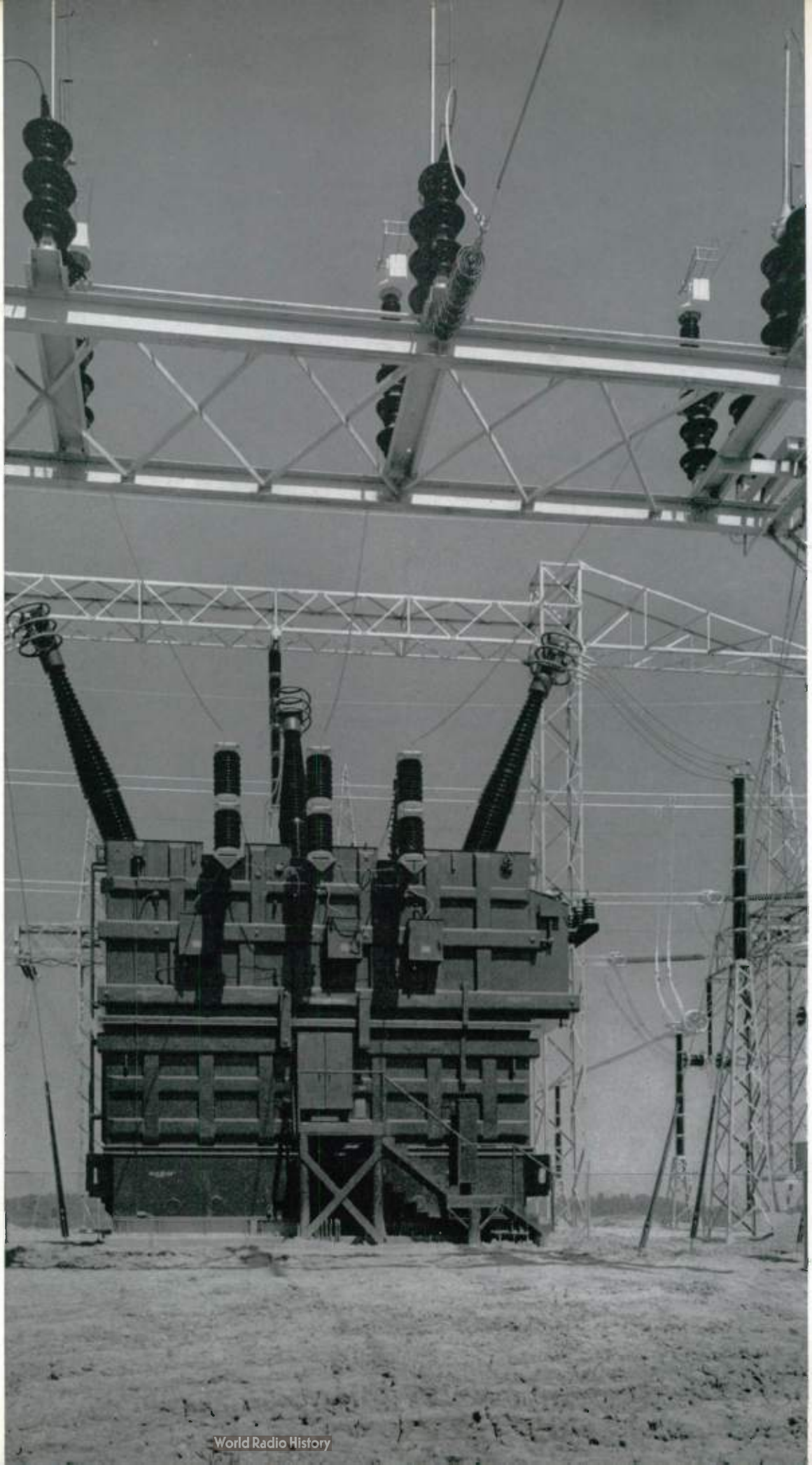
POWER GENERATION, TRANSMISSION, AND DISTRIBUTION



Shown here is part of the apparatus used in the extra-high-voltage test transmission line at Apple Grove, West Virginia. This 750-kv project is sponsored by American Electric Power Service Corporation and Westinghouse. A five year research and test program will develop the information and experience needed to transmit large blocks of power at voltages up to 750 kv.

The prime objective of the project is to obtain data on corona loss and radio influence performance of conductors at a nominal voltage of 750 kv.

Shown in the photo is the 138/750-kv transformer; a load break switch appears in the top foreground.

Toward Better Core Performance

In the drive to reduce the overall cost of nuclear power, one of the most promising approaches lies in increasing the performance of the nuclear core itself. The achievement of this goal depends upon many related core design factors.

Chemical Shim—For example, uniform power distribution throughout the core is highly desirable; otherwise the core must be designed to tolerate the maximum temperature found in any hot spots, even though the remainder of the core may be operating at considerably lower temperatures. Since the nuclear core consists of a large number of separate heat-producing elements, improvements in power distribution would seem to depend on an optimum arrangement of these fuel elements within the core. To a degree this is true, but unfortunately many elements of the core tend to interfere with uniform power distribution. In most water-moderated reactors at present, designers must contend with a ratio of maximum-to-average temperature rise of the coolant passing through the core of about 3.

One method that engineers are investigating for smoothing out power distribution is chemical shim. This is the use of neutron-absorbing boric acid, dissolved in the cooling water, to supplement the control rods. As the name implies, chemical shim is not a control system in itself. Since the concentration of boric acid in the coolant water must be varied to effect control, the process is inherently slow. Therefore, chemical shim is designed to compensate primarily for slowly varying reactivity effects, such as caused by depletion of the original fuel during the lifetime of the reactor, changes in the temperature of the moderator, and the poisoning effects of samarium and xenon. Control rods are required to handle all faster changes in reactivity, although even in such cases they are supplemented by the boric acid.

The potential advantages of chemical shim are several. For one, it is likely to reduce the ratio of maximum-to-average temperature rise in the coolant from about 3 to somewhere in the vicinity of 2 when used in conjunction with multiregion cores and fueled control-rod followers. Moreover, chemical shim holds promise for reducing the number of control rods to perhaps half the number now required. This in itself could contribute materially to a reduction in cost; each control rod and its associated driving mechanism costs tens of thousands of dollars, and a large reactor may have 45 to 70.

The concept of using a dissolved neutron poison for reactivity control is not a new one; it has been investigated in several experimental reactors. However, the problems of using chemical shim in a large power reactor have not as yet been thoroughly explored. Studies of the effects of boric acid on corrosion of materials and many other aspects must be made in more detail, but chemical shim, as of today, offers promise of greatly improved core performance and more economic power from the atom.

Multiregion Studies—Despite the rapid progress in nuclear power during its first decade of existence, designers still lack the backlog of data based on experience that is common in older and more established fields. Enormous amounts of information have already been accumulated, but the surface has thus far only been scratched. A major effort is now being devoted to experimental procedures to gain new information and to enable designers to check design procedures by correlation of calculated values with experimentally measured values.

Such experiments are carried out in the Westinghouse Reactor Evaluation Center, where a flexible grid arrangement allows many different configurations to be tried experimentally.

For example, engineers and scientists have been experimenting with fuel rods of several enrichments arranged in various configurations, and have been measuring the flux distributions associated with each, in an effort to discover the different factors that affect power distribution in the core. Many multiregion core configurations were tried using fuel of 1.6, 2.7, and 3.7 percent enrichments. Another area of investigation was the effect of various nonfuel-bearing elements on power distribution. For example, a "water slot", which exists when a control rod is withdrawn from a core and water fills the space, or an aluminum plate in the same space, causes peaks in power distribution in the surrounding area. Stainless steel or boronated stainless steel, on the other hand, causes a local depression in power density. And different thicknesses or configurations of these materials change the degree of the effect.

The net results of such experiments are of interest to a nuclear designer. Much of the data deals with constants used in nuclear design. Suffice it to say however, that information obtained in a comparison of experimental data with calculations is essential to an evaluation of the validity of theoretical methods; and as a result of such comparisons, analytical methods used in reactor design are being improved continually.

Computer Calculations—The information gained from such experiments, plus much more gained from operating experience in power reactors, is incorporated in computer codes used for core design. Computers have played a vital role in reactor design during the past few years, principally because of the enormous number of individual calculations required; several billion arithmetic operations are frequently required in a reactor design, a feasible task for computers, as opposed to the practically impossible task of hand calculation. The net effect on computer design is that such factors as power distribution in a reactor are being predicted with increasing accuracy. A few years ago, 50 percent accuracy was common; now 10 percent is possible and the accuracy increases yearly. The effect of increasing accuracy is a gradual reduction in conservatism in design, which, in turn, can lead to better performance. ■ ■ ■

Nuclear Design Improvements

The nuclear design engineer has two things to rely on—the increasing body of knowledge and experience in the nuclear field, and his own ingenuity. There's ample evidence that he is using both to maximum advantage; this shows up particularly in some of the improvements made last year in reactor components. Several improvements illustrate this point.

Core Structure—The core of a water moderated reactor is normally supported between two heavy steel plates, each of welded sandwich-type construction. The rigid construction is

necessary because, in addition to supporting the core, these plates must also absorb other loads. The upper core support plate, for example, must absorb control-rod scram loads; the lower core-support plate must carry most of the core weight, and also may be subject to impact loads. At the same time these plates, because of their close proximity to the core, are subject to severe gamma heating and resultant thermal stresses.

A new design greatly reduces the problem by transferring the supporting functions and the impact loads to other mechanical structures further away from the core. By this means the effect of gamma heating is greatly reduced by the additional water shielding.

Loads formerly absorbed by the upper core-support plate are now transferred through the control-rod guide tubes to the support plate near the top of the reactor that holds these tubes. The upper core-support plate, now only required to position the fuel and guide control rods, then becomes a single ply, machined plate rather than a built up weldment.

Loads on the lower core support plate are transferred through the control rod follower shroud tubes to a heavier support plate at the bottom of the reactor.

Thus the two core-support plates in the new design are relieved of much of their load bearing requirements and can be of much simpler construction. The movement of the load bearing function to locations further from the core also simplifies the necessary structure; the net result is a significant saving as well as a better design.

One Shape for Two—While it is difficult to visualize without sketching on paper, at least two different fuel assembly shapes are normally necessary just to form the slots necessary for control rod passage through the core. For a variety of nuclear reasons, the fuel assemblies cannot merely be spaced far enough apart to allow the cruciform-shaped control rods to slide down between them. Instead, the slots for the control rods are set into the sides of the fuel elements, and this requires two different assembly cross sections in the core.

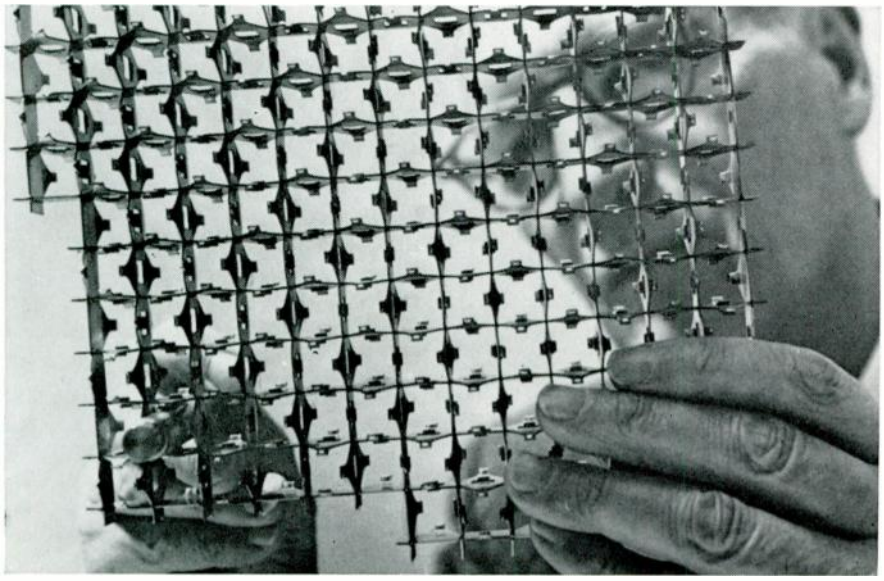
By changing the design of the control rod slightly, engineers have overcome this problem. A normal control rod resembles two L-shaped sections joined to form a cruciform shape. The new design is similar, except that the two L-shaped sections are overlapped slightly, so that the arms of the cross are offset slightly from the centerline axis, but still parallel to each other. This makes it possible for one standard fuel assembly design to be used throughout the reactor.

Obviously, this simplifies fabrication, but more important it allows any fuel element to be used in any portion of the reactor. This assumes importance in multi-region loading, in which case fuel elements are normally moved to a new position after their fuel content is partially depleted.

Less Wear on Control Rods—Materials continue to be a complicating factor to nuclear designers. Few, if any, materials have outstanding nuclear characteristics plus good mechanical properties, and the occasional material that is excellent in both respects is almost always expensive. But designers are steadily finding ways to circumvent this problem. A representative example turned up this year in the case of control rods. The prime function of control rods is to absorb neutrons; unfortunately, however, some of the best absorbers are poor mechanically, and can't be satisfactorily welded or brazed. Fortunately control rods are not exposed to serious mechanical stresses, but they are subject to wear from rubbing. The obvious answer is to attach strips of some stronger metal, such as stainless steel, to the outside of the rod to serve as a rubbing strap. But because no satisfactory method of joining stainless steel to the silver-indium-cadmium neutron-absorbing material is known, designers had to find another way. The answer was to machine slots on opposite sides of the control rod for the rubbing straps, then join the two straps by putting a stainless-steel pin through the rod and welding it to both straps. Thus the straps are not mechanically connected to the rod, but only to each other; however, their lateral or axial motion is restricted by their location in slots in the rod. Nuclear design is characterized by the necessity to "design around" materials problems such as this.

For Better Neutron Economy—The structural material in a nuclear core absorbs neutrons, which are then lost to the nuclear reaction. Therefore, a minimum amount of structural material in the core will help to preserve neutrons for the fission process, and therefore help lower the cost of power production.

In reactors built to date, the fuel element cladding represents most of the structural material in the core itself. This cladding must be thick enough to withstand pressures of over 2000 psi. In previous designs, the fuel elements were joined into assemblies by a brazing operation in which tubu-



Spring fingers on this "egg crate" structure hold nuclear fuel rods in place.

Above In 1961, the 20-mw nuclear reactor for the Saxton Nuclear Experimental Corporation moved into its late construction stages. The plant was expected to go critical in December 1961. Above, part of the core structure is inserted in the reactor vessel to check tolerances. This step is taken prior to shipment of the reactor vessel and core.

The primary purpose of the Saxton reactor will be to produce new information and enable testing of new methods of operation for water reactors. During operation, one objective will be to push core operating conditions above the limits now imposed by proven practice, to determine the effects. Part of the program will also involve the use of chemical shim as a method of reactor control.

Right These technicians are securing a fuel element for Belgium's first power reactor in its shipping container in preparation for the exporting of the nuclear core. The reactor, located at Mol, near Brussels, is rated at 11 500 kilowatts. A total of 40 such fuel elements, each packed in a hermetically sealed container, is involved in the shipment. The reactor portion of the plant was designed and built by the Westinghouse atomic power department for the Centre D'Etude de l'Energie Nucleaire, a nonprofit organization formed by the Belgian government, scientific centers of the universities, and industry.

lar ferrules were brazed to adjacent fuel rods to attain proper spacing. Unfortunately, this brazing operation requires high temperatures, and the stainless steel is annealed, thereby reducing its mechanical properties. Thus, a relatively thick cladding has been required to achieve final desired strength, and the type of stainless steel used is a more expensive grade than might be required if a different solution could be found.

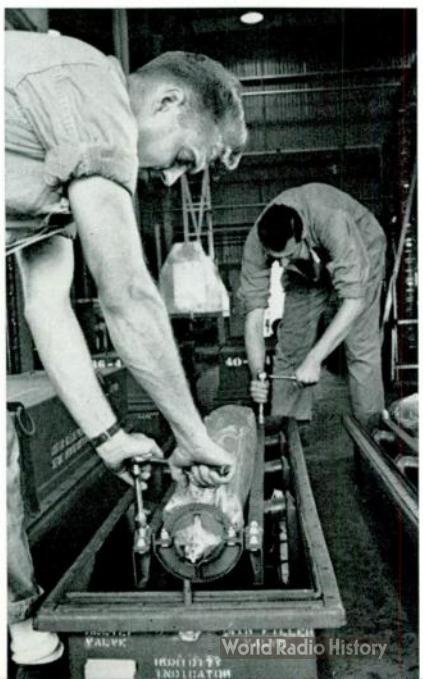
A new concept now under development may eliminate the necessity for brazing and thus allow thinner cladding of a less expensive steel. In the new design, the individual rods are held in place by a series of grids, each of which resembles an "egg crate" structure. Each rod is held in place by spring fingers in the grid. The box structure is brazed together before the fuel rods are inserted, thus the rods are never exposed to the high temperatures. Present indications are that the new structure can reduce the amount of structural material by over 20 percent, compared to the previous brazed design. ■ ■ ■

Transistorized Nuclear Instrumentation

Transistorization and simplification are the key ingredients in a new nuclear instrumentation system now in prototype stages of development.

This all-transistorized version will replace a previous system that used vacuum tubes in the sensitive startup ranges, and magnetic amplifiers in the power ranges. Circuit simplification will improve system reliability and at the same time result in a package reduced by 50 percent.

The new system will reduce the number of logarithmic microammeters used during startup in the source range and intermediate range. This is an economic advantage since these instruments are used only a minor portion of the operating time of a nuclear reactor. In the new system, two logarithmic microammeters will be employed: During startup both will be switched to the source range in cascade with the pulse integrators; as reactivity moves to the intermediate range, one meter is switched to the intermediate range and one remains in the source range. When reactivity is well into the intermediate range, both meters are switched to the intermediate range. In the previous system, two meters were used permanently in each range. Duplicate channels are used throughout the system for added reliability. ■ ■ ■



TURBINES AND GENERATORS

"Building Block 31"

The Westinghouse "pre-engineered" turbine program started in 1957. The first steam turbine to go into operation with a pre-engineered element—a high-pressure cylinder popularly known to its designers as "building block 31"—went into service early in 1961. Building block 31 is a high-pressure split-flow element, which can be applied on turbines rated from 175 mw to 325 mw. This pre-engineered element was used 17 times in succeeding turbines before any major changes in the design were required. After building block 31 have come a number of building-block elements and associated components so that turbines today can be built of completely pre-engineered components. Many components, such as building block 31, have been used extensively; others, which can be applied only to larger turbine ratings, have yet to be used.

One of the most recent pre-engineered building blocks to be put to work is an 1800-rpm double-flow low-pressure cylinder, employing 44-inch last row blades. This will be the first time that 44-inch blades have been used in two exhaust ends in a single cylinder. This development was made possible by improved spindle materials, which have higher yield strengths,

and therefore make possible smaller parts. This low-pressure building-block element has been engineered so that it can be used on the end of either a double-flow or a quadruple-flow machine. The first application of this low-pressure building block is on a 300-mw turbine scheduled for service by Boston Edison Company in mid-1965.

The first 3600/1800-rpm cross-compound turbine to be constructed of all pre-engineered elements and components is the 560-mw machine now being built for the Commonwealth Edison Company. In this machine, turbine elements, steam chests, interceptor valves, and all other major components are of pre-engineered design. The 3600-rpm shaft will use a high-pressure double-flow building block and an intermediate-pressure double-flow cylinder; the 1800-rpm shaft will use two low-pressure double-flow cylinders.

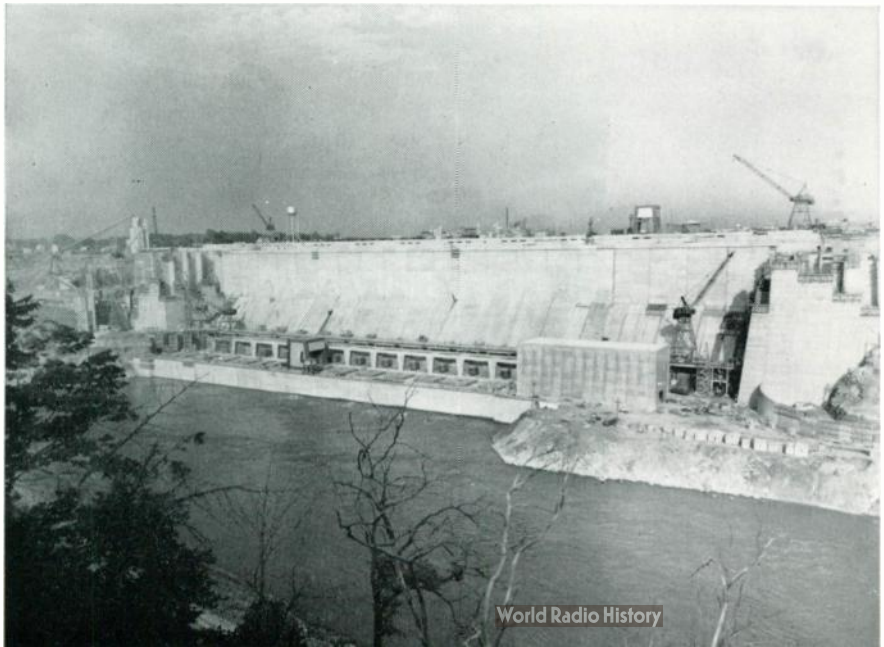
The extent to which the pre-engineered components are being applied is shown by the number of machines now coming out of the shop with pre-engineered components. During 1961, approximately 60 percent of the turbines shipped had building-block elements and components; in 1962, 90 percent of the turbines shipped will be building-block machines; by 1963, almost 100 percent of the turbines will be completely "pre-engineered" machines.

Improved Turbine Components—By using pre-engineered turbine elements, design engineers are able to make parallel improvements in the associated turbine components. A typical example is the improved steam inlet features that have been developed for use with pre-engineered turbines. By combining the horizontal throttle valve with the steam chest to form a single unit, two 90-degree elbows and three heavy welds have been eliminated. The new design improves the steam flow path and simplifies construction. A controlled-pressure-drop inlet package designed for use with the new valve-and-chest unit simplifies inlet piping. Pipes are appreciably smaller in diameter and, therefore, require less loop depth to get from the steam chest to the turbine.

Another improvement has been in the shaft-driven boiler feedpump. In the past, this feedpump has been located at the generator end of the machine. However, by relocating this feedpump on the turbine end, piping has been considerably simplified. The relocation required redesign of the pedestal, and also of the overspeed trip and auto-stop test devices. While the designers were at it, they also redesigned the coupling; the geared coupling used in the past was changed to a new bellows-type flexible coupling. This new coupling is simpler and does not require lubrication. The first use of the front end boiler feed pumps will be on the Morro Bay No. 3 unit of Pacific Gas and Electric. ■ ■ ■

Niagara Power

The first of the 13 waterwheel generators at the New York State Power Authority's Niagara Power Project began producing power in February, 1961. When the picture below was taken in August, 1961, the seventh machine was on the line. The thirteenth and final generator is scheduled for installation in the Robert Moses Niagara Power Plant in June, 1962.



The waterwheel generators, rated at 150 megawatts each, are the largest and most powerful ever made by an American manufacturer. Each generator weighs 1100 tons and is 40 feet in diameter. The rotor, weighing 590 tons, is driven at 120 revolutions per minute by a shaft weighing 55 tons and measuring more than four feet in diameter.

Manufacture of the thirteenth generator was completed at the Westinghouse East Pittsburgh plant in January, 1961. The units were shipped to the Niagara area in parts, by rail. They were stored prior to installation in a warehouse some ten miles from the project. The generators are presently being installed at a rate of one every seven weeks.

The Niagara Project will surpass Grand Coulee power development as the largest in the United States. Significantly, the world's first large alternating-current generators are located at Niagara Falls about five miles from the Moses Power Plant. Rated at 3750 kw each, ten units are located in the Niagara Mohawk Power Corporation's Edward Dean Adams Station No. 1. Made in the early 1890's by Westinghouse, these units have been retired after producing billions of kilowatt-hours of electricity during the past 66 years. (The entire output of Adams Station is 80,000 kw.) ■ ■ ■

Automated Hydrogen System

Steam plant automation is taking on a new responsibility—the complete control of the generator hydrogen and CO_2 systems. The first installation of an automated hydrogen system will be on the Carolina Power & Light Company's Goldsboro No. 3 generator, a 270-mva unit at 45 psig hydrogen pressure.

The hydrogen filling, purity, and pressure control operations will be initiated and confirmed by the station computer. In the past the critical operation of filling has always been done manually.

Westinghouse engineers developed the basic flow chart logic for the hydrogen system, and are providing the sensing devices and control equipment for handling the hydrogen.

This 352-mva turbine generator unit went into commercial operation at the Houston Lighting & Power Company's W. A. Parish plant in March 1961. Steam conditions for the tandem compound turbine are 2000 psig, 1000 degrees F, with reheat to 1000 degrees F. The generator is inner cooled, and its 352-mva design rating corresponds to 45 psig hydrogen gas pressure.

Ebasco, the consulting engineers, designed the final system logic to conform with the utility company's operating practices. ■ ■ ■

Brushless Excitation for AC Generators

The operating results on the first installation of a semiconductor brushless excitation system for a central station turbine-driven ac generator, which went into service March, 1960 on a 50 000-kva generator on the West Penn Power Company system, have confirmed the designer's hopes for excellent reliability, performance, and low maintenance.

Briefly, the brushless excitation system consists of a permanent-magnet pilot exciter, an ac main exciter and a rotating rectifier mounted on the same shaft as the field of the ac generator. The total excitation power requirements, including the power supply of the regulator, are obtained from the generator shaft. Key to the development are the silicon-diode rectifiers, which are small in size and have proved extremely reliable.

The new excitation system functions as follows: a small permanent-magnet pilot exciter furnishes excitation energy to the regulating system, which in turn energizes the stationary field of the ac main exciter. The ac exciter's rotating armature output is fed along the shaft to the rotating rectifier. The rectifier's output, in turn, is fed along the shaft to the field of the ac turbine generator.

The initial trial exciter on the West Penn Power Company system is a 180-kilowatt, 250-volt unit on a 50-mva generator. The excellent service record set by this unit has led to two new applications. One will be a 1350-kw, 375-volt system, which will be applied to a 320-mva turbine generator. This unit will also be installed on the West Penn Power Company system, and is scheduled for shipment in mid-1962.

A second semiconductor excitation system will be installed on a 221-mva turbine generator being built for the Carolina Power & Light Company. This excitation system will be rated at 1150 kw, 375 volts. ■ ■ ■

Electric Governor for Steam Turbines

The new requirements placed on turbine speed-governing equipment in computer-controlled steam plants has led to the application of a new wide speed range electric governor. The DACA governor (Digital Analog Control Apparatus) can control turbine speed from turning gear to synchronous speed, control speed while synchronizing, and then control initial loading up to approximately 15 percent of full load. The rate of changing speed can also be controlled so that the DACA governor can bring the turbine through critical speeds quickly, or change speeds very slowly during synchronizing.

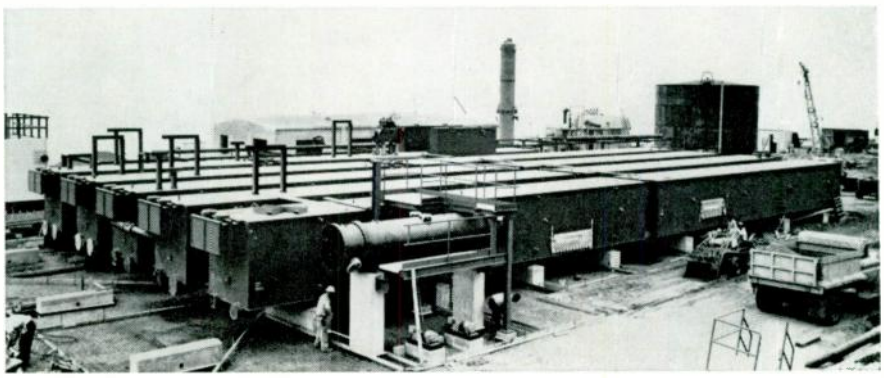
Briefly, the DACA electric governor functions as follows: Speed-sensing is accomplished with a magnetic pickup, which "counts" pulses from a notched disk fixed to the turbine shaft. This signal, which varies in frequency with turbine shaft speed, is amplified and converted to an analog dc voltage level, directly proportional to turbine speed. This speed-sensitive voltage is compared with a reference voltage that is obtained by amplifying and rectifying the output of a crystal-controlled oscillator. The difference between the speed voltage and the reference voltage is the error signal, which is converted to an equivalent oil pressure for operating the steam turbine throttle valve.

The electrical nature of the governing device makes it ideally adaptable to automated control. The first application of the DACA electric governor to a central station unit is on Southern California Edison's Huntington Beach unit No. 4, a 225-mw machine. Here, the DACA governor is under the control of an automatic synchronizer.

At the Sewaren Generating Station of Public Service Electric and Gas Company, the DACA governor will be used under Prodac computer control for the automated turbine-generator unit now being installed.

The governor is built of all solid-

This 1-million gallon per day flash evaporator shown during late stages of construction in 1961, will make drinking water from sea water. The unit is located at Point Loma, near San Diego, California. The unit was built for the Office of Saline Water, a branch of the U. S. Department of Interior, as a demonstration plant to evaluate the multi-stage flash evaporation principle. This demonstration program is an effort to develop needed future water sources for both drinking and industrial purposes. Westinghouse will also operate the plant during its initial phases.



state and magnetic components. Transistors are used in a switching mode so that they are not affected by temperature or individual component characteristic variations. The governor has an accuracy of 0.1 percent of set speed over a 10-to-1 speed range. ■ ■ ■

Power Islands

Designers of large utility power plants are borrowing a trick that has been used by small turbine designers for some time—the "island" concept in which the turbine and all of its associated plant components are arranged in one integrated compact assembly. The large utility power island has been made practicable to a large extent by the "building-block" concept. These turbine building-block components have been designed so that they can be readily integrated into the total island. This concept can be further extended to include heat transfer apparatus, switchgear, power transformer and other associated equipment. As a result, the apparatus can be arranged into a compact assembly with a minimal amount of piping and wiring.

The power island concept has a number of economic advantages. Plant savings result from the reduced piping, valving, conduit and wiring. Some equipment costs can be reduced, by such techniques as combining main and auxiliary power transformers into a single tank. Low-voltage isolated phase bus can be completely eliminated. Further savings in plant investment can be realized by using a completely above-grade installation, and use of a tandem-compound turbine which minimizes foundation requirements.

The first power island will be installed at the Handley plant of the Texas Electric Service Company in early 1963. The turbine will be a tandem-compound quadruple exhaust machine. Steam conditions are 2400 psi inlet at 1000 degrees F, with single reheat to 1000 degrees F. All turbine elements will be "building blocks"—a double-flow, high-pressure turbine element, an intermediate-pressure, double-flow element, and two low-pressure double-flow elements. The integrated power island design will lend itself to complete automatic operation, should this become desirable. A Prodac computer will be used to monitor the station and calculate performance trends. ■ ■ ■

Static Inverters for Power Stations

The inverter, a static device for transforming dc to ac, has found its way into the electric utility power station. The device offers several advantages over the traditional m-g set in that it provides instantaneous emergency standby power, is highly reliable, and requires little maintenance.

The first Westinghouse applications of the device to a utility station will be on the automated turbine generator and boiler for the No. 5 Unit at the Sewaren Generating Station of the Public Service Electric and Gas Company. Here, one inverter will be used to provide 60 cycle ac power to the Prodac computer from a separate 125 volt battery. A second inverter will supply 60 cycle ac power to essential elements of the combustion and burner controls, thus making these controls independent of system power disturbances. This inverter will also provide emergency power for instrumentation. The dc supply will be from the 250-volt station battery. ■ ■ ■

More Kilowatts in Tandem

Tandem compound 3600-rpm turbines continue to grow. Early in 1961, the present recordholder, a 325-mw machine went into service at the Helena, Arkansas station of the Arkansas Power and Light Company. The tandem-compound rating will be extended to 400 mw by a new unit now in design, a new record in the U. S.

The turbine will be a tandem compound, quadruple exhaust machine with double reheat. Initial steam conditions will be 3500 psig at 1000 degrees F, with reheat to 1025 and 1050 degrees F, and 1¼ inches hg absolute exhaust backpressure.

The turbine will consist of four cylinders: The very-high-pressure/high-pressure element will be a first in itself, since this will be the first time a very-high-pressure section and a reheat section have been combined in a single case; the second cylinder is a double-flow intermediate-pressure cylinder, and the two remaining cylinders are double-flow low-pressure elements with 28-inch exhaust blades.

The inner-cooled generator driven by the turbine will be rated at 486 mva 0.85 power factor, at 45-psig hydrogen gas pressure. This generator will have the highest armature current —16 000 amperes—of any machine yet built by Westinghouse.

The 3600-rpm turbine-generator unit is scheduled for shipment to the Hudson Generating Station of the Public Service Electric and Gas Company in 1964. ■ ■ ■

TRANSFORMERS

Cast Coils for Power Transformers

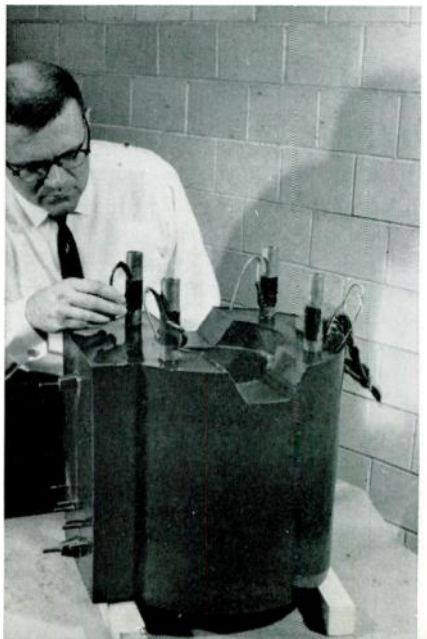
The power transformer of the future may have no heavy steel tank, no oil, and no large porcelain bushings; in fact it may well bear little physical resemblance to present transformers.

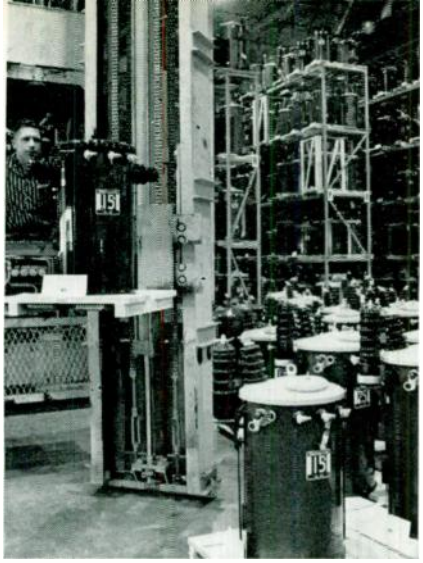
These possibilities are raised by a new experimental power transformer that has its coils cast in solid resin. Small versions of such a power transformer have been built, and a commercial unit that will be rated at 1000 kva at 15 000 volts is now in production at the transformer division.

The cast solid structure is more efficient dielectrically and structurally than cellulose insulation, and this leads to a potential reduction in size and weight of about 25 per cent. Moreover, this type of structure is not subject to deterioration and should have extremely long life.

One potential area of application for such a cast transformer would be in areas where hazards from fires cannot be tolerated, i.e., installations where sealed or air-cooled trans-

This is part of an experimental power transformer with coils cast in solid resin.





Shown here being prepared for shipment are a group of the new LL-65 distribution transformers. The LL in this case means low loss. The 65 means 65 degree C temperature rise. The transformer is designed for a loss ratio of 2.5 to 1, compared to the 3 to 1 ratio for conventional 55 degree units. This means that the copper losses are lower than the 55 degree transformer while the core losses are the same or less. The net effect of this new design is to reduce operating costs at any load, decrease customer voltage complaints, and increase revenue. The LL-65 has the same bonus overload capability as the 55 degree transformer, i.e., 180 percent of nameplate rating. A new Insuldur insulating system plus a new high-temperature oil permits the increase in operating temperature while increasing the safety factor, or life expectancy. This allowed designers to reduce the cooling provisions and thereby increase the amount of copper in the transformer while keeping total cost approximately the same.

formers are now used. Not only would the cast version be naturally fireproof, but also could be smaller than present units for this purpose.

Cast resin power transformers for wide-scale application are still some distance in the future; however, early experiments with small versions have led to the 1000-kva commercial unit previously mentioned. If progress continues as rapidly, the cast resin transformer may soon take its place in the transformer family. ■ ■ ■

Unoreg Grows

The Unoreg voltage regulator has been joined by a bigger brother, rated at 2½ kva. Whereas the original design, rated at 1¼ kva, was suitable for load kva up to 25, the new design extends the application of this regulation principle up to 50 kva. Both voltage regulator designs can provide regulation of ±5 percent at 240 volts.

The Unoreg voltage regulator is designed for use on the low voltage side of distribution transformers to provide regulation on secondary lines. It can be used in either of two ways: to *buck* the secondary voltage of individual transformers located at the head end of a feeder; or to *boost* the secondary voltage of distribution transformers located at or near the end of heavily loaded feeders. The device can now be applied to eight different transformer kva ratings.

The 2½ kva unit uses many of the mechanical parts contained in the lower rated unit, except that more iron is used in the core. New features include the addition of an adjustable output voltage control, which permits adjustment between 230 and 250 volts; this adjustment requires only the removal of the cover and movement of an adjusting knob. Among the other changes is the elimination of the limit switches formerly used to control the amount of rotor travel of the regulator; these have been replaced by a mechanical stop. ■ ■ ■

Underground Distribution

Although underground distribution systems offer many advantages—reduced voltage drop, fewer service interruptions, and better neighborhood appearance, to name a few—they have not yet been widely used. Two of the reasons: lack of uniformity in application practice, and the lack of a sufficiently flexible distribution transformer to fill the varying needs. A new primary service, pad-mounted transformer should help eliminate some of these problems.

Basically, the new transformer consists of three main components—a transformer compartment, a detachable high- and low-voltage terminal compartment, and a removable cover that provides isolation of all electrical connections and tank hardware.

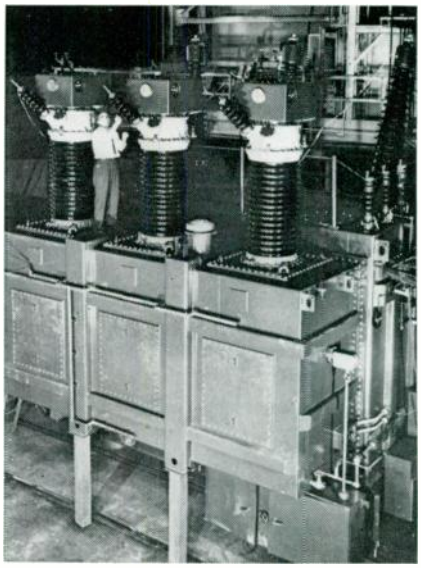
Optional features lend much flexibility to the transformer. For example, it can be equipped with a high-voltage load-break air switch, which has a visible disconnect suitable for isolating a transformer or sectionalizing the high-voltage circuit. The switch is an integral part of the bushing. For complete safety, a visible disconnect knife blade is located directly below the switch and mechanically interlocked with it. The visible disconnect blade cannot be opened until the load-break switch is opened; the circuit cannot be closed until the visible disconnect blade is closed.

A factory-built stress cone for cable termination also adds to the flexibility of the unit, eliminating the need for expensive custom-built stress cones. The high-voltage cable is merely fed through the cone, and the shield of the cable is grounded to the cone. One version of this stress cone also incorporates a fault indicator. Any overcurrent in the cable closes a magnetic circuit, and pops an indicator button to signal the condition. This indicator button is visible from the outside of the closed transformer.

Another element of flexibility is added by an optional meter box, with provision for four 200-ampere watthour meters. With this feature, the utility need only connect the service

This 200-mva power transformer is the largest unit in this country to use a resistance-switched high-voltage tap changer. The novel high-voltage tap changer (URH) achieves two purposes; it increases contact life, and reduces weight and shipping length. The unit is 10 percent lighter than conventional transformers with tap changers using series transformers and preventive auto-transformers; and the shipping length is reduced by 25 percent.

The selector switch for the tap changer is located at the lower end of the large porcelain bushing and contains a number of parallel contacts. The transfer switch is located in the compartment on top of the large bushing. All connections, both mechanical and electrical, between the transfer and selector switches are made inside the porcelain bushing.



entrance leads from the home to the terminal block provided in the low-voltage compartment.

These new primary service pad-mounted units are designed for residential underground distribution on grounded-wye loop or dual feed systems in primary voltages up to 15 kv. ■ ■ ■

SWITCHGEAR

SF_6 on Test

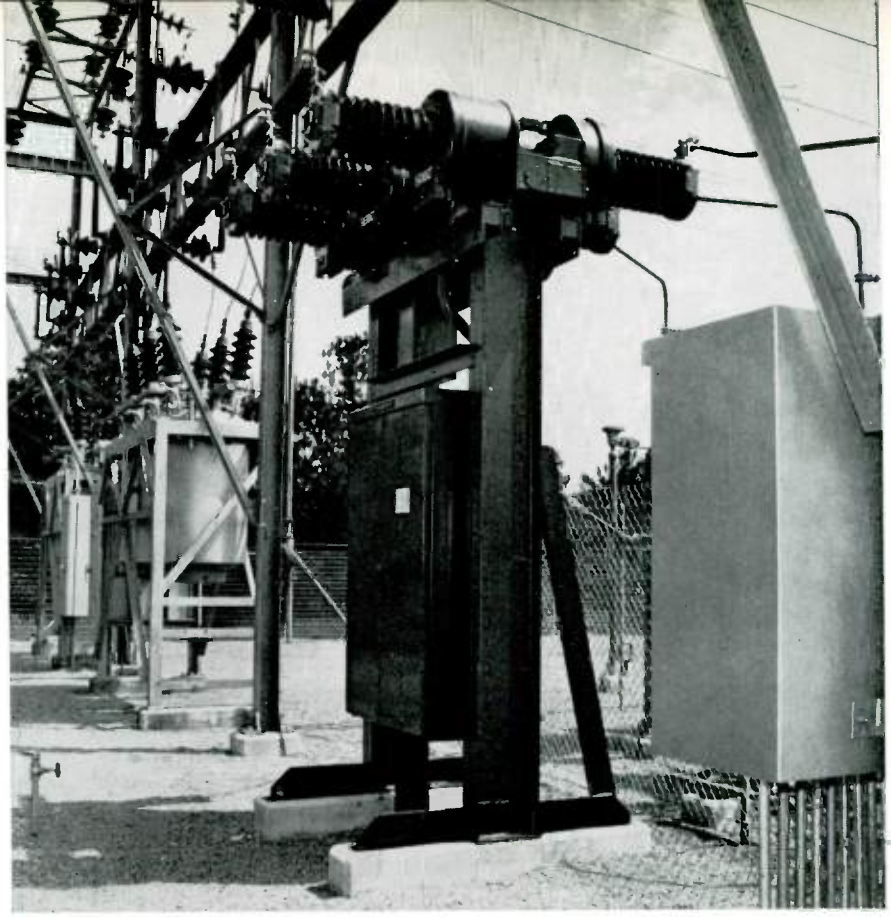
The 230-kv SF_6 breakers passed their undergraduate tests at the Westinghouse high-power laboratory last year. Now out in the field, several of these breakers are taking graduate exams. The Southern California Edison Company tested a 230-kv breaker for fault interrupting capability. The breaker is now installed at the utility's Mesa substation.

The Magrini Company, the Westinghouse Italian licensee, has also put a 230-kv SF_6 breaker through several types of tests. These tests were conducted at the Fontenay and the Plessis Gassot substations on the Electricite de France Power System near Paris. Several tests were performed. Transformer magnetizing current interrupting tests were successfully conducted with a minimum of overvoltage; fault-current interrupting tests were conducted with the fault located at the bus and also further out on the line to obtain maximum severity of rate-of-rise recovery voltage. The SF_6 breaker has passed all tests with "excellent grades." ■ ■ ■

Lightning Arrester Handles Higher Fault Currents

One problem arising with the application of many types of apparatus to electrical systems is how to safeguard against consequential damage that might result from the failure of the apparatus if such failures are likely to cause the flow of system short circuit current.

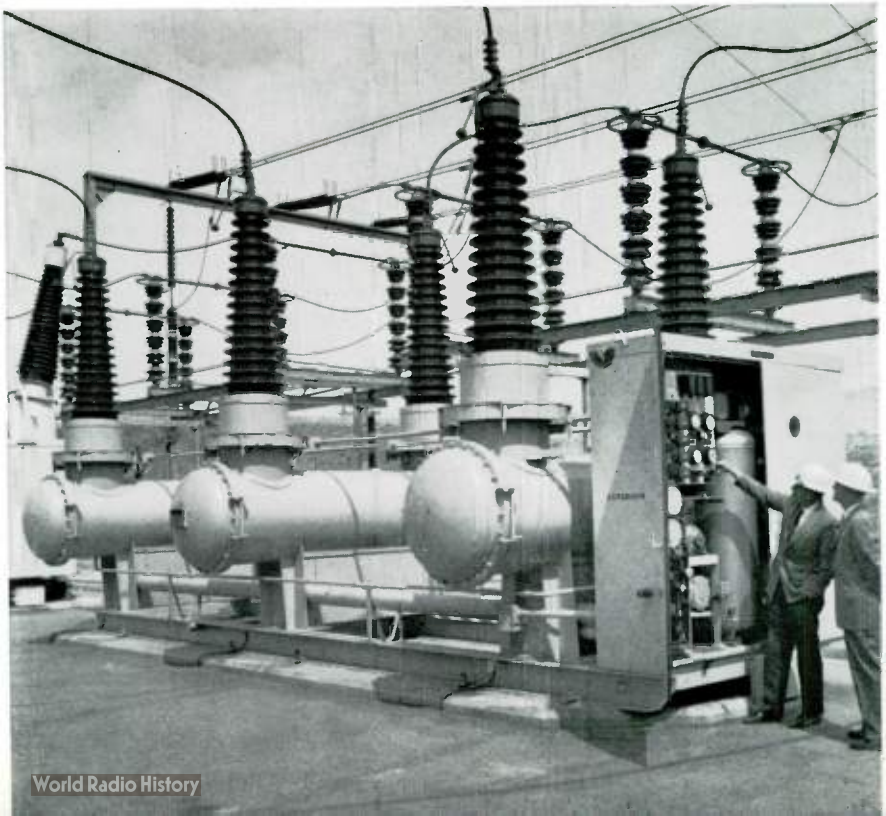
In the past, the typical safe fault current rating of the intermediate arrester has been 5000 amperes, whereas for the Westinghouse type SVS autovalve station arrester, the safe fault current rating is 45 000 amperes. This leaves a large application gap where the protective characteristics of the intermediate arrester were sufficient, but the safe fault current rating was too low. This area has



Above This 46-kv, 500-mva SF_6 breaker went into service on the Georgia Power Company system in July 1961. This is the first installation of this new type of moderate-mva breaker, which will be made with voltage ratings of 34.5 and 46 kv. A puffer-type interrupter is employed, which is closed pneumatically and spring opened. Each pole unit, including the porcelain bushing, is filled with gas at 45 psig. This pressure is sufficient for both insulation to ground and interrupting duty. The puffer-type interrupter forces gas through an orifice built into the moving contact to help extinguish the arc.

Design simplicity is the primary feature of this new breaker. Since only one set of contacts, one interrupter, and one break are used per pole, adjustment is simple and minimum maintenance is required. Engineers believe that this breaker can be placed in service on a five-year or longer maintenance basis.

Below A 230-kv sulfur hexafluoride breaker installed at the Mesa substation of the Southern California Edison Company.



been closed with a new design IVS intermediate arrester that has a safe fault current rating of 25 000 amperes. The increased rating has been made possible by a newly designed pressure relief device for the intermediate arrester. A small three-inch diameter plate soldered to the steel cap breaks free to provide a quick escape for the arc gas when the fault occurs through the arrester. Exhaust vents are located on the top and bottom castings which direct the arc gases away from adjacent equipment and also assist in transferring the arc to the outside of the arrester.

The arrester is also equipped with a low-current protective device, which is located at the bottom of the arrester. This safety device functions in the event that at low fault currents the arrester would not vent the internal pressure, thus becoming a dangerous device to be handled by the serviceman. ■ ■ ■

MEASUREMENTS, DISPATCH, PROTECTION

Meter Developments

As business computers come into more and more widespread use for such purposes as billing for electric power, devices that supply information for the computer are being made automatic. With a new demand recorder, power demand can be recorded on tape, and the results changed by a translator to a form suitable for computer use, either punched cards or paper tape.

The new demand recorder, designated the WR-1, operates in conjunction with a contact-equipped watthour meter. Pulses representing specific energy blocks are stored on one track of a standard quarter-inch magnetic tape. Timing pulses for the demand interval are imposed on a second track of tape. The translator counts the number of energy pulses between successive time pulses and records the resulting demand values on punched tape or cards.

In addition to eliminating the need for visual reading of demand charts and subsequent translation into information used by a billing computer, the new demand recorder is also suitable for system surveillance.

Several channels are available on one tape, which means that the unit has flexibility for other applications. For example, kwhr and rkvahr can be recorded on separate channels and the translator used to convert this to kva demands.

The new recorder will accept a maximum of 1000 pulses per demand interval, and is made in 15, 30, and 60 minute interval styles. Enclosures include Flexitest switchboard cases, or surface mounting units.

Remote Meter Reading—A new impulse receiver can be used to read meters remotely. Contacts installed on a watthour meter produce pulses with every revolution of the meter disc. These 120-volt pulses operate a stepping motor in the remote receiver; this is a motor that rotates a definite number of degrees for every pulse received. The output shaft is geared to either a kilowatthour register (Type W) or a demand register (Type WM). Since each register can be built with a large variety of gear ratios, an appropriate register can easily be selected to read kilowatthours or kilowatt demand directly, or with a multiplier of 10, 100, 1000, or 10 000. ■ ■ ■

Transfer-Trip Relaying

The application of transfer-trip high-speed relaying is gaining in popularity, especially where it is desired to trip a remote circuit breaker for a transformer fault at a station where no breaker is used on the high-voltage side.

The new Type TA audio tone equipment has been designed especially for transfer-trip applications using frequency-shift audio tones for pilot-wire or microwave channels.

In operation, the transmitter normally sends a hold or guard frequency. In the interest of security against undesired tripping, and to allow testing of the tone channel while the equipment is in service, two tone signals are used with their trip contacts in series. If a transformer fault occurs, the operation of a differential relay causes the two tone signals to be shifted from the guard frequency to the trip frequency.

At the receiving terminal, reception of the trip frequencies, and the absence of the guard frequency initiate tripping of the current breaker. A carrier deterioration detector is used to prevent false operation due to channel deterioration or interruption. The sensitivity of the device is set so that its relay will drop out at a predetermined value, disabling the trip function of the channel below this setting. The detector circuit operates on both the hold and trip frequencies.

The TA tone equipment is completely transistorized and is of modular construction, using plug-in units for various combinations to meet the requirements of each individual application. Each module performs a single function, such as frequency determination, amplification, or filtering. The modules are of uniform height and plug into a chassis which is suitable for standard 19-inch rack mounting. A single chassis provides for mounting of two transmitters, or two receivers, or a single transmitter-receiver combination. ■ ■ ■

Instrument Transformer Improvements

Instrument transformers for metering and relaying use on high-voltage systems continue to improve in two seemingly divergent directions—they get smaller and lighter, but at the same time capable of equal or greater electrical performance.

One new group of APT transformers covers the range from 25 through 69 kv, at BIL's of 150 through 350 kv. Compared to their predecessors, the new units are about 20 percent lighter on an average (typical reduction: 600 to 480 pounds), and 10 percent smaller. They also require less oil—a typical reduction being 14 to 12 gallons. At the same time electrical performance is equal or better than preceding units.

Aside from the difficulty of continually trying to improve upon what they have done, instrument transformer engineers have an added problem—that of increasing transmission voltages. A new APT potential transformer is designed for use on 345-kv systems, and transforms the voltage to 115 volts. This oil-immersed transformer is designed for 1300-kv BIL. A 900-kv BIL transformer for use on 230-kv systems was the previous milestone in this type of application. Interestingly, this new APT design is about 20 percent of the size and weight of similar transformers for lower voltage levels produced as recently as five years ago.

APPLICATIONS OF POWER

This log barker, located at the Dickman Lumber Company in Tacoma, Washington, can strip bark from logs as large as five feet in diameter. The log is fed through a rotating ring (at right in photo), to which are attached several cutter heads. These cutter heads are held against the log by air cylinders, and the ring is rotated by a 75-hp, two-speed wound-rotor motor (at left in photo). The log is driven axially through the ring by a 40-hp dc motor, which the operator can control from zero to full speed in either direction by a stepless adjustable-voltage drive system.

DRIVES AND CONTROLS

Computer Controls for Steel Mills

On-line digital computer controls were built for four rolling mills in 1961 and were being designed for others. By automatically computing the best combination of mill settings and passes for each rolling sequence, they make the steel-rolling process much more of a science than it ever has been before. The four mills in which the new Prodac controls have been installed or are being installed are a 134-inch reversing universal plate mill, a 56-inch hot-strip reversing mill rougher, a 210-inch plate mill, and a combination blooming, slabbing, and plate mill.

The controls are the first in the industry to combine digital on-line process computer control with punched-card programming. The details of each installation vary, but in general the computer draws on three sources of information: Basic information (such as slab dimensions and desired plate dimensions) fed in by punched card for each ingot or slab; permanent process information stored in the computer memory; and signals from the mill instruments such as screw and side-guide position indicators, hot-metal detectors that locate the metal with respect to the mill, pressure gauges that indicate roll separation force, and x-ray and length gauges that indicate the dimensions of the work in progress. The computer uses this information to compute the number of passes, the point at which the slab is to be turned, and the mill settings that determine the drafting (reduction) in each pass.

Priority-director circuits in the computer alter a rolling program immediately if high-priority signals, such as notification of changed process conditions, are received. For example, the computer changes the number of passes and the drafting in each pass if measured roll force and torque vary significantly from the computer's predictions. This priority direction permits one computer to perform many control functions—it can keep track of a number of pieces of steel while calculating optimum rolling schedules, printing data, and displaying information for the operator.

On-line calculation of rolling schedules permits the mill to roll each piece in the fewest number of passes, minimizing process time and increasing production. It also improves quality and permits duplication of product characteristics in separate runs. ■ ■ ■

Static On-Off Regulator for Industrial Drives

An on-off magnetic-amplifier regulator will provide optimum response for steel-mill auxiliary drives. In one of the initial applications, it was used in a precise automatic roll-positioning system that positions to an accuracy of 0.001 inch from a top speed of 45 inches per minute.

The regulator replaces combination magnetic-amplifier/exciter regulating systems for completely static control of adjustable-voltage drives.

It uses a bistable magnetic amplifier as the regulating element. The power amplifiers are fast-response 400-cycle magnetic amplifiers connected for push-pull operation to excite generators for reversing adjustable-voltage auxiliary drives.

The on-off characteristics of the bistable magnetic amplifier cause the power amplifiers to apply full forward or full reverse voltage to the generator field, alternating as required to maintain the average field voltage at the required level. Because of the generator field inductance, field current has only a small ripple. The regulator applies full field forcing voltage, when generator voltage is being changed, until voltage reaches the desired level.

Besides the advantage of fast response, the new regulator has such inherent stability that rate feedback adjustments are not critical. Its static components require little maintenance, and it operates on low-power control signals (about 20 milliamperes for full generator output).

The regulator's fast current-limiting action gives optimum protection on impact loads, and it is adjustable to supply more current at low generator voltage than at high voltage to match the generator commutating ability.

The regulator can be used to excite relatively large generators directly, with high forcing rates for fast response. It has been applied to generators up to 800-kw with full field forcing and up to 2500-kw with less forcing. Its output circuit permits use of generators with only one shunt field instead of the two required with many push-pull systems. ■ ■ ■

Control for the Paper Industry

Paper-making machines, and other sectional machines for continuous process industries, have long been controlled by systems that are basically analog in nature. These regulators serve admirably for many applications, and they are constantly being refined.

However, the voltage-generating tachometers and reference voltage generators in such systems are subject to inherent drift that limits the system accuracy and often makes frequent adjustment necessary. Consequently, digital control techniques have been devised for high-speed machines that require great accuracy.

The T-100 regulating system was developed for applications in which speed error must be held to about 0.1 percent of top speed. It senses section speeds with digital tachometers and digital counting circuitry, thereby eliminating one source of accuracy limitation in all-analog systems. The accurate speed information is converted to an analog signal for comparison with a reference signal. Besides improving accuracy, the digital speed-sensing equipment permits use of numerical readout and data-logging equipment.

One of the first applications of the T-100 system was to a 10-section, 231-inch paper machine that makes lightweight coated book paper in the St. Regis Paper Company mill at Bucksport, Maine. The control was designed for eventual machine speeds up to 2000 feet per minute. A printout typewriter in the system gives management a precise speed and speed-difference record in easily used form.

An all-analog variation of the T-100 system employs analog speed sensing but retains the other features of the system. It has been applied to a new 100-inch paper machine being built by Black-Clawson Company for production of facial tissue at speeds up to 2500 feet per minute in a Brown Company mill at Berlin, New Hampshire.

The control will regulate four independent machine sections, but only the highest-inertia section (the Yankee dryer) will be controlled by a master reference—the signal from this section's dc tachometer serves as a reference for the other sections.

Although the other sections will "follow" the Yankee dryer, their

speeds can be adjusted individually to secure the desired speed differences between sections.

For applications requiring the utmost in control accuracy, the first all-digital regulating system has been developed. This Pulsetter control gives overall machine steady-state accuracy of 0.01 percent and section-to-section accuracy of 0.025 percent under normal papermaking conditions. The initial installation is on a modernized paper machine of the New York and Pennsylvania Company, Johnsonburg, Pennsylvania. It is part of a new drive that replaces one originally supplied by Westinghouse in 1926. The new equipment increases the capability of the drive from a former top speed of 650 feet per minute to 1400 feet per minute. ■ ■ ■

DACA Working in Paper Mills

The DACA electric governor, described previously in this issue in conjunction with its application to computer-controlled steam plants, got its start in the paper mills. The first "breadboard version" was installed and tested at the International Paper Mill at Bastrop, Louisiana in late 1958. A prototype version of DACA was substituted for the breadboard version in July, 1959. Both of these versions were deliberately located near the turbine, where the most severe environmental conditions—moisture and heat—exist. Prototype testing also included an "oven test" at 160 degrees F. All of these tests were designed to prove the ability of the all-static circuitry used in DACA.

The DACA governor is designed to allow smooth acceleration from zero to the desired operating speed. It will hold within ± 0.1 percent of desired operating speed over a ten-to-one speed range, or ± 0.2 fpm for a 200 fpm machine. A major advantage of the electric governor over conventional mechanical-hydraulic governing devices is that the gain of the DACA governor will remain constant regardless of speed, whereas with a conventional mechanical-hydraulic governor, gain varies with the square of speed. A conventional governor is used with the DACA installation, and normally functions as an emergency control device. It is set to operate above the maximum DACA speed. Both governors are then set so that the lower speed setting will maintain control of the turbine. The mechanical governor will therefore assume control only if the speed should exceed maximum desired value.

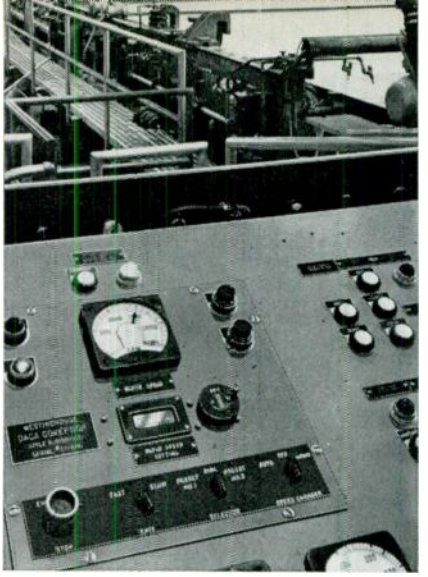
The speed-setting control can be manual or automatic. The DACA control also has a "preset" speed-setting feature. For example, one preset speed is normally set for "washup," so that the papermaker can preselect the speed and the machine will automatically come to washup speed for cleaning the Fourdrinier wire.

The DACA governor is a combination digital and analog device. A digital input signal is obtained from a reluctance pickup, located adjacent to a gear or notched wheel on the rotating shaft. This pulsed signal is compared with a digital reference signal provided by a crystal oscillator. Both reference and speed signals are amplified while in digital form. The signals are converted to analog voltages by identical saturating transformer converters, which are close coupled thermally, and an analog error signal is derived. The error signal after being amplified goes to the torque motor of an electrical-hydraulic converter, where a corrective oil pressure signal is produced. This signal or the signal from the conventional governor (depending on which is at higher pressure) actuates the servo-motor relay pilot to properly position steam admission valves on the turbine.

Two DACA governors were installed on paper mills in 1961. The International Paper Company had one go into service in January at their Georgetown, South Carolina mill. Another went into operation at the St. Regis Paper Company's mill at Tacoma, Washington. ■ ■ ■

Electric Log-Carriage Drive

Quick response and easy control are important in sawmill log-carriage drives, for the former saves time and thereby increases production and the latter permits the sawyer to concentrate on getting the most lumber out of a log. Steam drives, in which a large piston moves the carriage back and forth, have long been standard. They are fast and have good response, but control is a problem because the carriage movement is initiated and reversed by a valve lever operated by the sawyer. Operator error or valve malfunction can cause the carriage to get out of control and overshoot its safe travel limits. Also, operating the steam valve for control of speed and travel requires a large portion of the sawyer's attention.



This DACA electric governor is installed at the Tacoma plant of the St. Regis Paper Company. It starts, stops, and adjusts the speed of the turbine drive to within ± 0.1 percent over an operating speed of 200 to 2000 fpm.

Another consideration is economy. When sawmills disposed of large amounts of scrap wood and bark by burning it, steam was practically free. Now, however, so much "scrap" is converted into salable products that steam has to be generated, at least in part, with commercial fuels.

These considerations have led to development of variable-voltage electric log-carriage drives. The latest one, installed in the Council, Idaho, mill of the Boise-Cascade Corporation, is as fast and responsive as a steam drive and much easier to control. It is powered through a reduction-gear and cable drive by a dc log-carriage motor that is designed for high torque and low inertia. The motor is energized by an m-g set.

Current-limiting control provides maximum torque for acceleration with no overstressing of the equipment. The magnetic-amplifier regulator gives the operator responsive and effortless control. Limit switches at each end of the track prevent excessive overtravel. The carriage moves at 600 feet per minute for sawing and accelerates to 1360 feet per minute in one second for return. The drive system regenerates power when the carriage is decelerating, minimizing operating cost. ■ ■ ■

Static Control for Industrial Drives

Modern industrial machines are rugged pieces of equipment, and their control systems must be equally rugged. At the same time, the controls must be precise and fast acting, and their components should be standard and interchangeable.

These requirements point to all-static control systems. Such systems, based on semi conductor devices, have been developed. They are adaptable to all dc adjustable-voltage systems, including drives for steel-mill, paper-mill, lumber-mill, and material-handling machinery.

The new control systems were made possible by development of the Trinistor controlled rectifier. This static semiconductor device blocks an applied voltage from appearing across the load until a small controlled current pulse is applied to its gate lead. Controlled rectifiers are used to replace rotating exciters for supplying excitation power to the fields of main-drive dc generators.

A description of the use of these control systems in shovels and draglines will illustrate their principles.

A small Magamp firing circuit serves as a computer to time the gate current pulses that permit the Trinistor devices to conduct current to the load. By controlling the firing angle, or duration of conduction during each half cycle of ac power, the firing circuit controls the amount of load power transmitted through the controlled rectifiers. This permits a wide range of excitation voltage adjustment for the main drive dc generator fields. The system regulates voltage for the hoist and crowd motions of a shovel (or hoist and drag motions of a dragline) and current for the swing motion.

The response time of the Trinistor controlled rectifier is only about two microseconds, so its reaction to control changes is essentially instantaneous. Because the time delay of the Magamp firing circuit is also negligible, the only significant time delay in the system is that of the generator field. This eliminates stability problems and permits use of simplified regulating circuitry.

Fast response is especially important in shovel controls because the system is subject to difficult conditions such as "bucket stalling." The generator field excitation must be forced down quickly, when this happens, to prevent damage to the shovel structure, cables, and motors.

Another advantage is the reduced space requirements. Instead of an exciter motor-generator set, only a small panel is required. Space also is saved by the fact that the high gain of the Trinistor amplifier makes it possible to use a small Magamp device.

Finally, the control design lends itself well to standardized modular construction, with the resulting advantage of component interchangeability and easy maintenance. The firing circuit, called a pulse position modulator (PPM), is assembled on a printed circuit board and enclosed in a shock-absorbing compound. The PPM, 50-ampere Trinistor controlled rectifiers with their heat sinks, and protective surge suppressors are assembled with fuses and a fuse-loss relay to make up a Trinistor power amplifier (TPA). TPA panels will be interchangeable for all motions on any size shovel and interchangeable between most loader-size shovels. The larger machines will have interchangeable TPA panels for all motions but will require Trinistor devices of higher current rating than those used in the loader sizes.

The all-static generator field controls have been designed for a number of shovels and draglines, including the monsters of the industry. One of these is a 45-yard dragline being built by Marion Shovel Company for coal stripping; the others are two 115-yard shovels being built by Bucyrus-Erie Company, also for coal stripping. These will be the largest dragline and the largest power shovels in the world when completed. ■ ■ ■

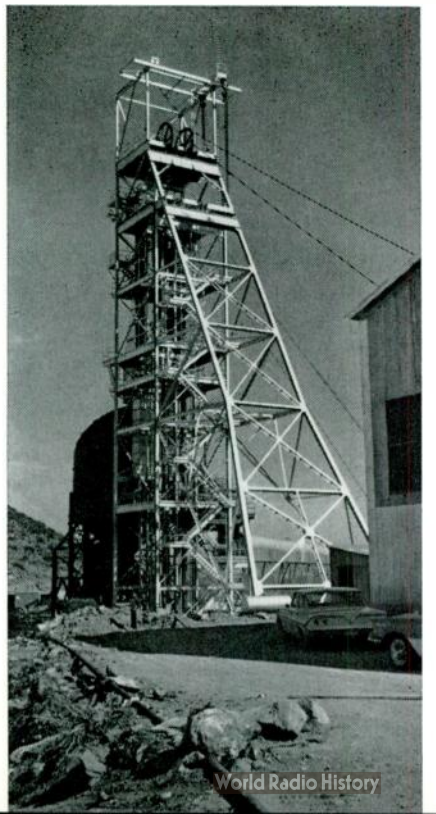
Automatic Control for Mine Hoists

Mine operations have much in common with other material-handling operations and, as in the others, automation is increasingly used to improve efficiency and increase output. One of the most rewarding areas for automation is in control of service and material hoists. Providing control of start, stop, and destination from inside the service-hoist cage has been difficult because the control signals have had to be transmitted up the shaft through trailing cables. These cables are heavy, cumbersome, and subject to damage from tangling, dampness, and abrasion.

A new system provided for the service hoist at the Inspiration Consolidated Copper Company mine near Christmas, Arizona, eliminates these problems by sending pushbutton control signals from the cage up the hoist rope on high-frequency carrier waves. The signals are taken off the cable by an antenna at the top of the hoist and transmitted to the control system.

A production hoist with balanced skips shares the shaft with the service hoist. Both hoists have adjustable-voltage dc drives with 700-horsepower motors—one motor for the service hoist and two for the production hoist.

The production hoist has two generators in its m-g set and the service hoist one generator. All the motors and generators are identical for minimum spare-parts inventory. Kvar reactive compensation in the production hoist drive increases the field strength of the motors when pulling heavy loads. This makes a flywheel m-g set unnecessary and makes it easier for the utility to supply this remote location.



Control signals for the service hoist in this mine are transmitted up the hoist rope on high-frequency carrier waves for automatic operation of the control system in the hoist house at right. The installation is at a new mine of the Inspiration Consolidated Copper Company near Christmas, Arizona.

The hoist controls have an electromechanical programming device that reproduces the conveyance travel with a moving replica advanced slightly ahead of the actual position of the conveyance. This advance selector anticipates the conveyance position and programs slowdown and stop at the selected levels. ■ ■ ■

MOTORS

Heat-Exchanger Cooling for Totally Enclosed Motors

Many applications, especially in the machine-tool industry, require adjustable-speed dc motors with speed ranges of 10 to 1 and constant torque. Cooling problems in such conditions have limited totally enclosed motor size to about 75 horsepower. A new motor with an independent blower system increases the range of sizes to 250 horsepower at 1150 rpm.

The new Life-Line "H" totally enclosed motor consists of a standard dripproof SK-H motor, a vertical ac blower motor, two blowers, an air-to-air heat exchanger, and an enclosure. The internal blower forces hot air from the commutator end of the dc motor through ducts in the aluminum heat exchanger, through the ac blower motor, and then into the rear of the dc motor.

The external blower forces room air through the outer ducts of the heat exchanger and discharges the heated air into the room.

This arrangement gives a constant cooling rate over the entire speed range, resulting in greater speed range with higher continuous constant torques than fan-cooled or nonventilated motors can supply. ■ ■ ■

CONTROL AND DISTRIBUTION DEVICES

Shrinking Control Relays

The increasing complexity of machine tools creates new design problems, one of which is the increased space required for the controls. To help overcome this problem, two new space-saving relays have been developed. They save up to 75 percent in control-panel space, with attendant savings in valuable floor space. In some installations they permit taking the control equipment off the floor and mounting it on the machine.

The type BF relay is $3\frac{1}{8}$ inches high and $1\frac{11}{16}$ inches wide, and its rated full-load current is 10 amperes at 300 volts ac. It is made in any combination of normally open and normally closed contacts from two to eight, with a maximum of four normally closed and eight normally open. The companion type AF relay is $3\frac{11}{32}$ inches high by $2\frac{11}{16}$ inches wide. Full-load rating is 10 amperes at 600 volts, and it is made in any combination of normally open and normally closed contacts from two to ten, with a maximum of five normally closed and five normally open.

One of the first major applications for the BF relay was in a control panel for an automobile engine transfer line, where its use saved about 40 square feet of floor space.

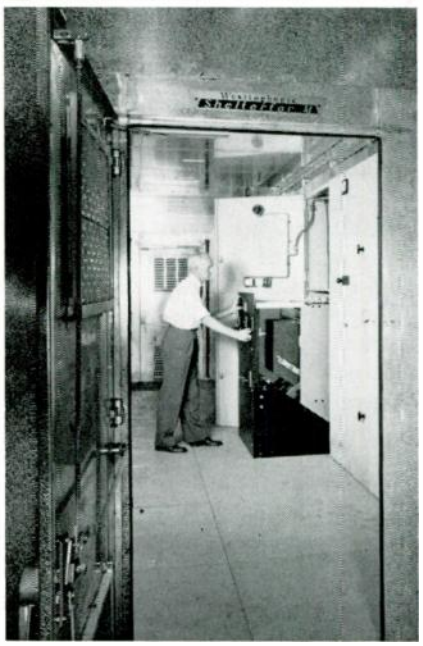
Designed for millions of operations, the relays have hardened magnet and armature pole faces, short operating strokes, and contact wiping action. Operating time for the AF relay is 0.0085 to 0.014 seconds on pickup and 0.005 to 0.011 seconds on dropout; for the BF relay, it is 0.0125 to 0.018 seconds on pickup and 0.006 to 0.0125 seconds on dropout. ■ ■ ■

Type DFS Switchgear—A Welterweight Contender

The application of metal-enclosed switchgear has been expanded into a new application range. The type DFS switchgear can provide compact, low-cost power switching for 2.4- to 13.8-kv circuits in commercial buildings or small industrial plants. This new switchgear can be applied where a circuit breaker is not really required, but reliable protective equipment is needed.

Load interrupting ability up to 500 mva at 600 or 1200 amperes is provided by a load-interrupter switch. A special quick-closing mechanism permits the switch to be closed into faults as high as 40 000 amperes. Fault interrupting ability is provided by current-limiting fuses. Both the interrupter switch and the fuses are mounted on a removable element, which can be completely withdrawn for inspection and fuse replacement.

The stationary metal structure has provision for mounting instrumentation, current transformers, or metering. Remote control operation can be added as a special feature.



Above The LBF load break switch is mounted on a versatile frame.

Below The DFS metal-enclosed switchgear can be used outdoors in the Shelter-for-M enclosure.

LBF Load Break Switch—The LBF load break switch is basically the same interrupter switch as used in the DFS metal-enclosed switchgear. However, it is mounted on a special frame for wall mounting or separate mounting. This switch is designed to operate under normal load conditions of 600 amperes at 5, 7.2, and 14.4 kv. The LBF is capable of closing into loads of 60 000 amperes at 5 kv or 40 000 amperes at 15 kv.

This switch employs a unique torsion bar for a drive to power the blades. The switchblades can be driven with a handle mounted directly on the switch assembly, or these same parts can be used with a remotely located handle. Separately mounted fuses can be used in conjunction with the LBF switch to provide positive fault-interrupting ability. ■ ■ ■

New Current-Limiting Fuse For Large Motors

The CLS-1 current limiting fuse has been specially designed to provide short-circuit protection for high-voltage, high-capacity motors. To force quick interruption, the fuse is designed so that a high arc voltage is generated and maintained. This arc voltage causes the current to be reduced to zero in less than ½ cycle. Quick interruption is needed to limit peak current, thereby keeping magnetic forces and internally generated heat in the motor and circuit to a minimum.

The fuse has also been designed fatigueproof. This is especially important on applications where motor starting is frequent, since the motor must carry locked rotor currents up to six times full load current for as much as 100 seconds. This high current heats the fuse and can cause a general fatiguing of the fuse element. The fatigue-withstanding ability of the fuse was accomplished by prebending the element in an accordion fold. This prebending causes the expansion that occurs in the element during heavy loading to be uniformly distributed, so that the variation in stress at any one point on the element is kept well within the endurance range of the metal used.

The fuse barrel is filled with a silica sand which absorbs arc energy and helps maintain the high arc voltage.

The fuses are designed for application on 2.5- and 5-kv motors, and will interrupt currents up to 64 000 amperes asymmetrical. ■ ■ ■

LAMPS AND LIGHTING

Lamps for Many Purposes

The already fantastic array of light sources for almost every conceivable general or special purpose lighting need continues to grow in number and variety. Consider, for example, two lamps developed during the past year.

In some applications for miniature indicator lamps a metal base and threads can be a nuisance. In automobile dashboards, for example, where space is at a premium, the necessary "maneuvering room" to screw in a bulb is hard to come by. Also, in some high-temperature applications for these miniature bulbs, cement holding the metal base to the lamp sometimes fails, so that the bulb can become detached from its base. A new bulb alleviates these difficulties; it has no metal base or threads. Instead the glass at the end of the bulb is formed into a flat wedge, and the bulb is merely pushed into a simplified socket. Electrical contact is made by two wires crimped into recesses in the wedge base. The new design is also especially suited for use in printed circuits, because the sockets can be automatically molded into the circuit board. Two versions are now being produced—a 12-volt, two candlepower lamp with a rated life of 500 hours, and a 12-volt, one candlepower bulb with a life of 1500 hours.

Another new variety of lamp is a combination of a bright light source suitable for normal household use and a low-brightness filament suitable for use as a night light. The new bulb is designed for use in conventional three-way sockets; on two positions of the switch the bright light is on, and in the third the low night light is on. The night light filament is specially designed for long life, since it is usually left burning for longer periods of time. The new lamp, called the Glow-Bright bulb, is made in two sizes, 150 and 100 watts. ■ ■ ■

The CLS-1 current-limiting fuse was developed for large motor protection.

Flexible Light Distribution

Proper control of light distribution from a streetlighting unit is an important consideration in adequate lighting. For example, some conventional streetlighting units are designed so that their reflectors and refractors distribute light in a long, relatively narrow pattern along the axis of the street; this works fine—unless the same fixture is to be used at a T intersection, or a crossroad, where the light distribution needs to be quite different. Until recently there was only one practical solution—use the same light distribution for many different situations. Otherwise, there arose the problem of special refractors for each situation.

A new concept involves the use of a refractor consisting of four separate segments. By proper choice of segments from six available panels, the streetlighting pattern can be custom designed to meet the requirements of the area to be lighted. The four segments, made of clear acrylic plastic, fit securely together in an interlocking design, creating four flexible joints. The six panels enable a variety of light distributions. One is an opaque shield that can block light; a second is a prismatic shield, which reflects light hitting its inner surface; a third "bends" light to the left; a fourth bends it to the right; a fifth beams all light striking its curved surface into parallel beams; and the sixth transmits light equally in all directions.

Any combination of the quadrant refractor elements can be placed in this fixture. The unit, the Quadroliner, is made for incandescent lamps up to 6000 lumens, and for mercury lamps up to 175 watts. ■ ■ ■

Light Plus Heat—In One Unit

Lighting and air diffusion for air conditioning are combined in one new recessed troffer that looks like a conventional fluorescent lamp fixture.

Air ducts rim the long sides of the new fixture, and therefore form an inconspicuous part of the element. Actually, despite its outward appearance, the Air-liner, as it is called, is two separate products wedded. One is an Anemostat air diffuser, the other a lighting fixture modified to hold the diffuser. The units are installed separately—the diffuser first, and then the lighting fixture. The combination of diffuser-lighting fixture requires only 5½ inches of mounting height.

The Air-liner can handle air for heating, cooling, or ventilating, and diffuses the air horizontally into the room. The unit is made in one-by-four foot fixtures that hold two or three 40-watt rapid start lamps, or two-by-four foot fixtures that hold two, three, four, or six 40-watt lamps. ■ ■ ■

SEMICONDUCTORS AND ELECTRONICS

Teletronic Watchman

The task of protecting plants and office buildings is falling into "electronic" hands. A new Teletronic plant security system has been developed by Westinghouse engineers to provide round-the-clock protection against such hazards as fire, unauthorized entry, or failure of an air-conditioning system; the system can provide continuous supervision of plant perimeters and gates, plant boiler pressure, or any other condition that can be indicated by a contact-closing device. The Teletronic system is applicable to almost any sized industrial, commercial, or military facility, and once installed can be easily expanded or modified to handle changes in system functions or arrangement.

The system "brain" is located in a central control console, where continuous signals are received from all parts of the plant. Any changes that occur are instantly indicated with visual and audible alarms. Command corrective action can be provided where needed. Thus, the system can operate fire-fighting systems, shut off motors, sound burglar alarms, etc. A continuous printed record is also provided.

Each building or a group of buildings in a large multiplant facility is equipped with an area-control panel, with a pulsing network capable of serving up to 50 unit indentifications across a single pair of signaling wires to the central control console. Up to 50 sensors or transducers can be connected to each area control console.

The Teletronic plant security system became a Westinghouse product line in early 1961 when the company acquired the assets of Teletronic Security Systems, Inc. ■ ■ ■

More Applications for Taut-Band Suspension

The taut-band suspension principle, introduced by Westinghouse three years ago, continues to find increasing application. Two major extensions of the TBS instrument line this year have been to a complete line of instruments for test equipment, and to a line of portable laboratory instruments.

The new TBS panel instruments (FX-372) have been designed for application in the general test instrument field, such as in vacuum tube volt meters or in multitest-set equipment. The advantages of the taut-band suspension principle—sensitivity, precision, and repeatability—have been incorporated into this new instrument line.

Sensitivity capability of the mechanism permits full-scale deflection with as little as two microamperes dc. (Normal pivot-and-jewel mechanisms have a sensitivity of about 10 microamperes for full-scale deflection.) With this improved sensitivity, a 500 000-ohms-per-volt dc voltmeter can be built with an accuracy of 1 percent, and repeatability within 0.2 percent. In contrast, a vacuum-tube voltmeter has an input impedance of about two megohms for full-scale deflection, but with an accuracy of only 3 per cent. Hence, the new TBS instrument is sensitive enough for many applications where a vacuum-tube voltmeter would normally be used, and can provide improved measuring accuracy.

Provision has been made for three distinct types of taut-band suspension mechanisms for panel instrument application. First, for applications where normal accuracy is satisfactory and low cost is a factor, a mechanism of concentric magnet design, somewhat similar to the standard panel instruments that do not employ the taut-band suspension principle, is provided. Where higher accuracy and higher sensitivity is required, a core-magnet design is used, which is basically the same design as that employed in the high-quality TBS switchboard instrument. Finally, for applications where nonlinear scales, such as logarithmic scales, are required, special magnet designs can be provided with taut-band suspension.

Portable Instruments—The aforementioned advantages of taut-band suspension—sensitivity, shock resistance, and repeatability—are all ideally suited to portable laboratory instruments. Two new portable instruments have been made available—the P-151 with a 100-degree scale, and the P-161 with a 240-degree scale. The longer scale of the P-161 (10½ inches compared to 6 inches) makes reading easier since more divisions can be employed. Both instruments have an accuracy of ½ percent.

Two basic mechanisms are used: For ac voltmeters and ammeters, a repulsion iron mechanism using the suspension principle is employed; for dc voltmeters, ammeters, milliammeters, and microammeters, the core-magnet mechanism is used. All mechanisms are thoroughly shielded from stray magnetic fields. The dc mechanism is inherently self-shielded to the degree that the 100-degree core magnet mechanism can withstand a stray magnetic field of 500 oersteds with less than 1 percent error. ■ ■ ■

DC Power Supplied in Stepless Increments

A readily adjustable and widely variable source of dc power is needed in many industrial and research applications, ranging from metallurgical furnaces to solar-energy simulators. A new power supply, developed to meet these needs, supplies current in a stepless range from 200 to 3000 amperes.

The type SRF power supply has a three-phase stepdown transformer and dc-controlled saturable reactors for control of the ac power fed to a silicon-diode rectifier. The reactors provide the means for adjusting output current and also provide the drooping volt-ampere characteristic desired for arc loads. Reactor control current is adjusted by a motor-driven powerstat, which is easily adapted to remote and automated control.

Protection for the rectifier diodes is afforded by an overvoltage suppressor in which capacitors absorb peak voltage and dissipate it through resistors. Other protective devices take the unit off the line if a diode fails or if the fan motor stops.

The unit can be operated in parallel with other type SRF units or in parallel with fixed-output dc power supplies. The first applications were for metallurgical arc furnaces. Other possible applications include arc plasma generators, submerged-arc welding, carbon arc lamps, anodizing, and plating operations. ■ ■ ■

Solid-State Transmitter

Radio-frequency transmitters which use solid-state active elements rather than thermionic active elements are being developed. This switch to static components will provide several benefits—the reliability obtained by eliminating heated filaments, efficiency, instant starting, and extremely low standby power drain.

The improvements possible in efficiency can be a major advantage for some applications. The solid-state transmitter has a normal efficiency capability of 95 percent as compared to 70–80 percent in a comparable vacuum-tube transmitter. This amounts to a 10-to-1 reduction in the amount of power that must be dissipated in cooling equipment. In applications where heat is difficult to get rid of, this is a major advantage. The solid-state transmitter also offers advantages for applications, such as hardened communications systems or mobile systems, where ruggedness and reliability in a shock or vibration environment is needed.

Engineers are now testing a 5-kw transmitter built of transistors. This transmitter is a nonlinear class C amplifier, with a frequency range of 30 to 1500 kilocycles.

Another solid-state transmitter is being designed using Trinistor controlled rectifiers. This transmitter will develop 150-kw average power for a frequency range of 14 to 30 kc.

Power and frequency are limitations for solid-state transmitters. The Trinistor controlled rectifier, used in a switching mode, should be able to develop r-f frequencies up to 30 kc with power in the hundreds of kilowatts. Above 30 kc high-powered transistors must be used, but with present devices powers will be developed of less than 100 kw. ■ ■ ■

Silicon Diodes for Automobile Alternators

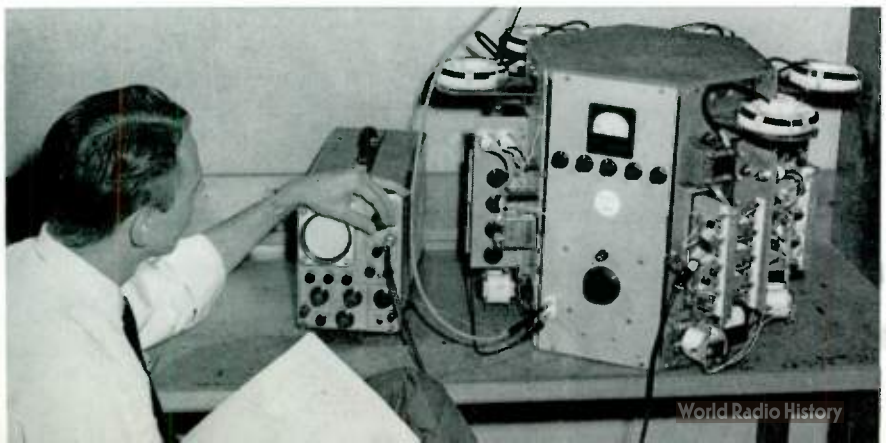
Development of reliable and inexpensive silicon rectifier diodes has made practical the use of ac generators in passenger automobiles. The diodes rectify the generator's ac output.

The main advantage of the ac generators (often called alternators) is that they do not need commutators and consequently can operate at higher speeds than dc generators. This makes them more compact and increases output at engine idling speeds.

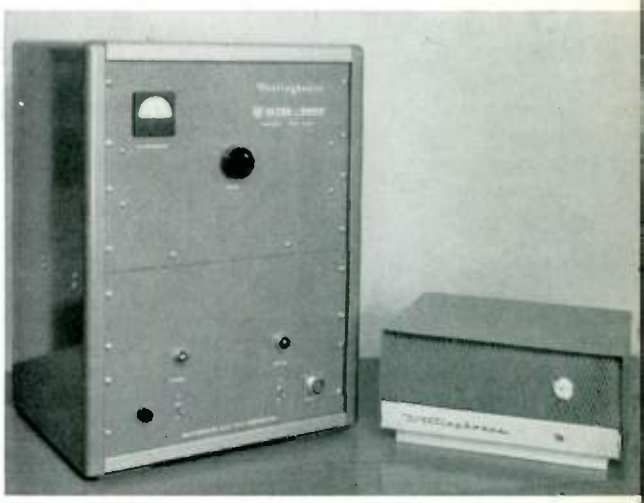
The silicon diodes not only make low-current ac generators for standard automobiles practical but also improve the high-current systems now used in vehicles such as police cars that have heavy electrical loads. These systems have had selenium rectifiers; the new silicon devices make them more compact and are less affected by heat, corrosion, and vibration.

The silicon diodes are pressed into a metal heat sink in the generator housing. Six of them are required per automobile, so they are designed for volume production as well as for reliability and efficiency. ■ ■ ■

This 5-kw solid-state radio-frequency transmitter now on test has a frequency range of 30 to 1500 kilocycles.



The size reduction made possible by solid-state components is illustrated in this comparison between the new one-kilowatt ultrasonic generator (right) and the former tube version (left). The new generator circuit has been simplified to reduce complexity and eliminate components, with the end result being a smaller and more reliable device. The basic oscillating circuit uses a single Trinistor controlled rectifier, and static devices are used throughout. These ultrasonic generators drive a magnetostrictive transducer on the bottom of an ultrasonic cleaning tank. Generator ratings range from 125 watts up to 1 kw, and standard tanks range from 1½ to 16 gallons.



Controlled-Rectifier Range Extended

Trinistor controlled rectifiers have found many applications in such areas as high-frequency power generation, variable-frequency control, pulse generation, ignitron firing, and welding control. They are also being used for direct replacement of thyratrons, contactors, and magnetic amplifiers.

Now the application range for these solid-state devices has been extended by development of more ratings—new 5-, 16-, 70-, and 100-ampere devices supplement the original 50-ampere trinistor controlled rectifier.

The three-terminal silicon devices are essentially switches that block forward voltage below a critical breakover level and switch to a conducting state when a proper gate signal is applied. They can switch high power levels with low loss at breakover voltages up to 300 volts. Their hard-soldered construction enables them to withstand vibration and thermal cycling for maximum life and reliability.

MARINE, AVIATION, AND SPACE

Nuclear Surface Ships

The nation's first nuclear powered surface ship, the USS *Long Beach*, officially joined the fleet on September 9, 1961.

The nuclear-powered cruiser is the first cruiser to rely solely on guided missiles for her major offensive and defensive power.

The *Long Beach* is powered by two nuclear reactors designed and developed by Westinghouse under the direction of and in technical cooperation with the Naval Reactors Branch of the Atomic Energy Commission. The nuclear plant is an adaptation of the aircraft-carrier prototype plant in Idaho, which has been run for the equivalent of five years of normal surface ship operation. The prototype plant was the first to use two reactors in tandem, and during its test program has been started up and shut down over 1000 times.

Some statistics about the *Long Beach* for the nautically inclined:

Standard displacement	16 200 tons
Length	721 feet
Extreme Beam	73 feet
Estimated Cruising Range	More than 140 000 miles

The exact role of the *Long Beach* in our nuclear fleet is difficult to predict, because her potential capabilities are so varied and unique that they qualify her for several missions.

As the *Long Beach* was being commissioned, a second nuclear-powered surface ship, the attack aircraft carrier *Enterprise*, neared its commissioning date, scheduled for late 1961.

In late October, the *Enterprise* completed her initial sea trials. During these trials she developed her design full power, and demonstrated her ability to go from full-speed ahead to emergency astern.

The aircraft carrier is 1101 feet long, has a flight deck beam of 252 feet, and a displacement of 85 000 tons, which make her the world's largest ship. Her eight pressurized water reactors enable her to operate for extended periods without refueling. In continuous operation she could circle the earth several times at high speed. ■ ■ ■

Two nuclear reactors in tandem power the USS *Long Beach*, the nation's first nuclear powered surface ship. She is also the first Navy surface ship to be armed primarily with guided missiles.

Static Line Voltage Regulator

A static device has been developed for regulating ac line voltage under variations in input voltage, load current, and supply frequency. Developed especially for shipboard use, it is lighter and more compact than motor-generator sets with regulators and is relatively unaffected by shock and vibration.

The static regulator maintains nominal output voltage within 0.5 percent despite 5-percent variation in input voltage, 5-percent variation in supply frequency, load variation from no load to rated load, and power factor variation from 0.75 lagging to unity. It responds to load change within 0.1 second, and it can be built in ratings up to 20 kva.

A change in voltage is detected by a voltage detector, and the error signal is amplified by a magnetic amplifier. The output of the magnetic amplifier decreases as the error signal increases, thus increasing the impedance of a saturable reactor. This reduces the voltage to an input autotransformer with consequent reduction in control voltage to an output autotransformer. The input voltage to this autotransformer is line voltage plus the input autotransformer voltage, so changes in the former are compensated by opposite changes in the latter. ■ ■ ■

Computer Programs for Marine Turbines

Because of the large number of variables and the complexity of thermodynamic processes, performance calculations and heat balances on marine steam power cycles are involved and laborious. Combined steam and gas turbine cycles, which have recently become of interest in the marine field, are also complex and difficult to analyze manually. Therefore, marine turbine designers have called upon the digital computer to eliminate this "manual labor."

A highly versatile computer program originally developed for heat balance work in the utility power field has been adapted for marine steam and combined steam and gas turbine cycles. The program, a culmination of four years development, includes a complete and accurate mathematical representation of the thermodynamic properties of water. A unique feature of the program is that virtually any conceivable cycle can be assembled from preprogrammed, "packaged" subroutines.

The computer program for a turbine is built up from separate stage and leakage subroutines. Thus, stage-by-stage turbine performance calculations, involving detailed efficiency and flow parameters, are performed simultaneously and in agreement with the heat balance calculation. In contrast, conventional heat balance programs require the input of information that must be estimated in advance.

In the subroutines for other equipment in the cycle, such as the boiler, feed pumps, heaters, and condensers, performance curves, losses, and thermodynamic properties are included as functions of flow.

Assembling a complete marine cycle for a typical ship can be done in a matter of days. This is usually less time than is required to manually calculate a single load point. Once the computer program for a cycle has been assembled, it can be used repeatedly for additional calculations. Control of the program permits accurate specification of any combination of main and auxiliary power or flow. An assembled program is very flexible in that any part of the data may be easily and quickly changed, either permanently or without destroying the original data. This feature, plus the speed of calculation, means that design optimization can be readily accomplished.

Turbines can be accurately designed to meet every requirement. Test conditions can be matched closely so that calculated stage performance can be easily verified.

The program also permits accurate prediction of cycle performance in cases where main steam pressure and temperature vary widely with flow. It automatically includes all significant variations in cycle component performance under widely different off-design operating conditions. ■ ■ ■

Quiet M-G Sets

Motor-generator sets for submarine service present special problems in control of structure-borne noise, for the vibration effects of motor and generator interact. Consequently, special vibration-minimizing design techniques were used in the latest auxiliary ship's service sets. These are 300-kw

60-cycle water-cooled machines of unit-frame construction. They are reversible, operating from the main ship's service ac power supply to charge batteries or from the batteries to supply ac power for emergency operation.

The motor and generator parts were first designed separately, with the flux density, number of slots, slot skewing, number of poles, stiffness of mechanical parts, and ventilating system details that would minimize vibration in each. Then a computer program was used to optimize the combined characteristics of the two machines, and design trade-offs were made to prevent reinforcement of vibration-exciting forces. Such vibration as remains is isolated by a unique resilient mounting system that damps vibration in all three dimensions. ■ ■ ■

ment at Westinghouse for the past three years. It is now in production and has recently become operational in Navy aircraft. ■ ■ ■

Starter/Generators for Aircraft

Combination electric starter/generators have been selected for the new 727 jet transports being built by the Boeing Company for United Air Lines. The machines, the first such devices to be used in operational aircraft, will function first as motors to start the jet engines and then as brushless ac generators to supply the aircraft's power needs. Combining starting and generating functions in one machine reduces the amount and weight of electrical equipment that has to be carried and also reduces the amount of ground support equipment and spare parts required.

A target-seeking radar system guides F4H-1 interceptors and their missiles.

Radar for Sparrows and Speed

The target-seeking radar system aboard the Navy's McDonnell F4H-1 carrier-based jet interceptor was fundamentally designed for guiding the aircraft's *Sparrow* missile towards enemy aircraft. The Navy recently put these "long-range eyes" of the radar system to use in setting a new record time for transcontinental flight. The radar enabled the F4H-1 pilots to establish earlier contact with the aerial refueling tankers by eliminating the need for a visual search for the tanker. This permitted the F4H-1's to fly more direct routes. An average ground speed of 871.38 miles per hour was established for the 2445.9-mile transcontinental flight.

The radar system is one of the most advanced pulse-radar systems in existence, and has been under develop-

The starter/generators provide 40 kva of constant-frequency three-phase power in the generating mode and, in the starting mode, can start jet engines requiring up to 250 foot-pounds of torque.

A special transmission engineered by Sundstrand Aviation Division of The Sundstrand Corporation serves as a constant-speed transmission for the generating mode and as a torque converter with variable gear ratio for the starting mode. The variable gear ratio permits using a minimum-size starter/generator machine.

The machine is essentially a constant-frequency three-phase generator. To start an engine cranking cycle, it is disconnected from the drive transmission and its excitation lead is opened. An ac power source is then connected to the machine's terminals, and it accelerates as an induction motor. When the rotor is slightly below synchronous speed, excitation is applied to the field. The machine synchronizes with the power source and is then capable of supplying considerable torque. The control reconnects the machine to the transmission and programs gear ratios to amplify torque as required. When the engine is running and self-sufficient, the loading on the machine is reduced and the power source removed. The transmission then reverts to constant-output-speed operation and the generator is switched to its generating mode. ■ ■ ■

Selective Erasure for Radar Display

Direct-view storage tubes have many radar display applications, such as in fire control or weather radar. The tube displays a picture somewhat like the television cathode-ray tube. However, the picture can be "frozen" at any time for careful examination. After the information has been examined, the picture is "erased." However, in present devices erasure must include everything that has been written. A new tube is being developed in which selective portions of the display can be erased without affecting other areas on the tube face.

A typical application for the new tube might be in military radar indicators. For example, if several targets were being displayed, the operator (or a suitably programmed computer) could erase targets as they are identified, thus eliminating extraneous information from the display. ■ ■ ■

Frequency Multipliers and Helical Resonators

Progress in radar and communications systems depends upon improvements or new concepts for the components that go into these systems. Two new devices have been developed by network synthesis engineers for application in high-frequency, very-high-frequency, and ultra-high-frequency systems.

Solid-State Frequency Multiplier— The solid-state frequency multiplier is a four-terminal network with a nonlinear reactance incorporated between the low- and high-frequency portions of the assembly. This nonlinear reactance under certain bias conditions becomes a source of har-

monics of the fundamental input frequencies. The nonlinear reactance used in the frequency multiplier is a varactor (or nonlinear capacitor) whose capacitance depends upon the voltage applied.

This solid-state frequency multiplier permits the elimination of expensive klystrons and similar devices in the microwave region, and at UHF frequencies can be substituted for transistor multipliers.

A key accomplishment was the development of a complete analytical procedure for matching linear and nonlinear elements. One of the most unique applications was the matching of an inductance-capacitance filter through the frequency multiplier to a helical resonator, the next device to be described.

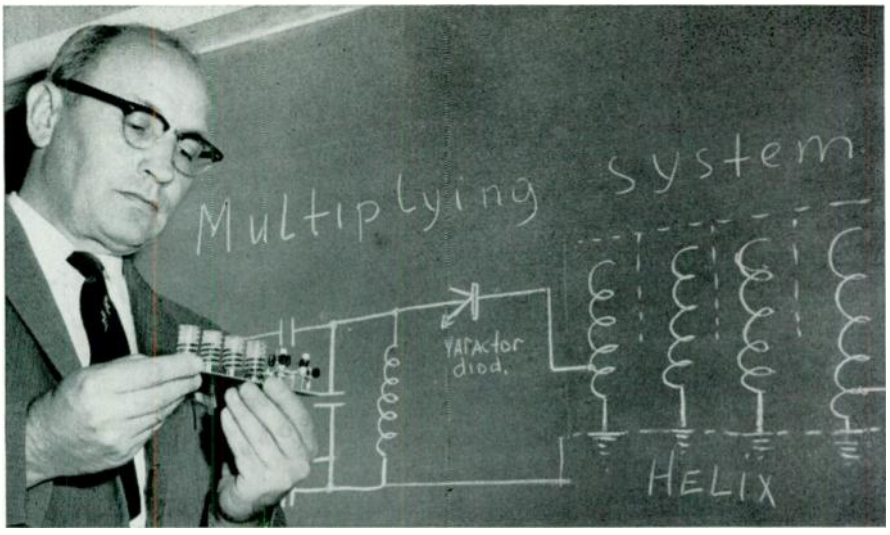
Filters with Helical Resonators—A filter has been designed using helical resonators to separate VHF and UHF energy into narrow or wide bands of frequency for radar or communication purposes. The helical resonator was borrowed from the adjacent engineering field of antenna design; the helical filter was then developed by combining circuit theory with microwave technology.

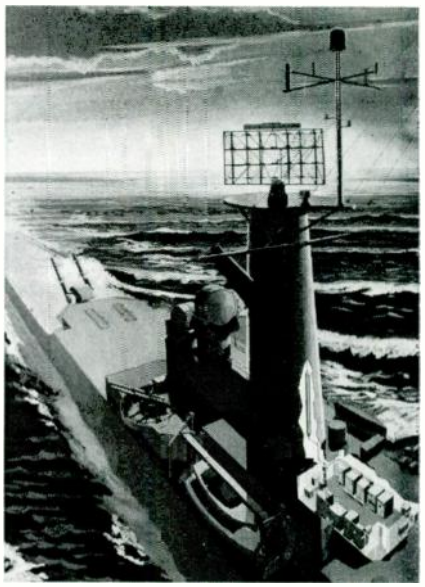
The construction of the helical resonator is unusual in that the single-layer coil is connected to ground at one end and is left "unconnected" at the other. This single-layer coil is surrounded by a nonconductive material and is completely enclosed in a specially designed highly conductive shield, such as copper. This device resonates at one specific frequency and exhibits an extremely high impedance at this frequency.

The filter consists of a series of cavities with these helical resonators in their center. High-frequency energy is introduced into the cavity network at one end by means of a probe or loop and leaves by a similar coupling arrangement.

The use of these helical components is a new approach to filtering energy and partially replaces the conventional coil-capacitor networks. The advantages of the concept are numerous. For example, multiplexing equipment could be designed directly in the VHF range. Communication channels could be separated with no appreciable loss of the available frequency band. Because of the high-quality factor of helical resonators, band width could be very narrow and the power losses low. An unlimited number of resonators could be coupled together to create a selectivity curve of any desired degree of sharpness. The physical size of these filters, especially in the hundreds of megacycles region, is reduced so considerably that it falls in the category of a miniature device. There is no limitation to the power capability of the device—the only practical limitation is one of size if they are used at frequencies below 20 megacycles. The device was primarily developed to cover the "no-man's land" for filters between 30 megacycles and 1000 megacycles. ■ ■ ■

Filters with helical resonators are shown here as applied in nonlinear network design to produce a frequency multiplier.





Artist's conception of the SPS-43, a new shipboard air search radar developed for the Navy by Westinghouse. This new radar has increased range and performs more functions than its predecessor, the SPS-37 which is presently installed on Navy vessels.

Arc Air Heaters

The extremely high temperature of the electric arc has been harnessed for heating streams of air and other gases to 5000 degrees F and higher. Arc heaters are the only practical devices at present for imparting high enthalpies to gas streams for appreciable periods of time, so they have become important in studies ranging from space-vehicle re-entry to chemical processing.

Aerodynamic research is, at present, the principal application for arc air heaters. Isentropic expansion of the high-energy gases through a convergent-divergent nozzle system produces high velocities at relatively low free stream temperatures. Mach numbers of 10 to 15 can be obtained in this way with present heaters, and higher values can be expected in the future with operation at higher pressures.

With different operating pressures and different nozzle configurations, isentropic expansion of the hot gases produces high velocities but at high free stream temperatures and low mach numbers. (The Westinghouse prototype arc heater was designed to produce an enthalpy of 10 000 Btu per pound at seven atmospheres pressure, operating on direct current or single-

phase alternating current.) Mass-transfer testing is the major application for such a system.

The high-energy gases also can be discharged into a chamber at high pressure and temperature but at low velocity for heat-transfer studies.

An arc heater designed for aerodynamic use is being built by Westinghouse for the NASA Langley Research Center, Langley Air Force Base, Virginia. It will supply air to a wind tunnel for aerodynamic and heat-transfer testing. It is a dc heater designed to supply 6000 Btu per pound at 1500 psi, or 9000 Btu per pound at 60 psi. Its power supply will deliver five megawatts at the arc-heater terminals.

Design studies for an arc heater to be used in studying heat-transfer characteristics of hydrogen in scaled rocket nozzles are being conducted for the NASA Lewis Research Center, Cleveland, Ohio. The studies are aimed at developing a facility for testing nozzles for rocket engines that use hydrogen as a propulsion fluid. The gas stream for this purpose must meet strict temperature requirements (up to 5000 degrees F) and have uniform enthalpy in radial distribution and with respct to time.

Another possible arc-heater application is as a source of ionized gas for a magnetohydrodynamic accelerator. Velocities as high as 40 000 fps at pressure altitudes of 400 000 feet and at true densities could be achieved in a test section. The primary use would be in simulating space-vehicle re-entry conditions.

The Westinghouse arc heaters combine water cooling with arc rotation around toroidal electrodes to keep the electrodes from being heated beyond their structural endurance. This practically eliminates contamination of the gas with electrode material, an important factor in many applications.

Design studies and tests with the Westinghouse arc heater using a single-phase ac power supply have shown that it is feasible to build three-phase ac heaters capable of adding even more energy to the working fluid. The three-phase heater would have several advantages over single-phase heaters, especially when more than five megawatts of power input to the working fluid is required. Power and control-system cost would be reduced by as much as 50 percent, efficiency would be improved by sharp reduction of ballast losses, and there would be three times as much flow with an equivalent quality working fluid at the nozzle inlet.

Arc heaters consume large amounts of electrical energy, so their volt-ampere characteristics are being studied intensively to learn how to predict the kind of power supply a given installation will need. Effects of arc heaters on power systems also have been studied to learn how to avoid introducing harmful electrical interference into the systems. These studies have included computer investigations of the effects of a dc arc heater on the Langley Air Force Base power system and the effects of a proposed three-phase ac heater of greater power for the U. S. Air Force Arnold Engineering Development Center. ■ ■ ■

Precise Power Generation

An intercontinental ballistic missile will be blasted off from a U. S. Air Force launching site in California in the near future and will make its arching flight down the Pacific missile range. Radar in the distant Marshall Islands will pick up the hurtling target, and a U. S. Army missile defense system will try to intercept it in flight. The exercise will be part of the development program for the Army's Nike-Zeus anti-missile missile system for defense against intercontinental ballistic missiles.

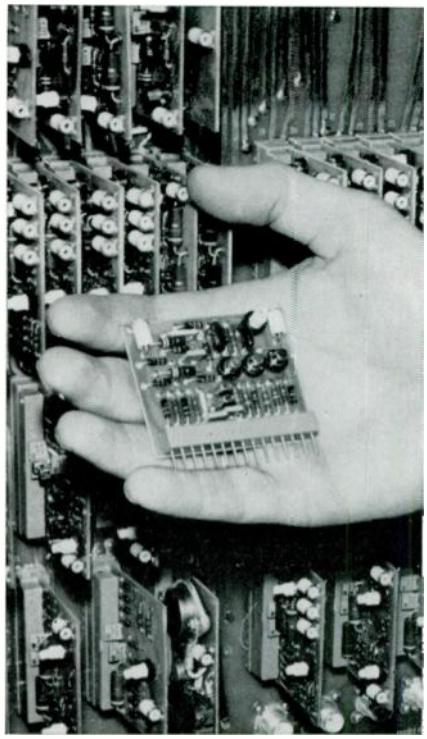
The precisely regulated electric power needed for optimum performance of the complex equipment is provided by Westinghouse generators, static exciters and voltage regulators, and switchgear. Seven 1500-kw diesel-generator sets on Roi Namur Island supply power for the Pacific Range Electromagnetic Signature Study (PRESS), which uses advanced radar to study incoming missile characteristics. Six 800-kw diesel-generator sets on nearby Kwajalein Island supply the Nike-Zeus missile battery, which includes missile launcher, target-tracking radar, and decoy-detecting radar. The diesel engines for the two installations were made by Alco Products Incorporated and White Diesel Engine Division, White Motor Company.

Engines, speed governors, generators, and regulating equipment are designed to supply much stiffer and better regulated power than the commercial-quality power output normally specified for diesel generators. Special attention was given to improving voltage and frequency characteristics under transient load and to optimizing voltage wave form. ■ ■ ■

20 Million Bits

New digital computing circuitry designed for military applications can handle up to 20 million information bits per second. This will extend the logic ability of military systems by a factor of ten, since most previous logic elements were limited to about a 2-megacycle logic rate. The new computer circuitry consists of ten basic circuits, such as a squarer, a flip-flop counter bit, a reset driver, and logic gates. Each circuit is mounted on a small printed circuit card (see photo). Interconnection between these logic elements is also done with printed circuits to eliminate the wiring inductance. A prototype data-processing system for an advanced radar application has been demonstrated. The high logic rate has been made possible by recent developments in silicon semiconductor devices. ■ ■ ■

Basic circuits are mounted on small printed circuit cards in a new high-speed digital computing system for military applications.



Power for Space Vehicles

The electric power system in large space vehicles of the future may well be the primary power system—providing power for ion or plasma propulsion as well as for guidance, communications, and utility systems. For the immediate future, at least, it appears that the large amounts of power required by such systems could be supplied by rotating equipment.

Design of a 423-kva inductor generator for a nuclear turbogenerator system has been undertaken. The proposed machine would be cooled by liquid potassium at an average coolant temperature of 600 degrees F. It would operate at 24 000 rpm and produce 120/208 volts at 3200 cycles.

The inductor generator design was chosen because it has no rotating windings; its solid rotor makes the projected high operating temperature and high rotational speed feasible. The stationary windings, though not subjected to rotational stress, would be exposed to hot potassium vapor leaking from the potassium-vapor turbine. Consequently, the insulation must be protected by a material that will withstand the vapor. The present approach is use of a ceramic liner in the generator air gap to isolate the winding insulation. ■ ■ ■

Satellite Motion Simulator

For an exotic new environment such as space, engineers are apt to come up with some rather novel and previously untried ideas. For example, engineers at the Westinghouse Air Arm Division have suggested a method for magnetically "dumping momentum" as a means for stabilizing a satellite in orbit.

In this proposed system, the unwanted "twisting or turning" energy of the satellite would be transferred to self-contained inertia wheels. And in turn, the energy stored in these wheels would be removed through the action of the earth's magnetic field.

Unfortunately, laboratory space for testing such ideas aboard presently orbiting satellites is extremely expensive and difficult to come by. Therefore, a satellite motion simulator is being developed to imitate the motion of a satellite in orbit about the earth. A test table, which will hold up to 500 pounds of test equipment, is floated on a spherical "air bearing". The table will have 360 degrees of freedom about the yaw axis and 120 degrees of freedom about both pitch and roll axes. The table has such accurate balance that even the air moving in a normal room would disturb it.

The magnetic field of the earth is simulated by an encircling coil, whose position and current density can be varied as desired. A simulated "earth" about which the satellite is orbiting is provided by an aluminum dish, which is heated to a temperature that can be held constant to ± 1 degree F. This dish will simulate the earth at distances of 500 to 1000 miles.

Solar radiation is provided by mirrors which reflect the sun's radiation from outside the test enclosure and beam it onto the test table. The simulator is mounted inside an RF shielded room, air conditioned to maintain constant temperature. The table is controlled by a radio command link and data from the experiment is sent to the control console via radioed telemetry channels. ■ ■ ■

Satellite Communications

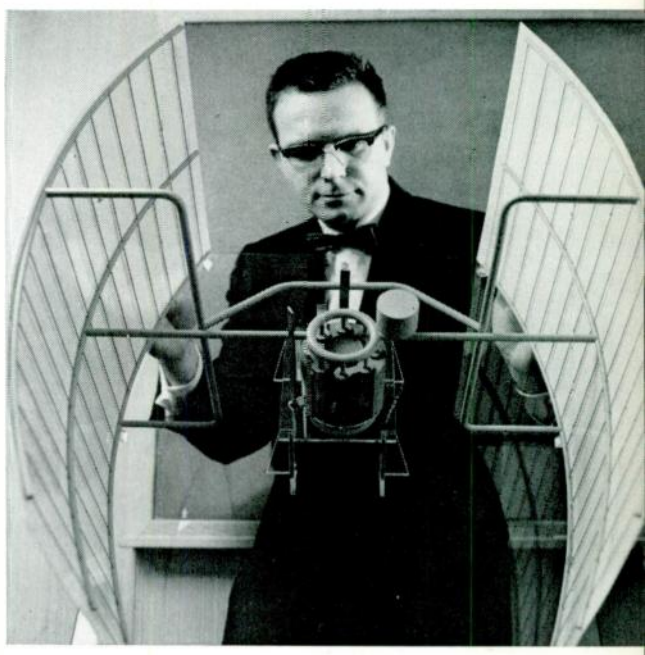
The success of the Echo satellite last year opened up a wide range of possibilities for using similar orbiting communication devices for relaying microwave communications between distant parts of the world. A next step in this approach is to orbit an active satellite containing equipment that will enable taping of messages from the ground, with retransmission of these messages at remote locations.

While the orbiting satellite quite naturally commands the most interest, of equal importance is the ground transmission equipment.

To meet the operating needs of a newly developed traveling wave amplifier tube for satellite communication, transformer engineers recently developed a dc power supply for the transmitter.

Each dc power supply consists of two compartments. A low-voltage compartment houses a circuit breaker, variable-voltage transformer, contactor, control transformer, relays, pushbuttons, and meters. The high-voltage compartment contains a transformer rectifier, transducers, filter capacitor, silicon rectifier, discharge resistors and a manual grounding switch.

The power supply will provide a dc output of zero to 23 kv at 1.5 amps, from a three-phase, 60 cycle, 480 volt ac input. Automatic voltage regulation must be $\pm \frac{1}{2}$ percent and the rms ripple content of the output must be limited to 0.4 percent. The dc power supplies will also be capable of remote as well as local operation. While this power supply was designed for a particular purpose, it is equally suitable for radar transmitters, and ultrasonic transducers. ■ ■ ■



This is a model of a nuclear thermoelectric power system for space, moon, and other uses requiring long-lived and maintenance-free operation.

Power Package for the Moon

A model of a nuclear thermoelectric power system has been designed for space, and other uses requiring long-lived, maintenance-free operation.

It uses the spontaneous decay of a radioisotope to produce heat, which is converted into electricity by thermoelectric principles. The system is designed to produce 50 to 60 watts for three months' life on the moon's surface. Curved shields serve as waste heat radiators. The heat is transferred by a liquid metal. Among other applications the compact system could be used to power instruments gathering scientific data from a vehicle on the moon. The power package also is feasible for automatic weather stations in the oceans, and for harbor buoys.

RESEARCH AND ENGINEERING

Superconducting Magnet

A long sought-after goal of scientists—a superstrength superconducting magnet—has been developed at the research laboratories. For its size, weight, and energy consumption, it is by far the most powerful magnet ever built. Ultimately, such magnets will revolutionize almost every aspect of the use of electricity, including generation, distribution, and application of electric power.

The new magnet is wound with a wire of a niobium-zirconium base alloy; nearly a half mile of wire about the diameter of sewing thread is used. About 5000 turns of the wire are wound into a coil two inches in diameter and one and one-half inches long. The coil is immersed in a vessel of liquid helium, which keeps it at a temperature near minus 450 degrees F. The energy required to cool the coil is only a small fraction of that needed to produce a comparable magnetic field with a standard electromagnet.

The threadlike wire from which the coil is wound carries a current of 20 amperes. At this current density, a scaled-up wire of one square centimeter, or about the thickness of a piece of chalk, could carry 200 000 amperes.

In early tests the doughnut-sized super-magnet, which weighs about a pound, produced a magnetic strength, or flux density, of 43 000 gauss. It runs from an ordinary automobile storage battery, and the only power the battery supplies continuously is a few watts to overcome the small losses in the wires leading to it. In contrast, a conventional iron core electromagnet as large as an automobile and weighing 20 tons, operated to the saturation of the iron, creates a magnetic field of only half the strength of the super-magnet. Such an iron-core magnet needs its own power supply to continuously supply the 100 000 watts or more to run it.

The development of this superstrength superconducting magnet raises many possibilities for the future. It enhances the chances for direct, large-scale generation of electric power; it makes possible a whole new generation of powerful atom smashers; it increases the possibility of a magnetic "bottle" in which the hydrogen bomb reaction can be harnessed for useful power; and it makes more feasible some of the methods proposed for long-distance travel in space. ■ ■ ■

This small coil of wire is wound from a superconductor—a niobium-zirconium base alloy. For its size, weight, and energy consumption, it is the most powerful magnet ever built. In operation it is immersed in liquid helium.

Electronic "Sniffer"

The human sense of smell is sensitive enough to detect certain odors in concentrations as small as one part in a million parts of air. A new electronic "sniffer" is even more sensitive and accurate; it detects and measures concentrations of gases as low as one part in ten million parts of air.

Called an electronegative gas detector, the instrument was developed primarily to detect and measure the concentration of sulfur hexafluoride, now widely used for electrical insulation and to quench arcs in high-voltage apparatus. One use of the instrument is to locate minute leaks through which SF_6 might escape.

SF_6 has the ability to capture low-energy electrons, forming negative ions, and this ability is used in the detector. The instrument takes in air suspected of containing SF_6, and bombards it with electrons. The SF_6 molecules form ions that are less mobile than others present. Thus, when the ions are attracted to an anode, the time (phase) delay is read at the anode by a meter, directly calibrated in parts per million of SF_6.

The electrons that bombard the air sample are released from a silver-sulfide surface by ultraviolet light from a four-watt lamp. The instrument also uses thermoelectric cooling to condense out water vapor, which could interfere with measurements. A tiny thermoelectric humidistat controls the cooling within one-fortieth of a degree F. Humidity control is within one-tenth of one percent. ■ ■ ■

Electron Beam Welds Fuel Elements

Many unusual problems are encountered in the design and fabrication of nuclear fuel elements, and in some of these the unique capabilities of electron-beam welding are helping to provide better solutions. A case in point is the fabrication of fuel elements for the Westinghouse Testing Reactor. These fuel elements are first formed in a flat plate shape, and the fuel itself clad with aluminum. Then the flat element is formed into a circular loop, and the two sides joined.

The joint itself must be made in the solid aluminum area; i.e., no fuel should be in the area affected by the heating involved in welding or brazing. Since, from the standpoint of achieving uniform nuclear flux, a complete circle of fuel would be ideal, this joint area containing no fuel must be kept to a minimum width. Brazing is one possible solution, but it introduces the possibility of contamination of the reactor coolant by brazing flux, unless the joint is thoroughly cleaned.

Conventional welding would provide satisfactory strength, but the normal weld requires heating a relatively large area to attain a weld of sufficient depth. This means that the "gap" in the fuel ring must be wider than designers would like it to be.

Electron-beam welding provides a solution. The high-voltage, low-current type of electron-beam welding makes a weld of deep penetration without covering a wide area. In effect, this means that the gap in the fuel ring can be made narrower. Other advantages are that electron-beam welding is faster than conventional welding, heats the material quicker, and therefore creates less distortion in the welded member. ■ ■ ■

Thermoelectric Cooling Applied

Ways of cooling with evaporative closed-cycle systems employing motor-driven compressors have been applied for years, but there remained neglected areas in which the size, weight, or noise of these devices made their use impractical. Also, there was no practical way to break the cooling system up into small units supplied from one power source. Consequently, the thermoelectric cooling effect produced when electric current flows through a junction of dissimilar materials has opened a wide range of new cooling applications. These run from home-appliance duty to electronic component cooling.

The nation's first thermoelectric consumer appliance was a bottled water cooler for use primarily in areas where good drinking water is scarce. Its cooling system occupies

only about 25 percent of the volume required by a compressor system. Vending-machine applications also have been developed, including refrigeration for a condiment bar and for cream in a coffee machine.

Parametric amplifiers, quartz crystals, gyroscopes, and other temperature-sensitive devices have been mounted on or enclosed in cooling elements for spot cooling. The component or circuit in which the temperature-limited device functions then is unaffected by high ambient temperature. Thermoelectric cooling is more effective than blower air cooling because it can lower temperature below ambient temperature. One industrial application is in cooling a vidicon tube for a closed-circuit television camera used over the soaking pits in a steel plant. A 5-watt thermoelectric heat pump in the form of a yoke around the tube keeps its temperature at a safe value. ■ ■ ■

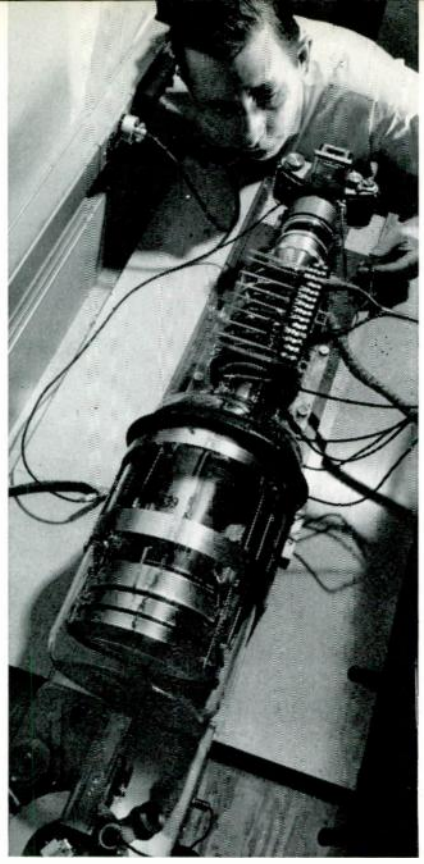
Further Insight into Matter

When x-rays pass through a crystal, they are diffracted by the orderly arrangement of atoms, and form patterns of spots characteristic of the material. These Laue patterns have made x-ray diffraction a valuable research tool to study the basic structure of matter, to identify unknown materials, or to select the precisely aligned crystals required by modern solid-state devices.

Unfortunately, however, x-ray diffraction has had certain limitations. The patterns could not be seen by the naked eye, and could be observed only by photographing each one separately, with each picture requiring an exposure time of an hour or more.

With a new technique, x-ray patterns are made visible to the naked eye, and, in fact, scientists can "watch" the atom locations continuously shift position as the crystal structure changes with temperature or other outside influence. For detailed study and measurement, photographs or motion pictures of the whole intricate process can be made. The advantages of x-ray diffraction can be achieved in a matter of seconds rather than hours or days.

These high-speed diffraction pictures are obtained with an experimental electronic intensifier system, which combines into a single device



Using a new experimental electronic system for brightening x-ray images, a scientist takes a picture of the atomic arrangement inside a piece of solid steel.

the functions performed by two earlier intensifier tubes developed at the research laboratories. These are the Fluorex tube, an x-ray image amplifier; and the Astracon tube, a highly sensitive light amplifier. X-rays from a small portable source are beamed through a crystal to form a typical diffraction pattern. The image of this pattern is transferred directly onto a sensitive photosurface deposited on the input face of the combined Fluorex Astracon tube. Here a pattern of electrons, exactly duplicating the x-ray image, is released. These electrons are accelerated and focused on a thin film near the rear of the tube. This film, about one ten-thousandth of an inch thick, is a two-layer sandwich composed of a film of metal and another of an insulating material. The film has the unique ability to eject from its rear surface up to 100 electrons for each one that strikes its front surface, or, in effect, it strengthens the electron pattern 100 times. The strengthened pattern is then accelerated and guided onto a sensitive output surface, or screen, similar to that on the viewing end of a television tube. Here the pattern of electrons is converted to visible light, producing a smaller, brighter, more clearly visible image of the original x-ray diffraction pattern.

The system has enough sensitivity that brilliant patterns can be clearly seen and made into photographs or x-ray movies with only a small portable x-ray tube as the source of energy. Using a more powerful crystallographic rotating anode x-ray machine in the laboratories, a brightness gain of some 1500 times will be possible, which will extend diffraction studies far beyond the capabilities of any previous x-ray diffraction equipment. ■ ■ ■

Progress with Thermoelectricity

Significant gains in the field of thermoelectricity were made during 1961. Continued research produced a whole new group of high-temperature thermoelectric materials. And while this research was proceeding, thermoelectric devices moved into several new applications.

Rare Earth Compounds—A major factor in the long-range potential of thermoelectricity is the availability of satisfactory materials—materials with the necessary physical properties that can yield acceptable electrical efficiencies. A major step in this direction came with the development of a new group of ceramic materials, which have good efficiency at temperatures as high as 2000 degrees F. These are compounds of two rare earth elements, samarium and cerium.

These metals are chemically combined with sulfur to produce different varieties of two compounds, samarium sulfide and cerium sulfide. For example, in the case of samarium sulfide, the samarium and sulfur are heated to a high temperature in a protective atmosphere. The rate of temperature rise, final temperature, and length of reaction time are carefully controlled. The resulting sulfide is crushed, compacted into pellets, and sintered.

In some existing thermoelectric devices, to cover the wide range of temperatures usually encountered, several different thermoelectric materials are used in series or cascade. Each material operates in the narrow temperature range at which it functions best, and passes its waste heat along to the next lower temperature material. The new materials are especially suited to the top, or hottest,

range in such a series, and thus may permit higher overall efficiencies in future generators.

These new materials resulted from a continuing research and development program under the sponsorship of the Bureau of Ships, U. S. Navy.

Electric Power from Solar Energy—A newly developed self-contained electric power plant, which taps the heat energy of the sun and converts it to electricity with a thermoelectric generator, offers much promise for an improved standard of living in underdeveloped areas of the world.

A 50-watt prototype unit, developed in cooperation with the Solar Energy Laboratory of the University of Wisconsin, has already been built and tested. A unit with a capability of up to 200 watts is under development.

The new unit is particularly suited to such applications as water pumping for irrigation or for supplying household water needs. The larger unit will pump enough water from a depth of 20 feet to irrigate about four acres of land at the rate of 24 inches of water a year. Or, from the same depth, it can supply the personal needs of 1200 people on the basis of five gallons of water per person per day. To provide this amount of water, the system must operate 10 hours a day for only 250 days a year, which allows a safety margin for cloudy days when the solar-powered unit would not operate.

The solar thermoelectric system uses an eight-foot parabolic mirror, which focuses the solar energy on the thermoelectric generator. The generator itself is in a metal enclosure about eight inches square and two inches thick. Inside the generator are 72 thermoelectric couples, connected in series. Operating temperature is 840 degrees F, and the cool side is at about 150 degrees F. The entire generator weighs just over 16 pounds.

Conceivable next steps might well be larger generators capable of serving lighting needs, and mechanization of small village industries.

Air-Conditioned Suit—Heating or cooling of an experimental self-contained air-conditioned suit is accomplished by thermoelectric means. The new suit, developed by Westinghouse and the U. S. Naval Supply Research and Development Facility, is capable of keeping the wearer comfortable in outside temperatures ranging from the bitter cold of the Arctic to the extreme heat of the tropics. Tests show that a temperature of about 80 degrees F is maintained when external temperatures vary from 40 degrees below zero to 135 degrees above zero Fahrenheit. Completely air tight, the suit is made of an insulated aluminum coated fabric. Air for breathing is supplied through a face mask connected to the side of the suit helmet, where incoming air is heated or cooled by a small heat exchanger.

During cooling of the suit, the flow of electricity through the elements causes one end of the thermoelectric couples to cool, thus lowering the temperature of a heat exchanger on the inside of the suit. The heat removed from the cool side flows through thermoelectric elements to the hot-side heat exchanger, from which it is dumped into the atmosphere by a small fan. Another fan, mounted on the same shaft, circulates the cool air within the suit. During the heating cycle, the functions of the two heat exchangers are reversed. Batteries permit the suit to be independent of any other power source for one hour. For more restricted movement over extended periods of time, the suit can be plugged into a dc outlet. ■ ■ ■

Ebiconductivity for Imaging

The electron bombardment induced conductivity (ebic) principle has been put to work by Westinghouse research scientists and electronic tube designers in three new imaging devices.

In each device, electrons are made to strike an ebic film at high velocity. Each incident high-velocity electron can yield a charge of several hundred electrons. This electron bombardment causes an amplified electrical charge pattern to be built up on the film.

The Ebicon tube, the first developmental tube to use the principle of ebiconductivity, is a television imaging type tube with a sensitivity com-

Top A new thermoelectric material—samarium sulfide—is prepared in this specially designed vacuum furnace.

Center An engineer is shown adjusting the thermoelectric generator of a new solar-thermoelectric power plant.

Bottom This man is garbed in an experimental air-conditioned suit developed by the Navy and Westinghouse.

Above This time exposure shows the corona formation and sparkover of a gap formed by two 1-inch diameter, 50-foot conductors, spaced 3 feet apart. Flashover occurred where two of the corona channels met.

The channel formation along the entire gap produces an appreciable predischarge current—in the order of hundreds of amperes between electrodes—before gap breakdown occurs.

A voltage (from a surge generator) of about twice that needed to cause breakdown is applied to the upper conductor; the bottom conductor is grounded through a current shunt.

These and similar tests represent one of the many aspects of lightning which are being studied today, and based on past results, will ultimately be translated into greater immunity to transmission line flashovers, and improved economy of construction.

Below Right This experimental helium-neon optical maser, in operation since April 1961, was built to study the possible application of the device to military communications and ranging.

The optical maser (also called laser) develops a highly monochromatic coherent electro-magnetic wave (light of a single frequency).

The extreme "sharpness" of the wave is obtained by selective reinforcement of the optical radiation developed by the atomic resonance of the helium-neon gas. In addition to such military applications as long-range outer space communication, or short-range ship-to-ship communication, engineers suggest several possible industrial applications for optical masers.

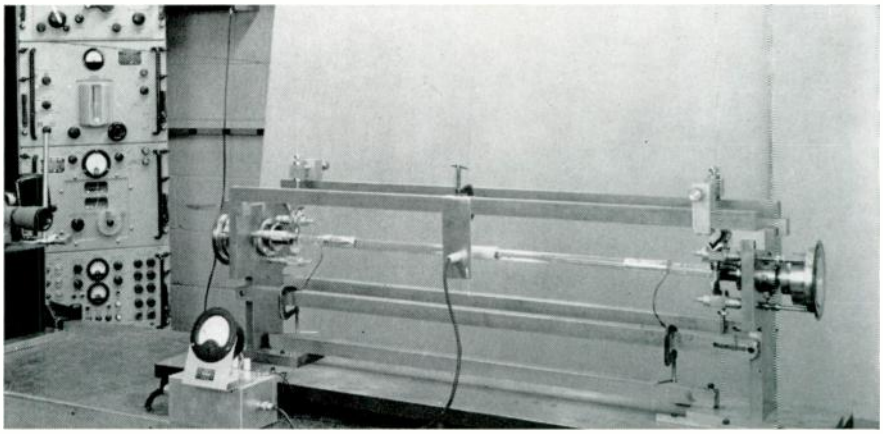
The optical maser may also provide an extremely sharp reference for measurement of length. The standard meter is presently calibrated in terms of wavelengths of radiation of a known frequency source. The optical maser can provide a frequency source that is thousands of times "sharper" than those presently in use.

parable with that of the image orthicon. A light image is optically focused on the surface of a window which is coated with a photoemitting material, which releases electrons proportional to light that strikes it. These electrons are accelerated to the rear end of the tube where they strike the ebic film. The electrical charge image built up on the ebic film is scanned with a beam of electrons (much like a vidicon) to obtain an electrical "image" that can be amplified and broadcast. The primary advantage of the Ebicon tube over a conventional image orthicon is that the Ebicon tube has no need for supplementary magnetic fields (which the orthicon requires for deflection and focusing), and no return beam multiplier with its associated circuitry; multiplication takes place in the ebic target. These features permit much lighter and less bulky cameras since all focusing and image reading can be accomplished electrostatically.

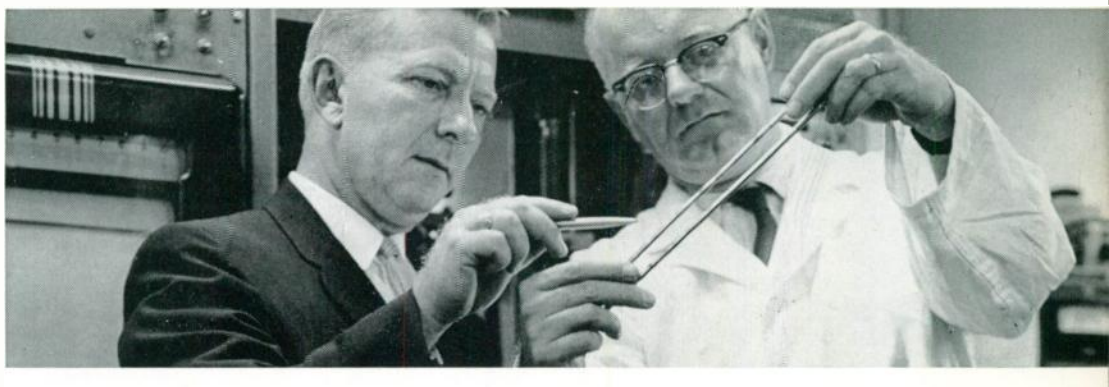
The second imaging device, the Uvicon tube, is practically the same device physically as the Ebicon tube, except that the photo-sensitive input surface of the Uvicon tube responds only to light in the ultraviolet region. The Uvicon tube receives the ultraviolet image through a special window made of lithium fluoride, since glass would filter out the ultraviolet wavelengths. The photo-emitting material is also sensitive only to ultraviolet, and releases electrons accordingly. The Uvicon tube was developed for the Astrophysical Observatory of the Smithsonian Institute, Cambridge, Massachusetts, for the Observatory's Project Celescope. Project Celescope is one of several experiments planned to be launched in the National Aeronautics and Space Administration's (NASA) orbiting astronomical observatory program. The first of the orbiting observatories is planned for 1963. NASA will first launch a series of rockets to place the Uvicon tube and its associated electronic equipment well beyond the ultraviolet absorbing portion of the earth's atmosphere. The purpose of these tests will be to sample the strength and nature of the ultraviolet radiations to be encountered in space. This will provide preliminary data on the performance of the entire Project Celescope electronic telescope system.

The complete telescope will consist of three components: (1) an optical arrangement to form the ultraviolet image; (2) a Uvicon pickup tube and its associated circuitry, which constitute a TV camera that responds to ultraviolet images and converts them into electrical signals; and (3) a transmitter to broadcast these signals back to earth. Thus, in television fashion NASA hopes to get an ultraviolet image of the stars and interstellar space that has always been screened from man's view by the earth's atmosphere.

The third device to use the principle of ebiconductivity is a scan converter tube. This tube is in effect a cathode-ray tube built face to face in the same envelope with a vidicon imaging tube. This combination eliminates the need for optical coupling between the two devices, which would cause a loss in signal amplitude. Other types of scan converter tubes are available, but these work on the principle of charge transfer, where an electron charge pattern is established upon an electron permeable membrane separating the



The rods being examined at right are large single crystals of tungsten.



cathode-ray tube section from the vidicon-imaging section. In such devices, the ultimate coupling between sections is one to one. In the new scan-converter tube, the ebic film can produce a charge gain of several hundred. This feature makes it possible to write information with far less cathode-ray tube beam current, permitting much higher resolution in the write gun. This permits the complete tube to be contained in a much smaller envelope with equivalent or better resolution.

Moreover, inasmuch as the ebic film is not merely a passive transfer element, several varieties of scan converter operation are possible. For example, if an ebic film with fast response is used, the scan converter is suitable for such high-speed applications as TV-to-TV conversion between noncompatible systems. Another type of ebic film with storage capability can be used: Here, write-in can be intermittent, or continuous for a low-level signal with near-perfect integration, or continuous at frame times varying from fractional seconds to several minutes.

Similarly, readout can be done intermittently or continuously over the same range of frame times. These combinations have many possible applications, such as for audio-frequency graphic data transmission over telephone lines, or space-to-earth communication over narrow band-width transmission channels.

Still a third type of ebic film can be used which exhibits multicopy storage-type characteristics. In a scan converter with this type of film, either intermittent or continuous write-in can provide multicopy, nondestructive readout of useful resolution and amplitude for periods up to one-half hour. Such a device might be useful in air traffic control. The future of ebiconductivity in imaging devices seems bright indeed. ■ ■ ■

Single Crystals of Tungsten

Tungsten is usually considered a hard brittle metal that is very difficult to machine or fabricate. However, engineers have now shown that tungsten's ductility depends upon its purity. A newly developed practical method of producing large single crystals of tungsten with purity as high as 99.9975 leads to metal that is ductile even down to temperatures as low as minus 330 degrees F.

At present, tungsten rods 10 inches long and 0.2 inch in diameter can be produced as single crystals, which is large enough to permit the fabrication of small parts. The process starts with the production of special high purity ingots. The ingots are then used as the starting material for growing the single crystals, which is accomplished in zone melting equipment using the electron beam principle.

This research was triggered by the need for more knowledge about the fundamental properties of tungsten by lamp engineers. However, the knowledge gained will be useful to research men investigating other areas of application for tungsten, such as rocket motors. The ability to produce large single crystals should hasten the day when tungsten can be more easily used in many high-temperature, high-strength applications. ■ ■ ■

Thermally Activated Ceramic Batteries

Electric power-producing cells that have unlimited shelf life, need no liquid electrolyte, are simple and rugged, and are actuated by heat but require no hot and cold junctions have been investigated as possible practical applications of the Austin effect. The cells operate at temperatures where many conventional power producers are barred by temperature limitations.

The Austin effect was discovered during investigations of vitreous enamel as a high-temperature electrical insulator. Voltages were found where they were not expected, and detective work revealed that the combination of hot conductors and enamel was actually generating a potential. The experimental power-producing cells that have evolved from this observation are made by coating an iron electrode with a special vitreous enamel and then placing a layer of silver on the enamel to act as the opposite electrode. Present open-circuit voltage is about one volt per cell, and the cells produce about 1.2 watt minutes per square inch. They can be grouped in batteries to supply the desired output rating.

Research indicates that the Austin cell behaves as a kind of galvanic cell involving ionic transfer, with the enamel serving as an electrolyte. The solid electrolyte and the relative inertness of all the components gives the cells stability, reliability, and long shelf life.

The cells require a temperature of about 650 degrees C for maximum output, although some configurations start to produce electricity at considerably lower temperatures. They can be made in practically any shape, so they could be component parts of devices in which waste heat is available. The cells can be recharged by reverse electric current while hot.

A possible application for the cells is in fire-detection systems, where their stability and long life would be advantageous. They could also prove useful for producing electricity from waste heat and in supplying power in places where batteries cannot be used because of temperature limitations. ■ ■ ■

Water "Bullets"

A scientific "shooting expedition," which consists of firing "bullets" of water into solid blocks of steel at supersonic speeds, may lead to a better understanding of the action of water droplets on steam turbine blades. Over

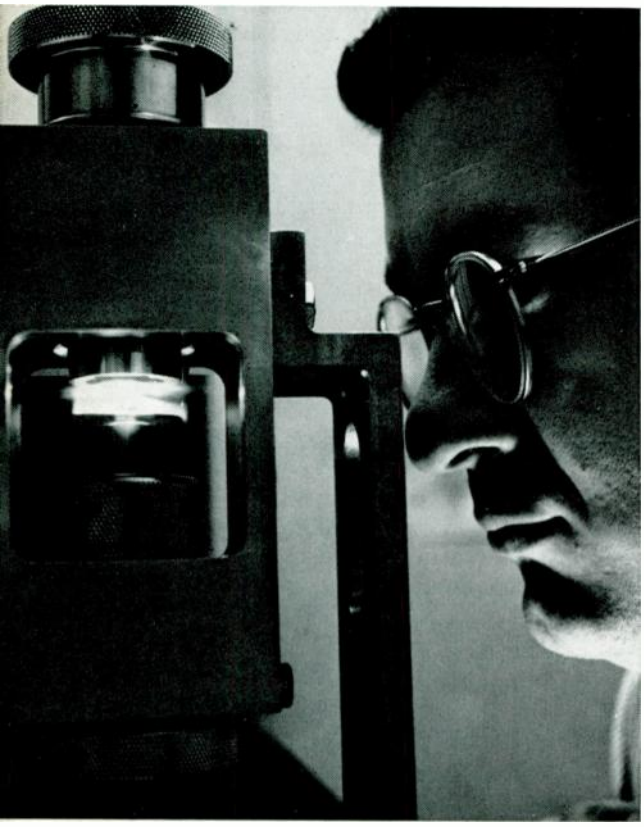
a long period of time, drops of water in moist steam erode the leading edge of the long turbine blades found in the low pressure section, where tip speeds range up to supersonic values. Similar erosion occurs on the surfaces of airplanes and missiles when they collide with raindrops during high-speed flight.

In these tests, drops of water traveling at velocities up to 3400 miles per hour penetrate thin pieces of metal like a rifle bullet; a single drop leaves a sizable dent in thick samples of copper, stainless steel and other metals. Interestingly, the supersonic water drops produce another effect—as they crash into the metal, a clearly visible burst of light is given off. Exactly where this light comes from has not yet been determined.

The supersonic water bullets are produced by compressed air. A small lead pellet is fired down a 30-inch metal tube by gas pressures of about 150 pounds per square inch. The pellet strikes a small sealed reservoir of water, which has a tiny opening aimed at the metal sample. The impact of the lead pellet squeezes out a jet of water, which crosses a one-inch gap and strikes the metal surface. The slug of water reaches the target in about 15 millionths of a second, so to study it enroute and on impact a high-speed camera photographs it at intervals as short as five millionths of a second.

Several facts have already been discovered by this process; uniform jets with a smooth leading face cause more damage than irregularly shaped jets; irregularities in the metal surface have little effect on the erosion damage; thin films of water or oil do not protect the surface of the metal; and visible damage, barely seen on the metal surface, appears to correspond to the actual threshold of water erosion damage experienced in the operation of steam turbines. If a correlation between experimental and operational damage can be established without question, the new water bullet test will provide a fast, simple, and inexpensive means for selecting erosion resistant materials for turbine use. ■ ■ ■

The flash of light in the photo below was generated by a single drop of water striking solid steel at supersonic speed.



No Bumps, No Sway

A radical new system can take the bumps and sway out of automobile riding. Believed to be the first fully active system, it uses power from the car's engine to force the body of the vehicle to stay in place at all times, no matter what the motion of the wheels. In contrast, ordinary springs and shock absorbers are passive. They simply tend to absorb and damp out the body motion that the wheels initiate.

Active control increases the effective body mass of a typical vehicle from four to six times its actual mass. The corresponding reduction in body motion of the vehicle is from two to two and one-half times. The overall effect is the riding comfort of an automobile with very soft springs, but even better road behavior than a stiff-sprung sports car on curves and turns.

The new stabilizer is an experimental hydraulic system, successfully road tested on an automobile over a period of two years. Heart of the stabilizer are four controllers mounted at each corner of the automobile. These act as mechanical "brains" to sense any tendency of the car to stray from a level position when bouncing over bumps, rolling out on curves, nose diving when the brakes are applied, or tipping on a high-crowned road.

Right The crowbar discharge switch is a protective device developed to protect critical output loads connected to an ultra-high-voltage power supply—in the neighborhood of 300-kilovolts dc. The new concept consists of a set of adjustable spheres, which can be made to automatically "track" power supply voltage, thereby adjusting the gap in accordance with intentional voltage changes. A triggering circuit will cause the main gap to break down. This breakdown takes place in an extremely short time interval, measured in terms of microseconds after the receipt of the trip signal, and discharges the power supply capacitor bank, thereby protecting the connected load. The first crowbar (photo) is designed for a 300-kv dc system. However, the device has an operating range of 37 to 300kv.

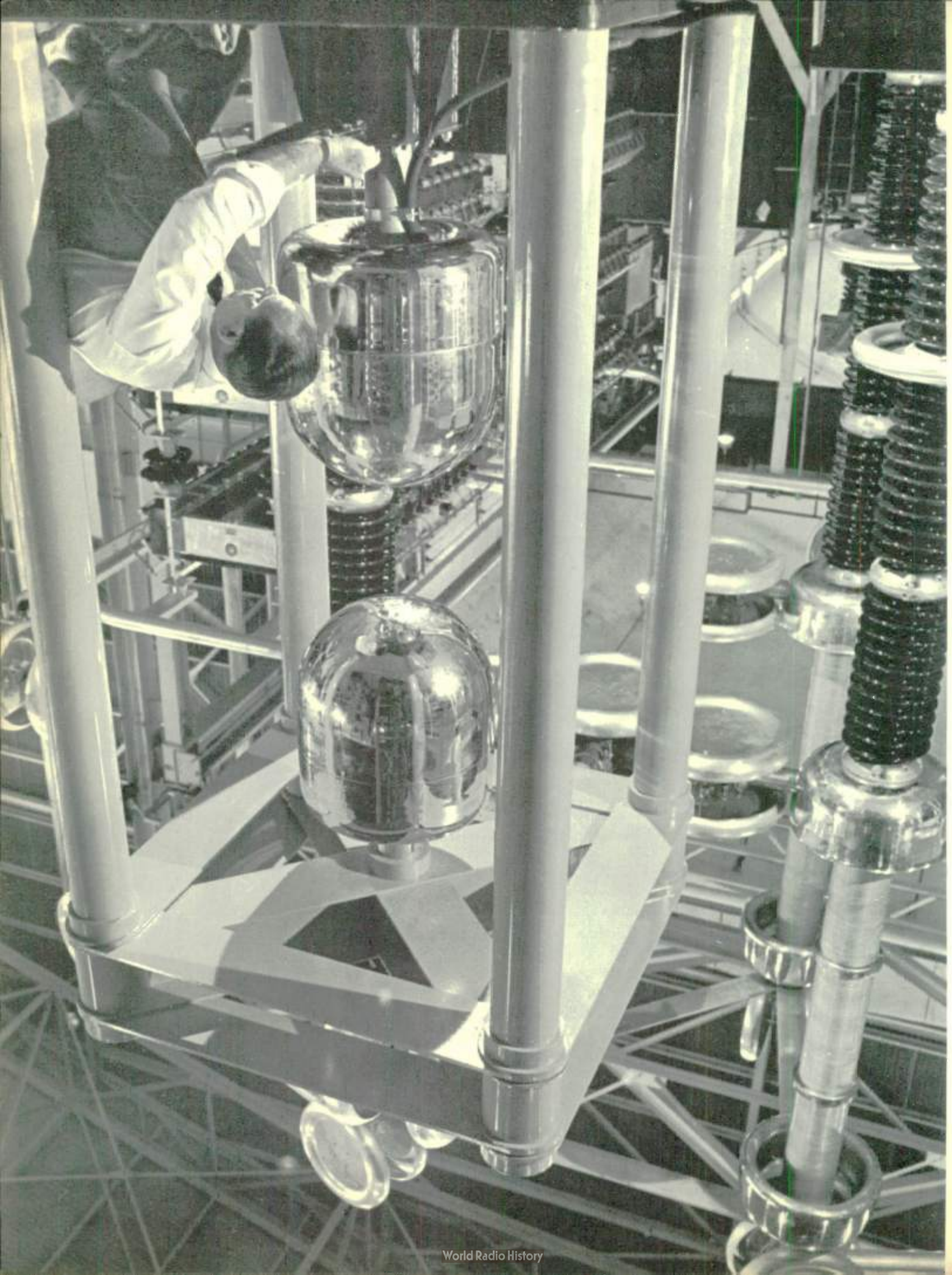
A two-pound weight in each controller detects any change in the rate of motion (acceleration) of the car body and immediately sets about to correct it. It does this by operating a set of valves that varies oil pressure in a hydraulic actuator.

Four actuators, also at each corner of the car, replace the usual shock absorbers. Pistons inside cylinders in the actuators react to the pressure changes by producing forces proportional to body acceleration. These oppose the usual motion of the car's body.

Thus, if a wheel drops into a hole in the road, oil pressure pushes the piston down, tending to hold the body level and helping the wheel to lower itself. On a bump, the piston moves in the opposite direction, holding the body from rising and simultaneously lifting the wheel in the direction it must move anyway.

In similar fashion, the controllers and actuators go into action if the car tries to roll out when rounding a curve or nose dive when braking hard. On a curve, lateral acceleration causes a car to roll out as its weight shifts to the two outside wheels and tends to lift the two inside wheels from the roadway. The stabilizer counteracts this tendency. It lowers the car's body above the inside wheels, raises it on the outside, and thus banks the car somewhat like an airplane tilts its wings in banking on a turn.

The power required to stabilize a vehicle depends upon the roughness of the road being traveled. On a moderately rough road it takes about five horsepower, a small fraction of the horsepower of the average automobile.



This rough equivalent of a missile launching scene is actually a casing for a large generator, standing on end, nearly 30 feet high. The metal scaffolding is supporting a welder. His torch and the sun's rays seem to be of equal intensity. When completed and installed, the generator with its turbine will produce 320 000 kva for the West Penn Power Company.