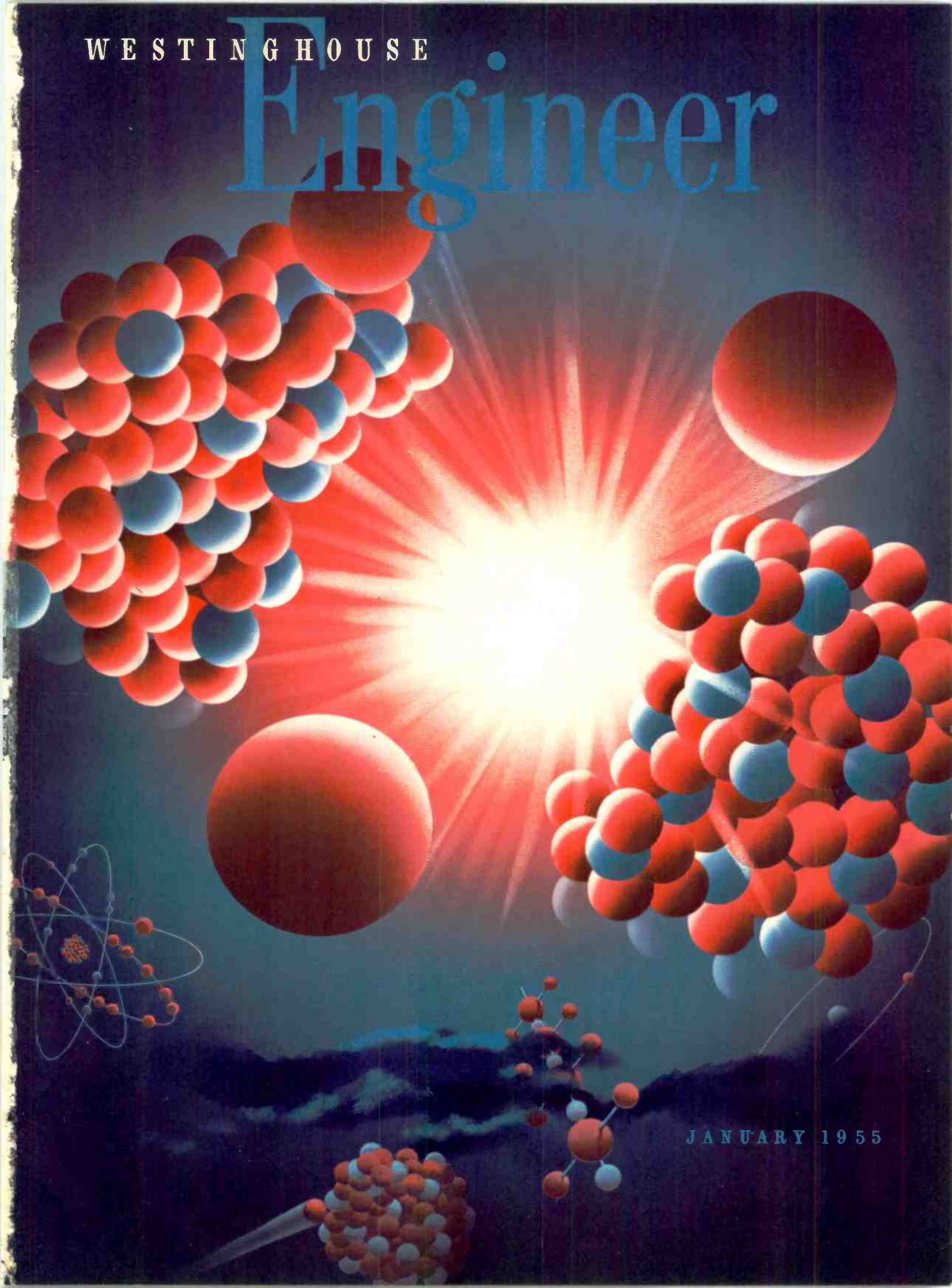
WESTINGHOUSE

# Engineer



JANUARY 1955

# closer to the ATOM

It's time again to view another year of technical endeavors at Westinghouse in retrospect. In this new report, now a tradition at Westinghouse of 35 years' standing, we find in familiar cross-section interesting and important developments in the full gamut of power devices from the turbine throttle to motor, lamp, heater, and radio. We'll let the brief accounts of these speak for themselves.

We'd like to comment on something else, not wholly new but far more conspicuous than ever before, that shows up in the recent record. And that is how much the atom and knowledge of it fits into the scheme of things. This trend we asked the artist, Mr. Marsh, to portray on the cover of this issue.

Looking at some of the places where the atom is more directly involved than previously, the most conspicuous is the nuclear-power plant. It hardly need be pointed out that the two submarine-type power plants, the big commercial nuclear-power station being built for Duquesne Light Company, and the many more uranium-fueled plants to come are based on explicit knowledge of atomic structure. You can build a motor without knowing very much about electrons, but you certainly can't build a power reactor without knowing a great deal about the uranium nucleus.

And there are other examples. We see the story of a new kind of permanent magnet, more powerful than any now commercially available. These magnets, not compounded of primary metals, were not accidental or empirical formulations, but resulted from a new concept of the magnetic forces within matter. It has been more common for a product or device to precede an understanding of it.

The most exciting area of technical development today is that of the semiconductors—particularly germanium and silicon. This past year power-type rectifiers of germanium became a commercial reality. Experimental silicon power rectifiers were built. Almost fantastic things are being done with transistor circuits, particularly of the switching variety. The behavior of all these rectifiers, amplifiers, and switches is far too complex to have resulted from chance experimental endeavor. They have come about because scientists and engineers picture how the crystal atoms and their electrons behave as clearly as you and I observe the action of players in a hockey game.

In the field of light we see that fascinating novelty, the dimly and greenish-glowing electroluminescent cell. But it is much more than a novelty, although we cannot yet count it a new light source. That time is probably years away. Its present worth is that the strange behavior by which certain phosphors placed in an electric field give light is another aspect of atomic phenomenon. It is being assiduously studied, with considerable progress already made, as another window through which scientists hope to gain a clearer view of the remarkable atom.

The study of the atom is occurring along a broad front and in many separate quarters. Sometimes workers in different laboratories are attacking essentially the same problem but from dissimilar approaches. Sometimes the problems show no early relationship.

In one laboratory, a staff of research people with familiar tools and several new ones are bearing down hard on phosphors—a gigantic field, but one of potentially immense rewards in clarifying our knowledge of nature's fundamentals.

In other laboratories men are looking at the atom freed from the disturbances of temperature. At near zero they can make the atoms "hold still." Here they are working in regions within a few tenths of a degree of absolute temperature. Other researchers are using the approach of observing solid matter in the almost complete absence of gases—atmospheres as rare as are found in outer space.

Scientists and engineers are moving in on the atom. From such knowledge, we can count on new, improved devices for man's use tomorrow. It gives assurance of technical progress to come.

A. C. MONTEITH
*Vice President in Charge of Engineering*

WESTINGHOUSE Engineer

VOLUME FIFTEEN
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JANUARY 1955

*The Cover*—The behavior of the atom is attracting an increasing amount of attention from scientists and engineers. Symbolic of the world of atoms and molecules is this month's cover by Dick Marsh.

As in the past, this annual review of engineering developments was written by C. A. Scarlott; Mr. Scarlott, former editor of the ENGINEER, completed this task shortly before leaving the magazine staff late in 1954.



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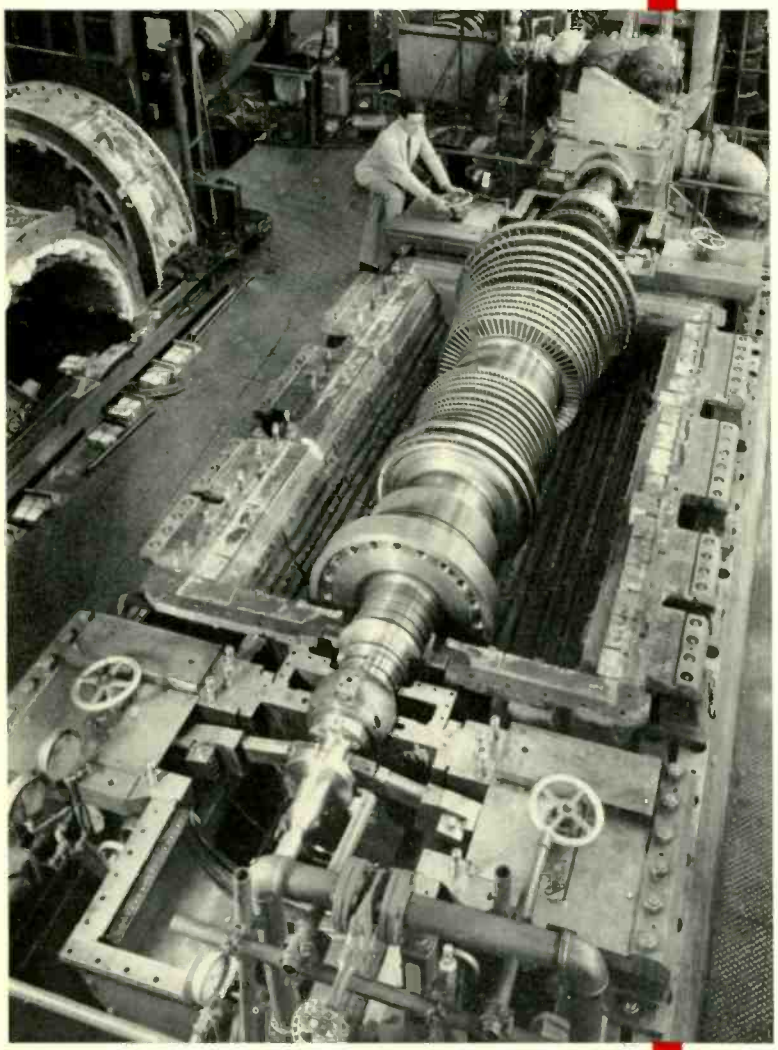
# Power Generation



A high-temperature, 3600-rpm turbine spindle being readied in the heater box to determine if it is one of the few that develops slight but permanent distortion in the first days of operation.

## 5000 Pounds—1200 Degrees

NO CASPER MILQUETOAST is the power-generation industry! With maximum steam conditions of any unit now in service or even in late stages of construction standing at about 2400 pounds, 1100 degrees, Westinghouse and Combustion Engineering have begun work on a generating unit to carry the following eye-opening numbers: inlet steam pressure, 5000 pounds; temperature, 1200 degrees F; kilowatts to the bus, 275 000. Showing its progressiveness is the Philadelphia Electric Company, which has purchased this record-breaking generating unit.

The long pause in steam pressure in the 1600- to 2400-pound zone has not been without reason. Just as in the field of flight the sonic barrier long stood as a line not to be made an operating point, so has 3206 pounds been a critical condition for steam men to avoid. At this pressure, water converts to steam with no boiling. Thereafter there is no difference in volume at the point of transition between water and steam. A boiler with pressure above this nice large figure needs no steam drum.

But if 3206 pounds has been an "immovable object," so is the desire for greater fuel economy an "irresistible force." The outcome is that engineers have decided to hurdle—and what a hurdle!—this barrier and tackle something that at present is close to, if not actually at the optimum Btu economy. (Somewhere in this pressure region the boiler-feed pumps begin to eat up more than the increase in pressure provides.)

Although the designs are in the early stages and all details have not been pinned down, the numbers associated with this plant are these. The turbine consists of four casings, tandem compounded, with triple exhaust to the condenser at 1.5 inches of mercury absolute pressure. Steam will be reheated in the boiler at two intermediate pressure levels, each to 1050 degrees F. Regenerative feed-water heating will supply boiler feed at 565 degrees F.

Preliminary plant operation is contemplated at 1150 degrees F initial steam temperature, other conditions being as stated above. At such time, the plant heat rate is expected not to exceed 8400 Btu/kwhr at rated output, corresponding to 40.6 percent overall thermal efficiency.

The generator is rated 352 000 kva, 0.85 power factor, utilizing inner-cooled rotor and stator conductors. It will be self-ventilated with hydrogen at 45 psi. Construction of this large 3600-rpm generator is made possible by Westinghouse development of hydrogen inner-cooling in 1950. Generator field excitation will be provided by an external motor-generator unit.

The boiler, by Combustion Engineering, will be drumless, of the once-through, forced-circulation, twin-furnace type.

## New Treatment Cuts Need for Field Balancing of Turbine Rotors

CONSIDER a half-dozen identical spindles for large, high-speed, high-temperature steam turbines. All were forged in the same shop using identical techniques. All were processed and machined in the same plant to the same drawings. They should be expected to behave alike when placed in service. However, on the average, five—after the usual balancing procedures—will continue to run smoothly. The sixth, after one or two days running at designed steam conditions, is likely to develop an unbalance serious enough to require shutdown, rebalancing, and perhaps even a small amount of re-

machining. The first few hours, operation has developed a permanent bow in the turbine spindle. It is not fully known whether this is caused by the high-rate, but short-lived, type of creep (there are two types of creep; the other is slow but continuous), or the final modification of grain structure for some reason not completed in the factory processing, or for another reason. In any case, a shutdown in the power plant for rebalancing is a complete nuisance.

To reduce and possibly eliminate this, Westinghouse now subjects completed spindles ready for blading to an additional seasoning and test. It has long been customary to run all such spindles for a short time in a "heater box" at normal speed and temperature for balance purposes. Now this run is extended to about ten hours. By the use of extremely sensitive instruments (changes in vibration amplitude of 0.1 mil can be detected) it is possible to determine whether the spindle is going to develop this permanent bow. If at the end of about 15 hours this tendency does not become manifest, the spindle is considered satisfactory, as experience has shown the improbability of any future difficulty. If, however, this spindle is one of the small minority that has this short-time bowing idiosyncrasy, it is further processed by cyclic speed and temperature, by balancing at speed; and in extreme cases by removing to another heater box where it is seasoned at a temperature considerably above that obtained in operation.

By the end of last year 45 rotors had been processed in this manner. Of those that had gone into service by November, none required balancing after initial start-up.

Because of the economy of time and money afforded by this technique, a multiple-temperature heater box is being built at the South Philadelphia plant at a cost of more than a half million dollars. This box will have several heat zones and will provide a facility for testing spindles that have the combination of long low-temperature blades on one end and high-temperature on the other end. The high-pressure, intermediate-pressure, and low-pressure portions will thus be seasoned at the temperatures closely approximating those experienced in normal operation.

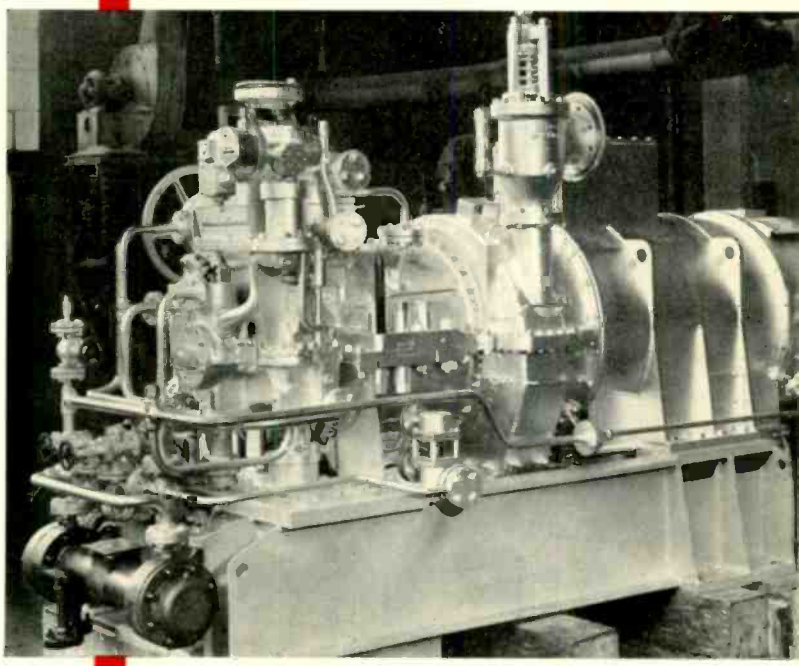
## Better Voices for Steam Turbines

NEW DEVICES better enable steam turbines to signal any circumstance of their operation that might lead to self-inflicted damage.

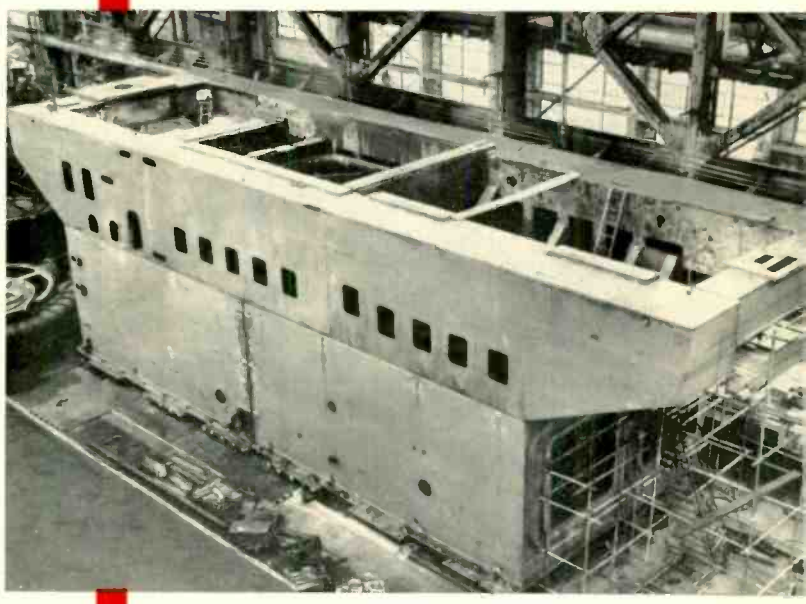
*Flange-Differential Temperature Meter* — The bolted flange joining the upper and lower halves of a steam-turbine casing is a massive thing. The two lips of metal may each be four inches thick, held together by a closely spaced row of bolts three inches in diameter.

That such a heavy structure could get into trouble is hard to imagine. But it can. If a machine is started cold and steam is applied too rapidly, the flange heats more rapidly than the bolts and hence expands faster. The result may be an increase in the compression of the flange surface sufficient to crush it. Contrarily, if the machine is shut down and permitted to cool too rapidly, the flange loses heat and shrinks faster than the bolts. The difference may allow the seam to open up and "blow steam." Both conditions have occurred in practice.

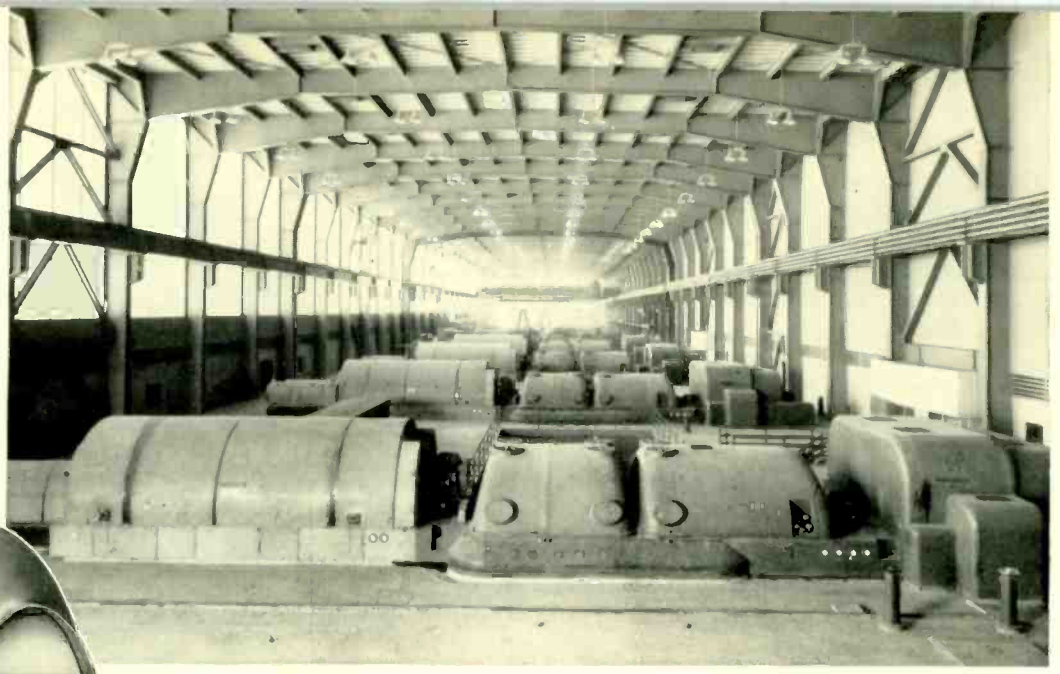
To prevent either occurrence, turbine flanges are now fitted with a simple temperature-differential meter of the thermocouple type. This gives a signal to the station operator whenever the temperatures of the flanges and bolts differ by more than 150 degrees F. He can then modify the start-up or shutdown rate accordingly.



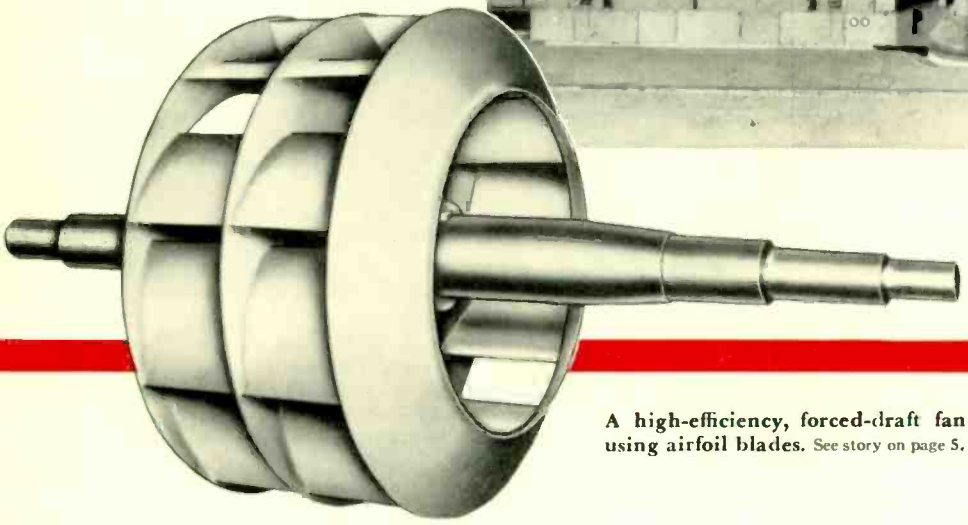
**The U. S. Navy, as part of its program since World War II to determine the limits of machines, asked Westinghouse to build several turbine-generator sets to run at 12 000 rpm and to develop up to 600 kw. Such units could be used to supply lighting or auxiliary power on naval vessels and would have the great advantage aboard crowded ships of being physically small and light. The units were successful—in spite of their high speed. In fact, the units were sufficiently successful to warrant the extension of their design principles to other naval units.**



**This condenser of monster size serves not only its normal function, but also as the foundation for a 125-mw turbine. It thereby saves several feet of headroom, some foundation construction, and much concrete. This 80 000-square-foot condenser is 60 feet long, 24½ wide, and 14 high—bigger than most new ranch-type houses.**



Above is a 150 000-kw turbine-generator unit installed in the Shawnee Station of the Tennessee Valley Authority. This is an 1800-psig, three-casing, tandem-compound, triple-flow unit.



A high-efficiency, forced-draft fan using airfoil blades. See story on page 5.

*Thrust Meter*—With the modern construction of steam turbines of high kilowatt rating, it is more important to know how many pounds per square inch are being carried by the thrust bearing. If the limit is seriously exceeded, the bearing will fail rapidly, allowing the spindle to shift axially in the casing with consequent rubs and serious damage. In turbines now being built the thrusts of the high-pressure and the low-pressure elements are opposed, leaving only their difference to be assumed by the thrust bearing. This is much less than the thrust carried in older designs where the thrust of the elements was countered in part by a dummy piston. However, the thrusts of the two elements are very large numbers and a significant change in one can mean a hazardous rise in load on the thrust bearing.

To warn of such an event a load-sensing device of the strain-gauge type is used as the main structural support for the thrust bearing carrying the entire axial-thrust load. It gives a continuous reading of thrust load in pounds on the operator's panel. In addition to field testing, a laboratory investigation is being conducted to study thrust-bearing constructions and the effects of different operating conditions on bearing wear.

*Excessive Spindle-Movement Trip Device*—If a turbine spindle should move axially by more than a few hundredths of an inch, destructive rubs will occur. This can come about by excessive thrust-bearing wear. If the indicators of such an incipient condition should be ignored, or the defect proceed with great rapidity, it is desirable as a "last-ditch" measure to trip the turbine off the line. A new hydraulic escape valve senses the axial position of the rotor, and at some position just ahead of a rub condition it acts to trip the inlet steam valve. While a shutdown thus results, costly damage to blading is averted.

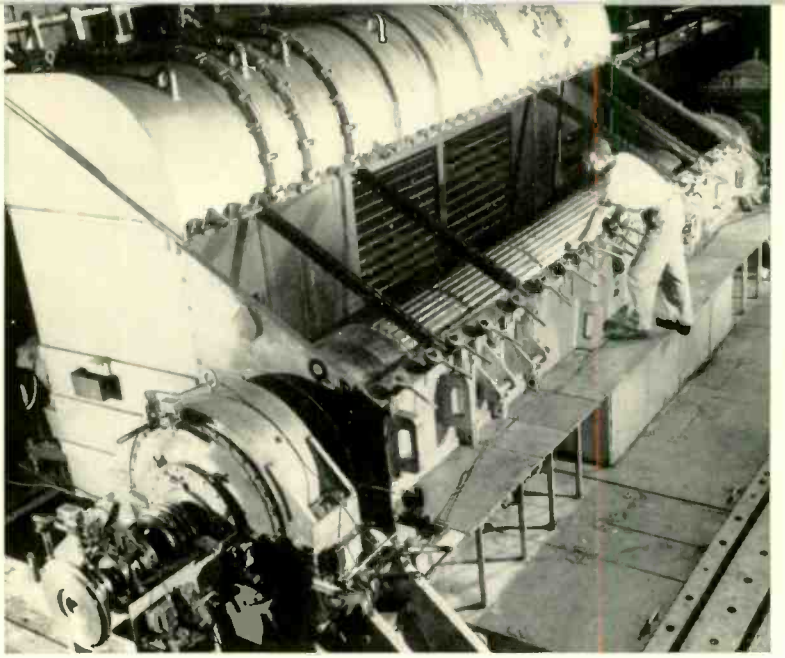
Wouldn't it be fine if the human machine could be equipped with better means for warning of trouble!

## Gas Turbine Gives Agriculture an Assist

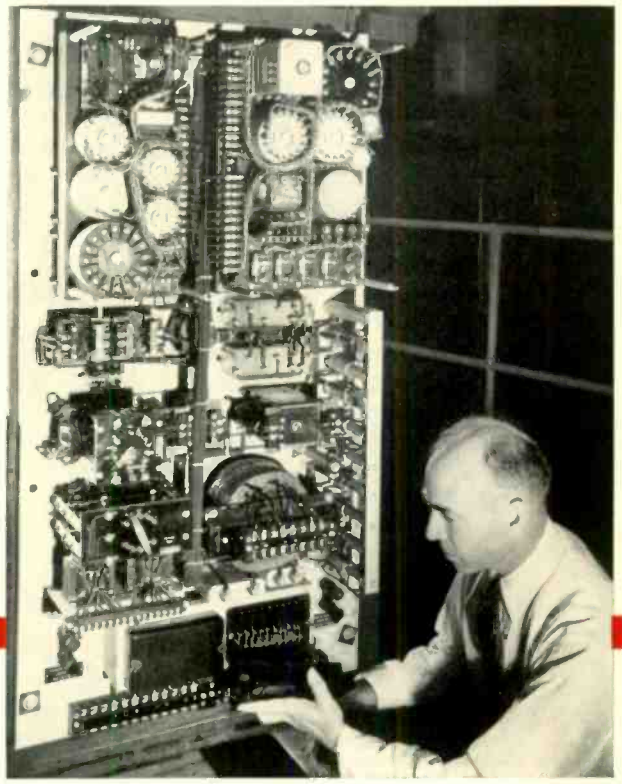
As EQUIPMENTS go, the gas turbine is very young. In its short life it has had far more than its share of interesting experiences: as propulsion for jet planes, in power plants and locomotives, along pipelines, on wheels for liquid-air production, and so on. Now comes a new adventure. A gas turbine is being constructed to gulp large volumes of hot nitrogen gases, produced as a by-product in the conversion of anhydrous ammonia to nitric acid, and thereby develop power to drive compressors used in the process. Anhydrous ammonia and its nitrogen derivatives are the fertilizers that have risen rapidly in popularity.

The turbine is a simple 1800-hp, open-cycle unit (actually it is one of two turbines used in the experimental gas-turbine locomotive whose trials have been concluded. The second unit is being installed to drive electric-power generators in Larned, Kansas). This novel power plant has no combustor. Instead, hot gases for the turbine consist of a mixture of nitrogen and steam at 1250 degrees F, by-product of the nitric-acid process. The turbine expands these gases to 800 degrees F and exhausts them to a waste-heat boiler that makes steam necessary in the process. Also the turbine drives a compressor to produce air at 120 pounds and 450 degrees. Nothing goes to waste in this chemical plant!

*Marine Booster Power*—Perhaps the most novel of recent gas-turbine applications is the use of six aircraft jet engines to drive a ship. Naval vessels operate at full power very infrequently—perhaps totaling only a few hours out of their entire life. The U.S. Navy is taking this into account with an experimental fighter vessel in which the cruising power is provided by an efficient steam plant. This is ample for all normal and cruising purposes. However, when a burst of power is required for a short time, any or all of six gas turbines—actually avia-



Turbine-generator rotors are balanced both cold and hot, thus making balancing after installation a rarity. Here a two-pole rotor is shown in the heater box being prepared for a hot balance run.



The magnetic-amplifier type of generator regulator is free of moving parts.

tion-engine power plants with an added power turbine—can be started up quickly. These aircraft units, only slightly modified, supply the hot high-pressure gases to drive the power turbine, which is connected by gears to the main gears between steam turbines and propeller shafts. These aviation engines weigh less and occupy much smaller space than the equivalent steam-turbine power plants, yet they add roughly 50 percent more power when burst power is needed.

*Gas-Turbine Power Train*—A 5000-kw mobile gas-turbine power plant will be on rails this year. This power plant will do in two cars a job that required eight cars for the steam power-plant trains built during the war. The 5000-kw gas turbine is identical to the units operating as electric-power generating units in the Venezuelan oil fields.

The power plant can be run to produce power at either 50 or 60 cycles. This required modification of the generator design and special regulators to insure that the output is the same at the two speeds.

## Big Fans

TWENTY-TWO high-capacity, forced-draft fans for power plants being built for the atomic-energy operation in southern Ohio are both highly efficient and particularly quiet. These qualities result from the use of airfoil-type blades.

The mechanical efficiency of each fan is 88 percent. The noise level is five decibels quieter, for any given air delivery, than other centrifugal fans. In other words, because of the streamlined air-flow pattern, the sound intensity is almost 70 percent less than with fans having flat blades.

Two fans are used in parallel for each boiler. Each pair of fans requires 3300 drive horsepower and delivers 1000 tons of air per hour. The rotor diameter is 87 inches.

## Inner-Cooled Generators in Service

INNER COOLING as a basic system of ventilating large turbine generators has moved from the unusual to the usual. It is now standard construction for all generators beginning at about 128 mva. As of November first, 22 of these machines were under construction at East Pittsburgh, totaling over five million kva. This includes the giant, 200-mw unit for the Philadelphia Electric Company, which will briefly hold the record for size among high-speed generating units. This record for size will be transitory, as the first of the 250-mw, 3600-rpm generating units for Gallatin Station of TVA is scheduled for operation late this year. Incidentally, a machine of this size could not have been built using the older, conventional ventilation systems.

The first inner-cooled unit to go into service was the 100-mw unit in the Huntley Station, Niagara Mohawk Power Corp. Trial runs began in January, 1953 with commercial operation starting in March. Although this was the first full-scale machine to be inner cooled, extensive tests while still in the factory proved that the designers had accurately calculated the operating temperature and performance. Experience with this first machine has been so satisfactory that, except for a few details, no changes in construction are indicated.

The Niagara Mohawk machine was tested in the factory at pressures up to 96 pounds, although the machine in service operates at 45 pounds. Tests were made at the higher pressures to verify engineers' predictions—which they did—and to provide test data for construction of machines for expected future higher operating pressures.

*Inner-Cooled Bushings*—Generator bushings, like the machines they serve, are benefiting by the principle of inner cooling. By comparison with a 6000-ampere conventional bushing, in which the heat has to flow through insulation, the

inner-cooled bushing can comfortably handle 10 000 amperes. For the very large machines this means that one set of bushings located at one end of the machine suffices, instead of two sets, one at each end.

The new bushing is substantially the same as those that have given years of reliable service. The conductor, however, is made hollow. Within it is placed a smaller tube that carries hydrogen from the main cooling system to the far end of the conductor. The hydrogen then reverses direction, flowing between the outside of its conducting tube and the inner walls of the conductor.

***Magnetic-Amplifier Voltage Regulators***—Last year marked the first use of production models of the magnetic-amplifier voltage regulator—the Mag-a-stat. This regulator has no moving parts and provides de luxe voltage-regulating performance. Operating from a 420-cycle supply, it has a high rate of response. As of November 15, six large generators using the Mag-a-stat were in service, all giving excellent voltage-control performance.

This static-type regulator is finding other application. In a simplified form it is being used to control the d-c voltage of ignitron-rectifier substations used in coal mines. The absence of moving parts and contacts makes it particularly attractive for this class of work.

***Geared Exciter***—The low-speed, high-capacity geared exciter is giving a good account of itself. It was developed to provide reliable excitation equipment for the larger 3600-rpm generators. The geared machines run at the low speed of 897 or 718 rpm, which makes for low maintenance and long brush life. As of last November, over a dozen of these exciters had been in service up to a maximum of over two years, with excellent performance.

***Generator Balancing***—Designers of large turbine-generator rotors are justifiably proud of the fact that very seldom does one of their machines have to be balanced after it leaves the factory. And this is more of an accomplishment than it first seems. Sure, a long generator rotor is balanced dynamically when hot and when cold. But that is not all. There also is what engineers term thermal balance. A rotor when run in its stator is inevitably subjected to some uneven heating because of slight irregularities in the flow of cooling gas. Hence, it is Westinghouse practice, after a rotor has been given hot and cold mechanical balance, to run it in the stator it is going to live with and check it for thermal balance, which is a function of load. Corrections are made by baffling the hydrogen-flow system to prevent the smallest thermal distortion at any load. Provision is made in the ventilating-duct system to accomplish this.

***Forging Inspection***—The men who inspect the massive multi-ton forgings from which turbine-generator rotors and waterwheel-generator shafts are machined have sharpened their ability to locate flaws even deep in the metal. Formerly, inspection of a hole bored through the center of a rotor forging was the only way of ascertaining its quality, but now with the help of ultrasonic techniques the quality of the material between the bore and the surface of the forging can also be determined. The sensitivity of the test, dependent on the frequency used, is such that fine porosity, slag, inclusions, and cracks can be detected easily. At present a frequency of 2¼ mc, which is more sensitive than the lower frequencies generally used, is being applied in the inspection of the large rotor forgings. The forging is given an extremely thorough ultrasonic scanning, even to testing across a chord, which can show up radial cracks that might be missed if the sound waves were all directed radially.

## The Growing Favor and Uses of Thermalastic

THERMALASTIC insulation for rotating machines is following a pattern common to successful developments, except that it is occurring with greater than average rapidity. Thermalastic was introduced five years ago as a new insulation system for the high-voltage half coils used in turbine generators, replacing asphalt-base materials. Since then it has been extended to the full coils of waterwheel generators and synchronous condensers, and a modification of it is used for lower voltage machines, particularly motors, where its extraordinary moisture resistance is of special benefit.

New life is coming to existing waterwheel generators, some of which have been in service many years. Stator coils are being replaced with new ones insulated with Thermalastic. Because of the higher electrical strength of the Thermalastic insulation, there is more room for copper. Hence in most cases rewound machines can carry more load or run cooler.

## Nuclear-Power Progress Continues

THE PAST YEAR saw notable progress in several phases of the nuclear-power program at Westinghouse. First highlight of the year came when the U.S.S. *Nautilus*, for which Westinghouse designed and built both nuclear reactor and steam-turbine generating equipment, slid down the ways at Groton, Connecticut on January 21; the vessel was subsequently commissioned on September 30. National security prevents publication of many of the important achievements that have made the *Nautilus* possible, achievements that could fill this magazine.

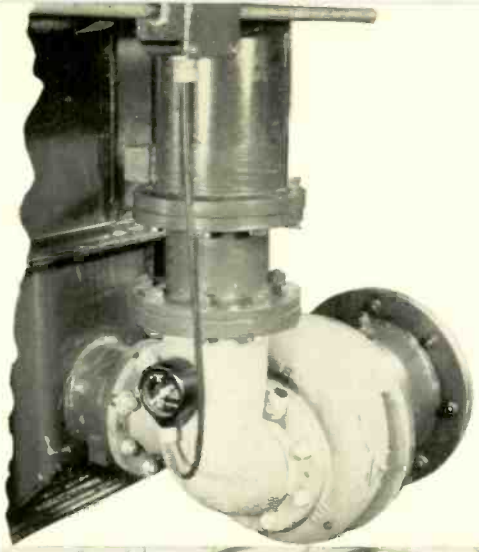
On June 13, 1954, Rear Admiral Lewis L. Strauss, Chairman of the Atomic Energy Commission, revealed in a speech that almost a year before another important milestone in nuclear power had been passed. As reported in *The New York Times*, on June 23, 1953 the STR Mark I, prototype of the *Nautilus* power plant, operating at the National Reactor Testing Station in Idaho, had been brought up to full power for a scheduled 24-hour test. The test was so successful that Admiral H. G. Rickover, Chief of the Naval Reactors Branch of the Atomic Energy Commission, decided to continue the test to simulate an underwater crossing of the Atlantic Ocean.

Naval charts were broken out and a great circle course was plotted between Nova Scotia and Ireland. The landlocked "submarine" steamed ahead, making a "landfall" in Ireland in what must have been record time. Not once during the simulated cruise did the Mark I have to stop or "surface," and power was reduced below full power only three times, and then for brief periods.

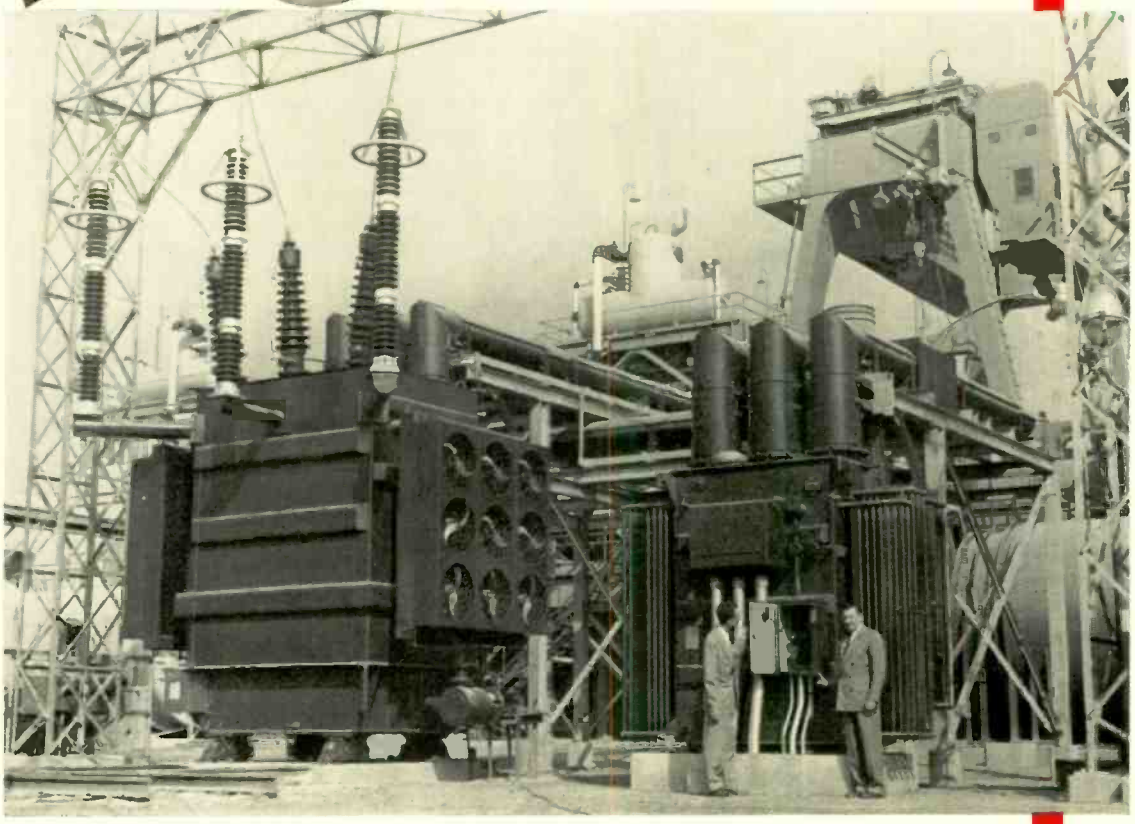
With the Submarine Thermal Reactor project rapidly nearing a successful conclusion, the central-station nuclear-power project gathered impetus. Announcement was made by the Atomic Energy Commission in March that the Commission would negotiate with the Duquesne Light Company for the construction and operation of the nation's first full-scale central-station nuclear-power plant.

Work on the power reactor is progressing, with important development and detailed design work well under way. Contracts have been let by the Atomic Power Division to Babcock & Wilcox and to Foster Wheeler for the construction of the four steam generators, which are to be the boilers.

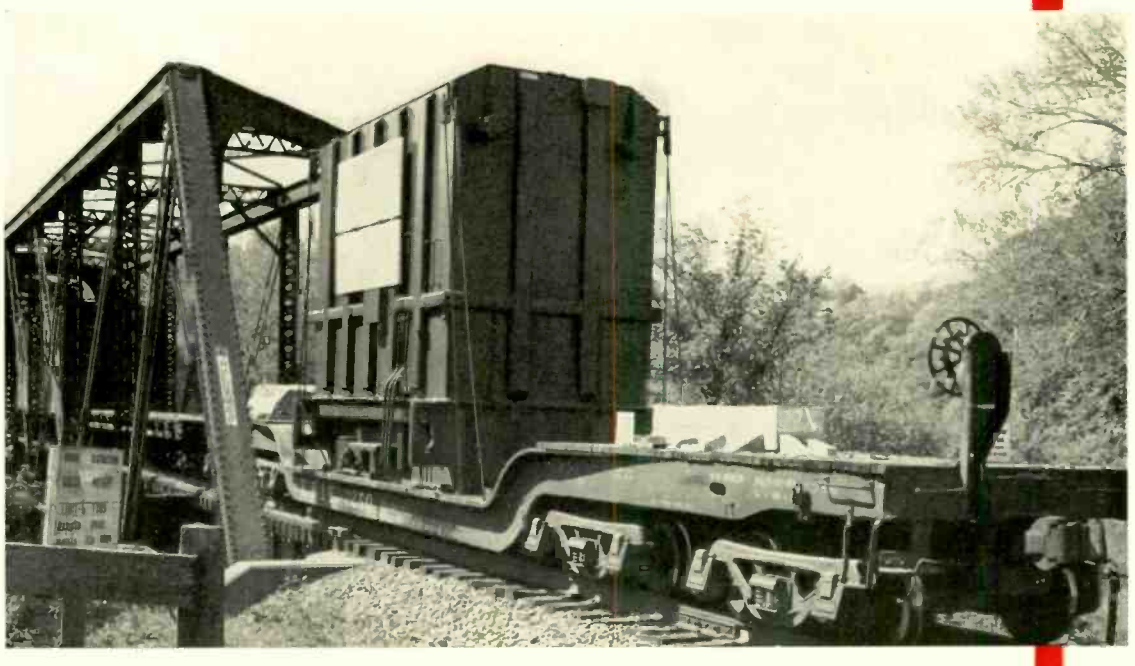
Following this announcement it was made known that Duquesne would erect the power plant at Shippingport, Pennsylvania, 25 miles west of Pittsburgh.



# Power Transformers



*Top left,* the oil pump of this transformer uses cast construction and sleeve bearings. Gauge indicates oil movement. *Left,* at the Muskingum plant of the American Gas & Electric system are four 150-mva, 330-kv autotransformers.



Power transformers sometimes make a glove fit with railroad bridges enroute. This is a 220 000-kva transformer on its way to the TVA system.

## A Report on Power-Transformer Progress

POWER TRANSFORMERS have sometimes been jokingly referred to as being "big as a house." This is no longer a jest. The giant 315 000-kva unit that will be installed on the Detroit Edison Company system this year stands 25 feet high and covers a ground area of 18 by 26 feet. This machine, electrically the largest transformer in the world, weighs about 450 000 pounds when installed with all its auxiliaries. It will be connected to a 129-kv line.

Small only by comparison with this 315 000-kva unit are four 220 000-kva, 161-kv transformers placed in service on the TVA system last year. All of these transformers, while large, have required no new principles of construction to meet either operating or shipping requirements.

A sizable number of transformers have been built or are undergoing construction for the new higher voltage systems—330 kv. These include generator transformers, autotransformers, and units equipped for tap changing under load. One 330-kv autotransformer has the out-size electrical rating of 400 000 kva. A point of interest in transformer progress is that one of these 330-kv transformers weighs 617 000 pounds. This is the first time this weight has been reached since a 30 000-kva unit was built 25 years ago, even though kva and voltage ratings have been increasing all these years.

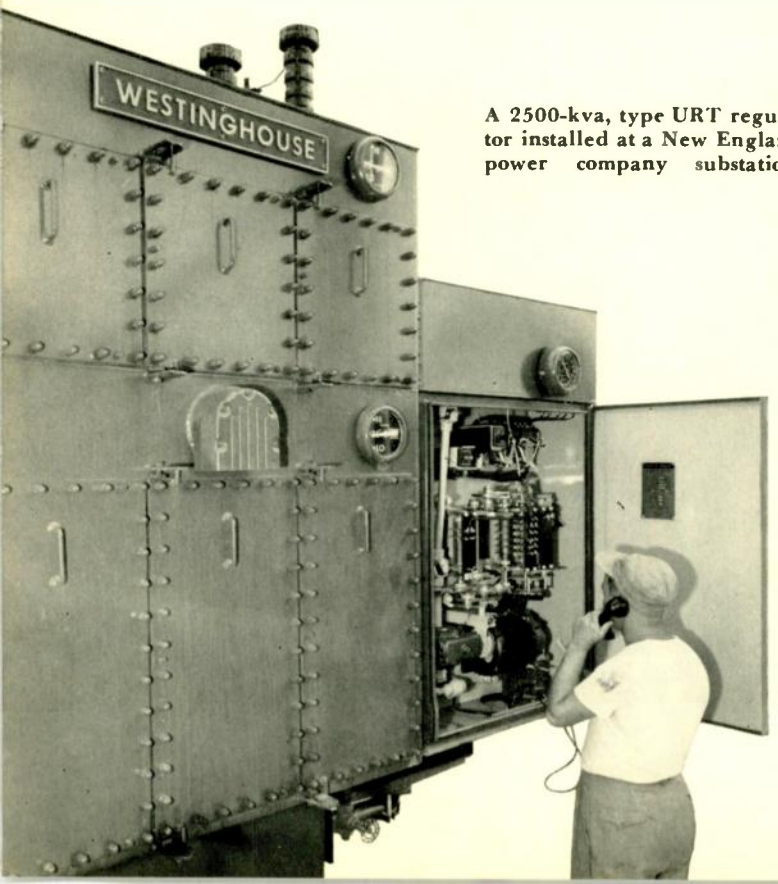
Another significant installation of large units is that of six 133 000-kva transformers on the system of the Bonneville Power Administration. These are single-phase devices, which means that each bank totals 400 000 kva.

***Standardized Bushings***—The new industry-standard high-voltage bushings, 25 through 69 kv interchangeable, on both transformers and circuit breakers of all manufacture, were placed in production last year.

***Radiator Valve***—The valve on oil-filled transformers between the tank and the radiator bank should be something installed and forgotten forever, for all practical purposes. But the fact that the flapper has a cemented-on gasket sometimes places doubt on that goal—gaskets being what they are.

A new way of providing a seating surface on the valve flapper lays that matter to rest. Hycar rubber is vulcanized and hot molded to the aluminum flapper to insure a bond that is permanent.

***Transformer Oil Pump***—Both the oil-pump housing and motor have been improved. The housing is of cast instead of fabricated construction and is provided with a direct-reading oil-flow gauge. Previous indicators depend on the existence of oil pressure across the pump, which could exist with no oil moving. The motor has been provided with sleeve-type bearings to give it longer life with less maintenance.




**A 2500-kva, type URT regulator installed at a New England power company substation.**

## Tap Changer Coordinated, Smaller, Simpler

THE POWER transformer tank has become a beast of many burdens. Radiators, arresters, tap changers, relays, indicators, and other devices cling to the tank walls like warts on a pickle, leaving almost no bare wall space. One of the big offenders has been the load tap changer. The control equipment, operating mechanism, and the tap-changer switches each enjoyed the solitude of individual cabinets. A complete redesign of all elements of the tap changer has combined them into a single housing with a number of compartments, making all parts accessible from the front. This new tap changer, known as the URT, projects from the tank only one third to one half as far as previous designs. The selector switch can now be examined from the front, instead of through side inspection doors behind the transfer-switch panel. The tap position is now shown on an external dial-type indicator, rather than on a drum viewed through a port in the cabinet door. The arcing and main contacts—with increased current-carrying capacity—are now separately adjustable to obtain maximum contact life. The transfer-switch compartment is sealed against inbreathing to prevent oil deterioration caused by the entrance of air-borne oxygen and moisture into the oil. Gaseous products of the arc interruption are vented when the pressure reaches a definite positive pressure.

## Voltage Regulator—Rearranged to Reduce Size

IT IS sometimes amazing what can be accomplished when the components of a major piece of equipment are studied simply for rearrangement—with no major design change. The station-type step regulator has had such a recent going over. The results: in the case of the 13.8-kv, 239-kva unit, the floor area has been cut from about 40 square feet to 19 (52 percent) while the weight has been dropped 35 percent.

The control and tap changer were in separate cabinets mounted on the tank wall. They have been combined into a common housing. Not only that, but part of the housing, containing the tap-changing mechanism, projects into the tank above the core-and-coil assembly. Meaning that it doesn't take up room outside; instead it fills up volume inside that was previously occupied with non-working oil. This accounts for a sizable hunk of the weight reduction; the oil weight comes down from 5000 to 3230 pounds. The benefit to the eye of these amalgamations is another large gain.

While the regulator has been given no major design change, some detail improvements have been worked into it. For example, a geneva-gear drive is used in the cam-switch assembly, with a gain in simplicity of adjustment. An added feature is an external dial-type position indicator with resettable hands for maximum and minimum position. The new SJS voltage-regulating relay with all electric settings has been used.

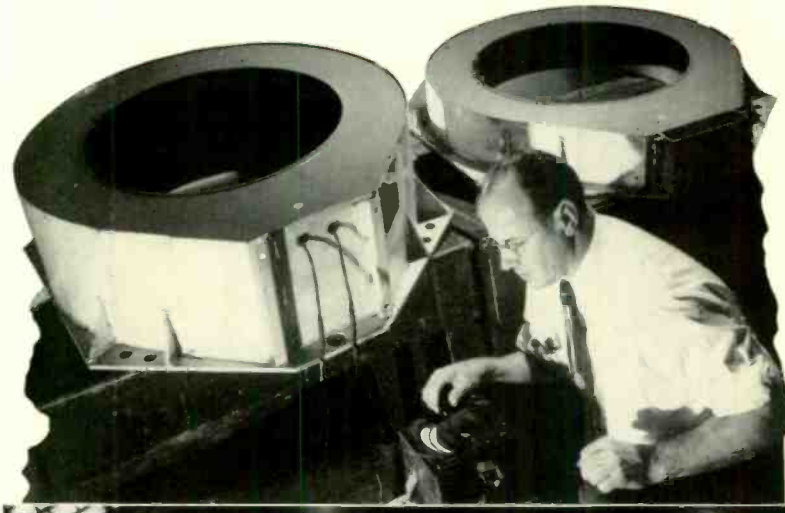
# Circuit Interruption, Relaying, and Protection

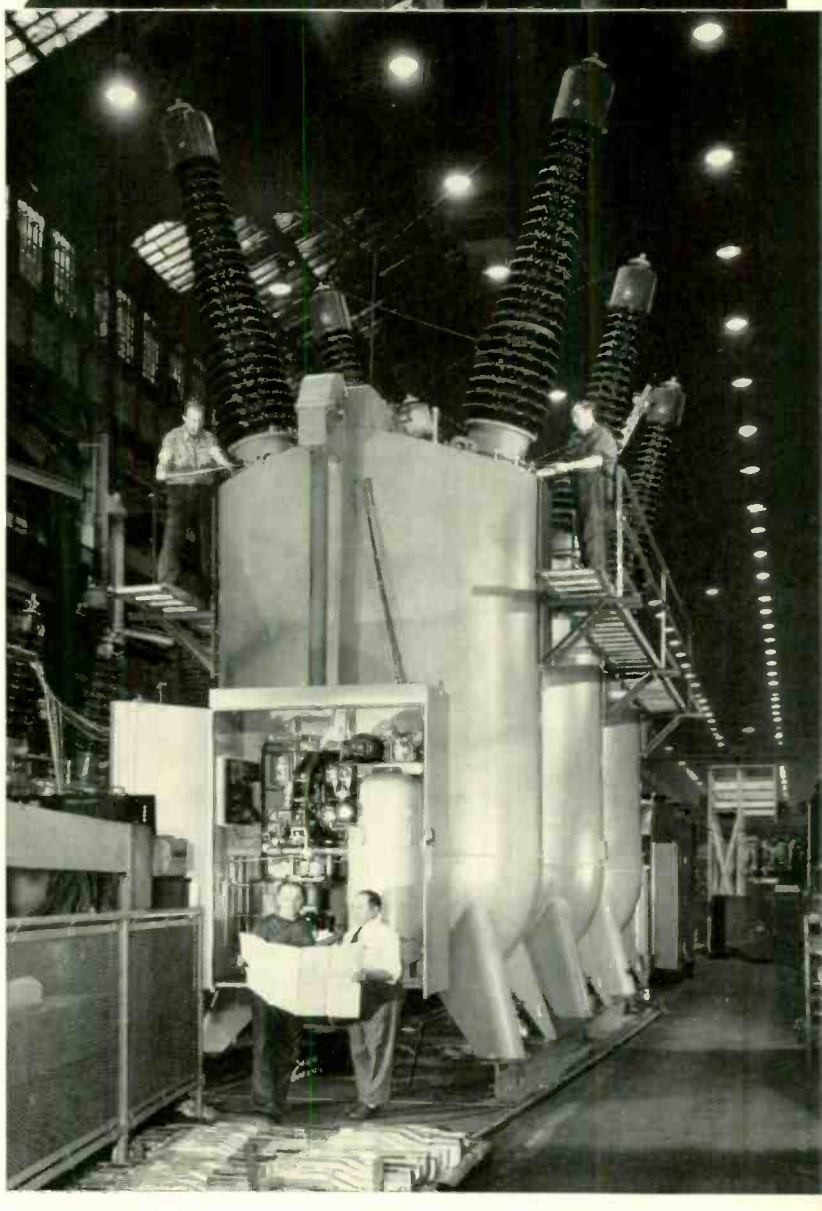
## 330-Kv Breakers Meet Their Tests

EQUIPMENTS for the new, higher transmission voltage began taking up their positions last year on the system supplying the AEC plant in southern Ohio. Among them were the circuit breakers with the breath-taking interrupting rating of 25 million kva. Of the 35 breakers being built by Westinghouse for this project and connected transmission lines, more than 20 are already installed.

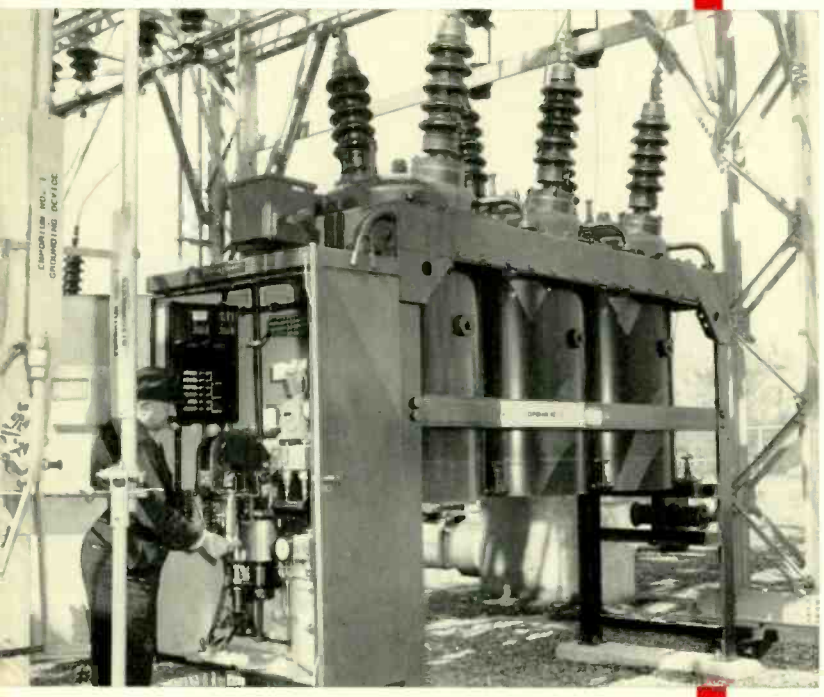
Breakers of a new type or a new voltage class would always be given the full treatment of all the tests required by industry standards for a new design. But the 330-kv interrupters were treated to a far more severe dose of tests than that. For example, the interrupters were required to take a full wave of surge voltage directly across the open contacts in the grids with the isolating gap still short-circuited by the iron bar. This difficult test, and others, the interrupter met handily.

The 330-kv interrupter is not simply the 230-kv unit sized proportionally larger, although it might have been so made. But there would have been the problem of how to test such a single-break interrupter, because no laboratory can come within a country mile of making such a 25 000-mva test. Instead, a new type of multiple-break interrupter was created for this service. The interrupting job is divided into four identical arc-quenching units per terminal, each of which can be tested separately, and which is comfortably within the range of testing facilities. Then a new scheme of resistors and capacitors was provided to make sure that of the four breaks each takes its share of the interrupting duty. The resistors assure equal division of the recovery voltage, while the capacitors reduce the maximum gradients on the insulation under surge conditions. This scheme is not wholly new, but recent developments in materials for the electronics industry have resulted in an extraordinarily compact capacitor, consisting of ceramic blocks containing titanium oxides and sealed in a heavy plastic. This makes it possible to assemble the capacitors, as well as resistors, in small tubes running the length of the interrupter.





**At top of page, bushing-type current transformers for 330-kv, 25 million-kva circuit breakers. At right, the breakers themselves at the factory.**



**Frame-mounted circuit breakers—which cover the voltage span from 14.4 through 69 kv—have come in for streamlining and simplification. The breaker tops are now smooth domes with the lever mechanism inside. This not only improves the appearance but keeps the breaker cleaner and makes it easier to paint and maintain. The frame itself has been modified to use fewer but heavier members with the channel-shape top horizontal member replacing the transformer secondary conduit and condulets. Magnetic-type De-ion grids have been retained.**

**A new, low-voltage air circuit breaker soon available has improved performance characteristics but uses less space. Sample shown interrupts 75 000 amperes at 600 volts, 3 phase, and extends rating of DB breakers to 3000 amperes.**

Each arc is drawn inside an interrupter block of fiber plates. An important feature of these blocks is that each is easily removable, which not only permits its own inspection but also provides a porthole in the side of the interrupter. Through the opening the contacts can be inspected without disturbing their alignment. Each interrupter assembly has a spring-driven oil pump to assist in interruption of light-load and charging currents. The principles of this unit-construction 330-kv interrupter can be applied to breakers for systems of higher voltage, and may later be adapted to those of lower voltage but higher interrupting duty.

A new operating mechanism, similar in basic principle to that used on breakers of lesser kv rating, is used. However, it has been improved in numerous details. It is larger, of course; its 14-inch piston develops twice the closing force of the previous largest mechanism, an important feature in maintaining simultaneous closing of all phases. All three poles of the breaker are driven by a single mechanism. A new type of linkage gives a straight-line motion to the piston rod without heavy guide rails, reducing friction and increasing reliability in spite of the heavy load.

*330-Kv Current Transformer*—The bushing-type current transformers for these 330-kv breakers are in themselves rather spectacular. To begin with, the particular application required an unusually high number. Never before have the bushings of a three-pole high-voltage breaker been asked to carry more than 12 transformers, 9 being more common. These 330-kv breakers have 15. Furthermore three of these are used for revenue metering and must have billing metering accuracy, which means they are extra large to provide adequate cross-section of the core. Each transformer is encased in Fosterite and contained in its own aluminum housing, which protects it from damage during assembly as well as in service.

*High-Power Testing*—To expedite the testing of these high-capacity, high-voltage breakers, a new test cell has been added to the high-power laboratory. Thus, while one breaker is being set up on one cell for test or being removed, a test can be under way in the adjoining cell.

## Circuit Breaker Integral with Its Bedplate

A CIRCUIT BREAKER now embodies a feature that makes it a single unit integral with its own bedplate, but without adding any height. Breakers have before been bolted to a bedplate of I-beams for handling, shipment, and placement as a unit—but this has added the height of the beam to the total. In the new construction the tank bottoms have been lowered to fit down in between the I-beams, and the oil-drain connection is brought out through a hole in one of the beams. This small saving in height is more important than it sounds. In some cases it has permitted shipment of the breaker with bushings in place, where otherwise they would have to be shipped separately.

## Relays Better Adapted to Conditions

*Network Relay*—If you put any electrical device within a box, place this box within another one containing other electrical devices that under some operating conditions may dissipate a substantial amount of heat, and put the second box within a third box that also contains a source of heat, the centrally located device may reach a temperature that damages its insulation no matter how little energy it con-

sumes. It is for such an environmental problem that the network relay must be designed. The relay in its housing is put inside the network protector that is installed in a vault below the street.

Recognizing this situation, a new network relay has been developed that is just as able to withstand the high temperatures occurring under certain overload conditions as the protector and transformer. The relay has class H insulation. Silicone-enameled wire, only recently available, is used.

*Primary-Network Relay*—On primary networks, which are growing in popularity, swings in voltage are many times wider than on secondary networks. Just the same, the protective relays must be sensitive to magnetizing current, which drops markedly as voltage goes down. Also, the standard secondary-network relay, for which operating conditions do not require response to magnetizing current at voltages much below normal, is itself considerably less sensitive when the voltage is reduced. The problem has been to make the primary-network relay sufficiently sensitive without a voltage-regulating transformer, which would unduly complicate matters. Last year relay engineers developed a way to modify the internal and external connections of the relay so that it does not become less sensitive as the voltage is reduced and thus will meet the requirements of primary networks without need of external devices.

## Same Arrester—But Better

TO IMPROVE a device without changing it is a neat trick. But that is what lightning-arrester engineers did last year to both station- and line-type arresters. It is not possible to manufacture Autovalve arrester blocks (of silicon-carbide) precisely alike. Their discharge characteristics cover a range. In any typical large batch of production blocks a few are inferior. These are discarded. The vast majority possess the normal protective characteristics, while a few are definitely superior. Arrester ratings, for obvious economic reasons, have been based on the performance of the predominant unit.

An effort to apply much more restrictive control both on raw materials and on processing methods has paid off by greatly increasing the number of blocks with superlative characteristics. This has been so effective that it has warranted rerating both the station- and line-type arresters. This improvement is sufficient to permit using line-type arresters for some applications where the better performance of station type had been needed. On the other hand the new station-type arresters have been bettered so that protective margins and zones of protection are increased.

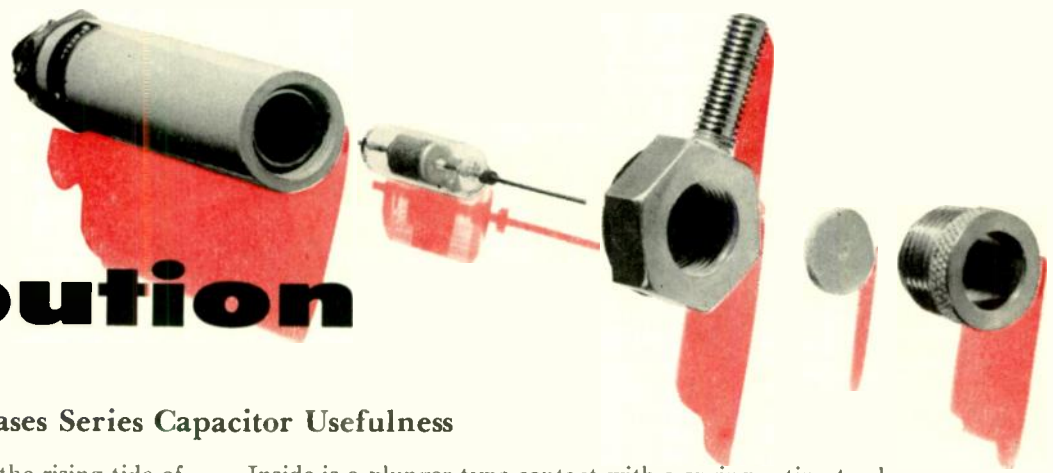
## Substations Get Direct-Stroke Protection

THE PROPER amount to spend for insurance is always a question. Those who design high-voltage substations are continually faced with this issue. To provide 100-percent protection against lightning is inordinately expensive; not to provide enough may result in costly outages. Generally it has not been considered possible to provide complete protection to transformers against heavy, close-in direct strokes, the probability of which is, fortunately, extremely low.

Recently, in studying plans for two very large high-voltage substations, the protection engineers took a fresh look at the problem. These two substations are to be supplied by high-voltage cable. The transformers are widely separated from the switching equipment. The study revealed that protection against close-in direct strokes is possible. If the first towers have low footing resistances and the first spans out on the lines are well shielded, the presence of the cable capacitance makes arresters adjacent to the transformers unnecessary. The saving is considerable.

With the use of cable at substations becoming increasingly common the results of this survey will be used to lower station protection costs.

# Distribution



## Simple, Low-Cost Protector Increases Series Capacitor Usefulness

ONE OF the new problems washed up by the rising tide of air conditioning and other motor loads is light flicker on distribution circuits. An obvious answer is to apply series capacitors, which have the nice ability to add corrective capacity proportional to the load and at the instant of need. However, if a series capacitor were allowed to take any short-circuit current that developed, it would be ruined. The need is for a protective device that instantly bypasses all short circuits. A new one (shown above) is simple, effective, and relatively inexpensive. In a form for use with 230-volt capacitors, used on single-phase 2400-volt applications, there is a fiber tube about two inches in diameter and eight inches long. Inside is a plunger-type contact with a spring acting to close it. It is held open, however, by the point of the terminal resting on a small wafer compounded of aluminum powder and a plastic binder. This wafer is electrically conducting but has a high contact drop at the surface. In series with the contact is a gap sealed in a tube of glass (or for higher capacity circuits, metal). In it, separating two electrodes, is a disc of material having an extremely high dielectric constant. On a short circuit the drop across the gap rises; the concentration of stress formed by the disc causes the gap to break down; and current flows through the electrode resting on the aluminum-powder wafer. A hole melts through it almost instantly, allowing the

spring to close the main contact, forming a low-resistance path for the short circuit around the capacitor. To return the capacitor to service it is necessary only to insert another wafer in the tube.

## Distribution Transformers—Better Inside, Better Outside

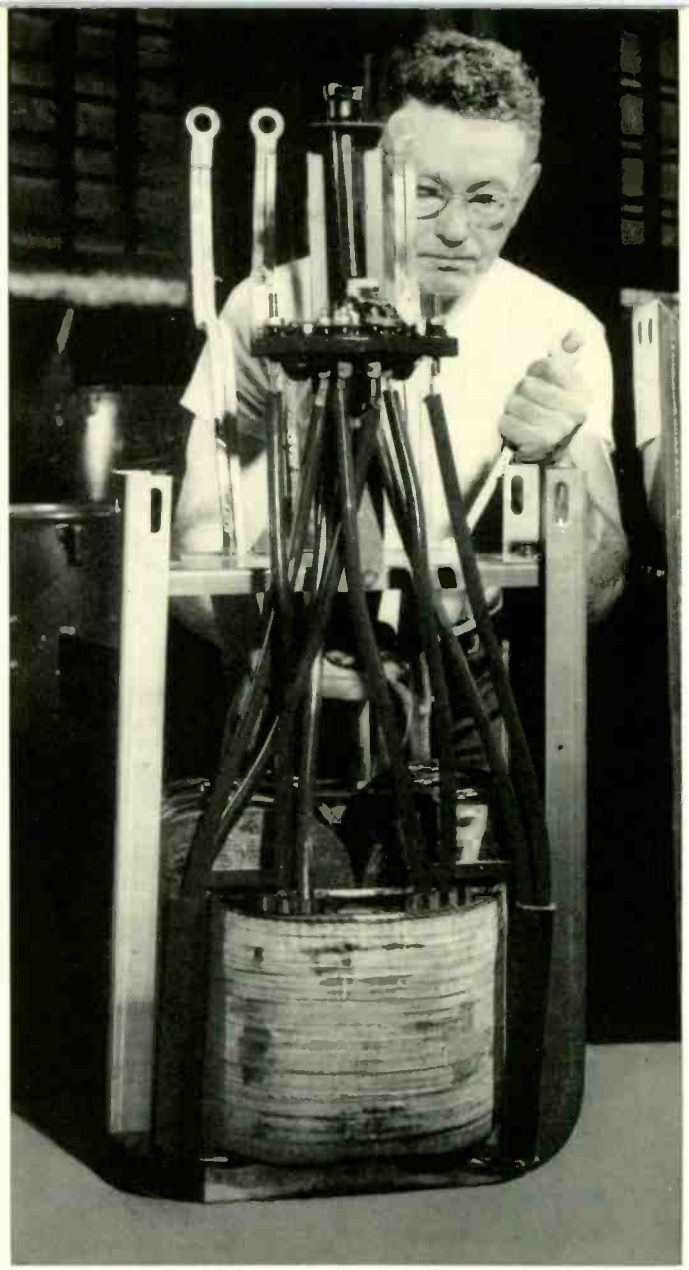
FOR THE OLD, well-developed devices such as distribution transformers, one or two significant improvements in a year's time is a pretty good batting average. Last year, distribution transformers scored several.

*Tank*—Automatic machinery is now used to form a new type of tank rim, in which the former rolled shape is replaced by a rectangular-shaped bead. The flat upper surface of the bead permits the rectangular-shaped Corprene gasket to be placed in position in full view of the operator. The new shape is more "streamlined" than the old, and this effect is enhanced by completely eliminating all clamping brackets for holding the cover.

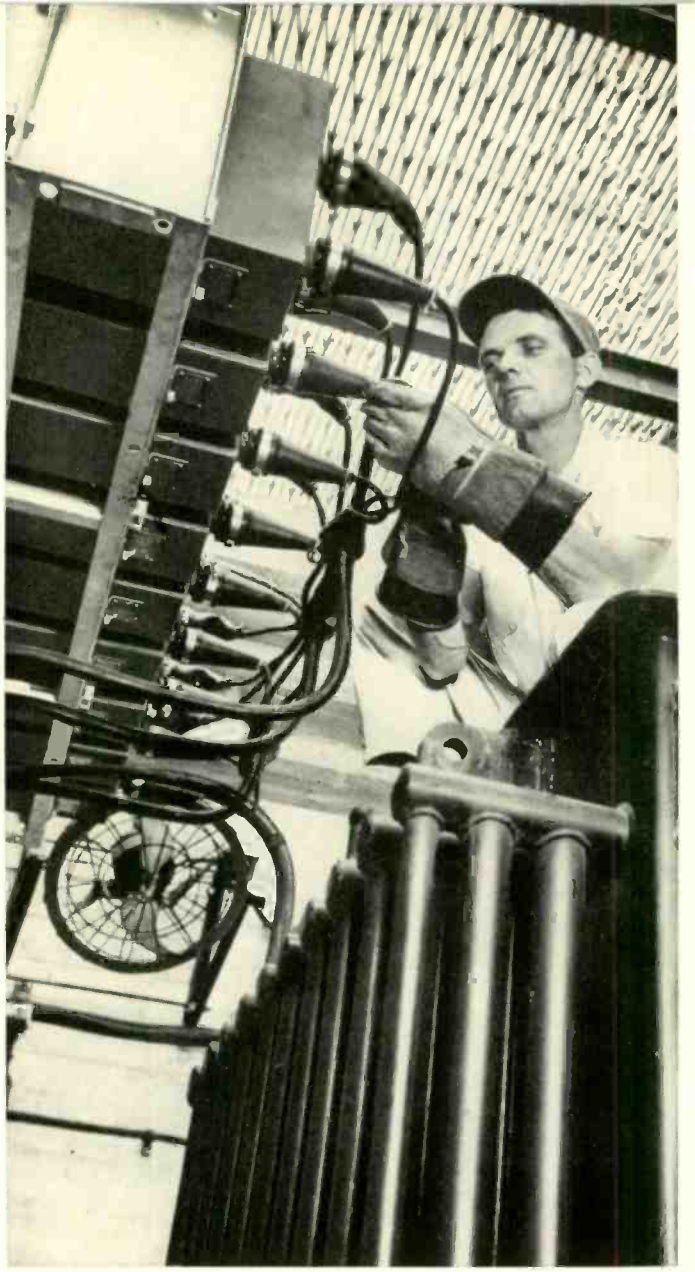
Hanger lugs, with flanged feet projection-welded to the tank wall, presented the possibility of leaving minute spaces between the underside of the flange and the tank wall, where moisture can accumulate and become a corrosion hazard. Now a new U-shaped hanger lug with wavy edges, which form the projections for machine welding, has replaced the old. The lug is placed in the welding machine, butted against the tank wall, and the welding cycle fuses the projection scallops solidly into the wall. The corrosion hazard is eliminated.

The metal hook on the side of the tank wall, used to hoist the transformer to the pole top, seems like a small thing, but it is not so unimportant that it has been overlooked in the development program. It has been reshaped, with two objectives in mind: better looks, and a smoother underside to avoid cutting the lifting rope. It is also projection welded to the tank wall by the same method as used for the new hanger lugs, thereby eliminating the corrosion hazard at this point also.

*Tank Cover*—The main cover has been reshaped with a steeper crown to give strength and ready drainage of moisture, and the flanged rim portion has been designed to cooperate with the tank bead in such a way as to retain the cover gasket completely—top and bottom and both sides. Now a single bolt holds the cover on, and it does a better job of it than the four previously used. This single bolt goes through the center of the cover and engages a structural member firmly by two brackets welded to the tank wall just below the top rim. By this means, pressure is automatically applied evenly on the gasket all around the rim. With the older method, if the four bolts, fastening into lugs equidistant around the edge, were not tightened equally, warpage might result. The flexing of the cover itself in the new design acts to produce a continuous spring follow on the main cover gasket. Also, with the single-bolt system, the possibility of scraping the paint is eliminated. The new cover contour gives no resting place for water, and provides a smoother, neater appearance—a quality enhanced by omission of lugs.



***Left,*** **the spiral-core expulsion arrester (Valvex), described a year ago as having been developed for 3 kv, has now been extended to the 6- and 9-kv classes. Laboratory tests, as well as several years' experience in the field with the type LX crossarm-mounted arrester (the original spiral-core arrester), have shown that the long path provided by the spiral cut in the fiber filler gives a high arc-extinguishing quality and a life expectancy of 30 years or more.** ***Above,*** **the new core-and-coil assembly, showing the new U-shaped, one-piece end frame and the step-type core construction.**



Secondary networks are often underground, and an underground vault with the possibility of flooding and poor ventilation "ain't a fittin' place" for ordinary capacitors. However, the 230-volt, 15-kvar capacitor has been modified to make it suitable for underground service. Also, network engineers get a break. The standard 230-volt, 15-kvar capacitor applied to 216-volt circuits has a rating of 13⅓ kvar, which is just the right amount of derating required by higher ambient temperature. Thus three units provide 40 kvar, or just the right amount for a 300-kva transformer.

Consistent with the increasing capacities of distribution devices, the current rating of the 2500-volt, pole-type regulator has been raised from 150 to 200 amperes. The contacts of the tap changer have been made larger for longer life. Bushing terminals have been modified so they can accept a wider range of cable sizes—from number 8 wire to 250 000 circular-mil cable. New bolt-down lugs have been added by which the regulator can be securely anchored to a platform. Regulators for higher voltages have been developed. These are rated 36 and 72 kva for 14.4/24.9-kv circuits.

*Handhole Covers*—The handholes in the transformer cover bushing are extruded from the main cover to produce a gasket seat similar to that furnished by the bead in the tank wall. Similarly, the handhole covers are flanged to retain the Corprene on all four sides. The handhole cover is held to the main cover in the same manner that the main cover is held to the tank wall, that is, by a single bolt engaging a yoke bar, which in turn locks on the underside of the handhole extrusion. By loosening this one bolt, the yoke bar is backed off its holding position and is withdrawn with the handhole cover as a unit assembly.

*Bushings*—The high-voltage bushings have been redesigned for more modern appearance (style in porcelain "petticoats" too!) and for better matching with the arrester porcelains. The bushings now "flow" into the tank wall or cover, with no exposed hardware. They are held in place by internal bushing-retaining flanges.

As an overall result of this new design, the transformer is improved in appearance and made completely sealed—preserving the internal transformer and oil and excluding all moisture and foreign material from the outside.

*Core-and-Coil End Frame*—The standard way of holding the core-and-coil assembly in position in the tank has been to place it in a rectangular frame fabricated from angle or channel sections. The improved method is to fold a single flat strip of steel into a channel member. In the small sizes, this takes the form of a top frame, which is banded securely to the transformer core. In the larger sizes, it takes the form of a U-shaped cradle for holding the core-and-coil assembly. This results in a more accurately dimensioned assembly because the frame is formed to fit the core.

*Stepped Cores*—There has always been the wasted space problem attendant to fitting a coil around a rectangular core. A better match of shape has been effected by winding the

core with the inner portion of iron with a slightly narrower strip than that comprising the main body of the core. This gives a stepped effect at the edge and permits filling a greater portion of the coil opening with active magnetic material. This gain makes for a more compact core-and-coil assembly and aids in producing better performance.

## Crossarm Transformers—Larger Ratings, Same Weight

RESIDENTIAL LOADS are getting heavier but poles and crossarms are not any stronger. Which poses the problem of how to get more transformer capacity on the pole without passing the weight limitation.

Last year, distribution-transformer engineers took the existing design and gave it their all toward paring weight. Right successful they were, too. The upper limit of rating for crossarm mounting has been boosted from 100 to 167 kva.

Use of oval radiator tubes instead of round ones gives more cooling. Shop facilities have been extended so that the larger size wound-type cores (type C) can be built. This is made economically feasible by the large increase in numbers of these transformers. (Stacked cores were used before.) A better grade of Hipersil grain-oriented iron is used, with reduction in iron losses and weight. The core and coils have been redesigned to get a more favorable proportion of iron and copper. All these result in a 167-kva transformer that weighs under 1500 pounds instead of 2000, and stands 46 inches high instead of 58.

## Lighter Current-Limiting Reactors

BECAUSE current-limiting reactors are subjected to tremendous mechanical forces during heavy short circuits, they must be stout. This means they have been heavy and bulky.

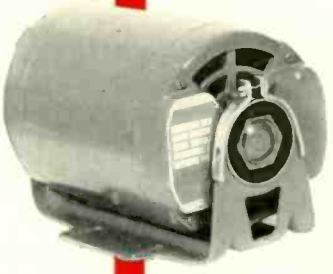
Lately some of the "beef" has been taken out of them without giving up any performance. The practice has been to form the conductor into layers of concentric coils, each layer being supported by heavy cleats. These layers are held between cast-concrete discs at top and bottom by several vertical tie rods. Because of a new tie-rod construction, the top concrete disc has been eliminated. The vertical tie rods have been moved in from the periphery of the cleats and made smaller. An important result is that cleat space is better used. Two or more turns of conductor can now be placed in this space, thus giving an average coil-inductance increase of 20 percent for a given diameter of reactor. The tie rods—which cannot be of magnetic or conducting material—consist of fiber-glass cord cast into resin. When the cords are in place the space around them is filled with an epoxy resin, giving a solid, strong bond. In place of the usual supporting insulators of porcelain, supports are made of polyester glass fiber and arranged so that one can be removed without jacking up the unit. The total weight saving amounts to 15 to 20 percent.

*Pole-Mounted Feeder Reactors*—With load rising on distribution systems there has been a growing need for a reactor that can be mounted on a crossarm to keep line-fault currents within the interrupting abilities of line reclosers. The problem has been to get a reactor that is light enough and has adequate surge strength. By using the newest high-strength materials, a 48-kva, 200-ampere reactor weighs only 360 pounds, which is within crossarm weight limitations. The reactor turns are held in compression by glass tape. Mounting fixtures are of stainless steel.

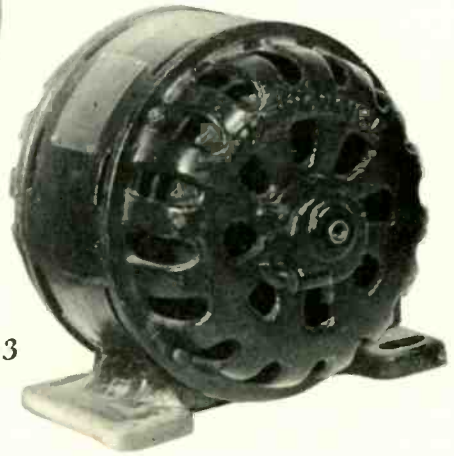
**Comparison of the new Life-Line A motors (left) with type CSP. Top to bottom: 10 hp, 5 hp, 2 hp.**

# Motors and Drives

**Compare the old and the new ¼-hp motors. Old motor weighs 69 pounds, the new but 16. The new 48-frame motor has a high-volume, low-noise ventilation system. Voltage or rotation changes are made on the terminal board.**



1954



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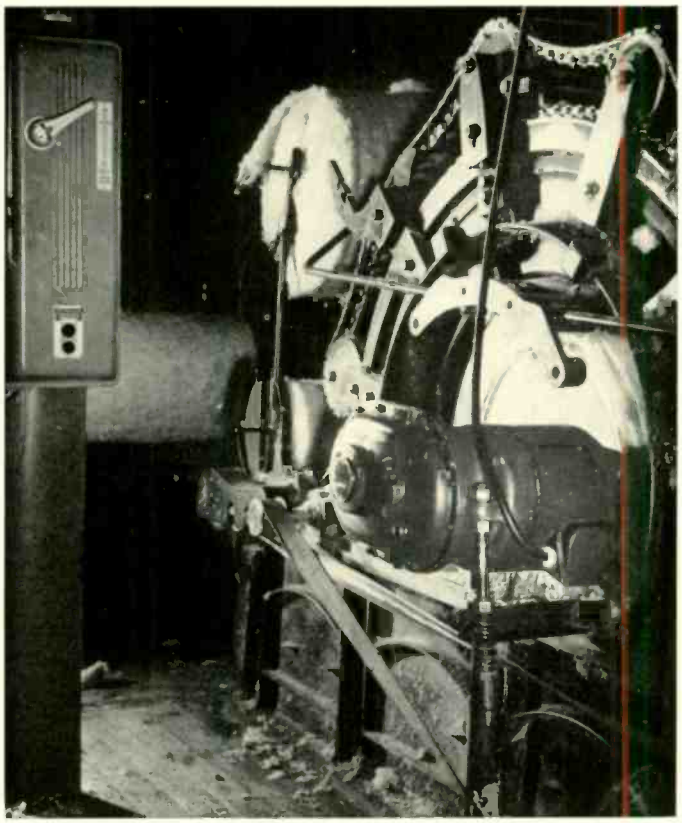
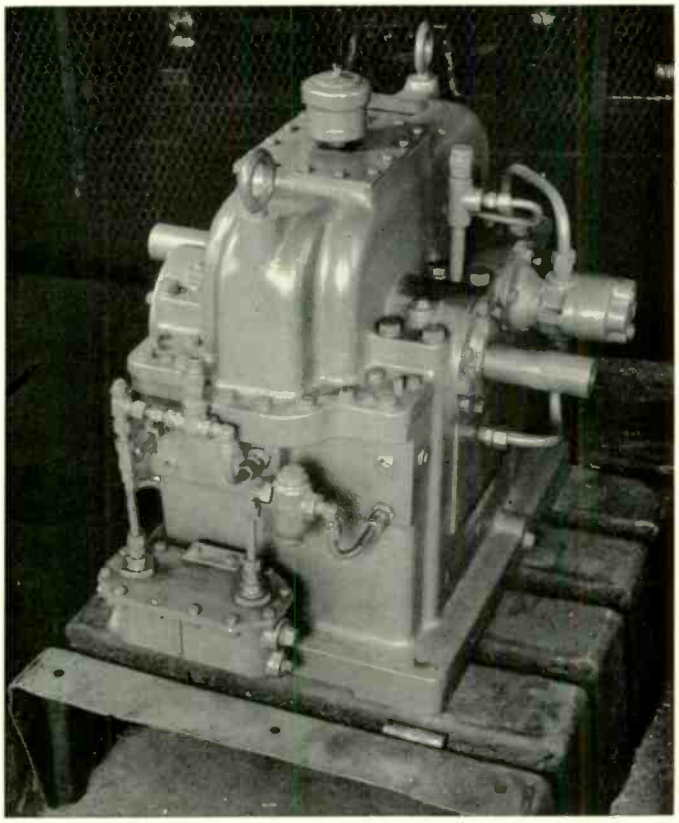


A *coup de grace* may be in the making for belt drives—at least in the textile industry. Most cotton cards—machines for preparing cotton fiber for processing into yarn—are still belt driven. A new gearmotor has been developed to eliminate the belt by making the gearmotor slip right onto the card-cylinder shaft, with a tie rod to keep the unit from turning. A 1750-rpm motor will turn the cylinder shaft at 165 rpm. This will reduce maintenance and hazard of belt drives, and keep cards at the correct speed.



To get more horsepower into smaller packages, speed must be increased—high-speed centrifugal compressors, fans, and pumps are typical of this trend. Speed increasers, which step up motor speed to the compressor, have been designed to handle the job. The principal problem in the new design is taking care of increased heat losses. To provide the additional cooling capacity necessary, a larger oil sump is incorporated, and greater cooling capacity has been designed into the oil-to-water heat exchanger.

## Completely New and Smaller Squirrel-Cage Motors

INDUCTION MOTORS are now smaller. By the end of last year Westinghouse had in production the new motors in frame sizes 182 through 256 (1 through 10 hp at 1800 rpm); this is part of the industry-wide program of again reducing the sizes of squirrel-cage motors.

The presently produced motors are the two basic forms, i.e., drip proof, and totally enclosed. Trailing these basic types in production by a few months are the many modifications required for specific purposes such as explosionproof, flange mounting, single phase, etc. It is expected that all of the basic types up through the extent of the program—30 hp—will be in production this year.

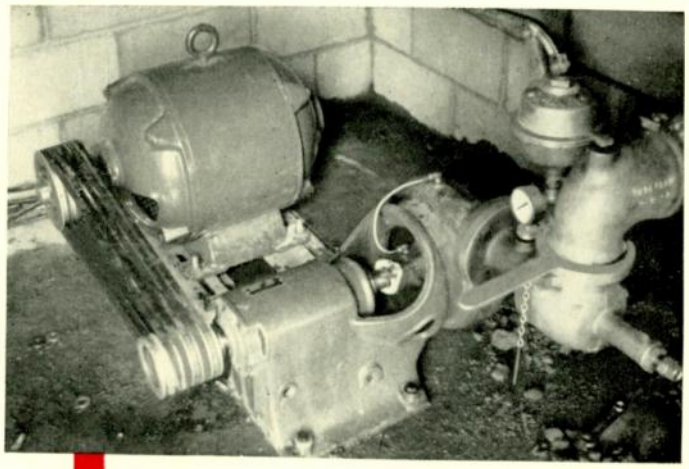
The new motors are a summation of many recent developments. Just to cite a few examples, the wire in the stator is insulated with a synthetic resin (Bondar) that has a life three times longer than that used in the previous motor. Slot-cell insulation is a combination of Mylar polyester film and rag paper instead of varnished cambric and paper. It is three to four times stronger electrically and thermally, yet occupies less space. The phenolic-alkyd thermosetting-type varnish in which wound stators are dipped has a life of 170 percent of the older varnish.

The weight of copper used in the stator windings is practically the same as now used. The effective volume of electrical sheet steel is about 15 percent less than the present motor. By proper selection and processing of the higher grade silicon steel, the losses for a given flux density have been reduced by 20 percent with no penalty in permeability. The punchings of the previous motor were essentially square, with rounded corners. The ineffective corners of the laminations have been removed to make circular punchings, and a smaller diameter frame is used. Stray load losses have been kept at a low level by design, processing, and treatment of rotor surfaces. Ball bearings, seals, and lubricants likewise have been significantly improved.

Despite the drastic change in size and weight, performance characteristics—torque, inrush current, rated temperature rise, and overload capacity—are maintained.

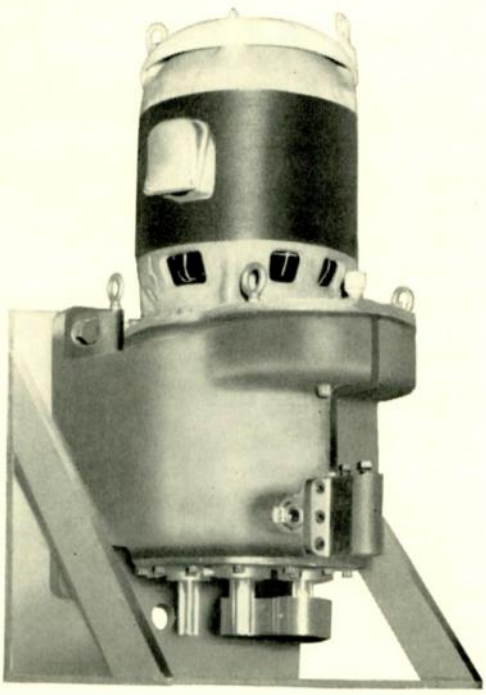
## Big Motors Get Bigger

THE 1954 CROP of big motors built or building shows several that are novel for the use to which they are put or because they set new limits for size. Conspicuous among them is a 4000-hp d-c motor that will drive a stand used for testing helicopter blades. This is the largest vertical d-c motor ever to go through Westinghouse shops. It is quite similar to vertical waterwheel generators, with a thrust bearing at the top and a guide bearing at the bottom. It is being designed so that the power on this test stand can be subse-



A 20-hp single-phase motor installed on a farm. This is a capacitor-start, capacitor-run motor.

As the farmer and fruit grower go deeper for their all-important water, the problem for the pump and driving motor stiffens. A new kind of motor that goes down into the bottom of the well with the pump helps ease that problem. This new submersible 40-hp motor (left) is only 9½ inches in outside diameter and thus can be fitted into a ten-inch casing. To eliminate troublesome and expensive shaft seals inherent in oil-filled motors, the motor is designed to operate with water inside the bearings as in marine service.



One motor does the work of four in a new design for driving pumps on nylon-spinning machines. The triple-reduction gearmotor (below) has a 30-to-1 speed reduction, with a four-gear cluster around the third reduction pinion. Four output shafts operate at identical speeds. The gearmotors are of two sizes, 2 and 4 horsepower.

quently doubled by adding an identical motor in tandem with this first unit.

Helicopter blades must not be subjected to sudden accelerating torques, especially at slow speed. In addition to a "soft" start and smooth control over the entire operating speed range (125 to 275 rpm) extremely accurate positioning of the rotor blades for adjustment is necessary. The control can index the shaft within two degrees over a sector of 45 degrees.

*Taconite-Process Motors*—The reduction of rock-hard taconite iron ore to usable blast-furnace feed is getting under way. These large-scale production plants being built in the Duluth area are requiring great numbers of 800-hp synchronous motors to drive the rod and ball mills. Because the dust—containing iron oxides—is extremely abrasive, special attention is given to dust-tight seals for the bearings.

*Record-Size Motors*—Indicative of the increasing size and pressure of boilers is the fact that several two-pole squirrel-cage motors rated at 4000 hp are being built. The biggest heretofore was 2500 hp.

In the pulp industry bigger chippers are being built to chew up logs. A new-size synchronous motor is 1750 hp, exceeding the previous largest by 250 hp.

## A 20-Hp Single-Phase Motor with 10-Hp Starting Current

THE ENGINEERS who build motors for farmers have their heads spang against a ceiling. The ceiling on starting inrush current, for reasons of light flicker and other evils of voltage dips, is set by the power companies. This has made a 10-hp single-phase capacitor motor about the biggest that one can get under these limits. For many jobs—say feed grinding—a farmer needs more horsepower.

Now, if you please, the engineers have turned a neat and very practical sleight of hand. They now offer a 20-hp motor with less inrush than a 10-hp motor.

How do? Really the trick is quite simple. For the most part it has to do with a new way of connecting, at start, the two windings (main and auxiliary) every single-phase capacitor motor has. Normally the circuit of one winding contains a series capacitor to shift phase relations, which gives the partial effect of a two-phase motor. When running, these two windings are in parallel across the single-phase power line.

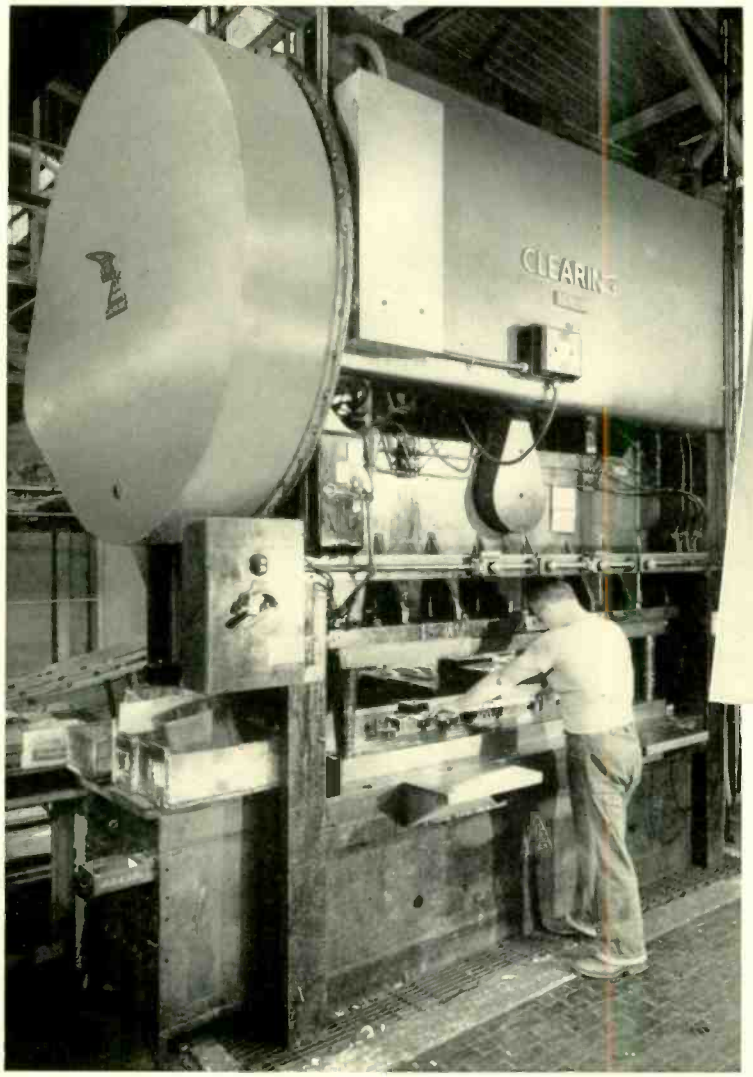
In the new single-phase motor these two windings are arranged so that at the instant of starting they are connected in series, with the capacitors in parallel with the auxiliary winding. The greater impedance afforded holds down the starting current. To make the most of this idea other modifications were made in the iron and electrical circuits.

The motor has a starting current of 190 amperes as against 400 for an ordinary 20-hp single-phase motor. Yet it has 150-percent starting torque.

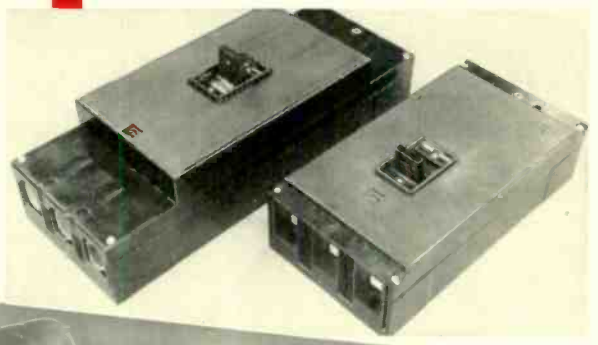
## Miniature Gyroscope Motor

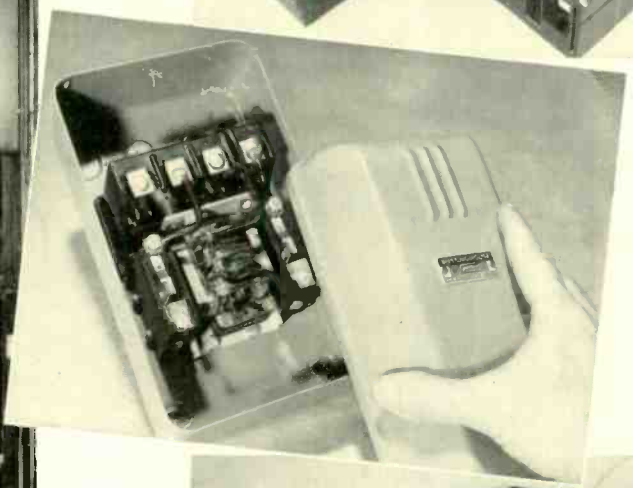
A DIME-SIZED gyroscope motor, probably the world's smallest, has been designed for application where space is really at a premium—on the moving antenna of aircraft fire-control radar. The "inside-out" synchronous motor has a tiny wound stator; the rotor is also the inertia wheel of the gyroscope. This permits an element with a large polar moment of inertia to be built into a small space. The 2-phase, 400-cycle motor operates on less than a volt per phase.

# Control



Typical installation of d-c braking on punch press.





*Above,* comparison between 600-ampere type L breaker (left) and 400-ampere type KL (right). *At left,* a 30-ampere air-conditioning starter (enclosed type).

Two-pole, common-trip circuit breaker.

## Developments in Control Devices

THE FIELD of devices to protect and control low-voltage circuits and motors is, as usual, generously dotted with improvements to make the devices more capable, more reliable, easier serviced, or in other ways better.

*400-Ampere, De-ion Low-Voltage Circuit Breaker*—A representative result of the relentless pressure to cram more capacity in a given volume is a 400-ampere De-ion low-voltage panelboard-type breaker. The two top current ratings for these long-famous molded-case breakers (AB) have been 225 and 600 amperes. This is a sizable span in rating and there has been a growing demand for an intermediate one. A 400-ampere unit is the result.

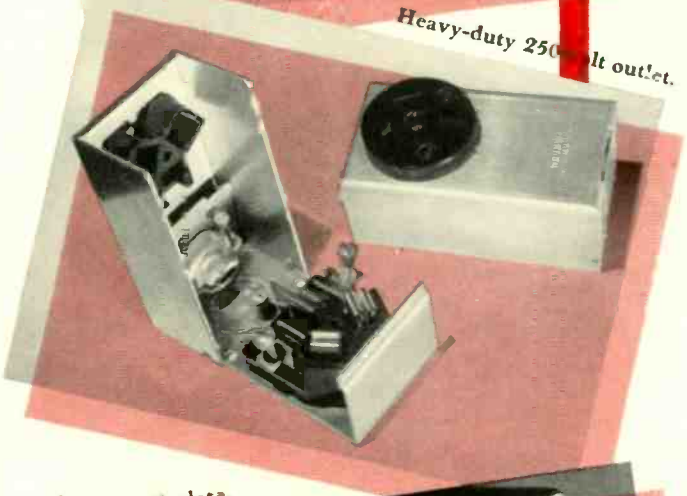
The interesting thing about this is that the 400-ampere unit (type KL) is the same size as the 225-ampere breaker, except it is one half inch longer (16 inches instead of 15½) to give space for the necessarily larger terminals. To provide the greater continuous-current rating (the interrupting rating is unchanged) larger terminals are incorporated to accommodate larger cables.

*Latched-in Relay*—A new, small, latched-in control relay used on machine tools, where absolutely quiet operation is necessary, is much more rugged and has much longer life than its predecessors. This relay employs a mechanical latch to hold the relay closed so that the closing coil can be de-energized and thus rendered noiseless. The new latch mechanism employs a Micarta-to-metal contact instead of metal to metal, and has been life tested to several million operations. The relay is being built in two-, four-, and six-pole varieties rated at 10 amperes, 600 volts. Contacts can be made either normally open or normally closed.

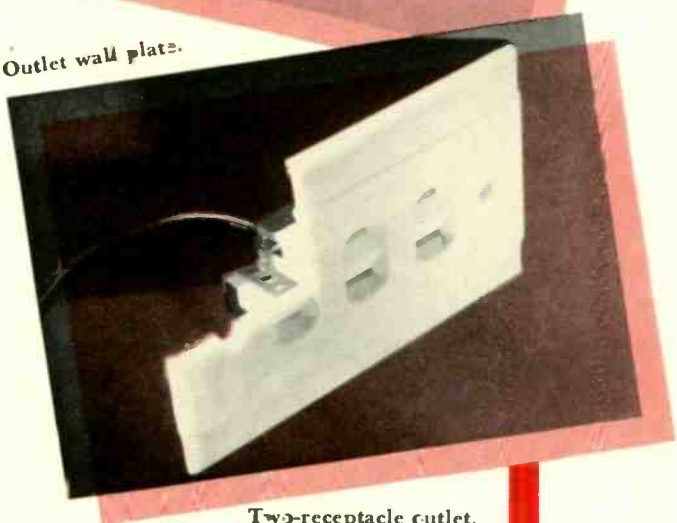
*Double-Pole Quicklag Breaker*—Several million little circuit breakers for domestic and other low-capacity circuits have been built in the past twelve years. Most of the Quicklag breaker production has been of the single-pole variety. Double-pole breakers have been obtained in the past by linking the handles together by means of handle ties and obtaining single-pole tripping. Now this popular breaker has a companion, a double-pole unit with a single handle, in which both poles trip at the same time to open both sides of the 120/240-volt a-c circuit simultaneously. The double-pole unit has an

A new waterproof switch.

Heavy-duty 250-volt outlet.



Outlet wall plate.



Two-receptacle outlet.

integral mechanism locking the two operating and trip members together, providing simultaneous tripping, but with the two compartments electrically isolated. The bipole breaker is being made available in current ratings up to 50 amperes. This breaker is expected to have extensive application in lighting and appliance load centers and panelboards.

*Direct-Current Braking Control*—The use of direct current as a means of quick, smooth, accurate stopping of induction motors is fast increasing. This is due in no small part to the development of a compact d-c braking control unit. This employs selenium rectifiers to provide direct current, thus avoiding electron tubes or moving parts in the rectification circuit that require servicing.

Direct-current braking had its first major use in the textile industry, where rapid but smooth stopping of a loom is essential when a thread breaks. The practice has spread to a large variety of industrial drives. For example, it is used on a bottle-filling machine to provide accurate stops of the conveying system. On an envelope-making machine it acts to prevent pile-up of spoiled paper should a tear occur. On a punch press it saves time, as it cuts the deceleration period in one case from about seven minutes to one-half minute.

*Thermally Compensated Circuit Breakers*—Sometimes a control is so located that its temperature is quite unlike that of the circuit it protects. A control mounted on a pole in the summer sun is overly pessimistic as far as the load-carrying ability of the wiring to the motor is concerned. The reverse might be true in winter.

In new circuit breakers of types E, F, and G this difference is now compensated. A second bimetal element is interposed in the latch mechanism. It is made sensitive to the ambient temperature and acts to increase or decrease the amount of latch travel, as necessary, to nullify the difference between control and wiring ambient temperature. This scheme provides at least 90 percent of full compensation.

*Aluminum Bus Duct*—When the outbreak in Korea pointed up the pending long-term shortage of copper, efforts were made to use aluminum. One attempt was in bus ducts. This goal has now been achieved. Bus duct is available with either aluminum or copper as desired. For a given current rating the aluminum duct is slightly cheaper, and, in the lower ratings, weighs a little less. The two types are identical in appearance; in fact there are no changes in enclosure or bus dimensions. The only difference is that the rating of the aluminum version of a given size bus duct is some 20 to 25 percent less than for copper.

## Static Regulator Holds Engine-Generator Frequency Constant

A NEW TYPE of electric governor—developed jointly by Corps of Engineers Engineering Research and Development Laboratories and Westinghouse—makes the frequency of an engine-driven generator "walk the straight and narrow" regardless of how the load behaves. The heart of this regulator is a magnetic amplifier—no tubes, no moving parts. With this fast-acting regulator in control, full load can be applied with the unit idle, or dropped from a loaded one with a maximum of 1¼-percent change in frequency and full recovery attained in one second. The regulator senses both load and line frequency, and, through a bridge circuit, develops a signal to operate a hydraulic throttle actuator. The static regulator can be used on reciprocating-engine sets of any size. Machines can be operated in parallel without the usual frequency drop.

## Wiring Devices Are Simpler, Better

THE LAST and vital link in the chain of equipments that start at the powerhouse with the generator is the humble and inconspicuous wiring device. The toggle switch, or plug-in receptacle must be compact, simple, have good life and be both trouble-free and safe. Also it must be built to cost but pennies. These requirements together form a stiff combination that calls for the maximum in design skill and fabrication ingenuity. A few examples will illustrate what keeps wiring-device engineers busy.

Particularly noticeable is the success engineers have had in eliminating screws, bolts, and rivets. Several devices are now held securely together without any of these time-honored fastenings. For example, take the three-outlet receptacle fitted into baseboards. The metal fasteners that join the two molded pieces after the contact members have been laid in position consist of a small wafer of metal with punched openings and with teeth along its outer edges. This is fitted into recesses in the two mating halves of plastic. When pressure is applied, the stamped-out openings allow the metal plate to deform, digging its edge teeth into the plastic. The ensuing grip defies any attempt, short of destruction, to separate the receptacle. Nothing can work loose. The unit cannot be repaired—but there is less need for it.

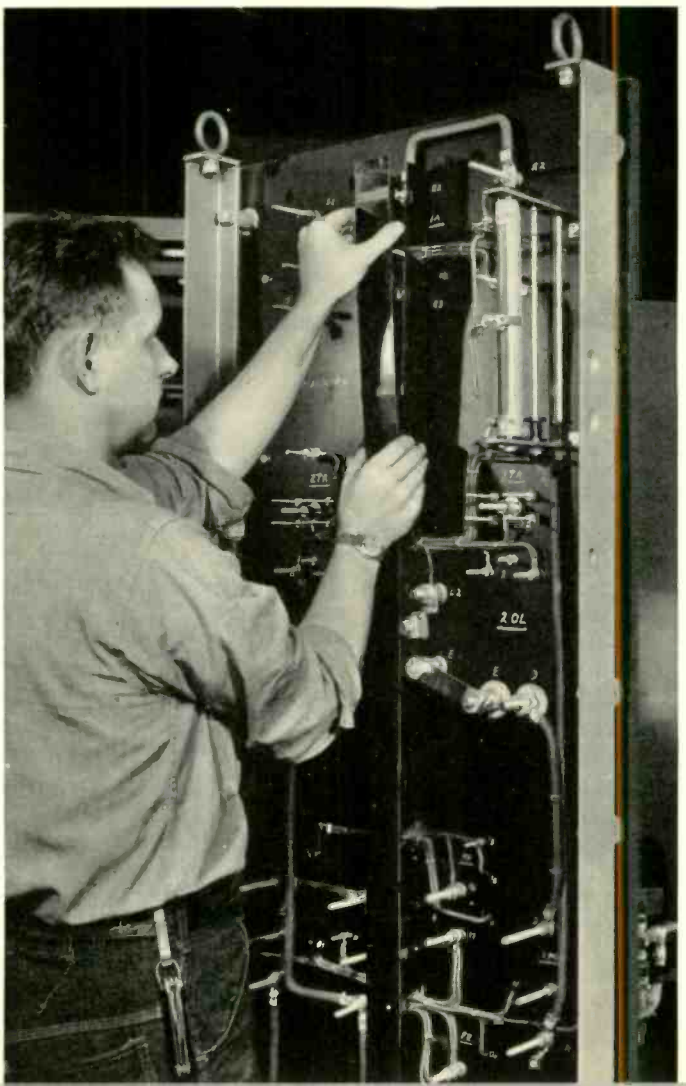
The new a-c wall toggle switches, announced a year ago, are also assembled without conventional fastenings. These switches, without the encumbrance of having to interrupt direct current, are almost noiseless. Operation is based on controlled, very short, and slow contact separation, to ensure current interruption at current zero, and rapid closure. This principle has now been applied to several a-c wall switches.

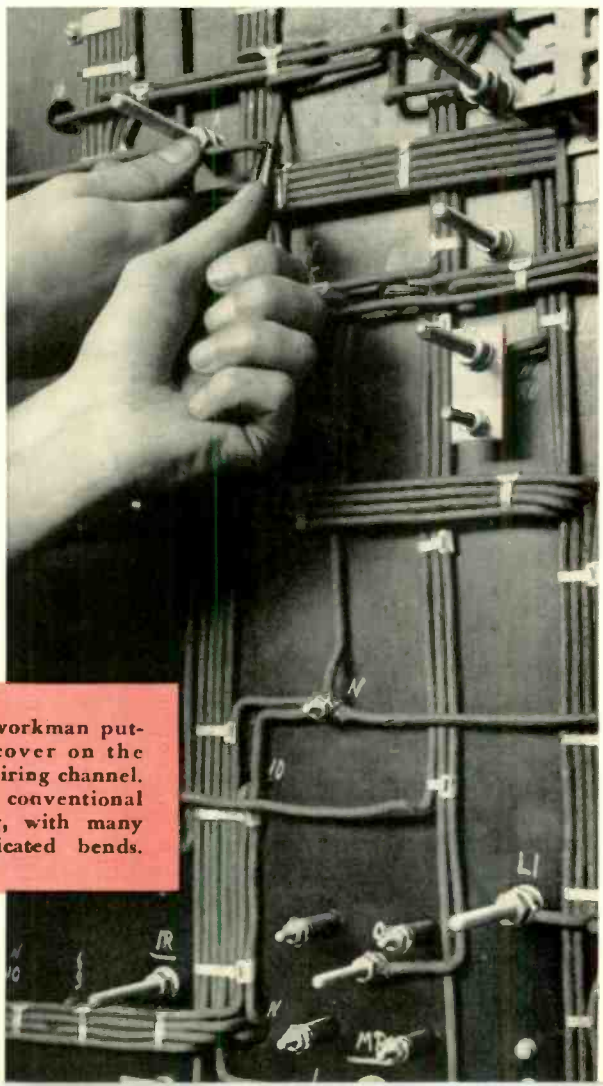
These, as do many of the improved wiring devices, make use of the quick-attach, quick-detach screwless connector. The wire end is forced into a slit punched into the copper conducting terminal. The wire can be pushed in but cannot be pulled out—even with pulls of 100 pounds. The harder the pull, the tighter the grip. Yet wire removal is easy. By pressing a blade or screwdriver tip between the metal edges of the slit and holding them open, the conductor is freed.

Some wiring devices have many functions to perform, but yet must be small. A new switch for electric ranges has eight positions—six load-carrying positions, one for a pilot light, and one off position. Yet it is about the size of a penny match box. A rotating central cam of plastic bears successively on four contact-making members, located in two planes. By proper combination of contacts, all eight positions are obtained. The cam is a precision device, its dimensions being held to 0.002 inch and the angles of its risers also determined with exactitude. Small and simple, yet handling 15-ampere loads, the switch survives a test of 60 000 cycles (i.e., complete rotations) at a speed of 180 rpm.

## Control Board Wiring in Channels

NOW THERE is a better way for organizing the hundreds of feet of wiring on the front or back of a large control board for a steel mill, a lift bridge, or a refinery. The previous way has been to run the wires from device to device, tying them together into groups where they run along together, and fastening them, whether it be one wire or a bundle of 50, to the board at intervals with clips. A nicely wired board, with wires straight and with neatly turned cor-





*Left,* workman putting cover on the new wiring channel. *Right,* conventional wiring, with many complicated bends.

ners, is a pleasant sight to behold. But it is a dickens of a lot of work. And to replace or trace a wire tied into a tight bundle is time consuming.

The new way is to form channels of Micarta for the multiple-wire runs, channels in which the wires can lie confined and covered but not tightly tied. To form these channels, two L-shaped pieces are mounted facing each other with their feet bolted to the panel. Cut into the sides at frequent intervals are slots (or knockouts for slots) from which the wire can emerge to run to its component. The two L-pieces form an open trough during the wiring. When this is completed the trough is covered with a flat Micarta strip, held in place by spring clips.

This method expedites wiring in the factory, makes a neater appearance, and simplifies wire tracing.

## Industrial Control—The Infantry That Does the Work

STARTERS, contactors, relays, and other elements used with the average industrial motor are seldom spectacular, but are tremendously important because it is by them that much of the work of the world gets done. These work-horse devices are reworked at intervals to bring them up to date, to incorporate new ideas, small improvements, better materials.

Such things as these:

In spite of the best efforts of designers to provide standard controls to save money and time, a large number of applications require something "special"—perhaps not a large variant from the standard, maybe only a component or two, but enough to keep it from being an "off-the-shelf" item.

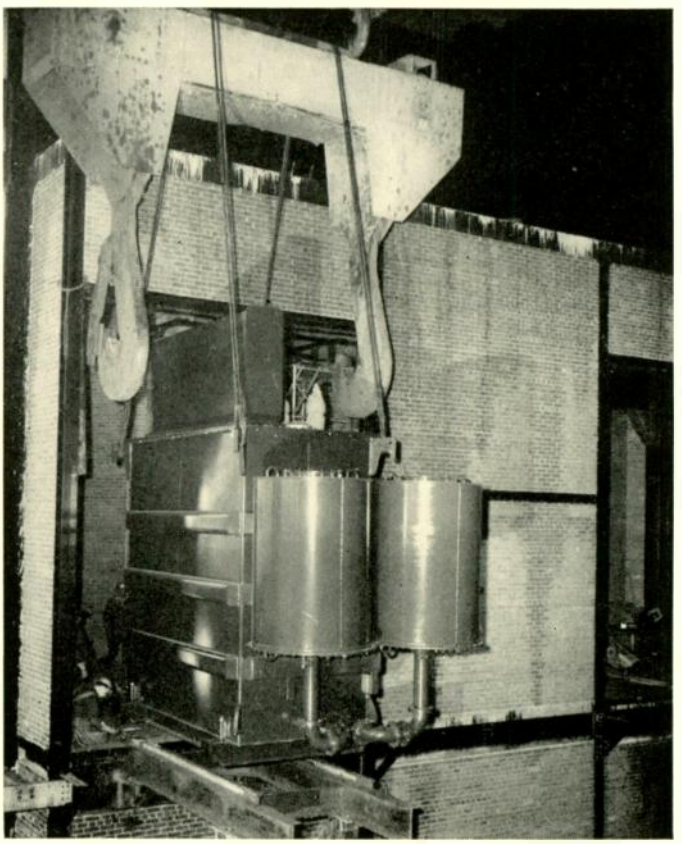
A pretty fair shot at an answer to this matter has been found. This is to build, say, a-c motor starters with all the components they need, punch holes in the panel for all of the other items that might be asked for and that would make the control nonstandard. The new controls, with most assembly work done, are set aside. Then, if someone needs an a-c motor starter of a certain NEMA size, but with the addition of a timing relay, or control fuses, or a current transformer, the component can be pinned on the waiting space and the "special" control is ready to go out the door. By this system most special controls can be shipped in two weeks instead of eight or ten.

This is an outgrowth of the Add-A-Part idea developed over a year ago for industrial a-c control. A great advantage to the user is that he can make modifications to a control after he has it in service.

***Direct-Current Motor Control***—Every few years designs for standard d-c motor control are put through the design wringer. This has just been done. As always the designs come out with improvements. They take into account all the intervening betterments in components. The control is repackaged for better appearance, better accessibility, better arrangement of elements. The new ones also relate better physically to a-c controls. Color-coated polyvinyl wire is an improvement. While it is not practical to drill the ebony-asbestos panels for all the possible future additions of elements, as in the Add-A-Part scheme for a-c panels (which are of metal), space is purposely planned so that such additions can be made.

***Oil-Immersed Control***—For chemical plants and oil refineries where atmospheres may be corrosive or explosive, a new family of oil-immersed motor controls has been produced. These include NEMA size 3, 4, and 5 linestarters and autotransformer reduced-voltage starters. They incorporate new contactors (NRK), which have both greater contact life and mechanical life and at the same time are easier to service.

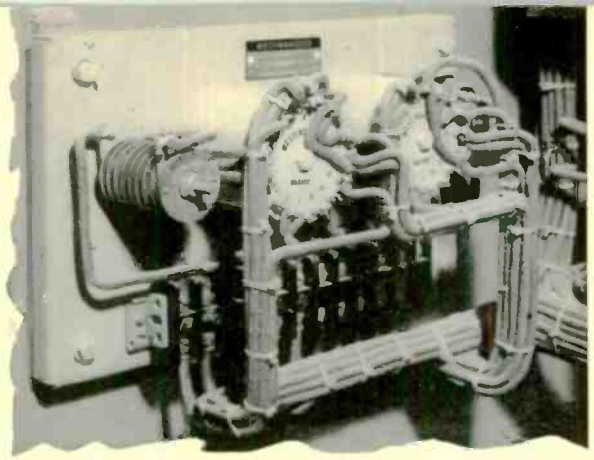
***Autostarters***—That hardy perennial, the induction-motor autostarter, has been completely redesigned. All sizes (up through NEMA 5) now use air-break switches, eliminating oil contactors that had previously been used in the larger sizes. Double-break, silver contacts (in each line) make this possible. A motor-driven timing device, adjustable between 3 and 17 seconds, gives a visual indication to the operator to place the control in the running position—and prevents him from doing so earlier.



**Steel-making arc furnaces continue merrily on, getting bigger and bigger. New record for size was set last year by two furnaces installed by the McLouth Steel Corporation. Each has a shell diameter of almost 25 feet and can produce 200 tons of steel per melt. The 25 000-kva form-fit, shell-form transformer and 1200-ampere, 34.5-kv compressed-air breaker are sturdy for furnace service.**

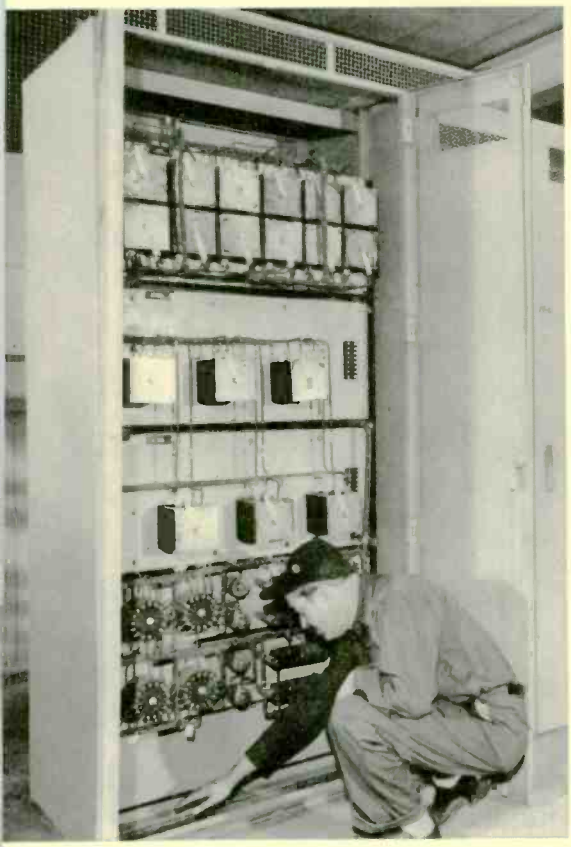
## 275 Miles of Rods per Hour

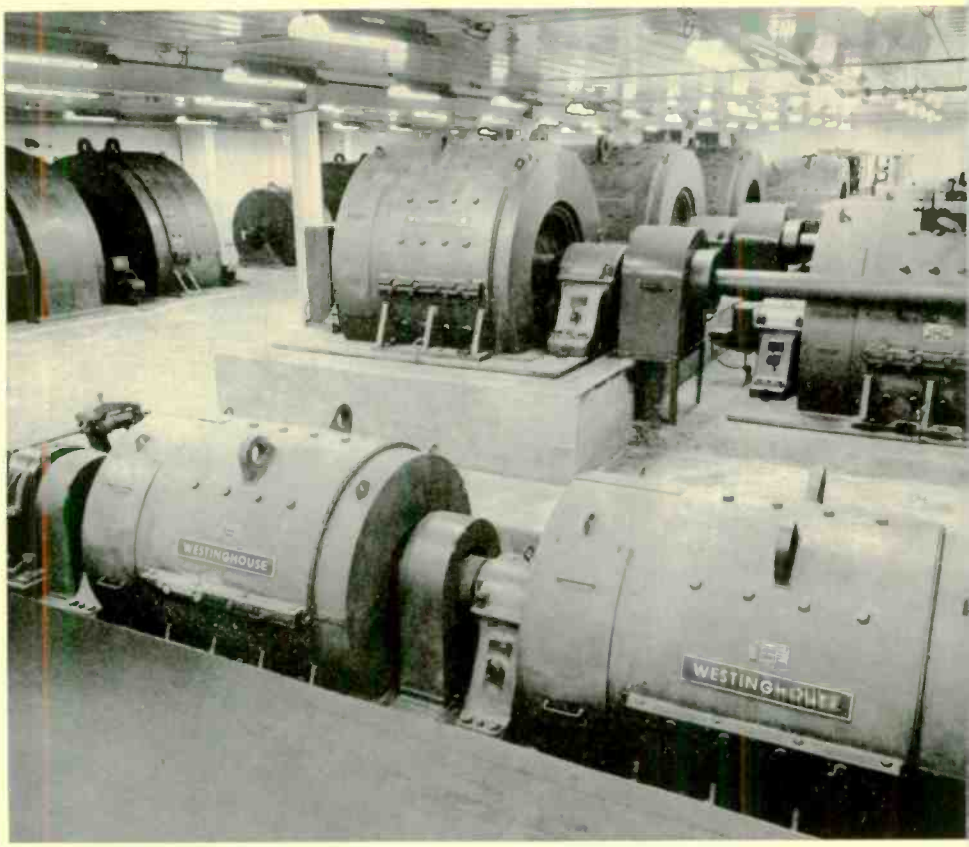
A NEW rod mill will be capable of producing in a single day a 0.218-inch-diameter rod that would reach across the United States and back. The mill capacity will be 100 tons of rods hourly. Most rod mills run from 2500 to 4500 fpm. The new mill will be powered to deliver rods at 6000 feet per minute (68 mph). Furthermore, in this mill, four strands in parallel will be delivered simultaneously to the reels. Usually a four-strand mill has two sets of finishing stands, each delivering two strands. The billets feeding this mill will be about 3¼ inches square and 34 feet long, and weigh 1200



This Magamp control detects paper breaks.
See story on page 23.

# Industrial Applications






**The magnetic amplifier passed with a mark of A+ its final examination as a regulator on high-speed tandem cold-rolling strip mills. The four-stand, 3190 feet-per-minute mill of the Pittsburgh Steel Company has been in service since last March and the performance of the 400-cycle Magamp regulators has delighted everyone concerned. The results of field tests of the regulators that control the voltage of the stand-supply generators and the current and counter-emf of the winding reel fully confirm the full-scale tests made in the factory in 1951. Among other tests, with the motor connected, the generator response to a 15-volt error signal at 50-percent generator voltage was completed in 0.1 second with no appreciable overshoot, three times better than rotating regulators.**

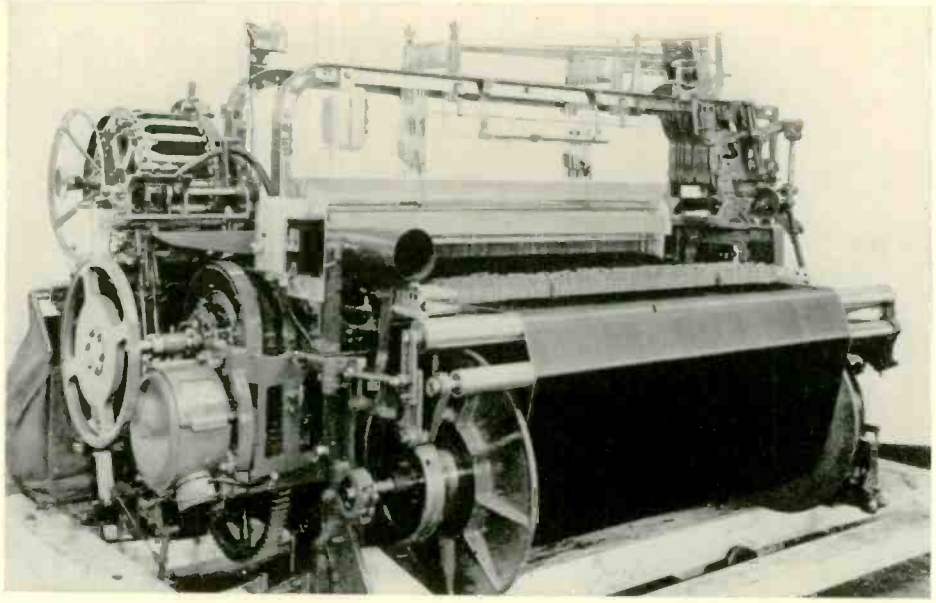
pounds, about twice the size of the average rod-mill billet. This is the new Cleveland mill of the American Steel and Wire Division of the U.S. Steel Corporation.

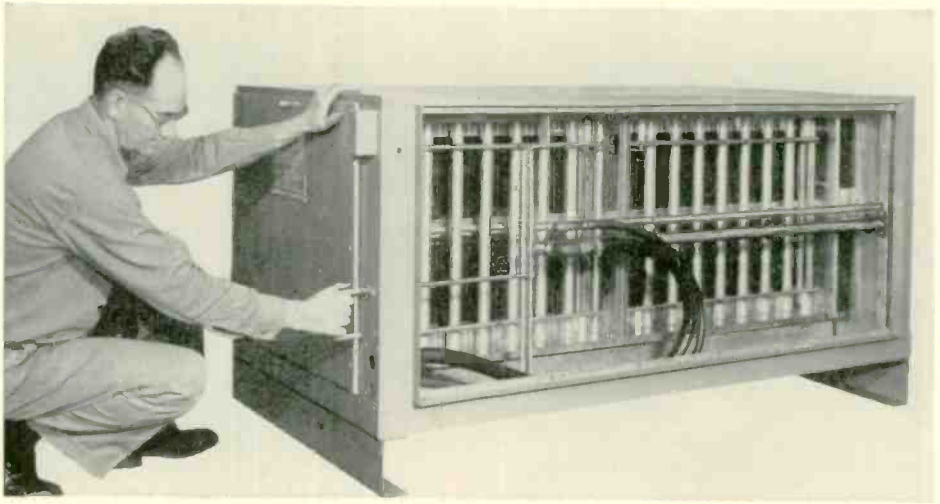
The mill will have 23 continuous stands in a line and two looping stands. Driving power is provided by ten motors ranging from 600 to 3000 hp and totaling 13 500 hp, which is approximately 3000 hp more than has ever been applied to a domestic rod mill. The drive for the last seven stands consists of one 1500-hp single-armature and a 3000-hp double-armature motor connected through a single drive shaft.

High speed and the high tonnage of this mill intensify the drive problems that are always present in rod mills in which there are many stands in series, and rods entering and leaving mills at different times. Because a change in motor speed as a rod enters or leaves a mill would result in a size change influencing the allowable tolerance of the rod, the system must be designed for extremely close speed regulation.

The regulating system calls for speed to change by no more than one quarter of one percent over the full range of operating conditions. The motors were designed to have extraordinarily low armature-circuit inductance and resistance. Careful attention was given to the design of the motors, Magamp regulators, and other equipment for effective operation as a system.

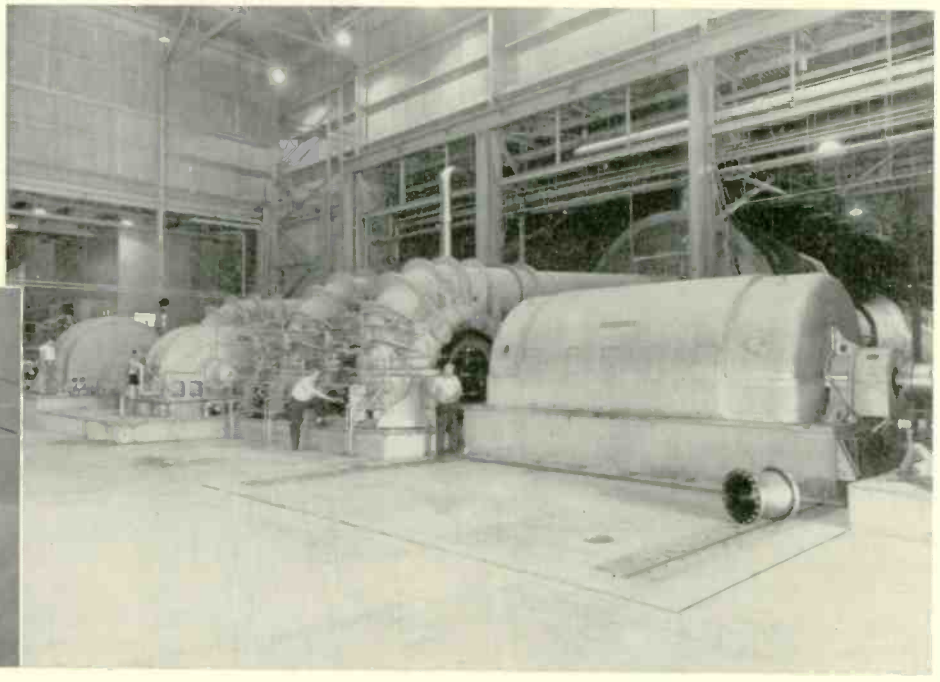
A textile mill may have 50 rows of looms. Thus even a few inches less space for the aisles between rows adds up to a sizable reduction in amount of building required. On a certain type of loom the motor projects into the aisle, hence becomes a real factor in building size. A new 2-hp, 1200-rpm loom motor (below) extends only $6\frac{1}{16}$ inches beyond the bracket on which it is mounted. The one before took $11\frac{3}{16}$, or $5\frac{1}{8}$ inches more. With 50 rows of looms, that's 21 feet. Actually the motor was crowded for space in the other dimension too. In fact to save another half inch in diameter, and allow the motor to fit between the loom crankshaft and bracket, the motor frame was cut away.

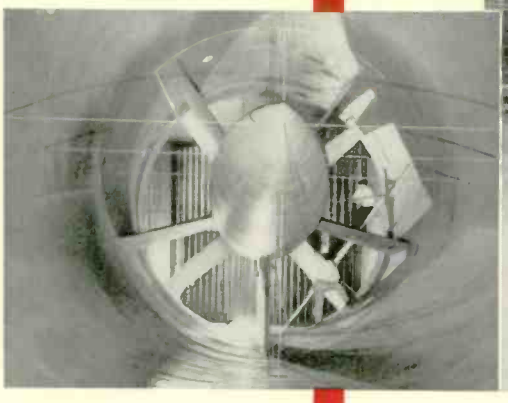




A new, packaged Precipitron air cleaner is easily installed. The unit requires no special foundation, and needs only simple connections to air ducts, water, adhesive, and drain lines, and electric power outlet.

At right is the main drive of the new supersonic 4- by 4-foot wind tunnel at the Langley Aeronautical Laboratory of the NACA. At the extreme left in this photograph is the 24 000-hp wound-rotor motor, and at right is the 76 000-hp synchronous motor. The photograph below shows the blower section of the new low-speed McDonnell wind tunnel. The 20-foot fan is driven by one 1750-hp motor.





## Packaged Air Cleaner

NEW PRECIPITRON air cleaners, featuring ease of installation, have been developed for commercial and industrial applications. Units are completely enclosed in a factory prefabricated cabinet requiring only simple connections to air ducts, water, adhesive, and drain lines, and electric power. No special foundations are required—the units can rest on the floor or can be suspended from the ceiling.

All units feature built-in moving-nozzle washing and adhesive application. Washing is accomplished with a movable spray header permanently connected to the water supply. A conveniently located handle at the end of the unit moves the header back and forth within the cabinet, giving full coverage and penetration of the wash water over the entire collector. The same mechanism also provides for spraying of water-washable adhesive fluid, which contributes additional dirt-holding capacity to the unit and also facilitates washing. A removable after-filter eliminates water carry-over into the downstream duct.

Units are made in 12 sizes, with capacities from 2000 to 10 600 cubic feet per minute at 90-percent blackness test efficiency. Right- or left-hand access is optional. All elements are removable through the access door provided. The 2000-cfm unit is 3 by 3 by 2½ feet high, the 10 600-cfm unit is 3 by 7½ by 4½ feet high.

## Magamps Watch for the Breaks

IN A PAPER MILL, the paper comes from the machine continuously and is wound on a motor-driven reel. When one reel is full the operators with practiced skill cut the sheet and thread it quickly on an accelerating standby empty reel. For these few seconds the operators are obviously extremely busy, just as they are if the web of paper breaks while a reel is partially full. In either condition—when the paper is cut purposely or breaks—the control reacts as though the reel were empty and tries to accelerate the loaded reel to the empty reel speed. Operators, even though extremely busy feeding a new reel or repairing the break, must be alert to prevent the loaded-reel motor from overspeeding.

Now this is done automatically by a magnetic-amplifier detector. A capacitor in the drive circuit cues the magnetic-amplifier control to distinguish a break from a true empty-reel condition. No dancer rolls, limit switches, phototubes, or electronic equipment are required. The Magamps, furthermore, do not mistake disturbances during acceleration for normal regulating actions and cause false shutdowns.

## A Spinning-Frame Gearmotor Yarn

A NEW two-speed gearmotor has been devised to drive Saco-Lowell spinning frames (devices that twist yarns). Spinning frames are usually driven by constant-speed motors, but motor speed is limited because of a tendency of the yarn to break with small yarn build-up on the bobbin. Faster running speeds are possible when the yarn is built up. How to change speeds without stopping the spinning frame? Very simple—reverse the motor!

If you haven't guessed the answer to this one, it really turns out to be very simple. The motor drives two over-running clutches; each clutch is free-wheeling in one direction, and positive drive in the other. But here's the clue; they are positive drive in opposite directions. Thus, when the motor runs in one direction, one of the clutches—say the running clutch—drives the output shaft of the gear unit at motor speed, 1750 rpm. When the motor is reversed, the other clutch engages, and drives a pinion, which in turn drives a gear on the output shaft. Hence, speed is reduced and direction reversed by the gear and pinion, so that the output shaft is driven in the same direction as before, but at a reduced speed of 1425 rpm. The spinning-frame inertia keeps it running while the motor is being reversed. It's all just a matter of closing a switch.

## Wind Tunnels—All Sizes

A LARGE and varied crop of new wind tunnels is coming to fruit, indicative that man still has much to learn about vehicles that fly.

The main elements of the huge transonic wind tunnel of the Arnold Engineering Development Center at Tullahoma, Tenn., have been put together. By midyear it is expected that checking and calibration will be under way. Equipment for the companion supersonic tunnel is now being assembled on the site. Each tunnel will be served by its own enormous axial-flow compressor and both will be driven by four motors totaling 216 000 hp, the largest concentration of motor horsepower.

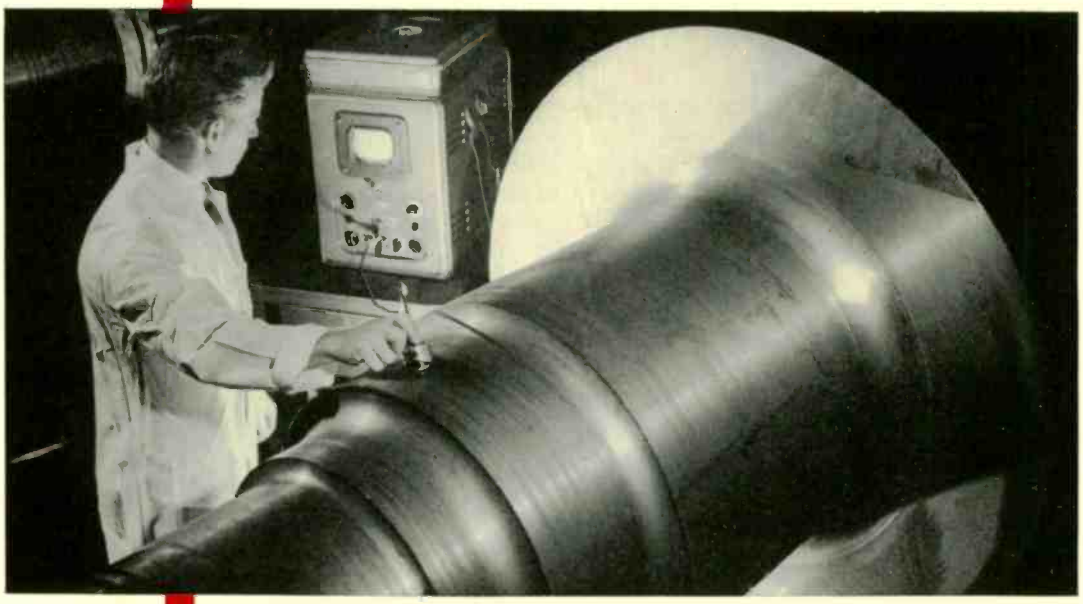
Nearing completion is a new 4- by 4-foot supersonic tunnel at the Langley Aeronautical Laboratory of the NACA at Langley Field, Va. This is a versatile tunnel for testing at Mach numbers of 1.5 and higher, and at pressures equivalent to a wide range of altitudes. Power to stir up these supersonic winds comes from a 24 000-hp, 685-rpm wound-rotor motor with gear and a 76 000-hp, 3600-rpm synchronous motor (30-minute ratings). The induction motor is used for starting and for supplemental power during full-power tests, or, for some work, will drive the compressors without the aid of the synchronous motor. A 7500-kva synchronous condenser maintains the power factor at a minimum of 97 percent, even during the accelerating period. The control is arranged to limit the rate of power increase or decrease. A turning gear, much like that used on steam turbines, keeps the rotor rolling after a test to insure uniform cooling of the synchronous motor and the six compressors.

Not all new tunnels are the spectacular ones with high test-section air speeds and driven by power plants of high horsepower. Several new tunnels are designed for the now seemingly zephyr speeds of 200 to 400 miles per hour. Aircraft companies need such tunnels for a vast amount of routine data collection in connection with new planes. For example, Chance-Vought is soon to have operating at Grand Perry, Texas, a tunnel with a 7- by 10-foot test section primarily to study problems of take-off, landing, and boundary-layer effect. This tunnel is powered by a 1500-hp induction motor. Stopping is by dynamic braking, the energy being dissipated in a liquid rheostat.

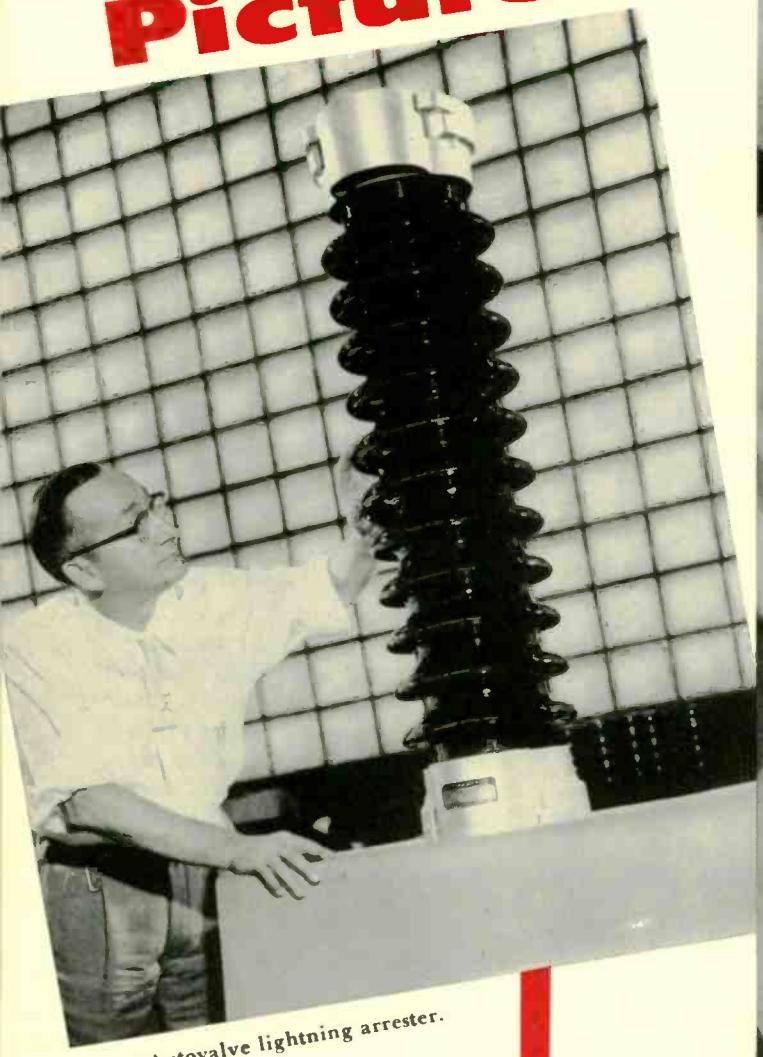
Quite similar is the new 8½- by 12-foot wind tunnel at the McDonnell Aircraft Corporation of St. Louis. The motor size is 1750 hp. Work done in this tunnel supplements that performed in the cooperative tunnel on the campus of California Institute of Technology, in which McDonnell participates. The low-speed tunnel is now in service, some studies having been made for the XV-1 Convertiplane.

At Grumman Aircraft Corporation on Long Island, a 1750-hp wound-rotor motor recently replaced a reciprocating engine driving a propeller-type fan for a low-speed tunnel.

# Hi-lites in Pictures

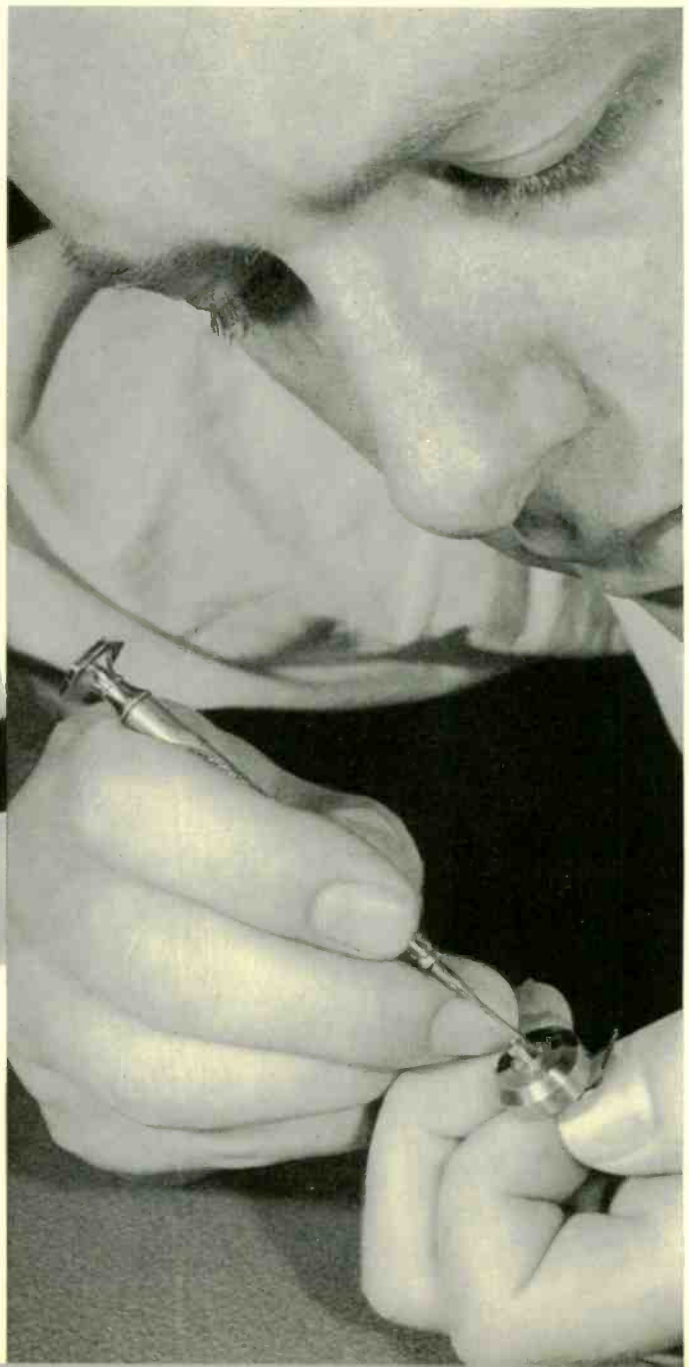


**Ultrasonic testing of a generator rotor forging.**
See story on page 6.



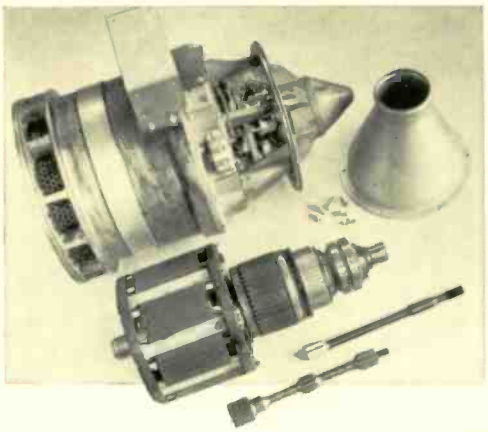
**A new Autovalve lightning arrester.**
See story on page 11.

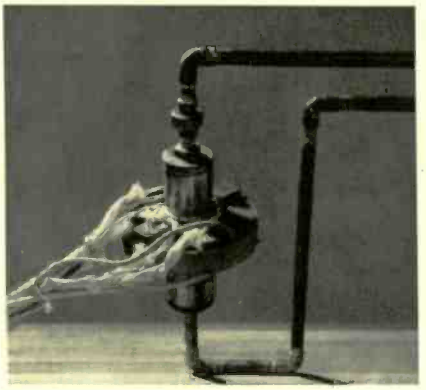
**A dime-sized gyroscope motor for radar antenna.**
See story on page 16.



A 330-kv interrupter for the 25-million kva breakers.
See story on page 9.

A tumbling test for new, rugged instruments.
See story on page 40.





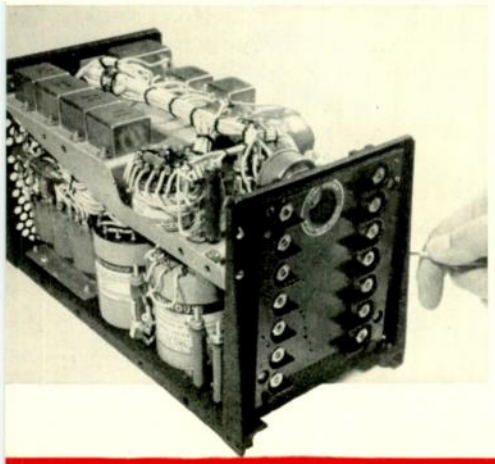
*Far left,* a 40-kva alternator. *Left,* laboratory analog of the rotating oil-cooled silicon rectifier.

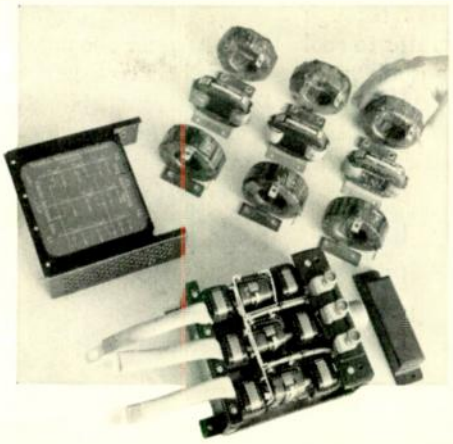
From left to right, a Magamp voltage regulator, an aircraft current-transformer assembly, and a transfer contactor and contactor control unit.

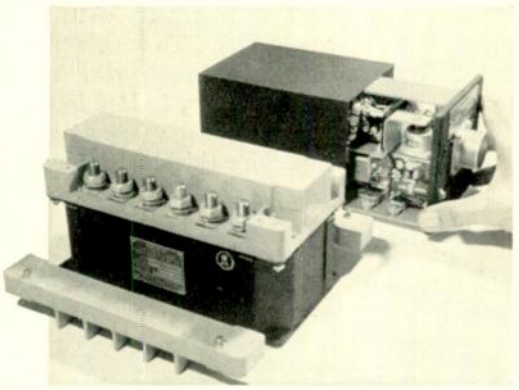
# Transportation

The 4500-hp steam-turbine locomotive with a high-pressure boiler began hauling revenue trains on the Norfolk and Western Railway last June 1st. By November it had operated approximately 15 000 miles in revenue service hauling coal between Bluefield, W. Va., and Norfolk, Va. Fuel consumption is about 30 percent less than that of a conventional steam locomotive. Consumption of water—an equally important matter considering the cost of obtaining boiler-grade water—is about ten percent less. The water-tube boiler operates at 600 pounds pressure and 900 degrees F.

During 1954 the New York, New Haven and Hartford Railroad placed in suburban service 100 ignitron-rectifier-equipped suburban cars. They are now operating successfully in commuter service between New York's Grand Central Station and Stamford. They may also be called upon to operate in express service between New York and New Haven on days of heavy through traffic. These cars represent the first commercial application of ignitron rectifiers with d-c motors to cars operating under an 11 000-volt, 25-cycle trolley. This system enables use of a-c transmission and d-c motors.







## Improved Controls for Aircraft A-C Systems

ALTERNATING CURRENT has become the accepted electrical system for military planes in a comparatively short time. Eight years ago no production planes used it. Now, nearly every type of fighter or bomber under development will have an a-c system.

To keep pace with this rapid sweep of a-c control, engineers have been busy creating the necessary new types of devices and reworking old ones.

*Current Transformers*—An a-c powered plane has need of several current transformers. Until now they have been stashed away in the plane wherever space—a very precious commodity—could be found for them. Now they have all been brought together under one cover—which also serves as a convenient wiring diagram. The aluminum frame holding nine transformers is only 3¾ by 6¼ by 6¼ inches.

Accounting for this small size, which importantly shows a weight saving of 4½ pounds, or about 45 percent, is a new current transformer. Instead of the conventional round opening in the core for the conductor, it is made rectangular—made just to fit a rectangular copper-braid conductor. This results in large savings in core mass.

*Automatic Generator Transfer*—In multi-engine planes, such as the 8-engine B-52, should one generator fail, another is cut in automatically by a newly developed transfer scheme. This comprises two units—a transfer contactor and the control unit that senses when transfer is necessary.

The sensing element embodies a saturating reactor operating in a high-gain circuit and includes a time-delay element to override system transients.

The contactor itself contains the six current-carrying contacts—three open as the other three close. A d-c magnet supplied from tiny selenium rectifiers effects the transfer. While developed for automatic-transfer purposes, the contactor can be used wherever a sturdy contactor is needed to open one 3-phase line as it closes another.

Both units can operate on the 115-volt aircraft system and the transfer occurs when line voltage drops to between 80 and 100 volts. Operation is from −55 to 71 degrees C.

*Magnetic-Amplifier Voltage Regulator*—Although the magnetic-amplifier a-c voltage regulator was introduced only two years ago, it shows every prospect of superseding the carbon pile for many aircraft a-c systems. Last year a lighter, improved version was produced. The regulator elements now are better able to cope with the wide swings in pressure, temperature, and humidity in jet flight.

## Cooling Alternators with Oven-Hot Air

SCIENCE-FICTION writers and even the serious space-flight enthusiasts like to amaze the populace with the rigorous environments the equipments for their activities will encounter—near absolute-zero temperature, little or no atmosphere, and flying meteorites. But one need not go quite so far for such out-of-this-world engineering problems. Builders of aircraft electrical equipment are smack up against similar toughies right now—problems posed by jet planes flying faster than the speed of sound. Try this set of conditions for size: the effective temperature of the air available for cooling an alternator of a Mach 1+ plane may be 120 degrees C (248 degrees F). That's in low-altitude flight. The high-altitude horn of the dilemma is no better; in fact, it's worse. While the outside air temperature at 60 000 feet is about −70 degrees F, the air is so thin that its heat-absorbing power is even poorer than the sea-level, oven-hot air.

The question facing the designer of a jet-plane alternator can be simply stated. Where is he going to find a place to put even the small amount of losses created?

He is reluctant to give up the air itself. Air is by all odds the simplest, and involves the least cost in weight and complexity. He will give up air-blast cooling only when its possibilities have been exhausted.

Three current developments—for different degrees of severity of the temperature problem—illustrate the effort to meet the issue of alternator-loss disposal.

One of these is a 30-kva, constant-speed (5700 to 6300 rpm) alternator built to contend with conditions of air temperature, flow, and moisture content that appear extreme by ordinary standards. Because of the plane's speed, the cooling-air temperature at low altitudes is 200 degrees F. The alternator also must be able to accept up to nearly two quarts of water per minute in the air stream.

Silicone insulation is used throughout the machine. This permits operation with hot-spot temperatures of 480 degrees F. Air is bled from the main stream at eight different places, in addition to through the shaft to maintain the rear bearing at normal temperature.

On the front or exciter end of the machine is a fan, which is a saucer-shaped solid disc with vanes on the exciter side. Thus it acts as a baffle to incoming water particles, flinging them off radially. By proper passages in the machine, air is reversed, caused to move forward over the exciter, and discharged radially (along with the water). Thus the exciter is cooled without getting the commutator wet.

Under some flight conditions the natural air flow through the machine may fall to zero. To enable the generator to cool itself, a large fan is provided at the rear. This fan is adequate to enable the machine to carry full load at all altitudes up to 4000 feet with zero pressure drop across it. A dead-air baffle at the rear of the machine shields it from conduction of heat from the fluid drive.

**The U.S. Navy's *Sea Dart* (XF2Y-1) is a sea-based jet plane that takes off and lands on skis.**


The "Crown City" is an ultra-modern addition to the fleet of ferries plying the bay between San Diego and Coronado. This double-ended ferry with a capacity of 300 automobiles is powered by a 1000-hp d-c motor in each end. To cut down resistance the idle (bow) motor is turned at 78-percent speed in reverse, at which speed the bow propeller causes no drag. Propulsion power is produced by three 300-kw, 250-volt diesel-driven generators. The plant is regulated for constant horsepower so that maximum acceleration is obtained automatically without engine overloading. In addition to the standard alarm system for engine-room control, a pilot-house remote-control system is also provided.

As though the conditions of heat and moisture were not enough for one machine, this 30-kva alternator contains other novel features. Instead of the usual terminal block, a new wrap-around block of plastic is made to hug the alternator frame and thus presents a smaller profile to the air flow. The alternator is designed to operate interchangeably with a carbon-pile or magnetic-amplifier regulator. The electrical harmonic content is low and the performance while carrying unbalanced load is excellent.

A second development concerns an alternator that represents the extreme effort to use air-blast cooling. This machine was designed to produce 40 kva of 400-cycle power with intake air at sea level at an effective temperature of 250 degrees F, and at 50 000 feet, of 100 degrees F. To make matters worse, the weight of air that can be allowed it by aerodynamic considerations at supersonic speed is only three fourths that ordinarily available at high altitude.

The most temperature-resistant insulating materials known are used-silicones. Bearings employ silicone grease. The best possible use is made of the cooling effect of the air blast—such as it is. Special efforts are made to direct the air to the most critical areas—the poles and the rear bearing.

But what happens when jet planes increase further to speeds that will rule out even the best efforts with air-blast cooling? It is known, for example, that at Mach 2, the blast temperature will be about 570 degrees F—obviously of no use for cooling alternators using any known insulating materials and lubricants.

One possibility, and the next being explored, is to seal the alternator off from the air stream (which the aerodynamics engineers are most happy to have them do anyway), and to use the engine oil as a heat-exchange medium. But that is no sinecure either, for the oil temperature is about 300 degrees F. One of the developments necessary to such a cooling system is a brushless alternator. One such alternator using a rotating selenium rectifier for field excitation was built two years ago.* This machine was successfully tested. However, its weakness obviously lay in the selenium rectifier. The recent rapid developments in semiconductor rectifiers, particularly of the silicon type, promise the end of this deficiency.

For a forthcoming type of supersonic military plane, manufacture of alternators with rotating silicon rectifiers has been started. These alternators will be cooled by the engine oil. The oil, which is also used to cool the bearings of the jet engine and the fluid drives between engine and alternator, is about 300 degrees F. The alternators will also employ this oil in their bearings, thus answering the lubrication problem, which has been growing increasingly acute with greases as temperatures rise. This well-worked oil is made to give up its heat accumulation to the plane's fuel—which in supersonic craft is the ultimate heat sink.

What comes after the possibility of engine-oil cooling has been exhausted? It's too early to say. Some other form of liquid cooling probably. Water, possibly, or even the jet-plane fuel itself.

## Jet Engines

IN THE JET-ENGINE field, the past year at Westinghouse has been one largely of transition and consolidation. The plant at South Philadelphia, where America's first design of the jet engine was created, has long since been outgrown. During the last two years the major production of engines

*See *Westinghouse* ENGINEER, March 1953, P. 78.

has shifted to the enormous government-owned 2 700 000 square-foot plant near Kansas City. Lately the engineering divisions have also followed the production vanguard, leaving at South Philadelphia only the advanced development group of engineers and a minimum number of laboratory and engine-test personnel.

These will follow as soon as the extensive new development laboratory with ultra-modern facilities is completed. The plant at Kansas City is already the largest self-contained jet-engine plant in the United States.

Something of a record was set last year when in March, just eleven months after the outset of design effort, a new engine was brought to test. This engine is the result of joint efforts by Rolls-Royce Ltd., and Westinghouse.

The carrier trials of the Chance Vought F7U-3 *Cutlass*, powered by two Westinghouse J46 engines, were successfully completed last February. This engine develops about 6000 pounds thrust and is designed for multi-engine airplanes.

## Better Unity Among Aircraft Electrical Units

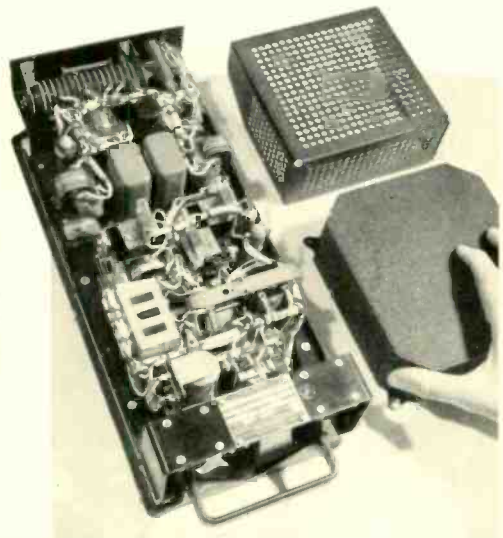
MOST EVERYONE agrees to the principle of coordination of the many components of an aircraft electrical system. In the past year, aircraft electrical-system coordination has widened in concept, grown in acceptance, and been greatly implemented by new facilities. The rewards are less duplication of equipment responsibility, some simplification of plane wiring, a net-weight saving, relief for the pilot, and a shortening of the time between the concept of a new airplane and the date of its initial flight.

While engineers can do much to integrate on paper the performance of the many equipment elements, it is vastly better to operate them together as they will be located in the airplane itself. In other words, a mock-up. Last year, Westinghouse created a mock-up facility for aircraft a-c electric-power systems that is much larger, more flexible, and can duplicate more conditions that might be experienced in flight than before available. This is a four-engine system. It starts not with the generators as before but with the hydromechanical constant-speed drives commonly employed in aircraft. The motors that supply the primary power are each of 200 hp, enabling alternators of 90 kva to be tested. (The previous Westinghouse mock-up was a two-unit system capable of handling 40-kva alternators.) Provision is made for quick set-up of a system. Instrumentation is far more complete, of a permanent type, and is supported with oscillographs, oscilloscopes, and recorders of the latest type. Meter readings can be recorded photographically—a necessity in view of the 60 instruments employed. Special provision is made for simulating the more common system faults. Such situations as an alternator slipping a pole can be tested.

It is from a mock-up that the development of such major improvements as automatic paralleling of alternators (story at right) is possible. Also illustrative of the lessons learned is how to improve and coordinate generator-voltage regulators to reduce the wasteful circulation of reactive power between generating units. Last year it was learned how to improve magnetic-amplifier regulators so that the flow of wattless power due to inevitable differences in apparatus could be cut in half. This was accomplished with no loss in ability under fault conditions to select the machine in trouble, and with no introduction of system instability due to the greater sensitivity of the regulators.

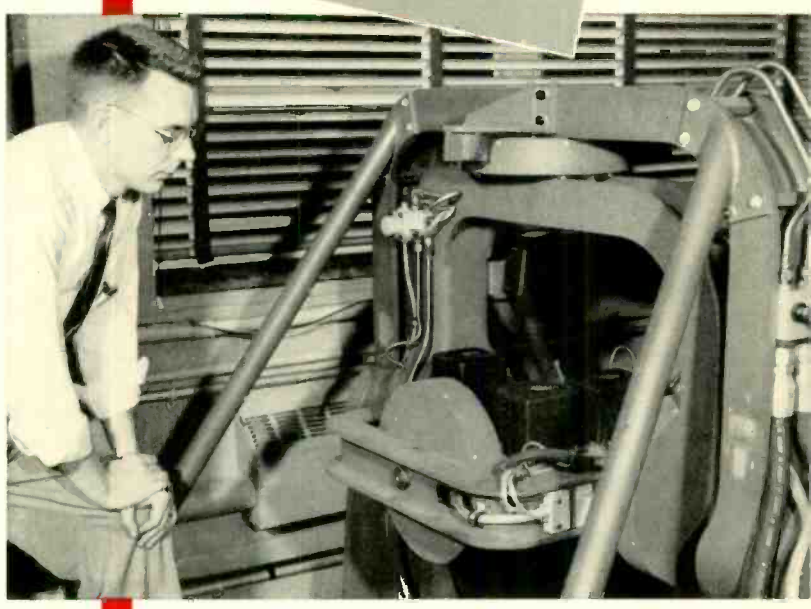
## Airplane Alternators Paralleled Automatically

PITY the poor pilot! His cockpit is crowded with a forest of instruments, adjustments, levers, and switches for him to watch, twiddle, and otherwise do something about. He doubtless suspects that engineers sit up nights dreaming up



**Control and protection panel for three-phase, paralleled a-c system.** See story above.

Gyroscope sensing devices for autopilot systems are given a thorough test in this three-gimbal flight simulator. The simulator platform has three degrees of freedom, corresponding to the roll, pitch, and yaw axes of an airplane. Each axis gimbal is controlled by a hydraulic servomechanism, which positions the axis according to the dictates of an analog computer, the device that calculates the airplane's position in space. Gyro sensing devices on the platform relay this information to the autopilot system, which acts to control the airplane position. Actions of the autopilot are measured for the analog computer, which recalculates plane position; the cycle continues.



more things to add to the already crowded cockpit wall, ceiling, floor, and panel space.

Thus, one important deduction from this mass of controls doubtless is welcome. The start-up and paralleling of the alternators of his electrical power plant is now fully automatic. Not only does this mean one less thing the pilot has to do, it also means better electrical performance, less likelihood of the pilot making an error, elimination of considerable wiring, and—believe it—a few valuable pounds net reduction in weight.

Automatic operation is accomplished by a control panel (AVP-39) only 4¼ inches deep by 6 inches wide and 15 3/16 inches long, and weighing but 8 pounds. Packed into that small box are several devices to superintend the start-up and running of a multiple-generator system: (a) a relay to detect either generator undervoltage or overvoltage—but with a time delay to avoid nuisance tripping on momentary under- and overvoltages; (b) a relay to insure that phase sequence of an oncoming generator is correct; (c) a relay for each line to give differential protection against generator and feeder short circuits; (d) an underspeed relay that insures generator speed is right before the generator is brought on the bus; (e) relays to sense over- or underexcitation of the generator; (f) a means for flashing a generator field when starting, to insure positive and rapid field build-up; and, finally, (g) the relay that closes the field circuit when all is well for it to do so. The unit is spring-mounted against shock. The cast-aluminum base appears to be mostly holes—for the ultimate in wiring facility and to save a few ounces.

With this system, the airplane's electrical plant is put into operation automatically by the pilot starting his engines. A switch is provided for shutting the system down manually when that is necessary.

## Elevator Controls That Use Judgment

ON A BANK of elevators operated without attendants, the doors must be kept open at intermediate floor stops long enough to permit a passenger to walk from the corridor pushbutton to the farthest car in the bank. If that time is made too short, the passenger will miss the elevator, or cause the door to reopen by activating the door-protective device; either result means that the car remains at the floor longer than if the proper time had been allowed.

In most cases only one or two persons walk in or out of the car and the maximum time allowed is much too long. Therefore, much car-standing time could be saved by a device designed to automatically adjust the car-standing time in proportion to the number of passengers who get in or out at each floor.

A new control—called the Traffic Sentinel—accomplishes that purpose. This device not only differentiates between one, two, or more persons getting into the car, but also recognizes the fact that it takes less time for one or more passengers to get out of the car than to get in.

The Traffic Sentinel consists of an invisible light beam projected across the car entrance; the interruption and re-establishment of this beam controls the length of time that the doors remain open. For example, if the car stops in response to a signal within the car, i.e., to let a passenger off, the doors remain open long enough for him to step out; however, ½ to ¾ of a second after the beam has been re-established, the doors start to close. When the car stops in response to a corridor call the situation is similar, except that under no condition will the doors start to close in less than two seconds after they have opened.

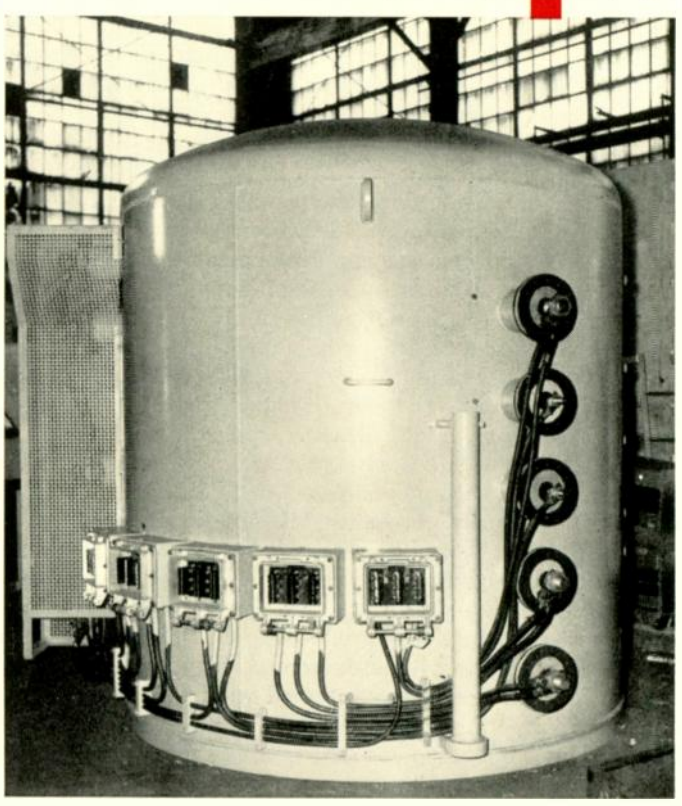
During the rush hours, when the *up-peak* or *down-peak* controls are in effect, cars are crowded and a longer time is required for passengers to get in and out; during these periods the time is automatically changed to 1 to 1½ seconds.

This device keeps the doors from closing until the first passenger gets in or out of the car and holds them open as long as people move in or out in a stream, closing ½ to ¾ of a second after the beam ceases to be interrupted. If, during this process, the car becomes loaded to 80 percent of capacity, the doors close immediately to prevent passengers from holding the car unnecessarily.

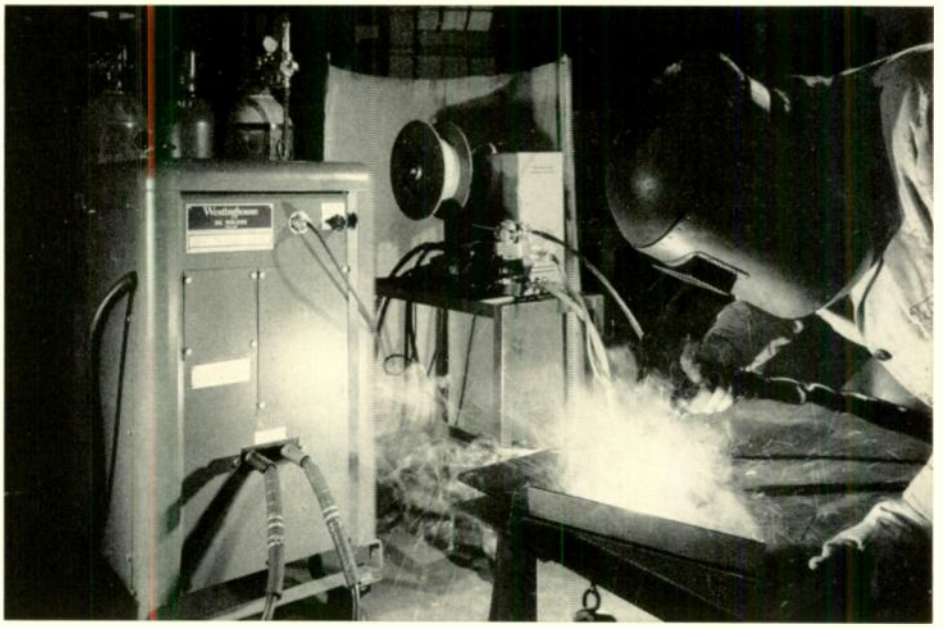
## Heating and

By capillary welding, these turbine blades are joined into groups.

Electric-resistor furnace for producing titanium sponge.



An experimental titanium arc furnace.



The new consumable-electrode arc-welding process. Story below.

# Welding

## Capillary Welding—High-Temperature Metal Joining

TO THE SCORES of new ways of joining metals, another important one has been added. It is called capillary welding. First off it looks like brazing, but the differences are so significant that it deserves to be classed apart.

It is used to join broad areas of metals. The members to be joined are heated to about 2200 degrees F, whereupon a special nickel-base alloy with a melting point of about 2100 degrees is caused to flow by capillary action into the joint. The alloy combines chemically with the mating surfaces to form a weld that is as strong or stronger than the parent metals. It is suitable for metals normally difficult or impossible to weld. The welding can be accomplished in a dry, hydrogen (reducing) atmosphere so the product remains bright and undistorted.

Capillary welding is being investigated as a means of joining steam-turbine nozzle-block segments and of joining impulse blades into groups.

## Electric Furnaces for Titanium Production

TITANIUM has risen rapidly to a place of importance in the world of metals. The two major factors in this rise have been the practical solution of its difficult production problems and, with the increasing speed of military planes, the growing demand for titanium's light weight (midway between aluminum and steel) and good middle-range temperature strength.

Electric-resistor furnaces play a major part in this drive for stepped-up titanium production. Several score electric furnaces have been built to convert liquid titanium tetrachloride to sponge titanium by reduction with magnesium. The furnaces are pit type, rated 210 kw each, and are divided into three control zones. After the necessary initial energy is supplied, the reaction is exothermic and only a small amount of external heat is required. In connection with these reduction furnaces, electric-resistor-type pipe heaters are used to and from the furnace retort. One set is used to keep the magnesium in a molten state as it is transferred from a previous melting operation. The other set is used to drain off magnesium chloride produced from the reaction that provides the titanium sponge.

The impurities in the titanium sponge are removed by treating in another electric-resistor furnace of a bell type. The retort containing the sponge is placed in the furnace and a vacuum is introduced, which allows the impurities to distill off. These furnaces are rated at 300 kw in three zones. The principal impurities removed are magnesium chloride and titanium tetrachloride.

To produce massive, ductile titanium ingots from sponge is a difficult task. For it, a special vacuum arc furnace has been developed. A consumable electrode of compacted sponge is lowered into an electric arc surrounded by a water-cooled copper crucible. The electrode is rapidly melted, forming a 3200 degree F molten pool that rapidly freezes in the intensely chilled copper crucible to form an ingot. The furnace is vacuum sealed to permit operation under either vacuum or an inert atmosphere of controlled pressure.

## New, Faster Arc-Welding Process

FIELD TESTS on a new consumable-electrode, inert-gas arc-welding process show a 15 to 20 percent faster welding speed at a 25-to-50-percent reduction in costs over other manual or semiautomatic inert-gas methods. No small order!

Key to the new process is a new coated wire (West-ing-arc MS-20). The special coating helps stabilize the arc, eliminates

spatter, and provides good penetration, thereby enabling the use of straight polarity (electrode as the negative terminal) with its higher burn-off rate. This means faster welding speed.

A major cost in inert-gas welding is that of the shielding gas, in this case argon. If the arc fluctuates, air is drawn in past the inert-gas shield and more gas is required. The stabilization of the arc by the new process thus results in sizable savings in gas—33 percent, or more.

Other elements of the process include a new, lightweight electrode gun, rated at 500 amperes; a new wire control, designed to supply wire at a constant preselected speed under all loads; and a constant-potential power supply, rated 220/440 volts, 60 cycles, 3 phase, with a continuous current rating of 500 amperes at 34-volt load.

The consumable-electrode process has long been used for welding stainless steels, aluminum, and other nonferrous materials. The new process now brings the advantages of this method—speed, higher quality, and cleaner welds—to the welding of mild steel, with economical operating costs. The new process produces welds that can be painted without cleaning. There is no slag covering on the weld. The end result is a high-quality weld at greatly increased speed.

Although inert-gas cost is not a problem in manual welding, the new process is so inherently economical that the cost per inch of metal deposited is still about 25 percent less than by manual methods. This cost includes time for welding, cost of materials, and time normally required for cleaning and grinding preparatory to painting.

## For Easier A-C Welding

TRANSFORMER-TYPE arc welders have been improved in several ways. The new type TA a-c welder, like its counterpart, the type RA rectifier d-c welder, is enclosed in a streamlined, drip-proof case. The designs of the two welders have been coordinated to use the minimum number of parts, most of which are common to all ratings of both types. The new TA welder employs a transactor, which combines transformer and reactor into an integral unit. This construction—in addition to an open-circuit voltage of 80 volts—imparts an exceptional degree of arc stability and enhances welding performance. Thermostatic protection of windings against overheating permits greater utilization of the wide range of welding-current adjustment inherent in this design, without danger of exceeding safe temperature. Aluminum windings are used, a weight-saving development that was introduced on the RA welder.

# Lamps and Lighting

**The new sealed-beam headlight. Note the filament shield to trap stray light.**

## Safety on the Beam

SAFER DRIVING at night, with improved see-ability in the fog, rain, or snow! A big order, but lamp engineers have developed a new, improved sealed-beam headlight that fills this specification.

With previous headlamps, reduced visibility in fog, rain, or snow results from stray upward light bouncing back in the driver's eyes from moisture particles in the air. A filament shield in the new lamp traps this stray light, and its shape provides "cornering" light for ease in making right-angle turns. On the Westinghouse version of the new headlight the shield is shaped and positioned to trap stray light on both the upper and lower beams.

Previous lamps were designed with a horizontal reflector axis, and the prism risers in the lens (steps between prism rows) actually contributed to the undesirable-upward-light component. The reflector in the new lamp has been tilted down two degrees, permitting inversion of the prism risers, and directing the light down onto the road.

Redesign of the lens to a new prescription results in the passing beam reaching farther ahead, and also directs more light to the right of the road onto the shoulder. In addition, vehicles being passed are better illuminated.

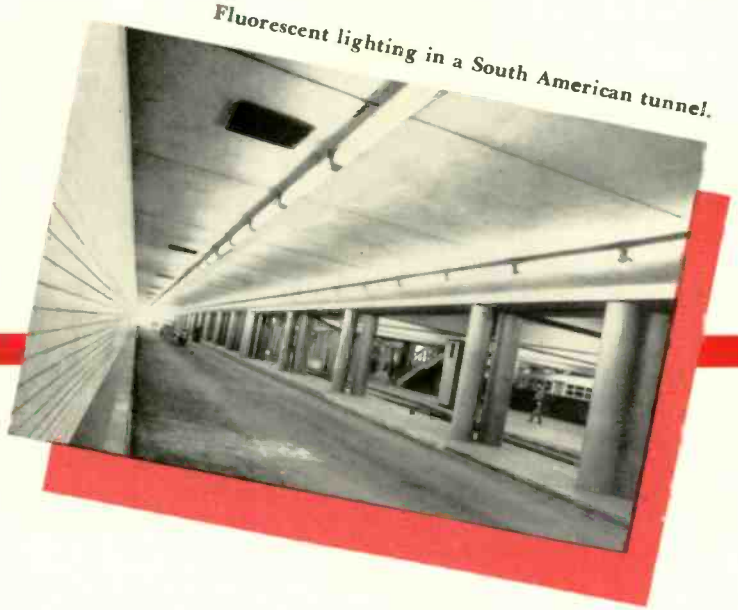
Taking advantage of improved light control afforded by the new lens, shield, and reflector design, the new lamp will be aimed slightly higher—with a two-inch drop in 25 feet instead of the previous three.

All of this and more light too! Filament wattage of the driving beam has been increased from 45 to 50, and of the passing beam from 35 to 40. Completely interchangeable with its predecessor, the new lamp is the result of industry-wide development. Now available in states that have revised their motor-vehicle codes, it will be in nation-wide distribution as soon as remaining states pass the necessary legislation.

## Cold Weather Fluorescents

LAMPS and air conditioning are in fundamental conflict. Every watt of heat that a lamp gives off in a cooled room must be pumped out by the air-conditioning equipment. Mostly this load is small enough to be ignored—principally because it has to be. But in large, refrigerated food-storage

Luminaire for new low-temperature lamp.



Fluorescent lighting in a South American tunnel.

Fluorescent street-lighting luminaire.

areas, which are rising in numbers, and where temperatures must be held down to zero and below, the lamp load becomes something to cope with.

The high-efficiency fluorescent lamp (an incandescent lamp of the same rating gives off nearly four times as much heat) becomes an obvious potential solution. The recent development of a fluorescent lamp specifically designed to operate in cold air makes this potentiality a practicality. This new lamp, designated 72T12, is a 6-foot, 1000-ma rapid-start lamp with characteristics chosen for high efficiency in the region of zero degrees F. Also this lamp comes up to full output much more quickly after it is turned on.

Bare and shielded fixtures have been created to capitalize on this "cold-weather" fluorescent lamp, principally for cold-storage areas.

*Fluorescent Tunnel Lighting*—The trend toward fluorescent lamps for semi-protected outdoor areas, noted last year, continues. For tunnels, underpasses, multiple-deck parking garages, etc., fluorescent units—based on this same outdoor-type lamp—are growing in popularity. The lines of light produced by fluorescent are a "natural" for such service.

A new design has been developed to meet the special requirements of these applications. It can be mounted in the center of the ceiling, directed downward, or placed at the side in a corner and tilted to the proper angle. The housing channel is a one-piece aluminum extrusion. The clear cover is fabricated from a one-piece extrusion of methacrylate. The hinged-cover assembly is removable, has no fastenings requiring tools to operate, and there are no loose parts to fall off.

*Fluorescent Street Lighting*—Fluorescent lamps have certain street-lighting applications; for example, in limited business areas of large and small cities to produce "white ways" that have high shopper appeal.

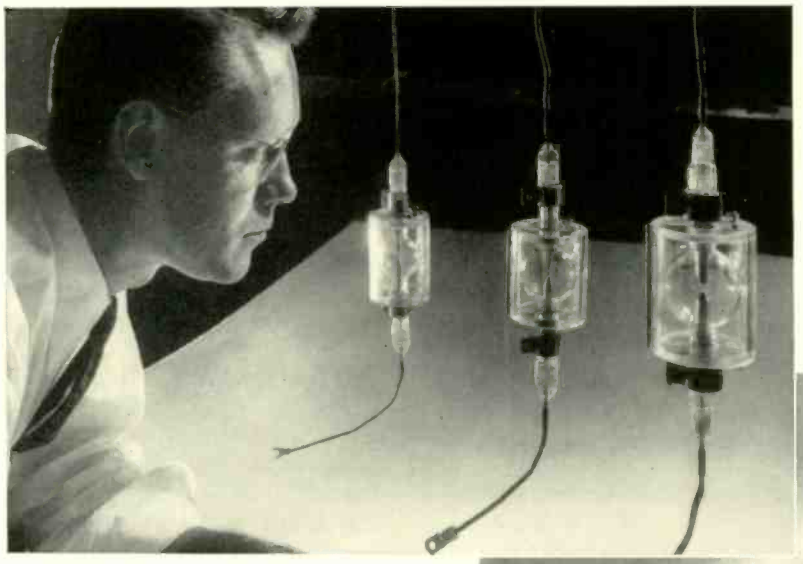
A new fluorescent street-light fixture possesses several novel features. The upper hood is of laminated polyester fiber glass (of sports-car fame). With internal pigmentation its color is permanent, requires no painting, and is inherently corrosion resistant. The clear, weather-protecting lower cover is also of plastic, with the main clear extrusion of methyl methacrylate chemically welded to opal ends of the same material. The internal, structural chassis is of steel and aluminum. The unit can be mounted horizontally or tilted at an angle.

## Making the Most of Lines of Light

THE FLUORESCENT lamp is a natural to produce lines of light. Engineers who design luminaires for offices like it that way. In fact, they design this equipment to have little or no interruption of light where luminaires adjoin each other to form this continuous line.

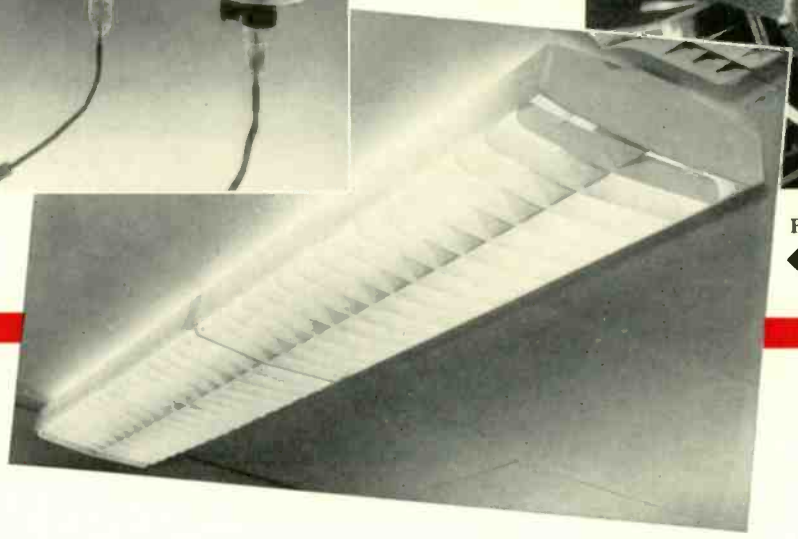
Translucent-plastic side panels are now ingeniously shaped at their ends so that they are not only luminous on their entire length but also at the corners. Thus when two or more units are joined end to end, there are no interruptions or dark areas —only a slight decrease in luminosity at the connection.

These office-type fluorescent luminaires, designated LC, have been otherwise improved. Ballast replacement can now be made easily and quickly, even though luminaires are mounted on the ceiling, by simply swinging down the louver assembly, which can be hinged from either side of the luminaire. This hinging is done without interference with the side panels. Snap-in spring fasteners prevent branch and circuit wiring from dropping out of place when the wiring raceway is open.



New xenon lamp emits nearly white light.

This lamp is designed to give greater flexibility in TV studios, by allowing burning from any angle between base down and horizontal. Entirely new filament supports grip the tungsten at both ends.



Fluorescent luminaire (LC)

By proper selection of a few basic parts, forty-eight different types of these luminaires are possible, covering combinations of two- and four-lamp designs in four-foot and eight-foot lengths, with either metal or plastic side panels.

## Xenon—A New Light Source

XENON. That's a new word you'll be hearing in connection with lamps. Pronounced *zee-non*, it is relatively new to you and me, but not to those who create light sources. Xenon is a natural element, one of the rare gases. The light-source characteristics of all of nature's elements have long ago been catalogued. But there are some new applications for xenon's unique light-giving features.

Outstanding is its color quality. When a high current is passed through this gas, the light emitted is a close match to white light, i.e., sunlight plus north-sky light. Importantly, that color does not change as the voltage on the xenon lamp changes. The output changes in amount but no shift in spectrum occurs, hence voltage-regulating devices are not needed to preserve color quality. Also a xenon lamp, being a gaseous-discharge device, can be modulated. The output ceases instantly each time the current goes through zero. The lamp relights each half cycle.

Another favorable attribute of a xenon lamp is the extremely concentrated source. Lamp construction follows the principles used with short-arc mercury lamps.

All is not peaches and cream, however. There are things about xenon that will prevent its being a general-purpose lamp—at least for quite awhile. Like all discharge lamps, starting devices and ballasts are required. For decent efficiency it must be used under high pressure. Present lamps hold the gas at 8 to 25 atmospheres. Even then its efficiency, while good (25 to 30 lumens per watt, compared to 15 to 20 for incandescent, and 50 to 60 for fluorescent), is not superlative.

All the same, some interesting uses are in prospect. One is for movie projectors. Its point source is a delight to optical engineers. Because the lamp relights each half cycle it offers the possibility of a shutterless projector. By a suitable circuit, voltage is withheld each time a frame is to be advanced. Thus, in addition to eliminating the shutter mechanism, the light cut off by it is saved.

These advantages combine to make an extremely efficient movie-projector lamp. An 800-watt short-arc xenon lamp delivers about 2000 lumens on the screen. A 1000-watt incandescent provides about 500 lumens.

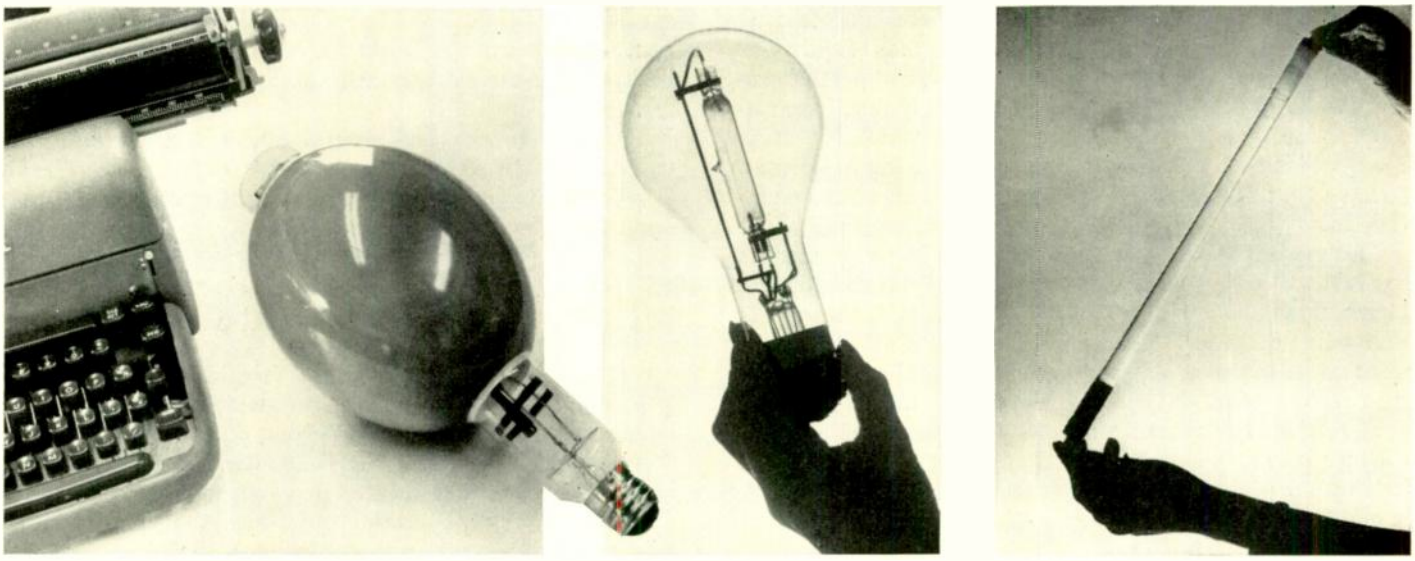
Experimental 16-mm projectors with xenon lamps have been built for military and training purposes. The development, while extremely attractive, is quite some distance from being within the cost range of the amateur.

Xenon lamps have also been produced in four wattages up to 2000 watts for military applications. Here the good white-light quality, concentrated source, and susceptibility to modulation were the appealing qualities.

## Mercury Moves Along

ANOTHER important step has been taken to improve the color quality of mercury lamps. For most industrial applications, the improvement effected by coating the bulb interior with red-producing phosphors has been adequate. For offices and stores, however, it would be desirable to reduce further the proportion of yellow-green.

A way has been found to do this. In addition to the inner coating of phosphors, the outer surface of the bulb is given a fired-on ceramic layer that absorbs yellow-green but is almost



*Above* (left to right), the de luxe color-corrected mercury, 175-watt mercury vapor, and 18-inch Sterilamp.

transparent to reds and blues. In addition, the bulb is made bigger, which in effect lightens the load on the phosphor. This helps to improve the color balance.

The new de luxe color-corrected mercury lamp is being produced in small quantities for experimental purposes. The lamp has a 400-watt rating and is identical in size to the 1000-watt fluorescent-mercury lamp. The ceramic outer filter absorbs some light. The net efficiency is reduced to about 36 lumens per watt (straight fluorescent mercury is 47).

The variety of mercury lamps includes units for new uses. To bring better lighting to the less-traveled streets, two new sizes—100 and 175 watts—have been produced.

A new short-arc, 2500-watt mercury lamp is being put to unusual use. This is as a light "fence" marking the residential area around an airport. Mounted in a fixture to throw a concentrated, narrow beam (only 0.8 degree wide) it gives a pilot his course on take-off, and tells him to gain altitude rapidly, to lessen the noise at the ground level.

For searchlights the high brightness and high output of a mercury-vapor lamp is in much favor. A great weakness for some applications is that a mercury lamp gives very little light when first turned on and for the first few minutes until it becomes hot. This has been in large part alleviated by a lamp in which xenon is added to mercury. Xenon gives light instantly when voltage is applied and provides a good white light. In two sizes of lamps—1000 and 2500 watts—enough xenon has been added to give the lamp at start 25 percent of the total output after the mercury vapor takes over. The xenon, however, is added at some sacrifice in the total lamp efficiency.

The use of Slimline Sterilamps in air-conditioning systems to reduce bacteria count and to destroy odors is increasing. In some air-conditioning systems duct height is quite small. For these systems shorter Slimline Sterilamps—only 18 inches long—have been provided, in two degrees of ozone production. These two short lamps are in a Vycor enclosure. The latest Sterilamp in a quartz envelope allows full passage of 1850-Angstrom radiation and is a highly efficient converter of the energy into ozone.

Photo-copying machines are fast increasing in number and versatility. This is calling into being new, low-cost mercury lamps. These extend from a unit of only 600 watts for desk models of copying machines to 3500 watts for the big central-office devices.

## Electroluminescence Opens a Window to the Atom

$$L = aV^{-b/(V+V_o)}$$

DON'T TRY to figure out the meaning of this formula. We put it here not for what it says but because its story illustrates uncommonly well the whole pattern of research.

In 1936 Professor Destriau of the University of Paris observed that if an alternating voltage is applied to two edges of a layer of phosphor material it gives off light. This was the principle of electroluminescence. Destriau didn't know why this happened. Scientists still don't—for sure, that is.

Soon after Destriau's discovery, scientists in other laboratories made electroluminescent cells. Generally these cells were several square inches in area. With the room darkened and with voltage applied, the cell can be seen to glow, usually with a greenish color. Each year these demonstration cells become more and more efficient, the light a little brighter. But still the performance in terms of lumens per watt is too low by an order of magnitude for an electroluminescent lamp to be a practical light source.

The layman, anxious to see something useful, asks the light-source researcher when a practical electroluminescent lamp will be on the market. The scientist tries to be polite, but makes it plenty plain that at this point he isn't interested in making a lamp to employ this principle. The problem first is to find out just how it is that phosphors extract energy from an electric field and convert it to light. Only then will research be able to give lamp designers the information they need for rational design of a light source better than the feebly glowing novelties of today.

And that is what they have been doing, amassing data on different kinds of phosphors—and there are scads of them—as to effects of temperature, voltage, frequency, manner of forming the phosphor layers, and so on. Until lately the accumulation has mostly been a disorganized mass of data. But there is enough of it that the scientists have been trying to devise a formula that fits accurately all the facts—whence the equation above.

This mathematical expression, developed just a few months ago in the Westinghouse Lamp Research Laboratories, fits the known facts about electroluminescence better than any developed to date. In fact, it seems to fit very well, although some minor modifications may later improve the fit or enable it to accommodate data still to be uncovered.

The formula has three constants and two variables. Now the task is to tackle each in turn to find out what lies behind it. Thus the problem of understanding electroluminescence is, in effect, compartmentalized. It is broken up into pieces that can be tackled separately.

Various theories of just how the energy conversion takes place are shaping up. Some are in conflict—a disagreement that will be resolved when the elements of the formula become fully understood. To cite two concepts, one is that light is produced by field emission within the phosphor crystal (i.e., the Zener effect), and another is that it is caused by impact ionization of the luminescent centers by electrons—accelerated by the electric field varying in step with the line frequency.

Much progress has been made lately in electroluminescent-cell construction. At 400 cycles and 400 volts, efficiencies of 7 to 8 lumens per watt (about half that of an incandescent lamp) have been attained.

## Mercury Lighting of General-Service Areas

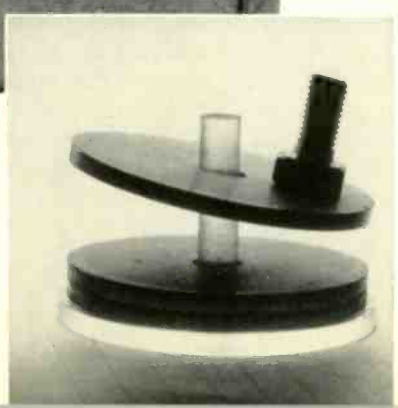
A FINE EXAMPLE of the gains obtainable in some lighting applications when mercury and fluorescent-mercury lamps are substituted for incandescent is afforded by gasoline-station pump-island lighting. These are lamps in reflectors above the pumps and directed downward.

The incandescent lamp and its housing can be replaced with a new mercury-vapor lamp and reflector. The result is that, with 50 watts less power consumption, the amount of light is about doubled, and lamp life is extended about six times. No change in wiring is necessary. The oval-shaped fixture containing the lamp is totally enclosed to protect it against wind-driven rain and insects, and is sealed against entry of dirt. The lamp housing pivots at the two ends so the beam can be directed downward, or at any oblique angle.

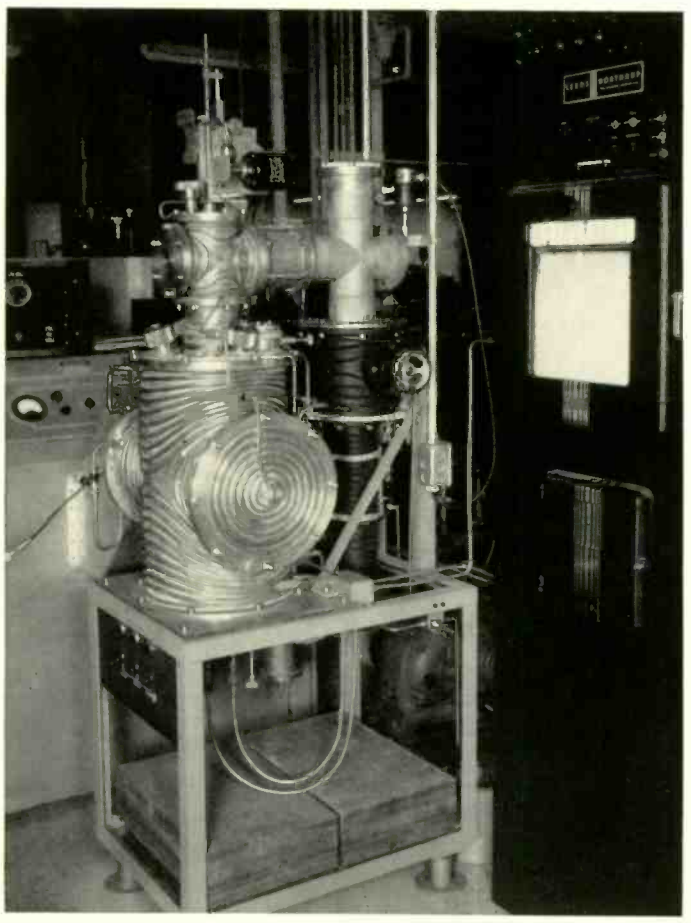
This new universal-area unit (UA-20) has many applications in addition to service stations. It is well adapted to general lighting of parking areas such as those around shopping centers, car-sales lots, and the approaches and service areas of superhighways.

# Materials and Processes

A furnace for making large single crystals of germanium or silicon.



*Above,* a germanium power transistor. *At right,* two discs of permanent magnet material support a third in space.



## Transistors, Magamps Present Wide New Horizons

IN VISITING the Westinghouse transistor and magnetic-amplifier laboratory one has a feeling akin to an explorer when he first sees a new land. The sights are breathtaking. Some vistas he had imagined, others he could not have dreamed of.

Transistors are available only in watt sizes and admittedly are in the infant stage of development. Yet, things are being done with them even now, mostly in conjunction with magnetic amplifiers, that are hard for electronic or power engineers to believe. Many of these things come from a fairly recently acquired concept that, while the transistor alone is remarkable, the things achieved by the new circuitry it makes possible are fantastic, particularly as larger capacity crystals become available in quantity.

The transistor can be used as a converter (or inverter). Any frequency up through the audio range can be obtained from a d-c input. The frequency, believe it or not, is a function of input voltage. The square wave naturally produced can be modified to a sine wave by proper filters, with a small loss in efficiency.

This converter characteristic is an extremely useful one. For example, the rate of response of a magnetic amplifier, and to a large extent its physical size, is a function of the frequency. It is to get faster response that power supplies of frequencies higher than 60 cycles are sometimes provided for magnetic amplifiers. This often requires a special power supply. For many applications this will no longer be necessary. The desired high frequency can be produced by a transistor circuit. Because higher frequencies—even up to ten kilocycles—are easily obtained locally by completely static devices, magnetic-amplifier circuits of extremely high rates of response and very small size are made possible.

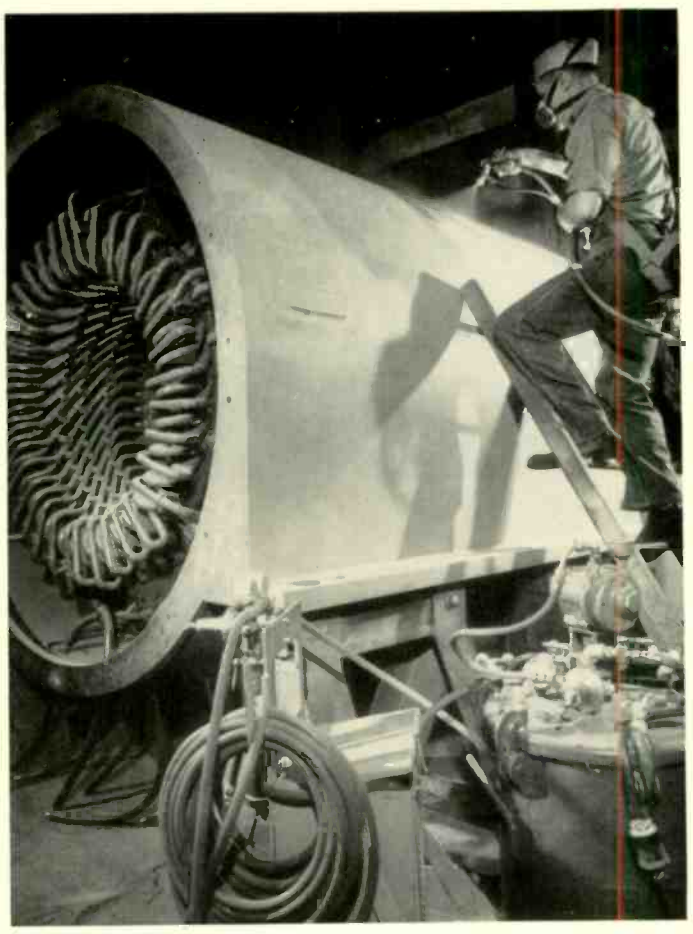
The old dream of a high-efficiency d-c transformer becomes a reality. Transistors, in a relatively simple circuit, can convert direct current to a square wave. This, being alternating, can be changed in voltage and, by full-wave rectification, returned to direct current. Overall efficiencies for circuits delivering a few watts are about 90 percent.

Transistors, in proper circuits, are being used as switches or relays. They make possible switches—completely static and with indefinite life—having an efficiency better than 90 percent, compared to the 50 percent of a class A amplifier stage.

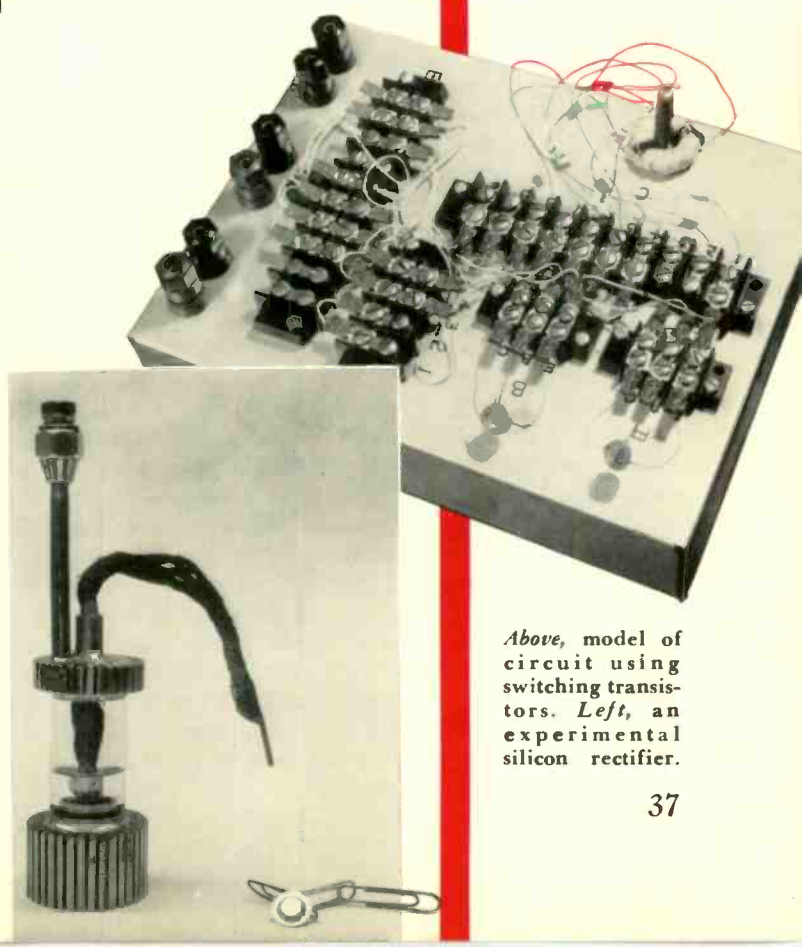
A combination of transistors and Magamps can be used to create a time delay of any given length. And always the accuracy is to one cycle of the basic frequency used. For example, a delay, even of days or weeks, could be provided accurate to 1/60 of a second, if 60-cycle power is used. This same circuit can be used as a counter of events or units, as represented by pulses.

Transistors are being teamed with improved magnetic amplifiers having cores of high quality to operate on signals of extremely low energy. Devices have been operated experimentally from signals of $10^{-12}$ watt (one trillionth of one watt). Such ability opens up the possibility of using signals from thermocouples directly, with no preamplification.

Virtually all the work done to date has been with germanium transistors. These are stable over a temperature range of −75 to 160 degrees F. It is expected that as silicon transistors become available these temperature limits will be widened, particularly upwards.



**A new paste filler can be sprayed on while hot. The new material does not become brittle with time.** Story on page 39.



*Above,* **model of circuit using switching transistors.** *Left,* **an experimental silicon rectifier.**

## Solid Advances in Solid-State Devices

THE TRANSISTOR need never worry about unemployment—new jobs are being found every day. One new line of 200 milliwatt *pnp* transistors (2N73, 2N74, 2N75) is finding wide usage in switching and control applications. They can do such things as convert small d-c voltages to a-c (choppers), or convert a-c to d-c (synchronous rectifiers), or just plain switch electric circuits on and off.

A line of experimental *pnp* transistors are encapsulated in metal, with a glass-to-metal seal for bringing out leads. This hermetically sealed core protects the transistor from effects of ambient atmospheres or environment. Metal-case construction allows small size, which makes the transistor a natural for hearing aids and similar applications.

A combination of mounting and physical design has made possible a one-watt rating for a new germanium power transistor (2N71) now in pilot production. A black, ribbed surface provides cooling for the one-watt collector. Additional cooling is obtained by fastening the unit directly to any metal surface, which then acts as a heat sink.

Germanium diodes, cousins of the transistor, are also being given asylum in hermetically sealed cases. A metal case replaces previous plastic or ceramic capsules, with glass-to-metal seals to bring out leads. The complete hermetic seal, not possible with plastic cases, results in a unit entirely impervious to atmospheric deterioration. Furthermore, the new case design is inexpensive to produce and is adaptable to mass-production techniques.

## Ceramic Permanent Magnets

A UNIQUE recent European development in the field of magnetic materials is being studied by Westinghouse engineers. Unique because of insulating ability, high coercive force, resistance to demagnetization by heat, shock, high- or low-frequency magnetic fields, this magnetically hard material has a coercive force higher than alnico, although its energy product is lower.

Containing only iron oxide and barium oxide, two cheap and plentiful constituents of ordinary dirt, magnets of this material can be formed into almost all useful shapes common to ceramic processes. Possible applications are to provide arc-blowout fields in contactors and breakers, speaker magnets, biasing fields in high-frequency devices, and a number of holding operations.

## Now, Powerful Permanent, Permanent Magnets

IN THE WORK to develop better magnetic materials, credit the scientists with another success. They have found a superlative new method of producing the compound of manganese bismuth from which the most powerful known permanent magnets can be made. This method is not only simpler and much quicker but the resulting powders are superior to those produced by other methods. The saturation magnetization of the powder at the Research Laboratories is 15 percent higher than values previously reported. Moreover, tests on a few magnets made with these powders indicate the practical possibility of permanent magnets two to three times stronger than alnico. Furthermore they hold the promise of truly permanent, permanent magnets. In resistance to demagnetization, they are up to 30 times better than the alnicos.

The superlative magnetic possibilities of the manganese-bismuth compound have been known for many years. The catch has been the lack of an economical way to prepare the compound. The previous systems have involved long, slow, and difficult processes that have simply licked them cost-wise. By comparison, the new method developed in the Research Laboratories is both simple and quick.

The purified manganese and bismuth are crushed and then ground in a ball mill under an inert atmosphere (manganese oxidizes readily) to particle size of about one micron (1/25 000 inch) in maximum dimension. This small size is important in order to achieve the proper compound. The mixture of fine powders is then brought into chemical combination by heating for two hours at a temperature just under the melting point of bismuth (273 degrees C).

From the resulting reacted powders and a binder, it is believed that permanent magnets can be formed in any desired shape. Magnets can be molded, perhaps even extruded. The usual problems of machining are virtually eliminated as manganese-bismuth magnets are soft so they can be easily drilled, sawed, or even cut with a knife.

The work thus far has done even more than provide the raw materials for permanent magnets superior to any others designers have known. It has verified new theories of magnetism; in fact this effort is really an outgrowth of work aimed at developing a true understanding of the mechanism of magnetism—theories that lead to the day when magnets can be designed from fundamental considerations, not produced on a cut-and-try basis.

**The new method for testing magnetic-amplifier cores.**

## Testing Magamp Cores without Windings

THE GAPLESS, high-permeability, toroidal cores used in magnetic amplifiers are somewhat like highly bred race horses. They are extremely sensitive and highly individualistic compared to the ordinary. All this has made the manufacture of cores to specifications a difficult matter. Until lately the only way to determine precisely the behavior of a core was to actually put regular windings on it and test it.

A production tool has been devised that obviates this need of actually winding cores to measure their quality. By means of a multi-contact plug connector slipped through the core,

three separate windings are placed on the core. Four readings, under specified conditions of control current or induced voltage, effectively define the performance of the core for magnetic-amplifier operation. Cores are accepted according to limits established for these readings.

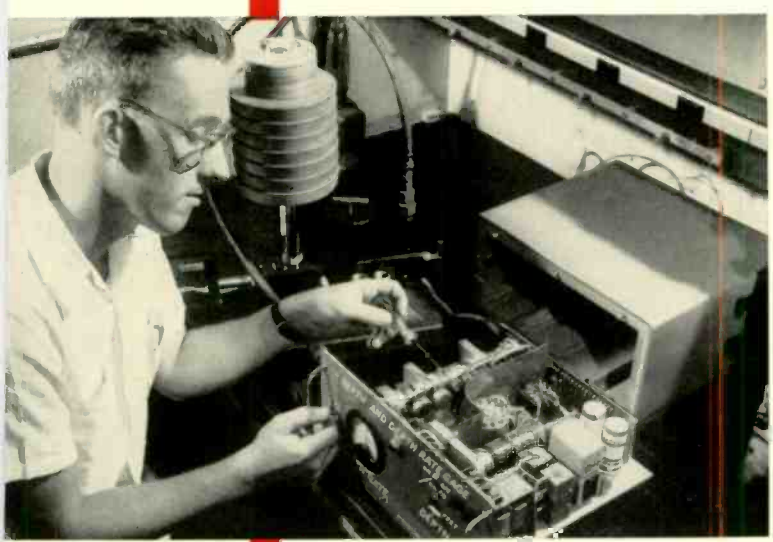
## Pre-painting Finish for Large Machines

WE MUST accord large motors and generators a privilege we grant the ladies ("we grant"—that's a laugh!). This is the opportunity to make minor corrections in the understructure before the final dress is put on. Rolled steel inevitably contains roll marks, small surface irregularities, and roughnesses at welds that must be smoothed up before final painting. For this reason, it has been customary to apply a compound to fill in the irregularities and to smooth the contours. To obtain the necessary pre-painting surface finish by grinding would be prohibitively costly—and pointless.

A new type of filler is not only better but also easier to apply. It is a highly pigmented paste that can be sprayed on while hot. A thicker paste-like version can be applied with a special knife where heavier layers are needed. It requires no sanding prior to spraying as previous fillers have.

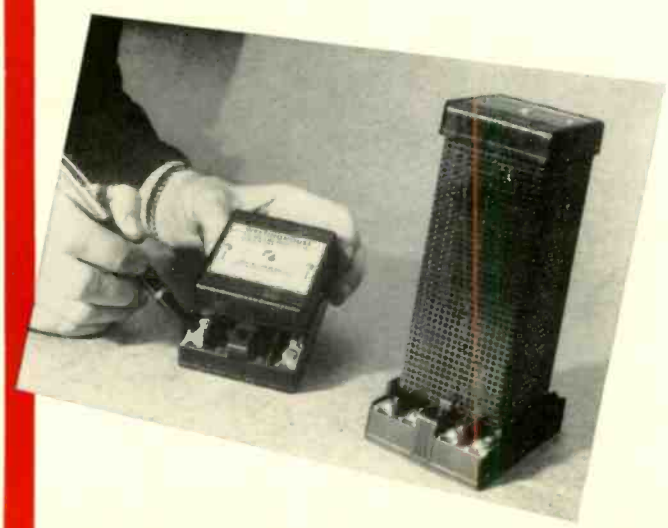
This filler has the great advantage of relative permanence. Under humid conditions it shows no inclination to come loose, with obvious destruction of the covering paint, which can happen to the black fillers that have previously been used. Neither does it become brittle with time, and thus susceptible to chipping.

# Measurement and Test

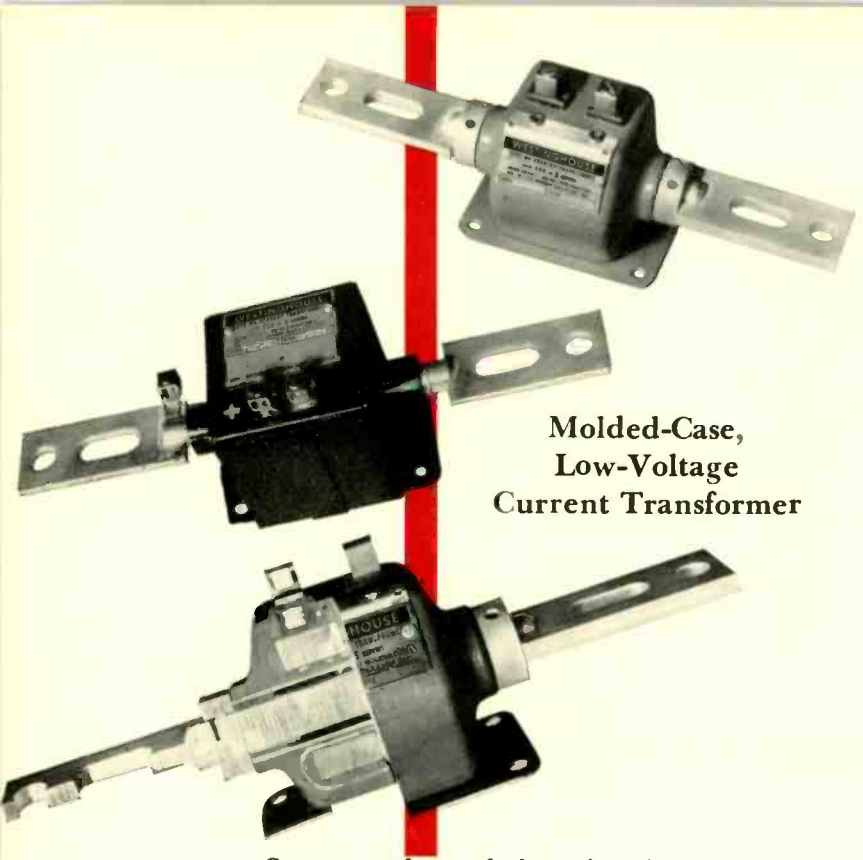


A model of the electronic depth gauge.

New instruments tested under two extreme conditions.



Many electrical instruments require as an adjunct a resistor that for reasons of size or heat dissipation cannot be contained within the instrument case. There have been many sizes, shapes, and no standardized mounting dimensions. That situation has been cleaned up. From a number of basic parts the external resistor for any instrument can be made. There is but one molded base for all. This simplifies production, and greatly eases the spare-parts problem.



**Molded-Case, Low-Voltage Current Transformer**

**Current transformers for low-voltage (up to 600 volts) metering have a new overcoat. It is a thick, very tough jacket of polyester elastomer, molded on. This unit can be used either indoors or outdoors, will go over the service cable or in a meter box. The through-type primary bar is split lengthwise so it can be easily withdrawn from the core. The base can be rotated 90 degrees or mounted in any position. Photographs above show comparison between new transformer (top and bottom) and previous model.**

## Instrument Ruggedness—The Ultimate

YOU WON'T believe this.

In preparation for a war emergency several thousand d-c instruments of different kinds have been designed and tested under conditions of torture of unparalleled severity. The engineers refer to these instruments as "ruggedized"—but that is an understatement. Space prevents the listing of the complete testing routine, but the following gives a good idea of the grade A-1 abuse to which these hermetically sealed, d-c instruments have been subjected—and which they survived with acceptable accuracy.

Following the normal tests, the instruments were given five swings in temperature between −67 and 185 degrees F and then dunked in ice water for ten 15-minute periods, following intervals of submersion in almost-boiling water. Then for 30 days, in a room maintained at 95-percent humidity, the instruments were taken through periodic temperature swings from room temperature up to 144 degrees F, with an occasional dip down to +14 degrees F for good measure. Through all of this the instruments were operating electrically with normal current or voltage. Then, to make matters really tough, the glass covers were purposely broken and the humidity cycles repeated for two days. The instruments had to function normally and within the usual error limits following these rigors.

So much for temperature shocks and humidity. Now some mechanical roughing up. First came six hours on a vibration table, the instruments being energized off and on during the process. Then—here's the crusher—the instruments were put in a rotating steel drum with barriers. The instruments were then tumbled like Monday's wash for 45 minutes. The engineers estimate this is equivalent to rolling their pride and joys down a set of foot-high steps as tall as the Washington Monument. Finally, for good measure, the instruments were treated to nine blows on the Navy high-shock stand (i.e., 2000 foot-pounds). The instruments survived and even remained accurate well within the five-percent limit.

Don't go away. There is more.

To find out the worth of the glass cover, steel balls weighing ¼ pound were dropped eight inches onto the face-up instrument. To prove the tightness of the seals around the lead-in wires of the cover to the housing, and of the housing to the base, a strong vacuum was created in the instruments while they were submerged for four hours in a tank containing salt water.

Finally the units had to pass a test of 3000 volts between metal case and ground.

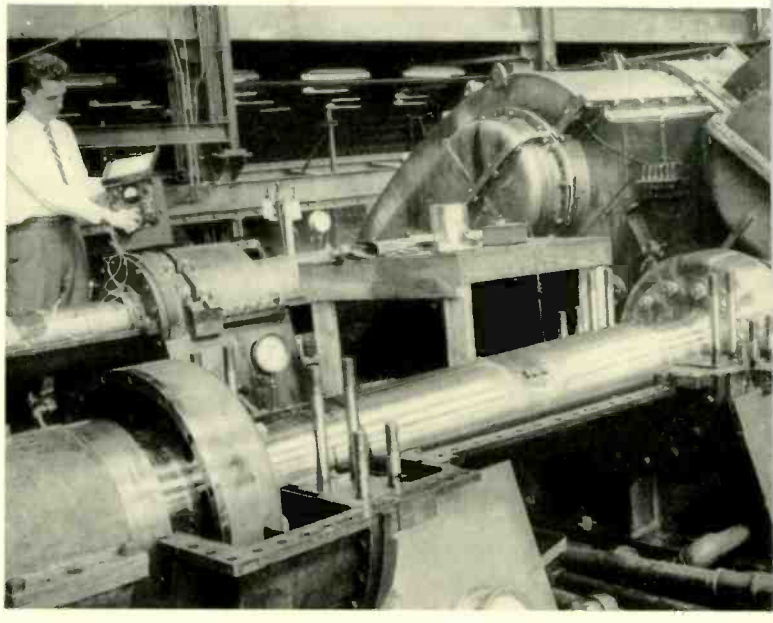
Many engineering features and manufacturing techniques, of course, had to be developed to enable instruments to survive this ultimate in abuse. Each part individually was made capable of meeting these tests—not just the assembly as a whole. No rubber or spring supports were employed to ease the mechanical shock. Special techniques of soldering the cases to platinum-rimmed glass covers were devised. Torque springs of beryllium copper were employed.

And so on. Should a serious war emergency develop, all this spells proved design know-how and manufacturing ability to provide the tens of thousands of tough fighting instruments required in a modern war. This work was done at the behest of the U. S. Signal Corps. It is not the intention to put the instruments in commercial production.

## A Better Answer to the Question: "How Deep Is It?"

A PRECISION-TYPE, electronic depth gauge, operating on entirely new principles, is able to show submarine depth below the surface to within a half foot, whether the depth be a few feet or a few hundred feet. Furthermore, the gauge shows

**Test arrangement for measuring gear-tooth stresses.** Story at right.



accurately any rate of dive or climb. Or, a traffic manager of an oil-tank farm could, without moving from his office, measure the quantity of oil in gallons in any tank to within one part in 4000. Furthermore he doesn't have to take into account the density changes due to temperature.

This remarkable depth-sensing genii is all contained in a flat box about a foot square and seven inches high. The weight is 27 pounds and its energy consumption is only 60 watts. Heart of the instrument is a highly accurate, sensitive Baldwin hydraulic-pressure cell. Physically this is a cylinder about 1⅝ inches in diameter and 7½ inches long. Its output is amplified three million times by four stages of sub-miniature vacuum tubes, each being not much bigger than a shelled peanut. After further amplification by a magnetic amplifier the signal is fed to a servomotor, which drives the rotating member of a precision potentiometer that is part of a Wheatstone bridge circuit. A change in pressure on the cell, i.e., a change in depth, causes the potentiometer to seek a new position to effect voltage balance. Hence the potentiometer position, which can be shown either on a counter or a dial, is an accurate indication of depth.

To show rate of change of depth a tiny a-c generator is located on the shaft of the servomotor. Its output voltage is proportional to speed and hence is also proportional to the rate of change in pressure.

Simply by insertion of different range pressure cells—with no change in electrical circuit—the gauge can be made to measure total pressures of a few feet, or up to many thousand feet of sea pressure. Or by use of strain-gauge-type load cells instead of a hydraulic-pressure cell, the instrument can be used to show total weight and change in weight.

## Strain Gauges, a New Voice for Turbines and Gears

ENGINEERS now have a way by which long blades of a steam turbine write the full story of their vibration at all speeds. Their means of communication is the tiny strain gauge. Many of these gauges, each the size of an aspirin tablet, are baked onto various blades on an assembled row. As they sense any vibration they send out signals by wires through the shaft to recording instruments on a control desk beside the test chamber.

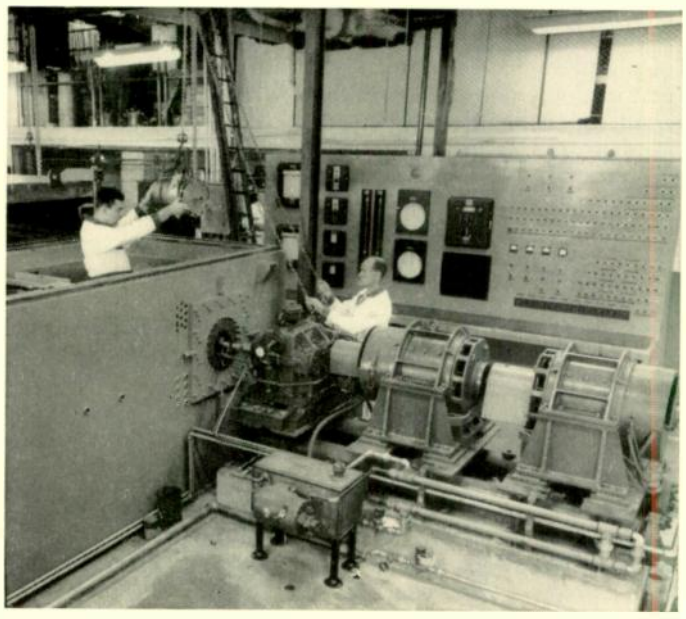
An optical method was previously used to record blade vibration. This was mechanically involved and has considerable limitations. A single tiny mirror was fastened to the end of a blade, and a light beam sent in through the spinning shaft was focused onto the mirror and directed back out again to write on film any blade movement.

The strain-gauge method, by comparison, can provide data on several portions of many blades at one run. There is no trouble with fogging of mirrors, and there is no scale limitation as is present with the light-beam system. Also the strain gauges can pick up fainter signals than have been heretofore obtainable. With strain gauges, the effect of different lashing-wire arrangements, and various blade groupings can be quickly determined for all speeds.

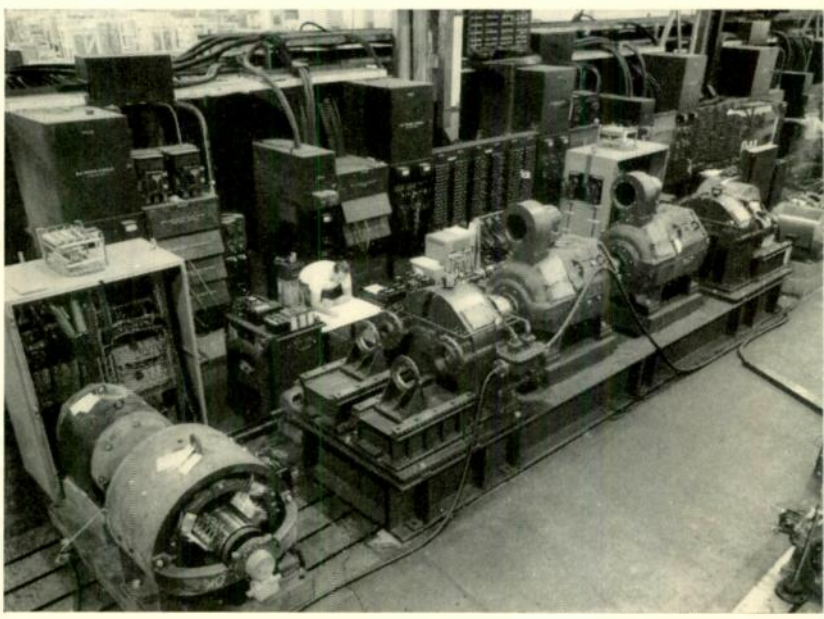
***Study of Gear-Tooth Stresses***—Strain gauges are also being used to ferret out the cause of tooth breakage on a new design of big gear. This gear was for extremely high horsepower delivery. The design loading was only slightly above normal, but this was compensated by the use of a somewhat better, harder gear material. Nevertheless, there were tooth failures even though the material painted on the teeth to show load distribution displayed a uniform pattern. Indicative that something fundamental is involved is shown by the fact that other manufacturers of gears have encountered the same trouble.

To get at the base of the matter, strain gauges (of both pressure- and temperature-sensing variety) were attached to various portions of the gear teeth and the leads brought out through the hollow shaft to an instrumentation board in a manner similar to the low-pressure, blade-vibration study. By this method, instantaneous stresses and temperatures at various parts of the tooth and at different locations along the tooth are obtained for each speed and loading; tooth marking gives only the integrated result. In this way the effects of slight misalignment, minute changes in tooth configuration due to centrifugal forces, and of different locations for the oil sprays and amount of oil flow are being fully catalogued.

**The new high-altitude chamber for testing aircraft alternators.**



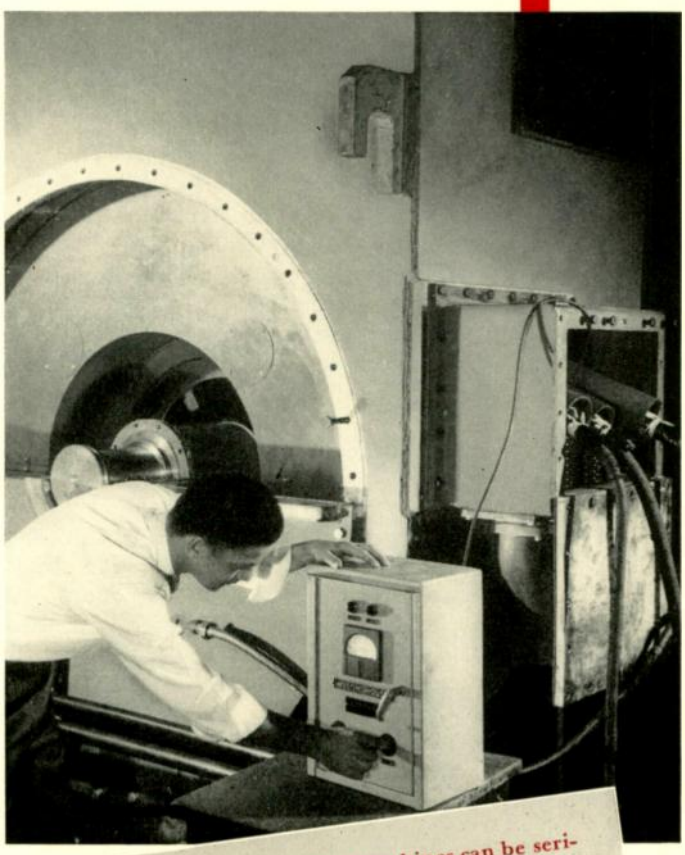
**Test stand for four aircraft alternators. Drives simulate jet engines.**



## A New Watthour Meter

WATTHOUR meters, like automobiles, undergo minor improvements regularly. Then at infrequent intervals sweeping model changes are made. Last year was a model-change year for the Westinghouse watthour meter.

The improvements in the two types of meters—detachable mounting (DS) and bottom connection (DA)—are numerous. The overload capacity, always important in watthour meters, has been greatly increased. For the 15-ampere rating it is now 100 amperes instead of 60. A new 30-ampere rating has an overload rating of 200 amperes, which gives it a higher overload capacity and less starting watts than the previous 50-ampere meter. These have been achieved by using heavier copper parts, solid instead of stranded wire in the current coil, and by molding the whole coil in a heat-conducting insulation recently developed by the Research Laboratories.



The windings of electrical machines can be seriously damaged if water from the heat exchanger should leak into the cooling air. A new moisture detector gets along without vacuum tubes. Also it delivers its signal to a meter as well as to an alarm system. This detector employs probes buried within the machine housing to sample the air. If moisture is present their electrical resistance decreases. This fact causes a near-balance in a Wheatstone bridge circuit which actuates a sensitive relay in the indication circuit. The unit is, therefore, completely fail-safe.

Meter insulation has been improved and made more stable thermally. Both potential and series coils have a 10 000-volt impulse withstand insulation level. The socket meter has a De-ion arrester to protect against lightning and surges. This arrester is located in the meter base so as to arc outside the meter into the socket.

Many features are of interest to the service man. Both the full- and light-load adjustments can be made from the front of the meter, and can be made with the fingers or a screwdriver. The meter can be disassembled readily by maintenance men for inspection or replacement of parts. The register and the nameplate are separate so the register can be removed without the meter losing its serial-number identity. A disc guard makes it possible to lay the meter, cover removed, on its face without damage to the disc. The cover rim is iridited aluminum, compatible with the new Westinghouse aluminum sealing ring and socket, to prevent corrosion due to galvanic action. All internal parts are also treated for maximum corrosion protection. Ball and jewel bearings, of the type that have given almost flawless service for 50 years, are employed.

## Mastiff and Toy Terrier

ON THE TEST floor at Buffalo last fall was a most incongruous looking device. Here was a row of machines on a massive bedplate about 30 feet long, of a size that might have come out of the largest electric shovel. In the line were two huge mill-type motors that could take care of themselves nicely in any steel mill. Connected to each was a large reduction gear. If one looked real close one would see overhung from each gear two small machines, each smaller than a nail keg. Each is about the size of the coupling between the motors. These are aircraft alternators. In fact, the function of this whole shebang is to test these generators. They are so tiny compared to their driving machinery that one is tempted to feel sorry for them. This test stand is shown on p. 41.

There are, of course, valid reasons for the disparity of size. The drives must simulate aircraft engines that, in a plane, drive the alternators. Accordingly they must be able to accelerate or decelerate one, two, or all four generators over a speed range of 3000 to 9000 rpm at any desired rate from zero to 2000 rpm per second. Although the driving motors would normally be rated at about 200 hp, their mechanical parts must be able to handle torques equivalent to 500 hp, resulting from high rates of speed change. The machines must hold speed when sudden a-c load changes occur.

The whole system, which can simulate flight performance of a four-engine jet airplane, has its own twin motor-generator supply units and twin control cabinets with electronic regulators to limit current, voltage, and acceleration. Interestingly, the ability of the whole test rig to perform was tested on the computer before any elements were built.

## Altitudes of 17 Miles—In the Laboratory

WRITTEN in the rise in requirements for environmental testing is the story of flight progress. These pages ten years ago pointed with pride to an altitude chamber capable of testing 20-kva alternators to the equivalent of a 50 000-foot altitude. It was supplemented late last year by one that can duplicate conditions of 65 000 feet on a 120-kva machine, or 80 000 feet on one of 90 kva. For some equipments, altitude equivalents of 100 000 feet are possible. The older altitude chamber occupies a space of about 600 square feet; the new quarter-of-a-million-dollar laboratory with its supporting

apparatus fills nearly 2500. Also, indicative of the circumstances of jet flight, the chamber can not only carry the temperature down to −55 degrees C, but also up to 120 degrees C. Thus, rotating machines can be subjected to a temperature range of 175 degrees C (314 degrees F). The new altitude chamber can provide the full gamut of moisture from extreme dryness to saturation. The very low temperatures are attained by two stages of mechanical refrigeration and one of dry ice. No air is recirculated, as the most minute contamination of the atmosphere from volatile substances in insulation, lubricants, etc., gives false results for brush tests.

### Simpler Measurement of Direct Currents

METERING d-c buses carrying thousands of amperes has always been a problem. When the current becomes 100 000 amperes or 125 000 amperes, as it is in some of the new aluminum plants, the problem is king size. Introduction of the magnetic amplifier a few years ago eased the pressure considerably, as it made possible the use of a-c instruments and made it unnecessary to have long d-c leads at bus voltage extending to the instrument panel.

However, large—and we mean large—d-c shunts are still used. On a big bus a shunt may weigh several hundred pounds. Obviously it is not inexpensive.

A much simpler and highly accurate d-c metering scheme is being tried. Tapped to each bar of a multi-bar bus is a small wire of the same material as the bus. The cross-section is chosen so that the current density in the wire is the same as the bus for all currents—a thing possible with direct current. This wire extends along the bus for several feet, passing enroute with the wires from all the other bars through the central core of the magnetic amplifier. Thus the magnetic amplifier converts into one voltage a signal proportional to the sum of the currents in all the bars. This signal, amplified and rectified, is passed to the d-c ammeter, which is thus insulated from the high-voltage d-c bus. Accuracies of better than one percent are obtained in the experimental systems to date.

# Radio, Communication, and Remote Control

A system of a coil spring and various levers that operates much like the farmer's "whiffletree" equalizes tension on the strands of a multiple-strand, thoriated-tungsten filament for large broadcasting tubes. Polyphase heating current reduces "hum" originating from filament current. The higher electronemissive properties of thoriated tungsten reduce heating power, thus saving power and further reducing "hum."

### Remote Control and Metering of Gas-Line Regulators

EQUIPMENTS that have long been used to remotely control the distribution of electricity are now being used also in the distribution of natural gas. The Manufacturers Light & Heat Company of Pittsburgh, Pennsylvania has a total of ten pressure regulators located at four stations several miles apart. These regulators have been operated manually, a man being sent out from the district office for this task. Now an operator at a central point has before him a continuous indication of pressure at each regulator and can change the setting of any regulator by simply operating the appropriate telephone-type lever switch on his desk.

The equipment to do this is a simplified modification of the kind of remote control and telemetering commonly operated over power-line carrier or microwave systems to effect control of electric-utility stations. To effect the operation of any of the ten gas regulators, a code of two positive and two negative pulses is automatically sent out over the telephone circuits to the regulator when a "raise" or "lower" lever switch is operated. The operator holds the lever switch in the "raise" or "lower" position until the metering indication (meanwhile coming back to him over the same wires) shows the desired pressure is attained. He then releases the switch, and the regulator remains in that position. Power at each remote point is commercial 60 cycles, backed up by a storage battery and vibrator.

## Microwave Progress

MULTI-CHANNEL microwave has taken its place as a major communications medium in several fields of industry and government. Recent events have proved its maturity. Within the past year, many large power systems that had initially installed some terminals of microwave to determine its worth have made sizable additions of the same apparatus. One large utility has an extensive system resulting from two major expansions, and is now planning a third.

By far the largest usage of microwave systems has been that by the United States Government. The equipments under construction are for use in sections of the world that have special communications needs. The installations, in friendly nations in Asia and Europe, when completed will provide services that are readily applicable to either military or civilian requirements.

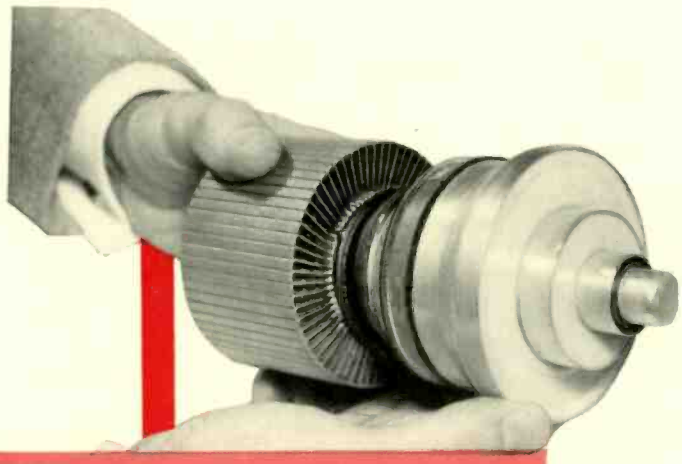
A large, expanding future for microwave seems assured. This is particularly true when one considers the needs of undeveloped countries, especially those contending with jungle or mountainous areas where the cost and lack of safety of wire lines make its use prohibitive. In addition, certain military aspects of security and secrecy are well served by the centralized-location nature, and directional characteristics of the type of radio propagation used.

Services available are basically of two types, telegraphic and telephonic.

Duplex voice channels are derived for transmission over microwave carrier by use of a single panel that contains both transmitter and receiver sections, complete power supplies, signaling equipment, and line jacking and terminating facilities. Extreme channel independence is thereby achieved. Telegraph channels for any type of service have attained the same measure of perfection.

Of particular interest are two units that operate on a frequency-shift principle. One unit is designed where telemetering is the principal service. By keying the multiplex equipment directly, that is, by using a radio-frequency shift tone instead of submultiplexing with audio shift tones, 60 channels can be derived on one microwave carrier that are capable of handling standard 100-word-per-minute teletype machines. The actual speed capacity of the channels is far in excess of this value, the limitation on its full utilization being one of limiting speed of existing teletypewriters.

The second design of equipment to provide frequency-shift channels was created specifically for relaying applications. It gives a completely noise-free circuit, is continuously monitored, and permits completely fail-safe operation. Both of these units, by utilizing multiplex-channel radio frequencies directly instead of audio frequencies working into radio-frequency channelizing equipment, have helped increase overall system reliability through greater simplification and appreciable reduction in the number of necessary components.



**This new 4-kw tetrode fills a gap in the power and frequency range of previously available tubes, particularly for point-to-point communication equipment. Internal spacing requirements necessitate rigid mounting; low-inductance lead-in conductors are required for operation at high frequencies. Both of these requirements are fulfilled by the concentric lead construction shown. The technique for making these leads and the seals has been improved.**

## Developments in Power-Line Carrier

ANOTHER major milestone date in transistor progress has been set. Late in 1953, an all-transistor power-line-carrier equipment was set up for field tests on the Potomac Edison Company system. This is the first time transistors have completely taken over from vacuum tubes in this type of equipment.

**A large number of point-to-point radio-communication equipments are being built to form a part of the Air Force's global communication system. They are patterned after equipment designed about eight years ago that has been highly successful in a tropical commercial communication network. The new equipments, however, take advantage of the numerous accumulated developments in electronic gear.**

The carrier channel consists of a transmitter unit linked to a receiver 24 miles away by a 132-kv transmission line. These field tests have provided valuable experience required for the design of practical transistorized power-line-carrier telemetering equipments, and, later, equipments for more critical functions. Very early experimental work has also been started on the replacement of tubes by transistors in microwave apparatus.

Transistors require no filament power. Hence, the total power required by a set is cut to between a fourth and a half. This means economy in power-supply apparatus and lessened cooling requirements. Transistors are, as is generally known, much smaller than tubes in physical size. While tubes have a finite life even under ideal operating conditions, transistors should have indefinite life if operated within their rating. Transistors are, however, very sensitive to overload. Thus, protective circuits or improved transistors are needed before satisfactory transistorized power-circuit equipments can be built.

Last year a power-line-carrier transmitter was designed for use exclusively for protective relaying. By eliminating elements necessary for handling voice, the number of tubes required has been cut to less than half.

For some classes of power-line-carrier application, some simplification of equipment can be achieved by a new method of feeding the carrier onto the power line. Instead of the resonant tuner that has been commonly applied, it is accomplished by a new broad-band coupler known as the Hi-coupler. One Hicoupler can handle several frequencies; one resonant tuner is required for each frequency. The Hicoupler, however, is used with a new design of coupling capacitor about three times larger in capacitance than the other system has used up to now. Neither system, however, will displace the other. The choice in a given case involves several engineering considerations.

## Magnetic Magnetron Modulator

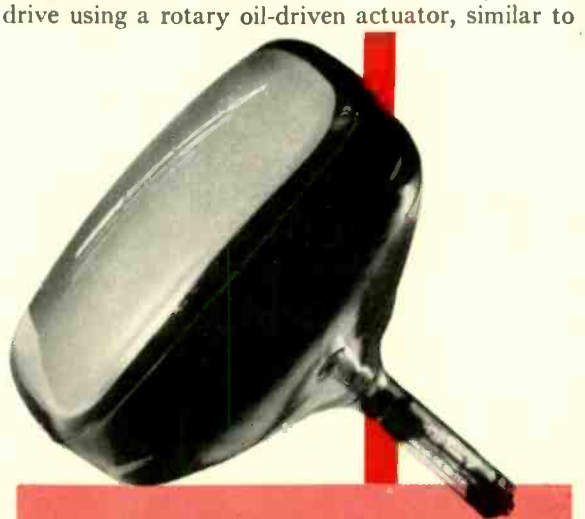
A NEW magnetron power supply for conventional magnetrons (such as the 4J50) used in radar systems is composed completely of static parts—saturating reactors, linear reactors, and capacitors. Operating as a pulse modulator, it supplies 400 or 800 pulses per second, with pulse widths from a fraction to several microseconds. The new device is designed for airborne radar applications where conventional tube modulators cannot pass vibration and shock specifications.

The new modulator was made practical by improvements in the reactor core material. Conventional tape-wound cores use a grain-oriented steel two to four mils thick. The new material is "ultra thin"—one mil or less—and consequently has much lower electrical losses.

The improved reliability of an all-static device makes it a likely candidate for ground-based radar equipment as well as airborne.

## Hydraulic Antenna Drives

THE RADAR antenna drive has been given a lot of attention. A common practice is to rotate the antenna with a high-speed, low-torque electric motor, through a 200- or 300-to-1 reduction-gear unit. However, at very slow tracking speeds, each gear tooth gives a "bump" and these bumps must be filtered; but a filter means less accuracy and slower response. The problem has been eliminated with a hydraulic antenna drive using a rotary oil-driven actuator, similar to

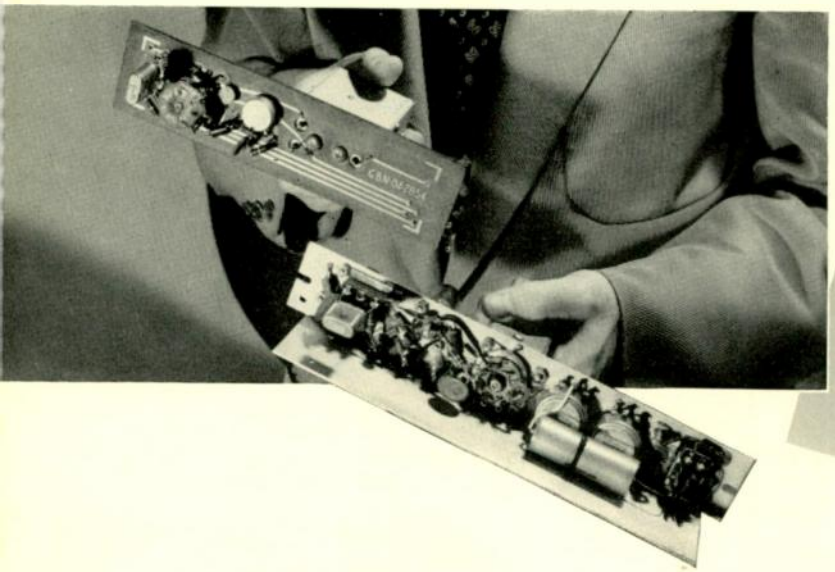


**Not to be outdone by color television, black-and-white picture tubes have also been improved. As screens increase in size, bulbs must get longer. However, by increasing beam deflection to 90 degrees (previously 70 degrees), about three inches have been taken off the length of 17- and 21-inch picture tubes. The resulting television cabinet is three inches shallower, and therefore fits the normal room better.**

To provide the ultimate in accessibility, the electronic gear on these Navy transmitters is not only mounted on drawers that pull out, but also, once withdrawn, the entire drawer can be rotated in either direction through 180 degrees. The drawer can then be locked in that position for intermediate ones for component servicing.

an automobile windshield-wiper motor, which is coupled directly to the antenna gimbals. The transfer valves that control oil flow to the actuator require less control power than conventional electric motors, resulting in considerable control-circuit simplification.

The problem in developing the actuator was to get a high ratio of output torque to friction. This required extremely close dimensional tolerances to maintain low leakage (high torque), and yet keep friction to a reasonable value—about a half percent of the maximum output torque.



This comparison of a transistorized, printed-circuit laboratory model (upper) with a comparable unit of conventional design and construction (lower), illustrates the gains possible in size reduction and circuit simplicity.

## Radar Eyes for Autopilots

PUSHBUTTON warfare is nearing reality—at least for fighter pilots. A newly developed radar coupler combines the abilities of the fire-control radar system with the W3A autopilot. Once the radar has picked up a target, it directs the autopilot, which then proceeds to align the fighter plane for the kill. The pilot need only decide whether he wishes to shoot the target aircraft down—there's always a chance that the radar has gotten overanxious and lined up on a friendly plane. If the pilot presses a button, rockets are launched automatically as soon as the enemy craft is in range. An indicator system then advises the pilot to bring the plane out of the attack to prevent a collision.

# X-ray

## The Image Amplifier Becomes a Much-Used Tool

IN 1941 a high-definition, bright-image fluoroscope—bright enough for daylight viewing—was but a gleam in research men's eyes. Last year it came off the production line in sizable numbers. It was the year in which the many doctors and hospitals using them (some now have two units) were finding out the different kinds of things that can be done with a fluoroscope whose screen brightness is a minimum of 200 times brighter than the conventional fluoroscope. Aside from vastly increased ability to diagnose disorders, the Fluorex image amplifier has been used to enable doctors to "fish" out objects swallowed or inhaled, while watching the progress of the bronchoscope and its contact with the object. In cases of diagnosis of heart malfunction, the physician has been able to follow visually the progress of a catheter into the heart. The image amplifier also is immensely helpful when taking x-ray pictures. It can be used to insure that film is in the optimum position to show the portion in question. This saves time, film, and eliminates the necessity of exposing the patient to additional radiation. By use of the recently developed double-view mirror the fluoroscopic image can be seen by two people simultaneously, which is very helpful in instruction, in consultation, and in those clinical situations requiring teamwork by a surgeon and radiologist.

The image amplifier, as it came off the production line last year, has been fitted with an extraordinarily ingenious optical system. With it the physician does not have to look directly into the fluoroscopic screen, which conventionally is in a fixed position with respect to the patient. He can fluoroscope either with the patient lying on the x-ray table or standing with back to it, adopting the position most convenient. The viewing mirror, on a universal joint, can be tilted to any angle. Dimensions are such that the physician can easily manipulate the organs while comfortably watching the resultant image.

The image-amplifier now possesses an important adjunct —automatic brightness control. A photo-multiplier scans the image and by controlling the x-ray tube current, holds the brightness to the value set by the fluoroscopist even though he moves the unit over different thicknesses of the body. In addition to holding brightness constant, it automatically insures that the patient and fluoroscopist will not be exposed to any more radiation than is necessary to obtain the desired x-ray image.

The brightness of the Fluorex image offers obvious possibilities for motion pictures of functioning organs, or of the passage of tracing dyes through, say, the heart. This desirable extension of usefulness of the image amplifier, however, requires a large amount of engineering developments before it can be made a routine tool.

## Power Steering for the X-ray Table

THE MEN who design x-ray apparatus hold to the principle that the doctor's physical work should be made the least possible. The doctor's attention should be focused on his patient; the distracting work of moving masses, levers, and

cranks should be brought as near the vanishing point as possible. Two ingenious and extremely practical steps have been taken in this direction.

One gives the doctor a sort of "power-steering" assist in the movement of the heavy mass of x-ray and fluorographic equipment longitudinally along the table on which the patient lies. As equipment has been developed to acquire more functions—for example, the addition of the image amplifier—it has grown heavier, requiring more effort to roll back and forth on its track. While the doctor intently watches the image of the patient on the screen, he must perform this horizontal jockeying by pulling, with considerable effort, a bar at the table's edge.

With the "power assist" he continues to do the same thing; except, with no conscious action on his part, moving the bar in the usual manner simply energizes a motor that applies enough force to overcome friction and apply some acceleration effort. Any real force applied by the doctor only augments that of the motor. In other words, the motor provides about 30 pounds of the effort required to move the mass, leaving just enough to the doctor to give him the proper feel of the equipment. Importantly, the actions required of the doctor are the same as always.

The motor that does this assisting is not an ordinary motor. To look at it one would most likely say that it is a transformer. It is, in fact, a linear motor, i.e., a squirrel-cage motor unrolled. The cage in this case is a smooth rectangular bar of copper fastened to the frame of the table. The wound stator is made in two halves surrounding the copper bar, and thus becomes the "rotor." This novel motor, in addition to providing the power assist, acts as the counterweight, hence there is no net increase in mass.

***Spot-Film Drive***—A second equipment to be taken from the manual to the power category is the spot-film device used on fluoroscopic machines. With this tool, after the doctor has made his visual survey of organs in question, he wishes to photograph the fluorographic image of that spot. Previously he had to reach across the two-foot-wide table—an act that tended to pull his eyes away from the observed spot—and move the film carriage laterally to the parked position. Now a motor does this for him. One problem was how to connect the motor to a film carriage that must move anywhere in two directions over a large area. This was solved by a flexible steel tape, similar to that employed in retractable steel rules. This provides a constant-tension spring. A slip clutch allows the motor to overtravel without causing damage to the x-ray filmholder.

## Photographing Explosions

WHAT EXPOSURE would you use for taking a picture of a detonation wave moving about 4000 miles per hour, or a little over a mile per second? The x-ray people have found it necessary to design a new low-voltage tube to handle just this type of "photograph."

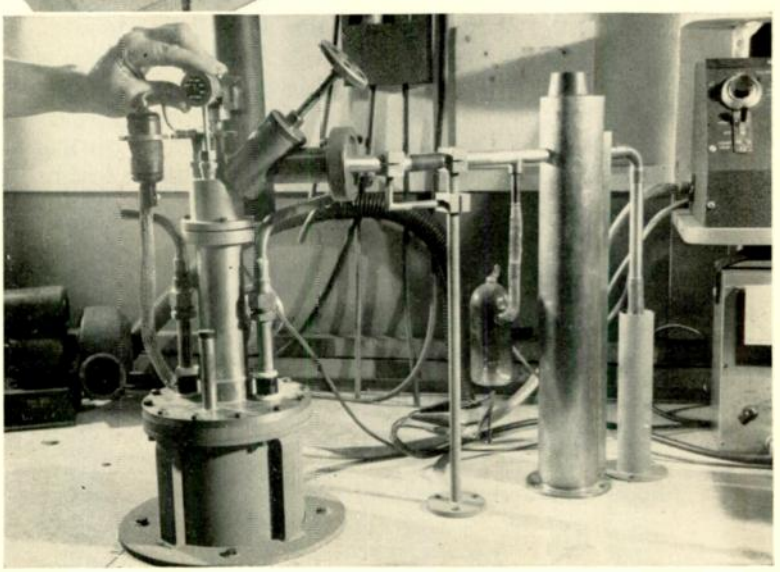
X-ray negative contrast is varied by adjusting tube voltage. Previously available tubes that operated from 300 to 360 kilovolts did not produce ideal results. Therefore, the tube has been redesigned for 60 to 120 kv. A thin window still allows high beam output, even for the "softer" rays. Furthermore, smaller focal-spot size produces a sharper picture. All of these features in the new tube have made it possible to get the best possible "exposure" of the aforementioned detonation wave.

# Research

## Ultra-Flat Surfaces Help in Electron Studies

ALTHOUGH the multi-billion-dollar electrical industry is based on the movement of electrons through metals, there are many large gaping voids in our understanding of the mechanism of that passage. Bit by bit those voids are being filled in.

One of these to which research spadework is being laboriously applied is how conduction electrons (i.e., outer orbital electrons that can be freed to make amperes) absorb energy from impinging light, and how much. The end product of such research, still in its early stages, is data for curves from which a theory can be drawn. These results, even the early ones, are of unquestioned value—but not exciting to the average engineer. However, some of the problems dealt with engender high respect for the investigators.



***Left,*** **low-temperature stage, showing single crystal copper target and ultra-black absorber mounted in place. Discs at right are enlarged view of copper target.** ***Below,*** **a view of the upper end of the test apparatus.**

For example, the metal specimens must be polished to a degree that make the surface of even a high-grade telescope mirror look like an array of hills and valleys. The highest "hill" on the surface is about five Angstroms or 0.000 000 02 inch. A wavelength of green light is 1000 times greater.

Such super-smooth surfaces are achieved by electro-polishing. This is a relatively old technique by which individual projecting atoms are gently removed. Variations in surface can be reduced almost to the distance between individual atoms, which, of course, is the ultimate.

Such superlative smoothness is required because the target is bombarded by light that penetrates metals to a depth of only about 50 Angstroms (0.2 microinch). For the results to be accurate, surface irregularities must obviously be of much smaller dimensions.

Getting a flat surface on the target is not the only problem that calls for superlatives. The surface must be from a single crystal of the metal. Furthermore, the crystal lattice must contain no foreign molecules—at least no more than one per million—and the lattice itself must not be distorted in any way. How that is achieved is a story in itself.

Another element close to the ultimate in attainability is required. This is a surface that absorbs *all* the light striking it. This is provided by a layer of "gold black," a spongy layer of colloidal gold particles that retains 99+ percent of the light energy impinging on it, which is much better even than carbon soot can do. It is so black that a thimble-shaped cup lined with it looks like a flat surface.

These ultimate elements accumulated, the research can begin. The super-smooth, single-crystal target of copper or silver, about the size of a dime, is placed in liquid-helium chambers (about four degrees Kelvin). A beam of light of a single color (i.e., one wavelength) is focused on the target and reflected onto the ultra-jet-black gold absorber. By minute electrical resistance thermometers embedded in the target and the absorber, the few thousandths of a degree rise in temperatures (i.e., energy absorption) are measured while the whole chamber is held at a pressure of one hundred millionth of a millimeter of mercury. Measurement of the absorber energy is necessary to know the amount accepted by the target. The measurements are in multi-microwatts.

At these near absolute zero temperatures, the electrons in perfect crystals have comparatively long, uninterrupted paths. For the first time, the laws for this phenomenon are being set down. The research has already resolved one anomaly in such electron behavior that has long puzzled scientists.

## Flame Study—Point by Point

IN THE NEVER-ENDING research to learn just how hydrocarbons react with oxygen—i.e., fire—some ingenious techniques and devices have been created. One phase of the study calls for a point-by-point examination of what is happening within a flame of propane and air.

First a special kind of flame had to be created so that the temperature and gas compositions might be accurately determined at closely spaced intervals within the flame. For this purpose a means was devised for creating a horizontal flat flame, i.e., all the burning takes place in a very short distance vertically. At atmospheric pressure it is almost the size and shape of a thin pancake; at pressure equivalent to 65 000-foot altitude it is somewhat thicker.

To measure the temperature at intervals of each millimeter vertically, i.e., along the thin dimension, very special thermocouples were devised. So that the thermocouples would not disturb the gas flow, the wires of platinum and rhodium were made as small as possible—down to 0.2 of a mil thick, or about one tenth the diameter of a human hair. Also, to prevent the platinum from acting as a catalyst in the flame, it had to be coated with an inert material.

To provide thieves for the extraction of gas from specific areas of the flame, special tubes with holes one mil in diameter were fashioned out of quartz.

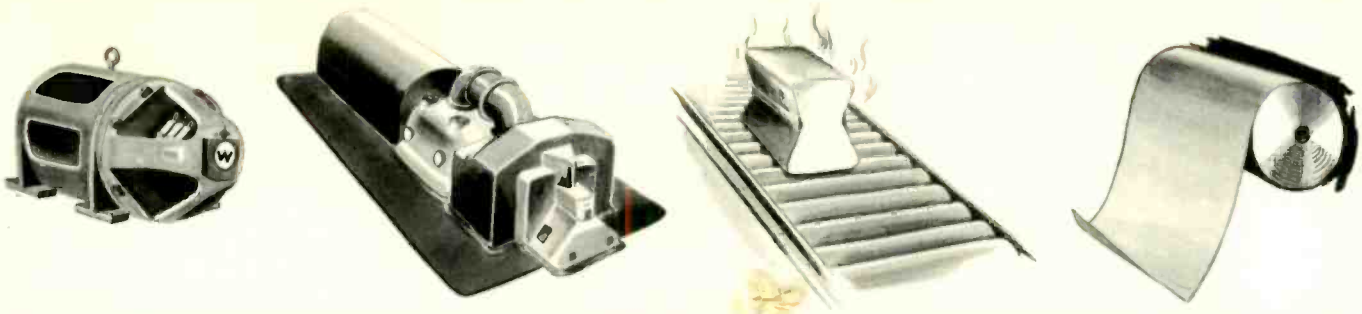
From such setups many questions about how heat is released in a burning reaction can be answered—questions that need to be answered as engineers work to improve jet engines for operation at extreme speeds and altitudes. To cite but one point: There has been some speculation as to whether the temperature at the point of most-intense reaction might not be higher than at the upper edge of the flame. This has been found to be not so.

## Tungsten Research on a Large Scale

WORLD politics can have a bearing on the lamps one uses. Wolframite, the ore of tungsten, varies considerably with the source. The lamp industry depends principally on ores from Australia, Brazil, and several from the United States are used. Some of their differences carry clear through to the finished wire.

These differences, plus the fact that many factors in the long and complex process of reducing ore to wire are not known, have led to the creation of a tungsten-powder production pilot plant. Until now research on tungsten processes or on the metal itself had to be done either on a beaker-and-test-tube scale or in the full-scale regular production factory. Neither is satisfactory. A brand-new laboratory of pilot-plant size that can produce tungsten powder for ingots suitable for normal drawing procedures corrects this. It gives opportunity for close control of variables on a large scale without interfering with normal production of tungsten for lamps and electron tubes.

Equipment used in flame study. *Below*, the special, flat flame created for this study, and in the photos at right the vacuum tank in which flame studies are made.



# NEW life for OLD equipment

Stories of new things, as in the preceding pages, always make interesting reading. They connote progress. They have natural appeal. However, often of equal technical significance and economic value is the refurbishing of the old. Several recent modernizations show, in cross-section so to speak, the advancements that have been made in equipment. Also they point up the extremely long lives of most power apparatus. Consider a few cases of reconstruction that underscore these facts.

## D-C Generator Commutator

Just a half century ago a 550-kw d-c generator driven by a steam engine began life in a Pittsburgh district steel mill. It ran merrily on for about 50 years, performing its job so well that it was all but forgotten except for routine maintenance. Then a few months ago the commutator needed major repair. To replace the machine and its drive with modern d-c production equipment was not feasible because several machines are now involved, as well as an extensive building reconstruction program that requires integration with other plans.

So it was decided to provide a new commutator. But how? The commutator is on the engine side of the generator, and the building walls will not permit withdrawal of the rotor. (The rotor had not been out of the machine since it was installed 50 years ago!) To accomplish this, engineers devised an ingenious, and, so far as is known, unique way of getting a commutator on a shaft that could not be opened. A new commutator was made in the factory, with prearrangements for splitting it, after assembly, into two halves. The two halves were then fitted around the shaft where the old commutator was, the two sections joined with a special clamp—and the d-c machine started merrily on its way again. Perhaps not for another half century, but there is no indication that it couldn't run that long if required.

## Paper-Mill Reconstruction

With the product at the shipping floor worth $85 per minute, a paper company doesn't want to waste much time in a shutdown to replace obsolete machinery, even if that revamp will increase the plant production capacity. Thus it was last year, when an eastern paper company decided to modernize its mill, that no time was to be wasted in the process. As a result, a changeover that possibly would normally require a month was finished in a week. This was accomplished by the utmost of careful planning and an almost minute-by-minute scheduling of the rebuilding program carried on around the clock until finished.

This is a kraft paper mill built in 1929 to operate at 800 feet per minute. It now delivers at 1500 feet per minute. An additional motor-generator set was installed, new motors applied to the calender sections, control wiring replaced, and the most recent development in speed regulators—the magnetic-amplifier, mechanical-differential type—applied.

## Turbine Generators

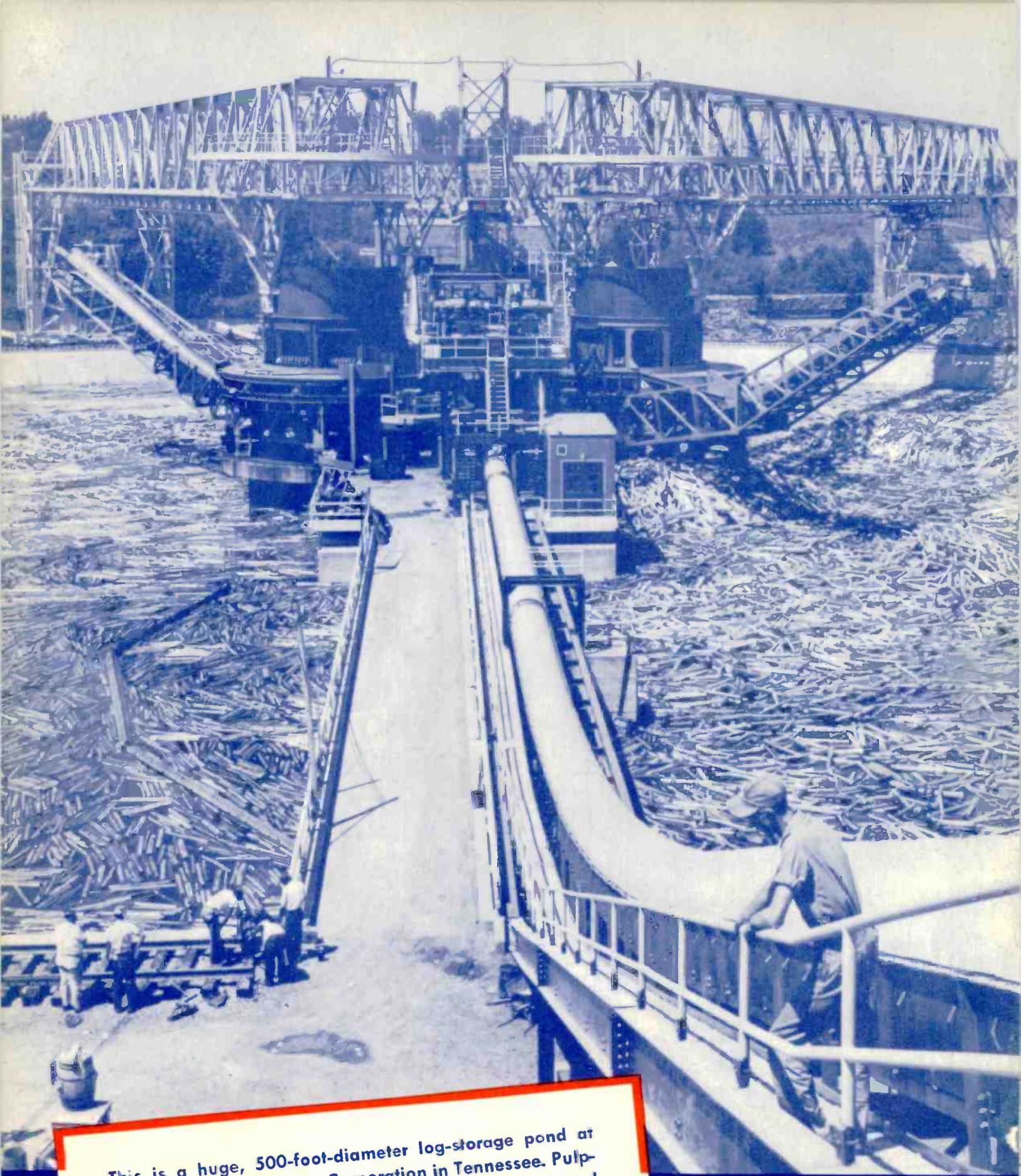
Sometimes old powerhouse-type generating units can be given complete overhaul with economic benefit. Last year a thirty-year-old 47 100-kva turbine generator was given the "works." It was dismantled clear down to the stator punchings, which were separated, cleaned, and reinsulated. New windings with Thermalastic insulation were provided. The rotor, stripped down to the bare slotted forging, was given new coils with more copper and modern insulation. A new blower provides better cooling. Modern retaining rings were applied. The turbine was also given a thorough overhaul.

The machine is back in service—far better than when it was new, and with some ten percent greater kilowatt capacity.

## Steel-Mill Modernization

Indicative that the life of even whole mills can be extended indefinitely and yet remain modern by occasional revamping is the case of a central Pennsylvania steel mill. It has just undergone its third rebuilding program, and is again in service—a modern plant with fully modern productive capacity. Its builders were quite proud of it when it started production prior to 1900, with its rolls driven by a huge reciprocating steam engine. But by 1920 the engine was pretty well worn out and the operators decided to replace it with a 5000-hp double-armature reversing motor. Then in 1940 the blooming mill became the first in the world to use the rotating regulator, which allowed the same drive equipment to make passes more quickly and to produce more steel.

However, by now the generators supplying direct current to the motors had become the limiting equipment. Recently, they have been replaced by larger ones of higher voltage. A new liquid slip regulator and an improved ventilating system and Precipitron air cleaner have been added. Incidentally, the new, larger generators fit into the same space occupied by the old units. So the mill, for the third time, is running with increased capacity, is cleaner, and is a better place to work.



This is a huge, 500-foot-diameter log-storage pond at Bowaters Southern Paper Corporation in Tennessee. Pulpwood—submerged to prevent deterioration—is retrieved by the huge automatic crane. The operator sets the controls once and the crane does the rest without attention.