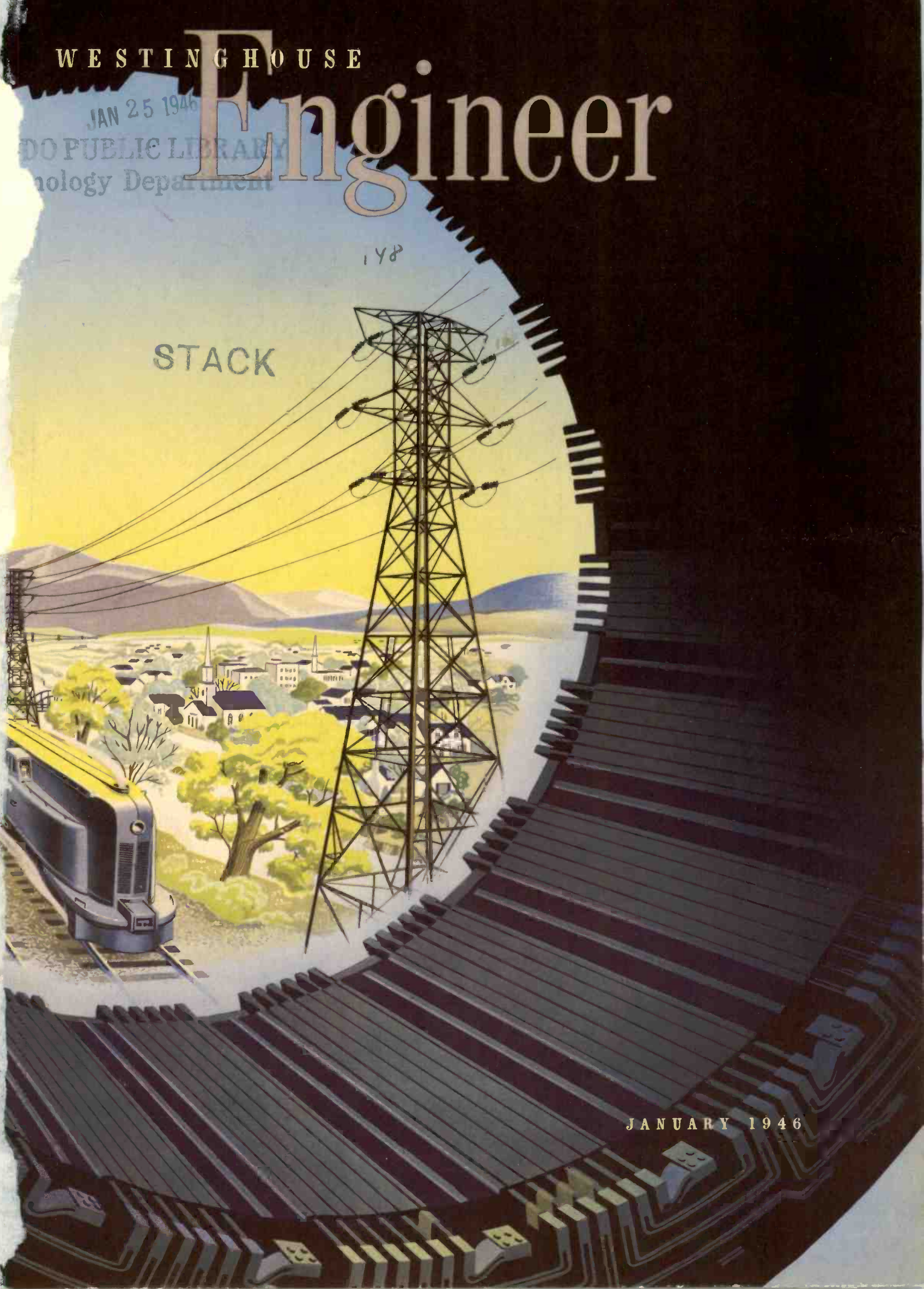
WESTINGHOUSE

Engineer



JANUARY 1946

Expanding Engineering Horizons

Engineering, even as recently as the start of 1945, appeared to many to be pretty well formalized. Many technical men believed that developments in principal forms of apparatus were a matter only of detail refinements, that techniques of power applications were fairly settled. To such thinking 1945 must have been quite a shock.

Apparatus engineering is quite deceiving. All types of machines experience plateaus in their development. For years a class of apparatus seems relatively static. It may appear to improve but little, giving the impression that there are no opportunities for further significant developments and, as a corollary, that opportunities in that phase of engineering are sorely limited.

But, sooner or later, almost without exception, staid and seemingly settled types of machines rise abruptly to new heights of excellence. The electric motor is an example. Certainly it appeared to have become well standardized. No startling improvement had been conspicuous for many years. But, with silicones completing the family of high-temperature insulations, motor sizes can be reduced by a fourth or outputs correspondingly increased where temperature sets the limit on rating. To make fullest use of the new insulations, completely new designs of some motors and generators are required.

Again, the speed variation possible with a standard direct-current motor has for fifty years been about four to one. Wider speed ranges have required some additional complication, such as variable-voltage control. Now the same standard d-c motor with minor modification as to field windings can be used over a speed range of eight to one. For many drives, as on some machine tools, the result is a great simplification.

Not only are there periodic major advances in established engineering, but also the science grows by the addition of whole new branches. The close of the war and the release of much restricted information bring this to a climax, making apparent the rapid changes occurring during the last decade. Radar! Jet propulsion! Atomic power!

With the engineer it has become a personal problem. If he graduated as an electrical engineer, for example, more than ten or a dozen years ago, he studied the well-channeled, distinct courses in math, chemistry, physics, and a-c and d-c theory and machinery. A course in communication may have been included as a matter of general interest and to show the breadth of electrical engineering. The same general idea of well-established subject matter held in other branches of engineering.

Any belief that such hard-and-fast courses still outline the boundaries of engineering is as obsolete as a 1930 radio. Atomic power may never displace steam-plant designers, but the technical man who chooses to ignore the new science of nuclear engineering is headed for obsolescence. Not only is the structure of the atom of absorbing interest but also knowledge of it is essential to an understanding of radiation, another subject of growing practical importance. Textbooks of a decade back treated the gas turbine little more than as a scientific curiosity. Reciprocating engines and turbines will continue in vogue for many years, but the mechanical or aviation engineer who does not acquaint himself with the principles of jet propulsion and combustion-reaction machines will find himself in premature retirement, figuratively, if not literally, by the young men to whom gas turbines are as simple as the Otto cycle. Electronics will not displace 60-cycle power and the engineers who have to do with it, but the man who does not find time to become acquainted with anodes, grids, and resonant cavities will be circumscribed in his engineering endeavors.

The accomplishments of science and engineering, herein sampled from the recent activities of Westinghouse, promote, we believe, two thoughts. Their ingenuity and variety give the technical man renewed pride in his profession. Also they point with an unmistakable finger to the necessity for an engineer to become a student again, else the swift pace of technical accomplishment will leave him far to the rear. The technical record of 1945 is an inspiration, a challenge, and a great hope of a better future for all.

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VOLUME SIX JANUARY, 1946 NUMBER ONE

On the Side

The Cover—The artist suggests the return of engineering to its normal, peacetime role of contributing to the comfort and general welfare of our citizens.

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High-Voltage Power-Transmission Test Line—Transmission of larger blocks of power over greater distances awaits the solution of the fundamental problems in insulation associated with higher voltages. More than a decade has elapsed since the last significant increase in transmission voltage. Mr. Philip Sporn, Vice President of the American Gas and Electric Service Corporation in cooperation with the Westinghouse Electric Corporation and other manufacturers has initiated an investigation to supply fundamental data regarding corona loss, radio interference, and insulation coordination at voltages as high as 500 000 volts.

Two experimental three-phase power lines, each a mile and a half long, will be built at the Tidd station at Brilliant, Ohio. Power for these lines will be supplied by specially built transformers and the corona loss will be measured by instruments developed for this purpose. The transformers and metering equipment, as well as the high-voltage lightning arresters, will be supplied by Westinghouse.

While the next step in higher voltage, say to 345 kv, could be made with little hazard, this investigation will permit a scientific approach to the design and construction of conductors, insulators, bushings, and associated equipment to operate at this and higher voltages. The data obtained will permit balancing of the factors that regulate high-voltage transmission and the determination of the most economical design for transmission of large blocks of power.

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In This Issue

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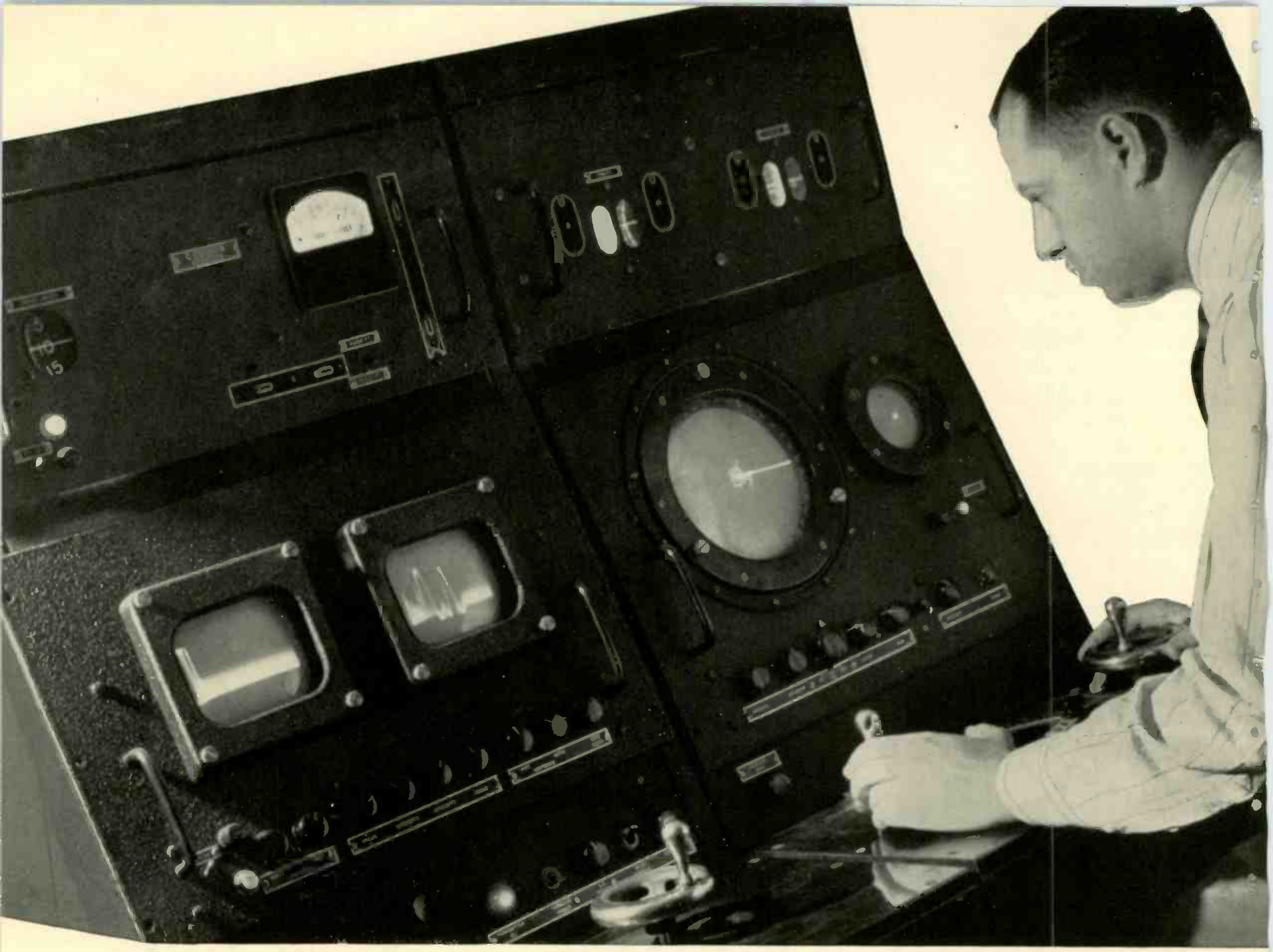
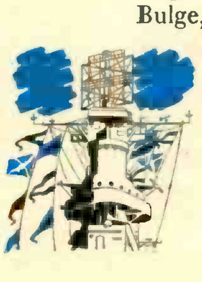


The peaks and white dots on the four scopes of this radar set, in actual operation, are indicative of distant objects.

Detection of Distant, Unseen Objects—Gift of Radar

An attempt to set down in an annual review of engineering such as this the year's story of radar is a hopeless task. Radar is, for one thing, a subject strewn with anomalies. A year ago it was scarcely more than a word even to technical men, except for the elect. Now it is a household term everywhere. Indeed, there are many who, with the unbounded faith in the unlimited abilities of science now so generally characteristic, fully expect 1946 home models of radar. Yet, even the man with engineering training finds it hard to believe the things claimed for radar. Is it really possible to detect a plane two hundred miles away and measure the distance to it within a few yards, its altitude within 500 feet, and its direction within one-half degree? It seems incredible even to an engineer that a flying radar set can spot—and accurately—anything as small as a surfaced submarine 25 miles away, or draw a map through thousands of feet of fog or solid cloud cover so precisely that bombers can demolish the unseen targets. Stories are told of how, during the Battle of the Bulge, pilots of pursuit planes, without radar or bombsights, were radio-voice directed from a ground radar station to targets they could not see and told when to unleash their bombs, all with such accuracy that railroad bridges were demolished. Progress of storms can be followed, invisible shore lines plotted like well-drawn maps, or an unseen plane identified as friend or foe. These things and more are simple routine for radar.



The scientifically trained man is hard put to explain radar, yet the average schoolboy readily states that radar is no more than sending out a directional pulse of energy, and then listening for any echo that is indicative of a radar-wave reflecting object. Measurement of echo time gives distance; observance of the antenna angle gives direction.

Radar, basically, is simple. But already in its short life it has developed into several hundred forms, all of them variants of a few fundamental types. The kinds made by Westinghouse illustrate nearly all of those basic forms. Many companies have built radar sets, almost always starting with a circuit design prepared by the Naval Research Laboratory, the Radiation Laboratory at M.I.T., or some other research agency. It was the duty of Westinghouse engineers, as well as the other radar manufacturers, to incorporate those basic circuit designs into practical sets for specific purposes. That meant consideration of many factors, such as weight, portability, simplicity of erection, operation, and maintenance—all under battle conditions—standardization and interchangeability of parts; simplified packing and numbering, fungus resistance, resistance to moisture, mechanical shock, and quick changes in temperature.

The simplest radar set, like the early SCR 270 for example, is used for search purposes. As its antenna scans the region in

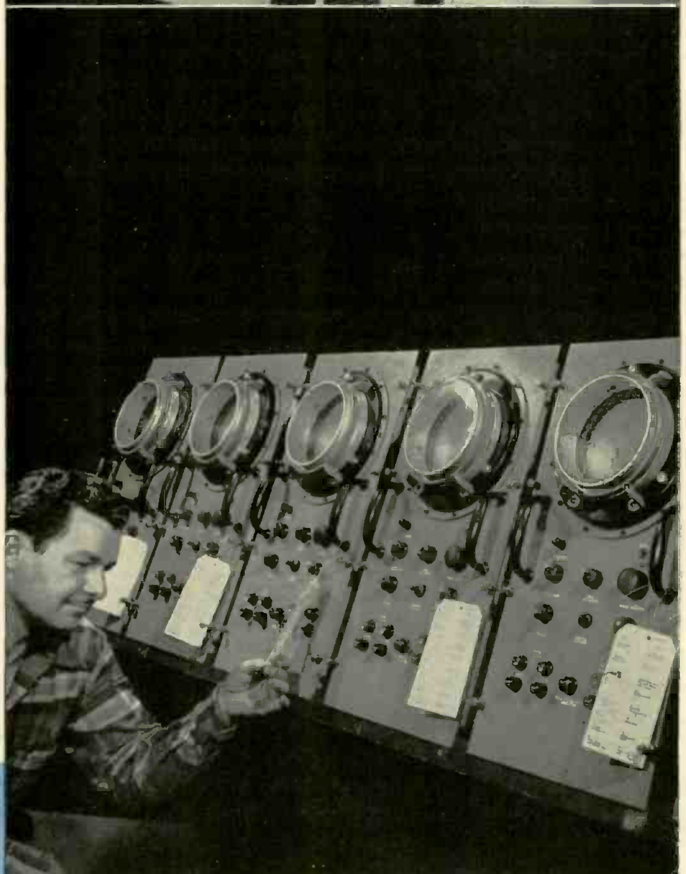
Electronics

Electronics is incredible both in its rate of growth and the kind of things it does. With the war over and restrictions relaxed on radar, electronics holds as bright a peacetime future as it did in war. Radar is doubly important because not only is it a major peacetime tool in its own right but also it contributes much know-how to television, heating, and associated electronic activities.

question, pulse reflections show up on its oscilloscope as a peak or "pip" in an otherwise straight horizontal line. This is the A-type scope. Distance to the pip from the zero point can be translated into distance to the target because it measures the time for the pulse to go out and return. Direction of the target is determined from the position of the antenna when the pip amplitude is a maximum. This set employs frequencies considered low in radar usage—about 100 megacycles. The range is about 200 miles. One of these Westinghouse sets, of which the Army had more than 100 by Dec. 7, 1941, gave the indication, unfortunately ignored, of the Jap planes approaching Pearl Harbor. Sets of this general class can be used to locate a plane or other target and automatically train a searchlight upon it. They are not suitable, however, for detection within angles close to the ground, i.e., 10 degrees or less. Hence attacking planes can fly in under the radar beam of an SCR 270.

When more than simple long-range search is required, a set of the SCR 615 class can be used. It operates on medium shortwave. It has a medium range—up to about 125 miles. However, it can detect objects close to the horizon, down to about one degree. Hence a plane cannot sneak in under it. It is extremely accurate. It has two A-scopes, one for azimuth and one for elevation. Each scope has two ranges, one for the complete distance and one that can "magnify," so to speak, any two-mile interval of that range. The screen of a third scope has a type of phosphor on which the luminescence persists for an appreciable time, so that as the pattern is traced and retraced, it remains visible in its entirety. The set also incorporates other refinements, such as a direct altitude converter by which the set makes the necessary trigonometric computation to determine the altitude of the target, knowing the distance to it and the angle above the line of sight. The converter even corrects for curvature of the earth by adding the amount the earth surface is below the sight line at the location of the target. One typical use for this type of set is for the interception of enemy aircraft.

But when the target—an enemy plane or a buzz bomb—gets close, the need is for more precise information of short-range objects than the SCR 615 can provide. A set of the SCR 584 type is built to take over from the 615. It, too, operates on medium short wave and is extremely accurate at short range. It uses two A-scopes in which the base line is circular, hence longer than on the straight-line type of A-scope. This set is arranged so that once it has located a target it keeps "focussed" on it, following its every movement, and automati-



Radar antennas take many forms, even like the skeleton of a large umbrella. At right, a few of the thousands of radar receivers, with plan-position-indicator scopes, march down the assembly aisle.

cally transmits continuously the data of target location and movement to a gun. Many a buzz-bomb was shot down with an SCR 584 controlling gun firing with no human hand intervening. The radar set, plus a gunfire control that computed the gun aim based on radar information, and the gun itself provided a robot team that proved an excellent match for the robot V-1 missiles.

These three types of sets embody nearly all the basic functions of radar, although many sets are built to emphasize certain qualities. Certain ones, like the SR for example, are shipborne and are tied in with the ship's compass to provide true bearing. Others are for automatic control of the big guns themselves. Still different types, airborne, are designed for the special functions of aerial combat, for submarine detection, by aircraft patrols, or for actual control of guns to fire on an enemy plane at night when it can't be seen. This last uses a still different type of scope such that when two horizontal loops that project right and left from a vertical center are matched and of the right combined length, the pilot can fire his gun knowing his ship is exactly aimed to hit the invisible enemy plane.

Radar, born of war need, has an enormous peacetime future. It will undoubtedly become the greatest boon in ship and airplane navigation. Ships at sea will be able to proceed at full speed regardless of weather, unimpeded by the threat of obstructions, while fogs will no longer delay their entrance to harbors. Aircraft will for the first time have a means of precise navigation independent of atmospheric conditions—particularly desirable for transoceanic flights. At the same time, the hazards of landing in overcast weather will be practically eliminated by radar blind-landing systems, and the utilization of radar in meteorology will vastly increase our knowledge of weather.

These direct applications of radar are obvious and real, but they give little indication of the full impact of the art. Indirectly, the knowledge and techniques gained in the ultra-high frequencies will expand and accelerate developments in the whole field of electronics. The extension of the radio-frequency spectrum is in itself a tremendous contribution and, to note only one other innovation, the development of circuit elements yielding short pulses and measuring microsecond intervals has revolutionized time measurement.

Radar Traffic Cops

Power engineers call a switch fast if it operates in one cycle (on a 60-cycle-per-second basis). That is an operating time of about 17 000 millionths of a second. But, to radar engineers, that is turtle speed. A device, prosaically known as the TR box, not only does a switching job in less than one millionth of a second, but does it a thousand times each second.

A radar set hurls a pulse lasting about a millionth of a second into space and then is quiet for the relatively long time of a thousandth of a second, "listening" for any echo that would be indicative of a distant target. The pulse transmitter and echo receiver are intimately associated and share together the one antenna. The receiver, being sensitive to the relatively weak echo signals, would be destroyed should even a small portion of just one transmitted pulse be fed directly into it. The receiver must be disconnected from the antenna during pulse radiation, then immediately reconnected—and quickly so as not to miss any nearby (and potentially most dangerous) reflections. This is the job for the TR box.

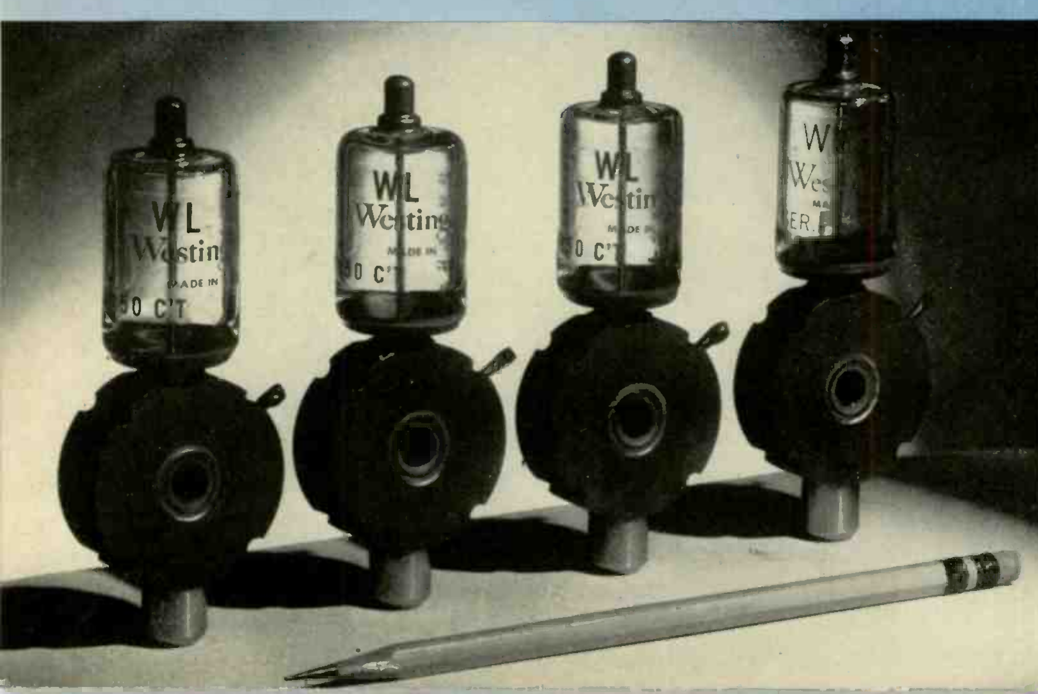
The switch is essentially a needle spark gap in a confined space containing gas at a definite pressure. When a pulse is sent from the transmitter, the relatively high voltage causes the gap to spill over, short-circuiting the receiver. When the pulse stops, the low-pressure gas space quickly de-ionizes (in about four millionths of a second) and the receiver is again ready for any returned signal. To insure that a few ions will be present when needed, a separate discharge is maintained within the chamber.

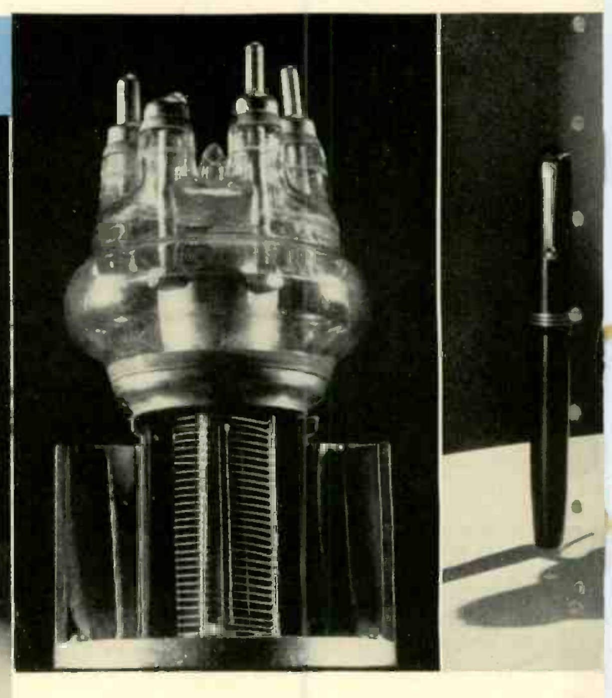
A relatively large glass reservoir acts as a gas chamber so that operation will not become faulty in service because of gas "clean-up" (loss of gas due to absorption). It also acts as the necessary high-voltage insulator. The TR box is a fine example of electronic switching.

Where Radar Frequencies Come From

The heart of a radar set is the device for generating super-high frequencies—from a few hundred million to a few thousand million cycles per second. As such, two new names, as generators of megacycle power, have joined the technical man's language—the resonant magnetron and the klystron.

Below are super-speed devices that switch radar receivers to and from the antennas a thousand times per second. At right is a 2-kw oscillator (partial cut away) for high-frequency heating.





The basic concept of the magnetron was born in England, while the klystron notion was conceived by two men while working at Stanford University. To each device, however, Westinghouse importantly contributed, not only by making numerous improvements in construction, but also by reducing the designs to forms that lent themselves to high-quantity production—and Westinghouse did turn them out in prodigious numbers.

The magnetron is the megacycle power generator, and hence is the tube commonly used in radar transmitters where large power outputs are desired. The magnetron at the war's beginning had the relatively weak peak output of a few kilowatts. The new magnetrons can deliver up to a thousand kilowatts during millionth-of-a-second pulses. In the magnetron, electrons are emitted from a cathode in the center of an evacuated chamber placed in the field of a strong magnet. The electrons are forced into spiral paths toward smaller, narrow-neck resonant cavities around the central chamber. The electrons are moved through the electric field extending into the central chamber from the resonant cavities in the direction such that their velocity is reduced by the electric field. Thereupon high-frequency power is generated in the cavities, which can be drawn out by a coaxial transmission line.

Although the magnetron is an oscillator of high peak power its frequency cannot be readily varied over a broad band once it has been assembled. A high-frequency tube more easily tunable over a broad band is the klystron, although less peak power can be obtained from it. Electrons from a cathode are hurled through a cavity toward a reflector. A high-frequency oscillation has been established across the cavity. Hence at one instant the electrons are hastened in their flight by the electric field. The electrons arriving in the cavity an instant later find themselves in an electric field of reversed polarity and hence are retarded. After the electrons leave the cavity they move towards the reflector, which has a negative voltage. Before they reach the reflector they are turned back to the cavity by the negative field. In travelling towards the reflector and back to the cavity, the variation in velocity produced in the cavity results in a high-frequency electronic current for short pulses.

Klystrons until recently have been able to handle maximum peak currents of the order of 50 milliamperes at 1000 volts or about 50 watts. At an efficiency of only about one percent this represents less than a watt of high-frequency power, but the tube is readily tunable. This power output for the most part limits the klystron to use in radar receivers where a generator of high frequency is required, but large power output demanded of a transmitting tube is unnecessary.

It has been conventional practice in some klystrons not to permit the bunched electrons to strike the reflector. Westinghouse electronic engineers wondered what would be the effect on the power output of allowing the bunched electrons to strike a reflector coated with a secondary emitter. They took a standard reflex klystron and provided it with such a reflector. They then found that the bunched electrons striking the reflector (primary electrons) knock from it many more bunched electrons (secondary electrons). This multiplication effect of secondary emission enables the tube to deliver a lot more power because of the high current. Furthermore, the efficiency has been about tripled. The secondary-emission klystron can absorb currents of 200 milliamperes at 2000 volts, which at three-percent efficiency is 12 watts of usable power. This is about 24 times as much megacycle power obtainable from essentially the same tube but with a new anode. With this high-power output, klystrons, which have the great advantage of being readily tuned, can be used as the megacycle generators in low-power radar transmitters.

High-Frequency Heating

High-frequency heating, although severely hampered by the war's call on electronic engineering talent, has begun to take the next logical step required in the development of a new industry. The first step is always to produce the basic successful device, in this case the high-frequency generators. This program of producing a family of standard generators in sizes of 2, 5, 10, 20, 50, 100, and 200 kw has been virtually completed. In addition, numerous standard accessories such as current transformers, remote networks, electrode cages and work-handling equipment, have been added.

The next important move is to adapt these basic units more specifically to the problems of factory production, usually in ways in which the word "automatic" appears. This includes automatic frequency control, automatic load control, and

These strange structures are from the world of radar. At left are klystrons used to provide ultra-high-frequency power for receivers. Below is a row of magnetrons for pulse transmitters.

automatic cycling or production controls and safety measures.

These were incorporated in the most spectacular high-frequency set of the year. Rated at 125 kw, 13.6 megacycles for the Firestone Tire and Rubber Company, it is for production curing and drying of Foamex, a new ultra-soft type of sponge-rubber used for cushions and mattresses. These are made in large sections several square feet in area and up to nine inches thick. Curing by conventional steam techniques requires 30 minutes and subsequent drying of four to eight hours. In the "dielectric" oven the curing is done in three to six minutes and the drying in thirty to sixty minutes. This represents a saving of 90 percent in time and a corresponding increase in production from expensive molds and equipment.

The set is fitted into the production line so that one side can be loaded or unloaded while energy is applied to the other. This provides a high use factor on the h-f generator.

Automatic frequency control is provided by using a crystal to furnish a standard or reference frequency, a frequency-sensitive circuit whose output is proportional to deviation of the actual from that of the standard frequency. The output actuates a motor-driven vernier capacitor which is a part of the frequency-determining circuit. This scheme holds the frequency within plus or minus 0.05 percent, which is the equal of the frequency control required of radio stations.

Automatic control of heating, regardless of variations in the work circuit as the heating progresses, is achieved by automatically varying the coupling of power from the r-f generator and by automatically keeping in tune circuit elements located at the electrodes. Similar automatic control functions, because of the flexibility of process control they afford, can be expected to appear for use with other standard r-f generators in the future.

At 30 megacycles and higher frequencies the generator-circuit elements of capacity and inductance become electrically and physically small. Current through coils and condensers becomes high with resultant high component loss. Capacitors of the mica type normally used for this purpose fail because of excessive internal loss. The solution is a device called the "Capaciductor," which in effect combines capacity and inductance in one unit. It looks like a capacitor of four or five fixed plates, but is some 20 to 25 inches long to give it the inductive reactance necessary for operation at 30 megacycles. It combines the important features of a conventional transmission circuit and the fixed capacitors normally associated with that type circuit. It eliminates complicated and expensive mica capacitors, is simple to manufacture and will work without failure. Simplicity and reliability are gains.

Numerous interesting applications of electronically produced high frequencies for induction and dielectric heating have been made in recent months. Several representative examples can be cited. A 10-kw r-f generator is being used by Firestone Tire and Rubber Company to preheat rubber preforms for solid rubber wheels and other thick-section rubber products. By bringing the temperature of the raw material uniformly up almost to the curing temperature before going into the molds, more uniform curing is obtained and production is greatly increased by a large reduction in press time—from five hours to eighteen minutes.

Three 20-kw, 450-kc r-f generators with special work-handling equipment were used last year to anneal the ends of 29 million steel pins for a chain-making operation. A dozen of the smallest sets (2 kw, 30 mc) are being used by a plastic manufacturer to expedite production of plastic ignition-timing wheels. A pair of 10-kw oscillators is providing high-frequency energy to replace steam in the curing of high-voltage condenser bushings. These are but representative of the work being done in regular production by high-frequency heating.

Compact Power Supply for Radio Transmitters

BECAUSE the motor-generator set for a Navy radio transmitter is the longest horizontal apparatus in the cabinet, it must be made as short as possible. In one case, between two commutators only seven inches apart, 128 coils for a 2000-volt winding and 64 coils for a 550-volt winding were packed in a single core 3⅜ inches in diameter by 3⅜ inches long. The utmost in insulation design was required to insure that the armatures would withstand the 7000-volt test applied between windings and from the higher voltage winding to ground. Each machine required about eight miles of wire. So much wire required extreme care in winding to prevent open or short circuits.

The d-c generators deliver 2000 volts at 0.175 ampere and 550 volts at 0.26 ampere. By use of a different motor for each

The electronic high-frequency laboratory is a busy place. Below, short metal cylinders on a rotating table are being inductively surface hardened.

input power supply, the m-g sets were designed to operate from 115 volts d-c; 230 volts d-c; 115/230 volts, single phase, 60 cycles; and 220–440 volts, three phase, 60 cycles. The d-c motors were provided with slip rings for supplying 200 watts single phase for heating vacuum-tube filament.

The motors and generators were built as separate units and joined with a flexible fan coupling. Rabbet fits on the brackets at the shaft extension end made possible assembly of motor and generator into a single compact unit which could be mounted in a lower compartment of the transmitter cabinet. Similar mechanical design of the motors allowed use of the same generator with any of the four types of motors.

Railroads and Radio

The evolution of many devices is a slow, halting procedure. Radio on freight trains is one example. Obviously a desirable feature for railroading, it has several times seemed on the verge of success yet failed to meet the final test of railroad-operator approval. Last year, however, tests made on the newest system on the New York, New Haven and Hartford were so outstandingly successful, measured both by the critical standards of railroad operators and radio men, that engineers feel that railroad radio has at last "arrived."

The biography of train radio provides an interesting sketch of the development of radio itself. It was just twenty years ago that Westinghouse experimented with train radios on the lines of the Norfolk and Western and in the yards of its own East Pittsburgh plant. These were fifty-watt, amplitude-modulated sets operating on frequencies in the band between two and four megacycles. Performance suffered badly from noise. Interference of many origins, even static from smoke in the stack and falling cinders, set up frequencies that could not be separated from the amplitude-modulated voice signals.

Experiments were repeated in the late twenties on the Pennsylvania Railroad, Chesapeake and Ohio, and on a classification yard of the C. C. C. & St. L. The experiments were equally abortive because no fundamental improvement had been instituted.

The first real advance came in 1933 and 1934 on the New Haven system. Short wave—by the notions of that day—was employed. Instead of two to four megacycles, 35 to 65 megacycles were employed. These frequencies, particularly the higher one, lie above most noise frequencies, hence a definite improvement in signal-to-noise strength resulted. Also new-type oscillators (but still no crystal control) provided greater frequency stability. However, it was still an AM system, hence static frequencies could not be separated and had to be tolerated as noise. Ignition static from trucks on highways paralleling the tracks was particularly troublesome.

The next chapter was written last year, again with the New Haven railroad cooperating. This time frequency-modulation radio was employed, which, with other developments such as crystal-controlled oscillators and new-type antennas, gave reception even in a laboring locomotive that rivals the ordinary telephone in quality. Noise became negligible. Even a tunnel between engine and caboose of a long freight train fails to diminish or distort reception significantly. Not only was clear conversation possible at all times between locomotive and caboose but also between train and wayside signalling towers up to ten miles distant. Even coupling with the overhead electrical system, previously serious, was absent.

Voice communication between crews at front and rear of trains and to wayside signalling towers, long a dream, has become a practical reality.

The frequency used for these last New Haven tests was 30 megacycles. Subsequent reallocation of frequencies by the government designates 156 to 162 as the railroad-radio band. The system has since been redesigned to operate in this spectrum. Certain benefits and a few minor disadvantages accrue from the frequency shift. The antenna, which has always been an extremely critical element in train radio, now becomes much smaller, no larger than an automobile steering wheel.

A New Fly-Ash Removal Team

Until recently the electrostatic precipitator known as the Precipitron, has confined dust-collecting activities mostly to offices, homes, and factory process or assembly rooms. Last year it teamed up with a Prat-Daniel cyclone-type mechanical dust collector to do the much heavier job of trapping the fly ash from the stacks of a large power station.

This marriage of convenience between the mechanical and electrical cleaners is blessed by the advantages of both without the shortcomings of either. The forte of the mechanical cleaner is the removal of large volumes of particles of substantial size. An electrostatic filter of any reasonable size would be overburdened by the tonnage of fly ash from a large power-plant stack. The fine particles, for the most part missed by mechanical filters, are, however, removed by the electrical filter with thoroughness.

All of the gas and dust enter the mechanical collector. This collector is made up of vortex tubes that spin the gas at high velocity. The centrifugal force removes the larger particles, constituting about 82 percent of the weight of dust. The gas leaving the vortex tube is still spinning at great speed so that the remaining 18 percent of dust is concentrated near the inside wall of the tube. By skimming off the 15 percent of this gas-dust mixture nearest the wall, containing 12 percent of the total dust, only 6 percent of the dust is expelled directly up the stack. The skimmed portion of gas and dust is conducted into the electrical precipitator which removes 90 percent of the dust passing through it. The remaining dust, constituting 1 percent of the original, and the gas are discharged into the stack. The dust emanating from the stack then is 7 percent of the total so that the overall efficiency of removal is 93 percent.

Smoother Than Velvet

TEN years ago these pages reported a production-type electronic device that could measure and locate unbalance to phenomenal accuracy. This new dynamic balancing machine, designated the Dynetric, was acclaimed for its ability to analyze vibrations, due to unbalance, that have an amplitude of twenty millionths of an inch. That was pretty good. It was then thought that a finer degree of unbalance measurement would never be required.

However, that ability to measure unbalance effects is too crude for many present-day high-speed rotating parts. This is particularly true of gyroscopes so important in bombsights, navigation instruments, and stabilizers. The rotors of superchargers also require extremely accurate balance. To balance such parts so they may function properly and without failure, it is necessary to reduce the amplitude of vibration due to unbalance to a fraction of a millionth of an inch.

To meet these requirements for extremely accurate balance, the fundamental principles of the Dynetric balancer were used in conjunction with a superior type of amplifier to produce the Microbalancer. This machine can measure and locate unbalances that produce vibration amplitudes as small as a quarter of a millionth of an inch—approximately a motion corresponding to the wavelength of x-radiation—100 times more sensitive than the standard Dynetric machine. The Microbalancer measures and locates the unbalance effect produced by a weight of one-millionth of a pound at a two and one-half inch radius on a ten-pound rotor. A piece of lint or a moist fingerprint weighs that much.

Many of the rotating parts that must be balanced to this order of accuracy are normally supported on ultra-precision anti-friction (ball or roller) bearings. Before these parts are balanced, the almost infinitesimal defects in the ultra-precision bearings produce vibration effects in addition to the vibration effect produced by the unbalance. These random vibrations due to the minute defects in the bearings frequently are 100 times as great as the desired minimum vibration of the balanced rotor. By use of extremely effective filters superimposed on the filtering characteristics of a wattmeter, the desired separation of vibration effect was obtained.

The device being balanced is made to provide a reference voltage without any contact being made to it. A phototube watches a tiny spot of contrasting color on the rotor. The weak synchronous pulse from the phototube is amplified to a usable reference voltage wave, which is used to provide synchronous flashing of a stroboscopic lamp by means of which the unbalance is located without random shifting due to speed changes or anti-friction bearing disturbances. This perfect reference wave is also used to supply the current coil of the wattmeter that is used to measure the unbalance.

A Westinghouse-Gisholt Microbalancer in operation. It can detect unbalance of fly-speck proportions, necessary on high-speed precision machines, as gyros.

Smoke-Free Passenger Coaches

"EVERY car a smoking car" is an objective of the railroads. As a part of the program of railroads in gunning for a better share of passenger travel, they seek to allow those who smoke to do so, but without annoyance to those who do not, and without having to provide separate equipments.

The only known method of removing more than a small percentage of particles as small as those that comprise smoke is by electrostatic attraction. A unit operating on this principle—the Precipitron—has been in successful operation in a car on an eastern railroad for several months. This electrostatic air cleaner is shaped so as to lie flat overhead just inside the head-end door, and thus occupies no revenue-producing space. It consumes but 75 watts. All of the fresh-air makeup, about 600 cubic feet per minute, and the recirculated air, 1800 cfm, are passed first through a mechanical filter that removes the large, bulky dirt and then through the Precipitron to remove the fine particles, the final product being relieved of more than 90 percent of total number of dirt particles.

This unit embodies the experience obtained with a passenger-car unit operated a short time before the war. It is now much easier to clean. It is necessary only to connect a hose to an outlet provided beneath the coach and run a stream of oil through the cleaner.

Another passenger-car electrostatic air cleaner is being built for use with a cyclone-type precleaner instead of the sieve type. This will make maintenance and replacement of the filter pads unnecessary.

Rotating-Machine Accessories for Radar

SOME radar sets, having found a target, tenaciously follow it. The reflected signal, picked up by the antenna, is very weak. It may be only a millionth of a watt—or even less. Certainly this energy is far too small to operate the motor that must keep the antenna pointed at the target. Some amplifying device is necessary. A servo-generator developed for this purpose consists of an exciter and a d-c generator, both driven by an a-c motor. The feeble radar signal is electronically amplified and is fed to the exciter, which amplifies it further and hands it to the fields of the d-c generator. This generator provides another amplification, delivering sufficient power to the motor driving the antenna. The polarity and magnitude of the generator voltage and hence the direction of rotation and speed of the antenna motor are governed by the differences of current in the exciter field coils.

Radar sets require power supplies with good wave form. Yet the characteristics of the radar load are such as to distort the wave form of conventional generators. Special motor-generator sets (inverters) are usually provided to power aircraft radar. But they are heavy.

To save weight on large airplanes with heavy radar loads an engine-driven 400-cycle generator that would maintain good wave form was built. Such a machine would save much weight by generating the a-c power in the first place instead of d-c generation and subsequent d-c to a-c transformation, thereby eliminating the weight of the inverters. Also the radar energy would be obtained more efficiently because the losses of the rotating electrical transformations would be obviated.

The resulting 8-kva machines weighed but 48 pounds, which in one installation represented a reduction in weight of 250 pounds using inverters. To achieve the good wave form under all conditions of radar load from a machine only six inches in outside diameter required every trick in the designer's "book." It meant crowding into an exceedingly small machine all the wave-form control features employed on large machines where space is not severely limited. This included the use of damper bars.

On the Air from the Air

THERE is a pleasant sensation that comes from overcoming a formidable obstacle or watching a sterling performance. It is that thrill that comes from sinking a long putt, from seeing a pitcher strike out a heavy hitter in a tight spot. It, figuratively at least, brings one to his feet. An accomplishment in television last year brings forth that kind of response as it bypasses the greatest obstacle blocking its general use.

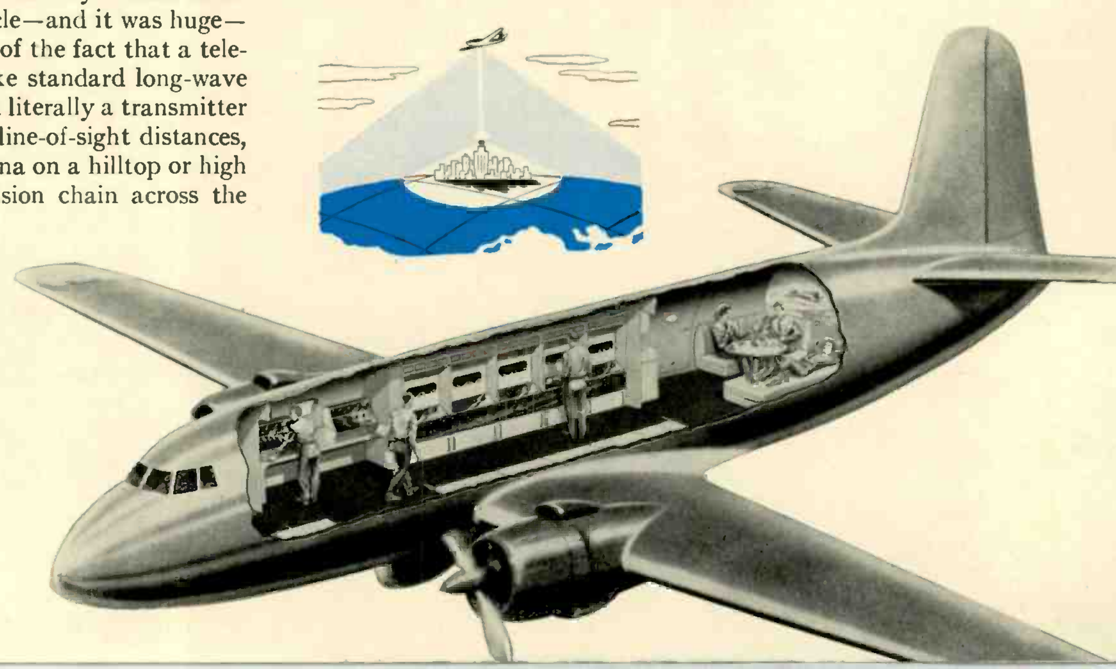
Here is how matters stood in television at the beginning of 1945. Electronic engineers close to the subject were generally agreed that the technical problems that had kept television "just around the corner" for so many prewar years had been pretty well solved. The developments that lay behind radar had taken care of that. The big obstacle—and it was huge—seemed to be financial. This arose out of the fact that a television or FM broadcast station, unlike standard long-wave AM radio, can't reach very far. Almost literally a transmitter of television frequencies is limited to line-of-sight distances, or about 50 miles, even with the antenna on a hilltop or high building. To establish a single television chain across the country—e.g., to broadcast a presidential inauguration to a San Francisco audience—seemed to require the investment of millions of dollars entailed in either a chain of more than one hundred relay stations or a transcontinental coaxial cable. The cost of covering just the major metropolitan cities of the country by either means would require staggering sums.

A young Westinghouse electronics engineer, contemplating the problem, and recognizing antenna height as the major limitation, came to the startlingly simple and seemingly obvious conclusion: put the antenna on a high-flying plane where it can be seen not just 50 miles but 200 miles away. This was not a wholly new idea, but, unlike others, he pursued the idea with vigor, providing a thoroughgoing analysis of the whole problem. As a result, the system of television and FM broadcast called Stratovision was born and is now undergoing exhaustive tests.

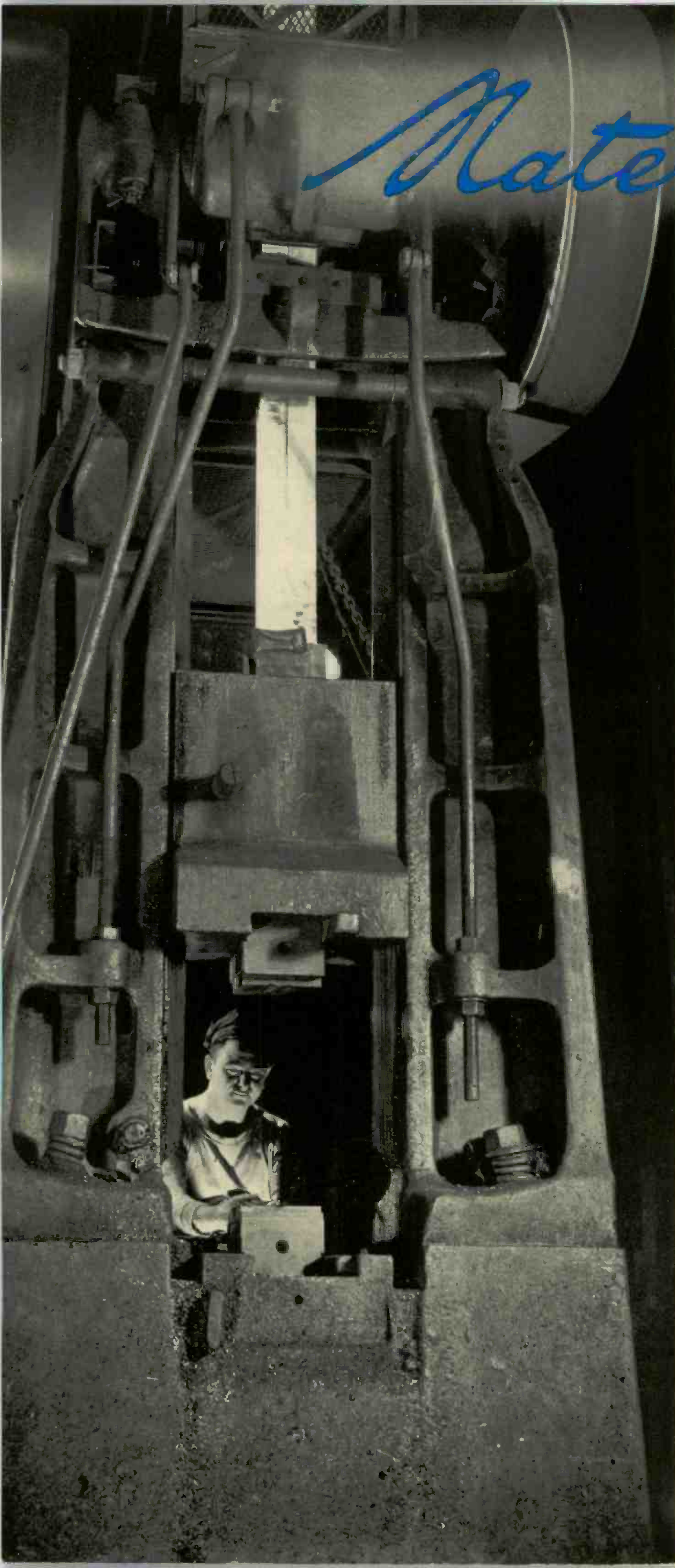
The proposition is to send up two airplanes equipped with television and FM broadcast receivers and transmitters. These planes will cruise in large circles at the relatively slow speed of less than 150 mph at a height of at least 30 000 feet, which is above most storms. One plane will be "on the air" while the other will stand by to take over immediately should its partner have to stop broadcasting for any reason. Each plane would do an eight-hour stint in the air, on a staggered schedule, followed by a four-hour period on the ground, for servicing. Four planes in all would suffice at any one broadcast relay point.

Aside from the obvious, tremendous reduction in station and apparatus investments, Stratovision has several engineering advantages. For one, the broadcast power is used much more effectively. Partly because of less signal blocking by surrounding objects, a 1000-watt transmitter at 30 000 feet can cover a 400-mile circle with stronger signals than a 50 000-watt transmitter in a 50-mile circle from a hilltop. This represents not only economy of transmitted power, but also smaller, less expensive transmitting apparatus, and equipment that can more readily be changed as improvements come along. Because the transmitting equipment is physically small and requires little power, each plane can carry not just one but nine separate transmitters. Hence the cost of the flying antennas can be divided among a total of nine television and FM programs.

Stratovision also eliminates another condition that plagues land-bound television and FM transmitters, that of ghosting. Reflected images, slightly out of time phase with directly received signals, are far more easily avoided by receivers whose antennas are pointed to a stratosphere plane.



In the Stratovision system the costly limitation of earth-surface antenna height is neatly circumvented by placing the transmitters in high-altitude airplanes. Thus a transmitter (and each plane can have nine) can cover a 400-mile circle instead of one 100 miles across —and with much less power.



Materials

Greatest counter force to the rapid depletion of our natural resources is the steady flow of new materials from the laboratories. Each new synthetic or alloy adds to our national wealth.

High-Temperature Metallurgy—Electronics to Gas Turbines

SEVERAL years ago research engineers were asked to develop a high-temperature alloy to serve as a substitute for tungsten lead-in wires of vacuum tubes. The requirements were for high strength at high temperature. The result has been of enormous consequence to gas turbines, jet propulsion, and superchargers. Specifically that original electronic-tube research led to the high-temperature alloys—K-42-B and Refractaloy.

These are not just two alloys, but a family of metals having high strength at high temperature. Few products appear more innocently simple than a bar of shiny Refractaloy. But few are more complex. To achieve a high-temperature alloy requires exact proportioning of constituents, some of them extremely critical as to the effect of slight variations in amount, precise annealing, and most careful rolling practices. Numerous qualities are required—many of which are conflicting—ductility, fatigue strength, corrosion resistance, strength in tension, high-temperature creep. All require a fine balance to achieve the result sought in a given case. For this reason there are many Refractaloys, which in general are replacing the earlier metals, K-42-B. Thus a Refractaloy suitable for high loadings at 1200 degrees in an industrial gas turbine is quite different from one used at 1500 degrees in an aviation unit where loads are lighter and shorter life is acceptable. Material suitable for blading may not be usable for the rotor supporting the blades.

High-temperature metallurgy is still a young science. But the significant fact is that in Refractaloy we have a metal around which high-temperature gas turbines can be built. The steady improvement represented by the most recent Refractaloys as compared to the first K-42-B is a promise of still better high-strength, high-temperature materials.

Silicones Prove Themselves

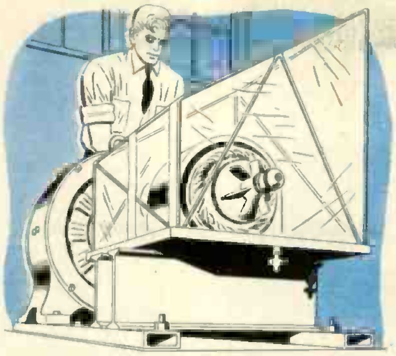
FOUR years ago, a new material appeared like a bright star in the insulation sky. It was silicone. By now engineers have had better opportunity to evaluate it, although that task is barely begun. This much is sure, it is a star of the first order of magnitude.

The engineers of Dow Corning, the firm that makes the stuff, and those of Westinghouse who apply it to electrical apparatus, set about on a test program over two years ago at Midland, Michigan. Direct-current and induction motors were equipped with silicone-impregnated insulation-glass tape,

A giant forge forms K-42-B into blades

mica, asbestos, etc. These motors were then placed on test stands and run on severe thermal-aging test cycles of load and temperature. Each run, at some selected high temperature, was followed by shutdown and a severe humidification dosage to determine when loss of moisture resistance occurred. Following insulation measurements another heat run would ensue.

The tests are still unfinished for even under this extreme punishment the motors (as of August 15) have not failed, although some induction motors have operated for a total of 3000 hours at 300 degrees C. It is apparent already that silicone insulation has far greater temperature stability than any previous comparable materials.



A silicone-insulated test motor, after each high-temperature run, is allowed to cool in a high-humidity atmosphere.

While the test engineers have been conducting the endurance marathon, others have been putting silicone insulation to work initially on machines where higher machine temperature is of greatest importance. A marine motor that had with conventional insulation been rated at 2600 hp at 280 rpm was equipped with silicone insulation and run at 320 rpm. It developed 3900 hp, of which increase the major part is credited to the silicone.

Motors for trolley coaches, streetcars, and mining locomotives have been so treated. Powerhouse auxiliary-drive motors that must operate in high ambient temperatures have benefited from silicone. An operating coil of a magnetic contactor designed for 100-percent duty with silicone insulation was fitted into the same space occupied previously by a coil built for 70-percent duty. A cable exposed to heat of a resistor for long periods must not absorb moisture during periods of shutdown. Rubber insulation could withstand the moisture but not the heat; asbestos, the heat but not the moisture. Silicone can survive both.

Silicone insulation, while not a cure-all for insulation problems, definitely ushers in a new era in insulation performance.

Fosterite, a Moistureproof Insulation

INSULATION engineers have in Fosterite a new weapon for their perpetual battle against moisture. It is a synthetic material, not just one but a whole family of them of the genus alkyd-vinyl. Each, as made and applied, is a thin liquid that sets by heat into a permanent solid material, which is tough and sheds water even better than the proverbial duck's back.

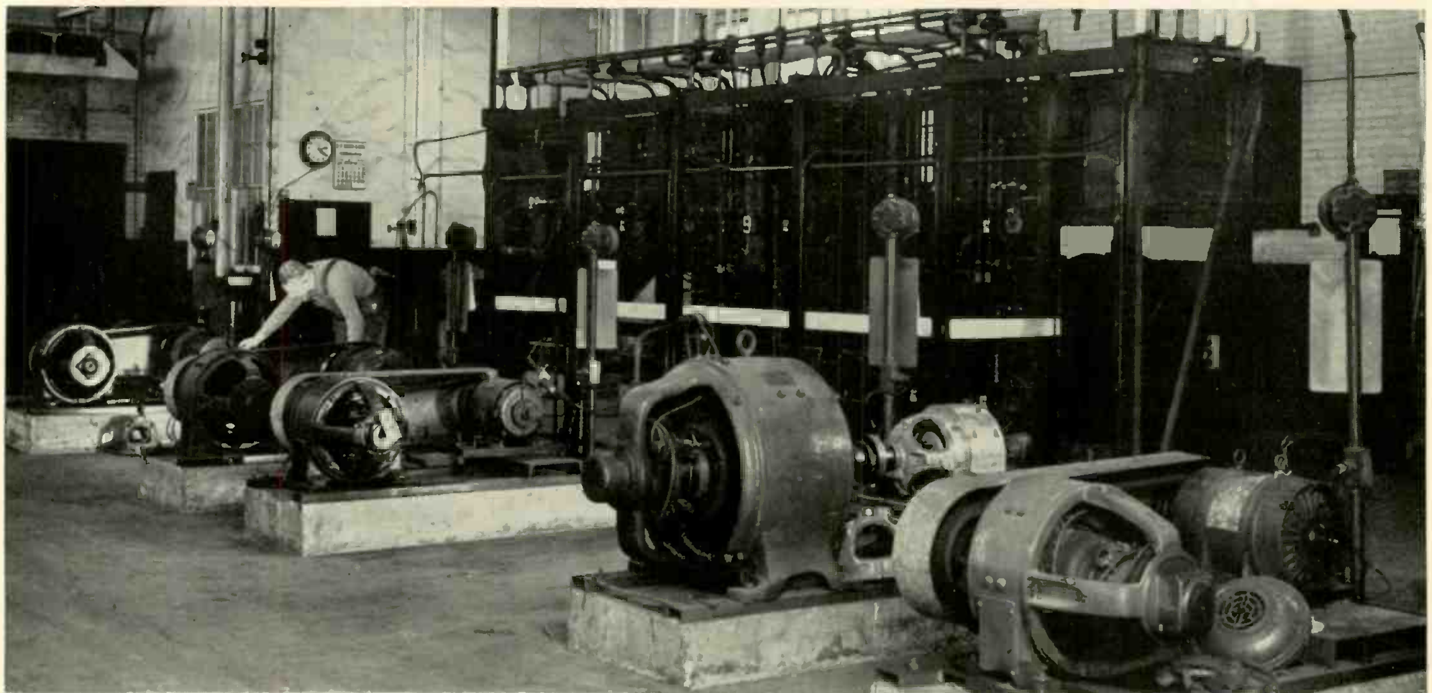
The need for moistureproof insulation has been recognized since the birth of the industry. World War II made a solution mandatory. Insulation on radio and radar apparatus in tropical and Pacific areas, for example, undergoes a terrific beating from temperature variation and moisture. It may be carried quickly from the boiling sun of a landing strip at a temperature of 150 degrees F to the 60-below-zero cold of a high altitude. On return to the humid air of sea level the apparatus frosts over heavily. This frost soon melts to penetrating and destructive moisture.

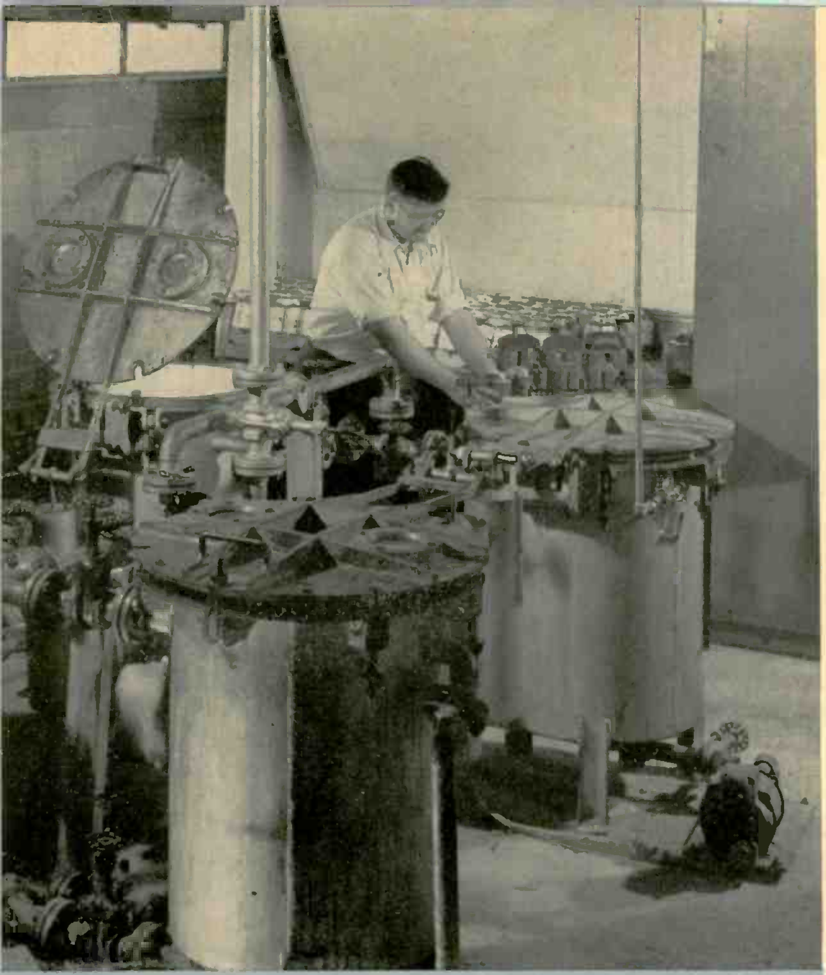
Most ordinary varnish-treated transformers can withstand these routine combinations of heat shock, humidity, and salt air for only a few hours, a few days at most. Sealing the units in a metal can provides effective shielding against these enemies of insulation. But this expedient takes much more space, which might not be available in already-designed and always-crowded communication apparatus. Worse still is the doubling or tripling of the weight.

N. C. Foster of the Westinghouse Research Laboratories applied a neat bit of reasoning to the problem. Ordinary varnishes are about 25 to 50 percent solids carried in a volatile solvent. The varnish sets by evaporation of the solvent, leaving obviously an insulation porous by the amount of space occupied by the solvent. If, Foster reasoned, an insulation could be made without volatile solvents, there would be no voids for destructive moisture to enter. He thereupon set about in his laboratory to create just such a material, which now carries his name. In Fosterite the solvents react chemically under heat with the solids to form the solid insulation. Assuming all air has been sucked out before the Fosterite is applied, there can be no voids because nothing is driven off.

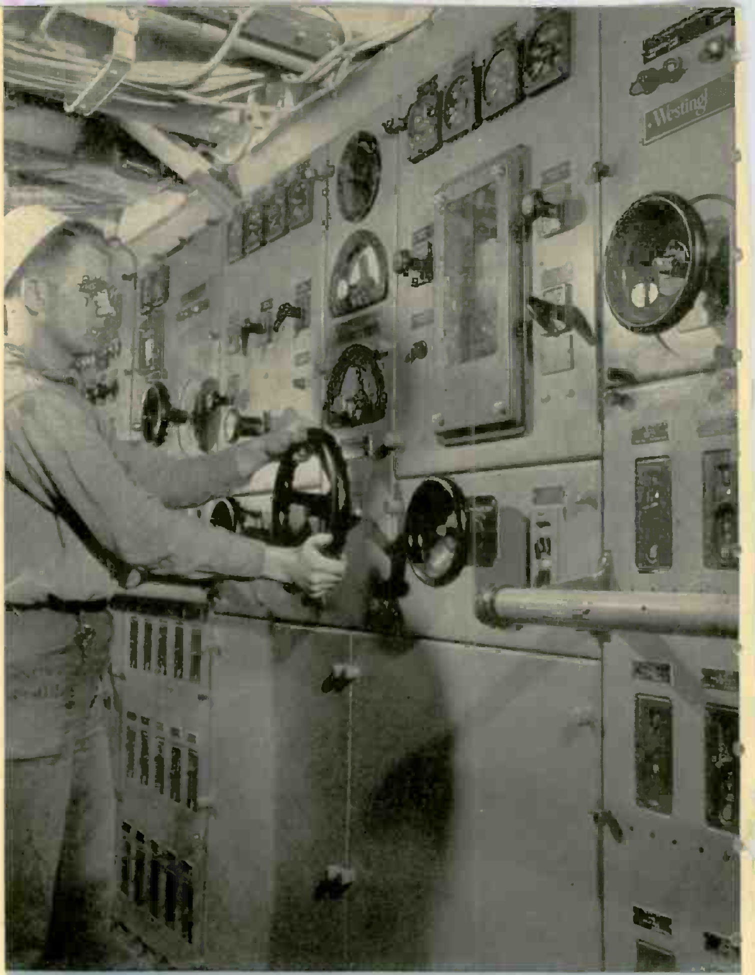
Fosterite-treated transformers have been made by the thousands for the military forces. No record of failure in service due to moisture has been reported. Some transformers so treated are, after assembly, allowed to soak for two hours in 150-degree F water and are then plunged into 75-degree F water for two hours. They must then be able to operate normally. And, with few exceptions, they do.

At Midland, Michigan, Dow Corning and Westinghouse have been testing silicone insulation for motors for two years.





The synthetic material, Fosterite, provides a moisture-resisting, void-free insulation. It is used extensively for communication transformers.



Insulating boards made of melamine-impregnated glass-fiber cloth are used where arcs might cause damage, as on marine panels.

Fosterite is an organic insulation and has the limitations of such. Also, it is adversely affected in setting by bare copper and by certain asphalts and gums that may be present in some insulations. Hence it cannot be applied indiscriminately. Fosterite insulation, in truth, should be considered a process as well as a material. However, beyond providing a moistureproof insulation for small communication transformers it has intriguing possibilities for more familiar apparatus—possibilities the engineers frankly have not yet been able to explore. Perhaps it may prove suitable for motor stators and armatures. Certainly it has already been useful as a binder for laminated plastics. Also, curiously Fosterite has served as a moistureproof filler for castings that develop blowholes or troublesome porosity.

Molybdenum Is New

How can a story about molybdenum—ordinary unalloyed molybdenum of standard purity—merit inclusion in a review of significant engineering as a "new material"? Molybdenum is one of nature's 92 basic elements Its chemical and physical properties, generally quite remarkable, were catalogued in handbooks long ago. Yet these properties, fascinating though they are, have been almost solely of academic interest to designers, because molybdenum has been available to them only as sheets the size of a playing card or rods little larger than wire, and in a few other simple, small shapes.

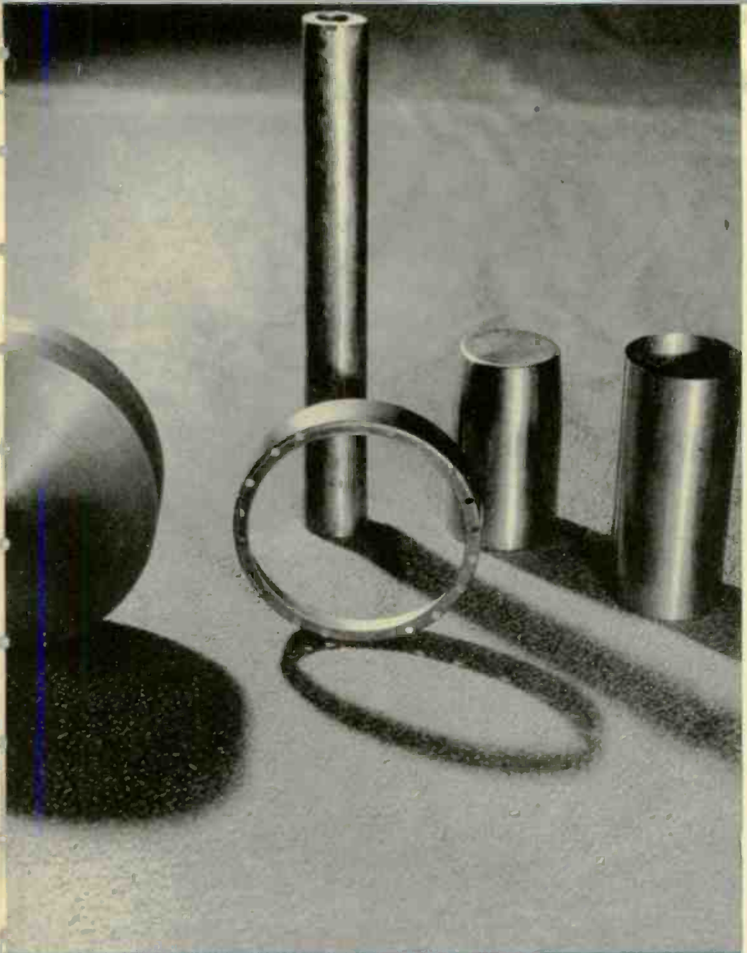
The limitations on the production of "moly" in chunks of large size and multiplicity of shapes have been removed. Furthermore, the cost per pound has been reduced to roughly one third. Oddly enough this feat of major significance in the metallurgical world has been accomplished within recent months in a plant devoted to the manufacture of lamps and electronic tubes.

The very qualities of moly that have seemed so long attractive to designers have been the very ones to block its production in large sizes and complex shapes. Moly melts at 4748 degrees F (iron, 2800; copper, 1976). Thus, although pure moly in powder form can readily be prepared from its natural oxide, it cannot be melted like other metals to form large solid pieces, because any container or crucible of known materials would melt first.

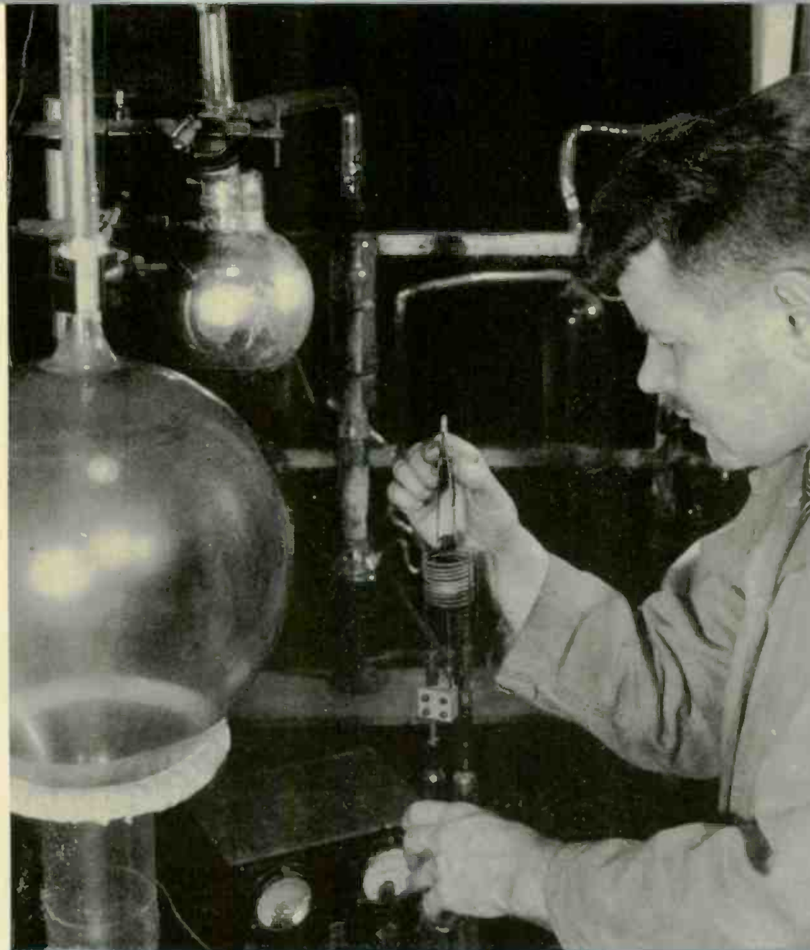
Westinghouse has made advances in a new process that removes the restrictions of both size and shape. The piece can have any desired shape that can be molded. It can be round, square, with fins, or angles, or holes and with much larger overall dimensions than heretofore possible.

The excellent properties of moly are now available for a variety of uses. The most important characteristics are its high melting point and great wear resistance at elevated temperatures. Also it has a higher modulus of elasticity, increased strength when hot, and better thermal conductivity than any steel. It is lower than the steels in specific heat and coefficient of expansion. Its corrosion resistance compares favorably in many media with tantalum, palladium, and platinum, each costing many times more than moly.

Moly is now proving valuable in the form of crucibles, electronic tube parts, electrical contacts, electrodes for resistance heating of glass, welding tips, thermocouple tubes, and for electric-furnace heating elements for high-temperature work in a vacuum or protective atmosphere. It is expected to be useful for welding alloys, high-temperature engine parts, and other places requiring high wear resistance at high temperature. Moly is truly a new material.



By a new process of manufacture molybdenum becomes available as a structural material in pieces of large size and complex shape.



From this lamp research-laboratory setup came the first small pellets of pure uranium, which has now become the world's most-precious metal.

The Race for Uranium

IN 1939 the scientists of this country, the leaders of the army, and our highest national officials found themselves in this plight: They had become aware, rather suddenly, that an atomic bomb was a distinct possibility. Worse still it was entirely possible that our enemies might already be well on the way to achieving it, and if so there was no doubt as to who would be the victors of the war.

The decision was made to embark, all-out, on the trail of atom splitting. The money was available. The manpower could be made available. The necessary scientific skill, the laboratory facilities were at hand. The country's leaders had everything to do the job except two things—time and the main ingredient, uranium itself.

It would be months before pure uranium would be available from the new plants. All the uranium in pure form that had ever been made in this country—and possibly in the world—could be placed in a small shoebox. Scientists had *almost* nothing on which to begin their experiments. But—and here was a vital fact—we had produced, so-to-speak, a shoeboxful. The difference between that and nothing was perhaps many months in the date of the final achievement of the bomb and consequent possible prolonging of the war with all its staggering cost in lives and money.

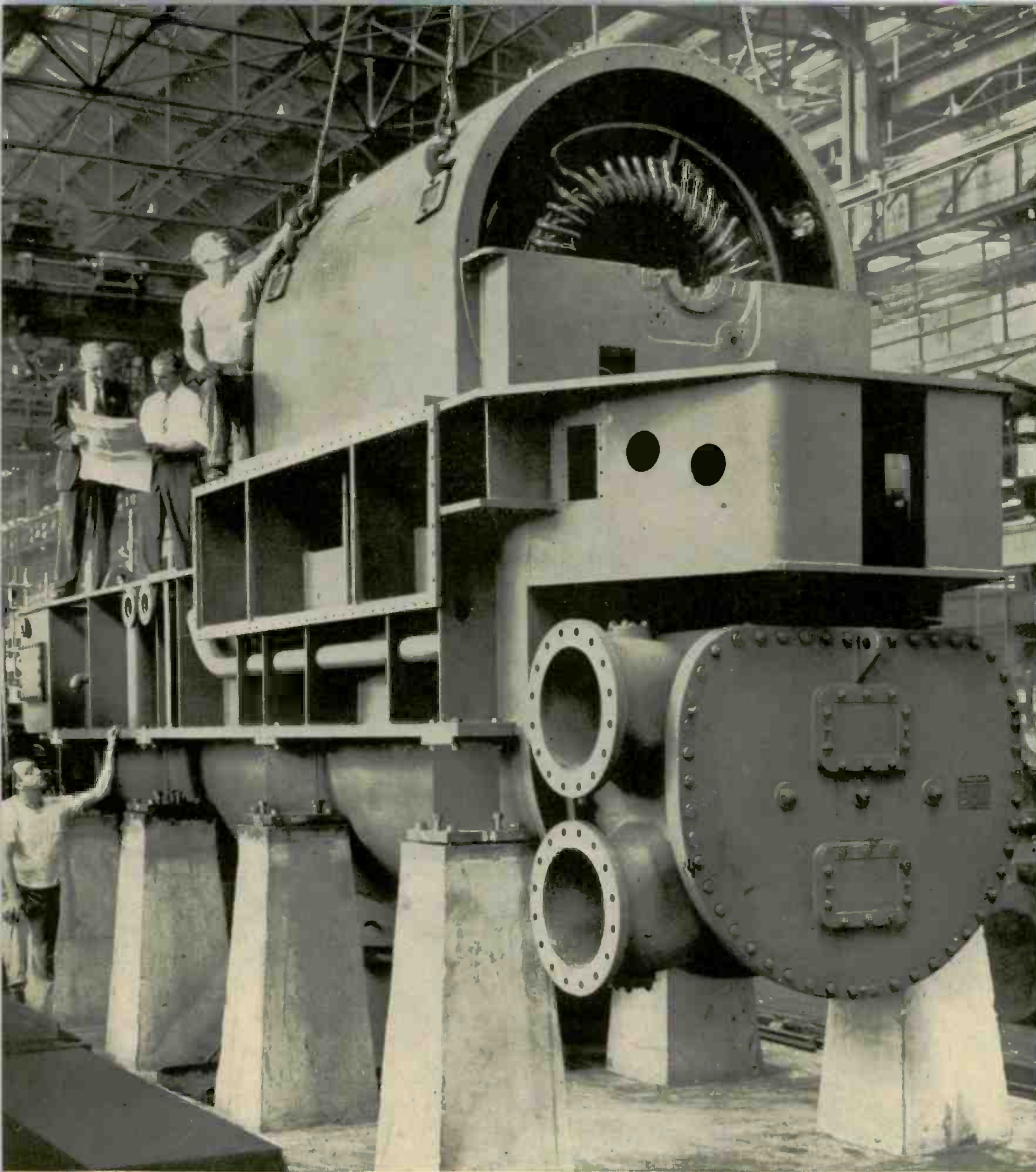
All of the few small lumps of pure uranium in the United States, incalculably more valuable than gold because they represented the existence of the know-how to make more, came from an inconspicuous, small-scale process tucked away in a corner of the Westinghouse Lamp Research Laboratory.

This providential circumstance had its beginnings soon after the close of World War I, in the scientific curiosity of Dr. H. C. Rentschler, present director of the laboratory. He was exploring materials, hoping to find one superior to tungsten for lamp filaments. Uranium was a possibility, but almost nothing was known about its physical properties. Its melting point was not known within several hundred degrees.

The first problem was to devise a method of making some, because pure uranium was not available on the market, possibly because the reduction of uranium from the oxide ores was extremely difficult. Dr. Rentschler and Dr. John W. Marden, assistant director of research, succeeded in making reductions which yielded uranium of a quality satisfactory for determination of certain properties such as melting point and hardness.

Although uranium proved worthless as a lamp filament, Dr. Rentschler and Dr. Marden continued to make small batches—a few ounces at a time—for further study and to supply demands of scientific investigators who soon came to know their crude setup as the only source of pure-uranium supply. By the end of 1941 daily production was in one-pound lots. Then came the great urgency for uranium. By the end of 1942 Westinghouse had speeded up production to 500 pounds daily—and still this was the only source of the super-precious metal. Not until the fall of 1943 were the government's own plants able to take over fully its production.

The first experimental atomic "pile," as the atomic power generator is called, was constructed at the University of Chicago and began operation on December 2, 1942. This historic producer of controlled atomic energy consisted of several thousand pounds of uranium, of which all but a few hundred pounds came from the Westinghouse "emergency" uranium factory. Thus, research intended to produce better lamps, by a strange twist of fate made a signal contribution to the winning of the war.



Power

Significant progress has been made in the generation and distribution of power in spite of all-out emphasis on the things that more directly bore on winning the war. While these developments have not been as startling as others, a glance up and down the power field shows many that are both ingenious and important. Only a few representative but varied ones can be included here.

Here partially assembled is a 5000-kw power-generation unit. It includes as one "package" a steam turbine, condenser, generator, and auxiliaries. The unit is essentially a combination of standard, thoroughly tried power units, integrated as to design for maximum compactness and simplicity. The condenser also serves as the foundation superstructure. Upon it rests the turbine, the generator, and auxiliaries. Steam conditions for this unit are: 600 pounds per square inch, 825 degrees F, 28-inch vacuum. It employs a fully hydraulic governor. The complete unit occupies a floor area of 31 by 13 feet and is 17.5 feet high.

Atomic Fires

An attempt to set atomic power into its proper place in the engineering world is about as difficult as a prophecy of the future of electricity might have been at the time of the first electric lamp. Only more so. Generation and production of electric power were allowed to follow a natural course as dictated by engineering developments and economics. But superimposed on the technical developments of atomic power will be political and military controls, the extent and effects of which are still undetermined. In appraising the technical and economic possibilities of atomic power, however, a few facts stand out clearly.

1—Atomic power is an actuality. The atomic-energy piles at Hanford, Washington, are continuously delivering several hundred thousand kilowatts of thermal energy, enough to raise sensibly the temperature of the Columbia River.

2—The cost of that energy, which is a by-product, if known, has not been made public. It would seem, however, that it must be high, probably many times that of other fuels. The costs of preparing sufficient purified uranium for practical piles are likely quite high. Furthermore, complete "burning" of a prepared lump of uranium is not possible. Just as ash accumulates around a chunk of burning coke, which tends to slow down or stop the combustion, so the nuclear processes produce substances that retard the reaction. In a relatively short time the "poisoning" reaches such a degree that a complete and expensive refining operation must be performed or the uranium discarded.

3—Controllable atomic-energy generators of smaller size and weight are possible now. However as the size comes down the richness of the fissionable material must be increased. Costs rise astronomically with degree of enrichment.

4—The fission products are strongly radioactive for periods varying from seconds to years. These radioactive products are extremely hazardous to any form of life. Protective measures require large masses of appropriate light-density materials. The bulk and weight of safety devices for small power plants would far exceed that of the pile itself.

5—Fission is now accomplished with uranium isotopes, and plutonium which is derived from uranium. The amount of uranium ore and its distribution over the earth, if known, has not generally been disclosed.

6—Nuclear reactions to achieve energy release with other elements is theoretically possible and may be practical although no announcement of such has been made. Thorium is one possibility. It should be remembered that heat is available either by fission of heavy atoms into elements near the middle of the atomic scale, or by synthesis of lightweight elements into higher ones. Heat from the sun is thought to be

Generation

energy released from the combination of hydrogen atoms with helium atoms by successive nuclear reactions.

7—Atomic power almost assuredly will become a practical power source, competitive in some fields to petroleum or coal fuels. The most likely apparent application is for ship propulsion. Large power plants using atomic fuel seem more distant, while small-size power plants for private vehicles appear quite remote. Above all—aside from governmental controls—the laws of economics will apply. Inasmuch as fuel costs are only a portion, sometimes quite small, of the total power-production costs, investment costs and special performance requirements may be the deciding factor. If the equipment costs for an atomic power plant are high, the plant may not be able to justify itself even if the atomic-reaction material were to cost nothing.

These practical difficulties, large though they be, should not obsure the fact that atomic power presents to the technical man enormous, fascinating opportunities and to the average citizen the greatest force of all time, for good or evil as he sees fit to use it.

The Lightning Gantlet, Routine for Power Transformers

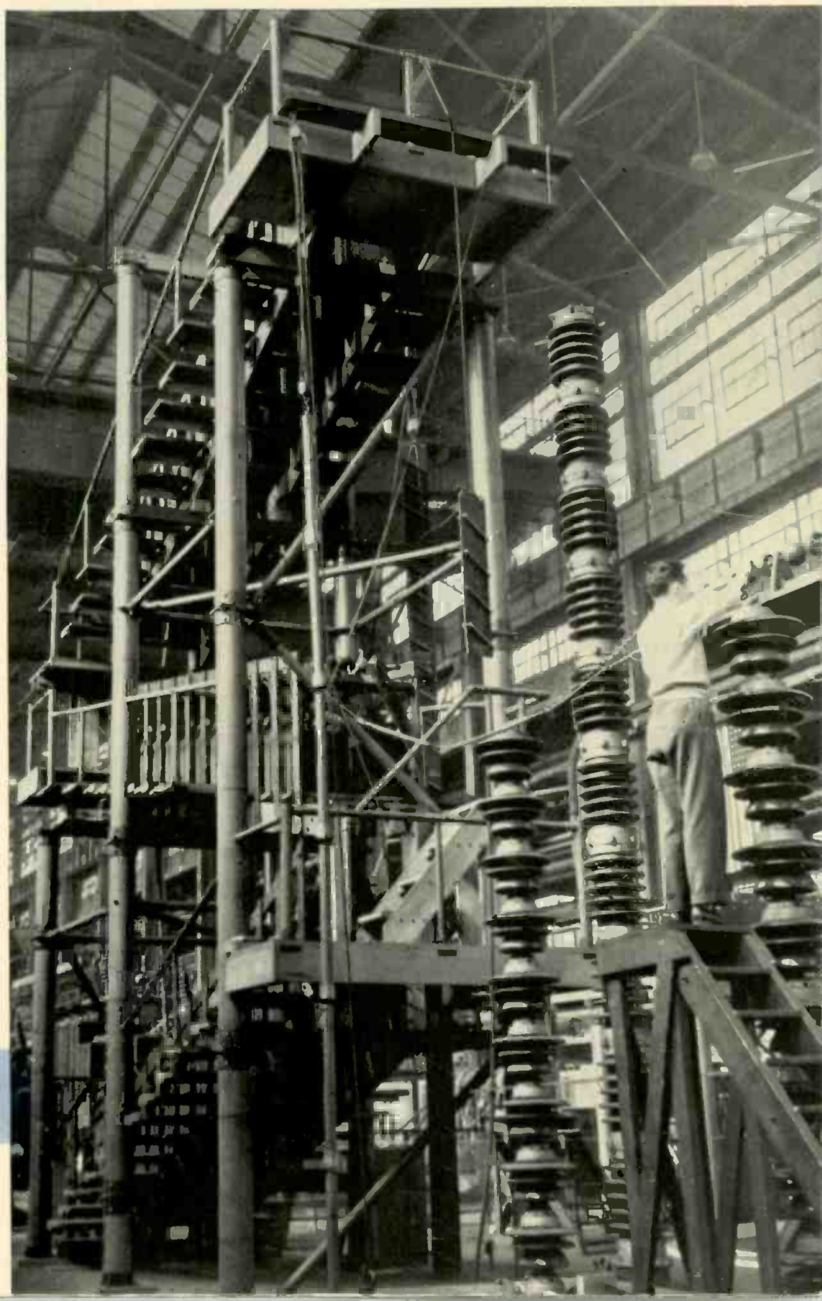
Now, as a routine matter, power transformers as they complete their trip down the production aisle get socked by man-made lightning, delivered by a three-and-a-half-million volt surge generator. Not once, but four times in fact. This is a bold thing to do, for the surges initiated by lightning are the sorest trials that transformers must endure throughout their lifetimes.

Surge testing of transformers is, of course, not new. Engineers began some fifteen years ago to impose surges from artificial-lightning generators onto transformers for experimental purposes. In 1939 Westinghouse began the then revolutionary program of testing all of the completely self-protected distribution transformers with surges. But until recently the big fellows—those power units connected to high-voltage systems where the lightning-produced surges may be severe—were subjected to artificial lightning only on an experimental basis to prove a new design or at the special request of and at additional cost to the user. Testing them as a routine production policy is a quite different procedure to be followed.

The fundamental objective of this test is control of quality. It is to make sure that a power transformer before it is installed on some transmission line is free from undetected weaknesses. Surge testing as a quality-control measure discloses foreign or faulty material, inferior workmanship, slips in assembly, or error in design. Revealing these faults precludes the possibility of failure of transformers by lightning. No weakness seems too small or remote for the test to detect. Weaknesses where less than one percent of the total winding is involved (i.e., turn-to-turn) have been determined in this fashion.

The 3 600 000-volt surge generator is located on the test floor at the end of the assembly aisle. Because of its location it is unnecessary to move the transformer to the high-voltage laboratory as heretofore. This permits testing each transformer rapidly under cover so as to cause no delay in shipment. The generator is arranged for quick, controlled application of impulses that can be varied as required for transformers of the various ratings. Test impulses consist of two steep-front waves that test the strength of the insulation nearest the incoming terminal. In these, the voltage rises to a high magnitude at a rate of 1000 kv per microsecond, representative of a stroke of lightning close to the transformer. Two full waves are then applied in which the surge builds up more slowly but lasts many times longer. These are representative of surges that have to travel some distance along the line before they reach the transformer. The insulation is tested throughout because the longer waves can penetrate more deeply into the windings.

Surge testing of power transformers on the assembly floor was begun in June 1944. By late fall 700 000 kva of power transformers had been surge tested.

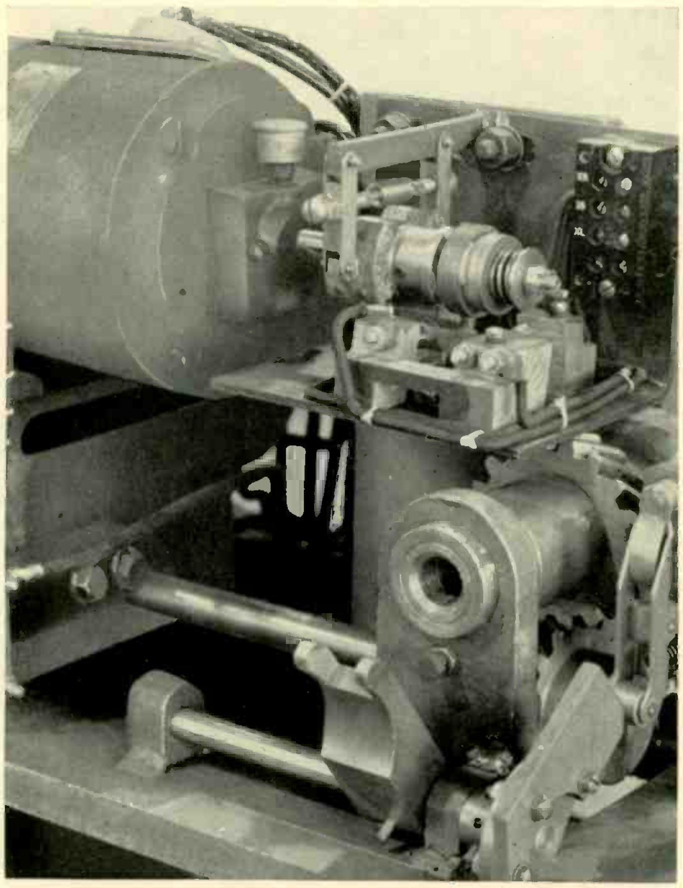


A three-and-a-half-million volt surge generator has become an integral part of a power-transformer production line for testing.

Quick Stopping for Tap Changers

In motors that drive switches to change transformer taps under load, accurate stopping is as important as the actual operation itself. Tap-changing motors previously have been stopped by a well-designed shoe-type brake. But friction brakes wear and cannot always be relied upon for consistent performance.

The newest motors don't use friction brakes. They are brought to a stop by plugging, i.e., the power is reversed, which causes the motor to try to run in the opposite direction. At the exact instant of stopping, the power is disconnected. By this means the motor, running at 3000 rpm, stops in from five to seven revolutions.



By reversing the power, this tap-changing motor can be stopped in about one-fifth of a second from an operating speed of 3000 rpm, without the use of mechanical or friction brakes.

Mounted on a motor-shaft extension, the new switch employs friction drive and stops the motor by electrical plugging action alone. A light, fixed drag prevents drift between operations. A traveling nut provides axial movement of the actuating lever to prevent hunting. Parts are self-lubricating and corrosion resistant. Life tests and service records indicate extreme reliability over more operations than can be expected in the normal life of the equipment of which these tap changers are a part.

Many Instruments from Few Standard Parts

The benefits of standardization have come to switchboard instruments. The number of permutations of the four-inch switchboard instruments used by power and industrial companies on regular switchboards has been almost any large number one cared to write down. In each of the basic types—ammeters, voltmeters, wattmeters, power-factor meters, reactive voltammeters, etc.—there are endless combinations of flush and projection mountings, internally and non-internally illuminated, white dials and black dials, internal and external shunts, ratings, etc. But even this almost hopelessly complex situation has been brought under standardization control. It was done by utilization of the idea of standard, interchangeable components worked out so successfully for the much simpler miniature-instrument family just before the war.

One standard base, with knockout openings in the back, fits them all. By punching out the appropriate holes the terminals for any of the several varieties of instruments can be fitted instantly. The shunts are made as units, to be inserted or not in spaces provided. Internal lamps on long stems can be slipped through knockout holes if dial illumination is desired. The one base can take either flush or projection cover without modification. And so on.

The resulting benefits are numerous. About nine tenths of the work of making any particular instrument is done in advance. Hence the final product is simply a matter of assembly of standard parts. Time is saved. Fewer parts need be stocked. Changes of instruments—in form, or rating, or mounting type—can be made readily in the field. It is estimated that from 50 standard chassis assemblies some 5000 different instruments can be made with almost no more tools than the average electrician carries in his hip-pocket for the usual wiring job.

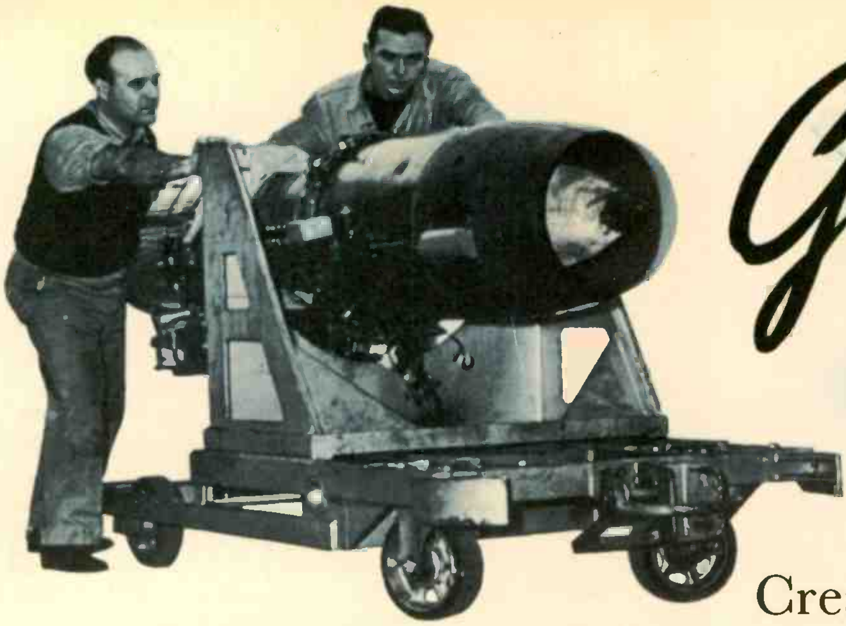
High-Speed Induction-Disk Relay Element

Speeding up directional-element action in relays has been accomplished by the design of an eight-pole, induction-disk element. The eight poles are arranged on both sides of the disk to utilize practically the entire disk to produce torque. In this way efficiency of the unit is greatly increased, resulting in high-speed operation with low-energy requirements, while vibration on heavy-torque conditions is practically non-existent. Speed of operation is less than 1/60 second over wide ranges of current and voltage, which eliminates the variable time of operation encountered on present directional-control relays when operating at low voltage. In fact, the element operates at high speed over a range of currents up to 100 amperes during voltage variations from one-half volt to 115 volts. Saturation of the magnetic circuit at relatively low current is responsible for this feature. The element can easily be dismantled and reassembled in the field, thus simplifying the maintenance job. By changing coils, the element can be made into other types of relay elements, for example, an instantaneous current or instantaneous voltage type. An important feature is that they can be directionally controlled without using auxiliary relays.

High-Frequency Transformers, New Peacetime Business

The war created a new business in transformers. It called for new materials, new engineering skills, new knowledge, new manufacturing techniques and facilities. Postwar, this new business remains diminished in total volume, but by no means eliminated. Also it finds much of the new skills and knowledge useful to old-established transformers.

The war need was for ultra-high-frequency transformers,



Gas Turbines

Create Big New Power Business

AMONG the many phases of power engineering the gas turbine stands second only to atomic power in impetus given by the war. And atomic power is still an uncertainty. Its practical usage must await a long development. On the other hand, the gas turbine has grown in this country since the war's outset from small and for the most part academic beginnings into actual engines. Plants involving millions of dollars in investment have been established for the production and further development of various forms of gas turbines. Last February the Westinghouse Company established an entirely separate division for this purpose, called the Aviation Gas Turbine Division, which operates a large plant that represents a combined investment of ten million dollars by the Navy and Westinghouse. Gas turbines for land and marine use are being developed separately by the Westinghouse plant building steam turbines. In addition to production facilities, various aspects of gas-turbine research, notably metallurgy, are being conducted in Westinghouse research laboratories located elsewhere. The gas turbine is no longer solely of academic or military importance.

The gas turbines currently of interest are of four types: for jet-propulsion, for geared-propeller drive, for supercharging, and for power plants for stationary, railroad, and marine use.

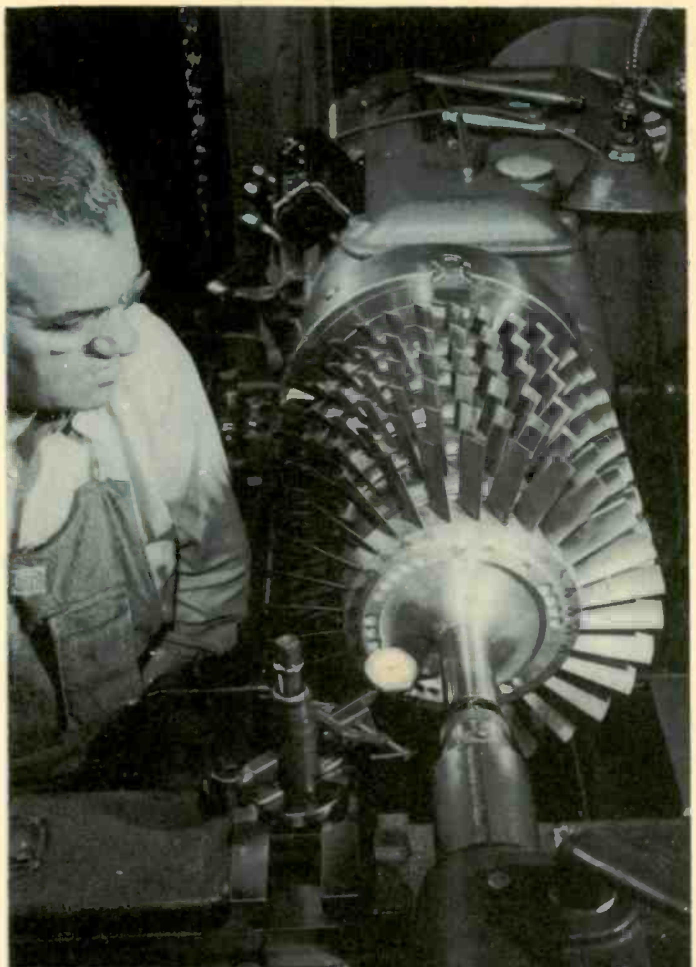
The most spectacular of these has been the jet-propulsion gas turbine. Although during the war years the work done on j-p units was enormous, it could then be little more than mentioned and a few unrevealing pictures of jet-propelled planes shown. The details of the most recent work still are military secrets, but information about the early units has been released. The first two types of engines developed by Westinghouse for the Navy were units of 19 and 9½ inches in diameter. The big one was for aircraft propulsion and was flown for the first time nearly three years ago, in March, 1943. The little one, basically just a small edition of the 19-inch engine, was intended for a robot bomb.

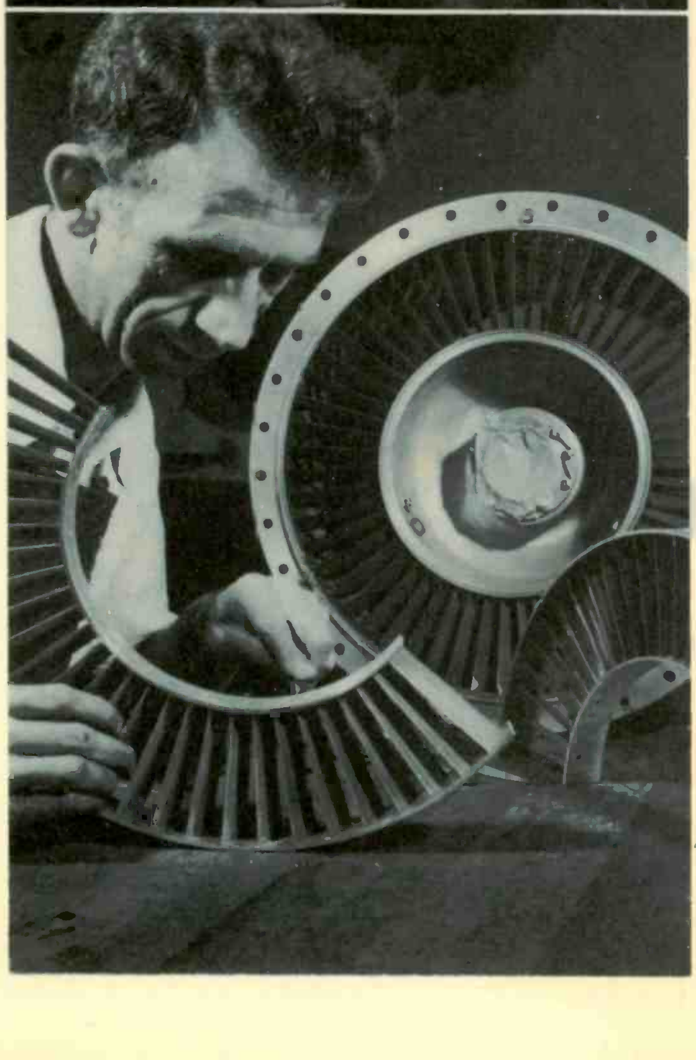
Externally, the larger appears to be a cylinder about nine feet long, with opened front end and a tapered nozzle at the rear. Except for a fuel line, and small starting and control mechanisms, nothing more is seen.

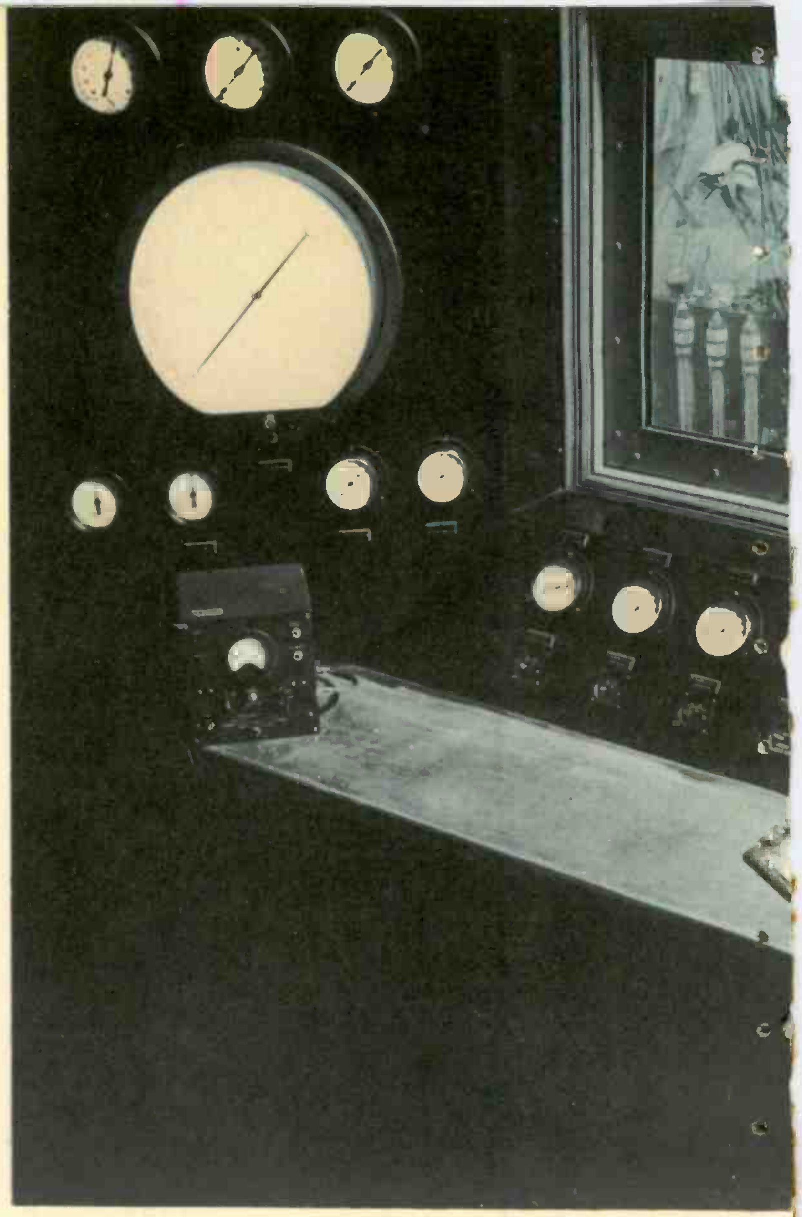
The interior also appears simple. Near the air-inlet end is an axial-flow compressor of several stages. Next, in about the mid-section, is the combustor, which is a basket with holes arranged for proper mixing of air and fuel. Immediately behind this is the single-stage turbine with its shaft extending forward through the combustor to the compressor. The exhaust gases from the turbine are expelled to the rear through the nozzle.

The significant features of these jet engines are their obvious simplicity, complete absence of reciprocating parts, and, even in comparison with other jet-propulsion units, exceptionally small diameters. The 19-inch engine weighs but 780 pounds, but delivers at take-off 1365 pounds thrust and at 400 mph (sea level) 1200 pounds thrust. It runs at 18 000 rpm. (Jet engines are rated in terms of thrust because, to determine horsepower, speed

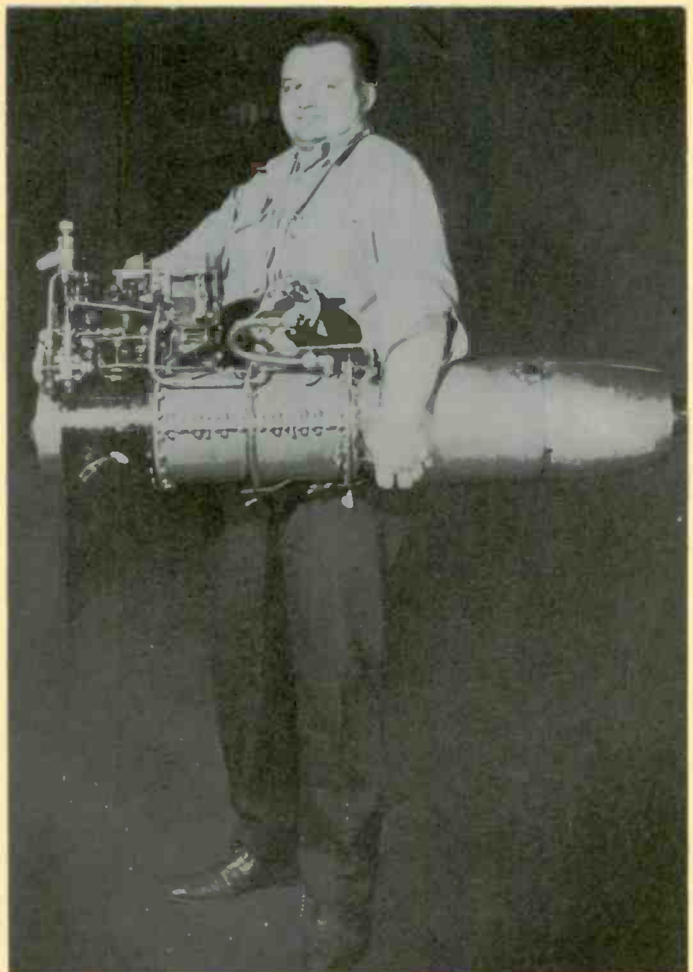
Like muzzles of huge guns stand these intake muffles of jet-engine test cells.

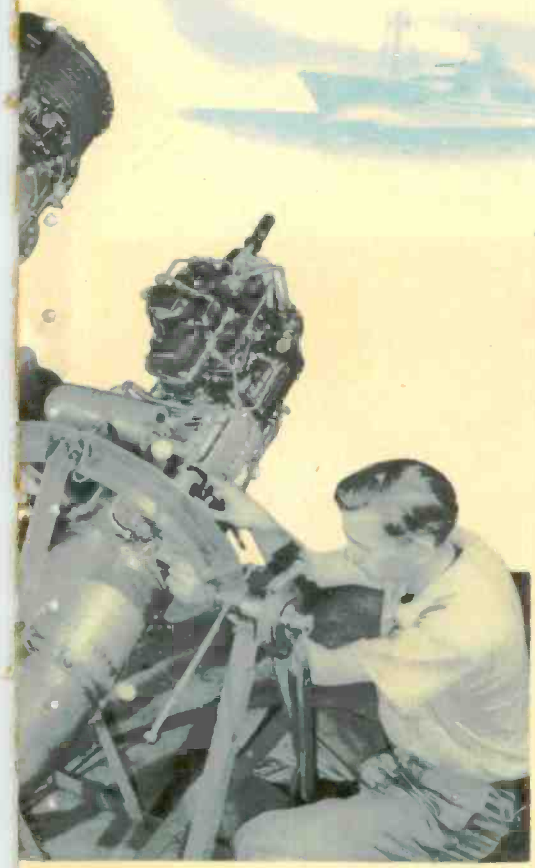




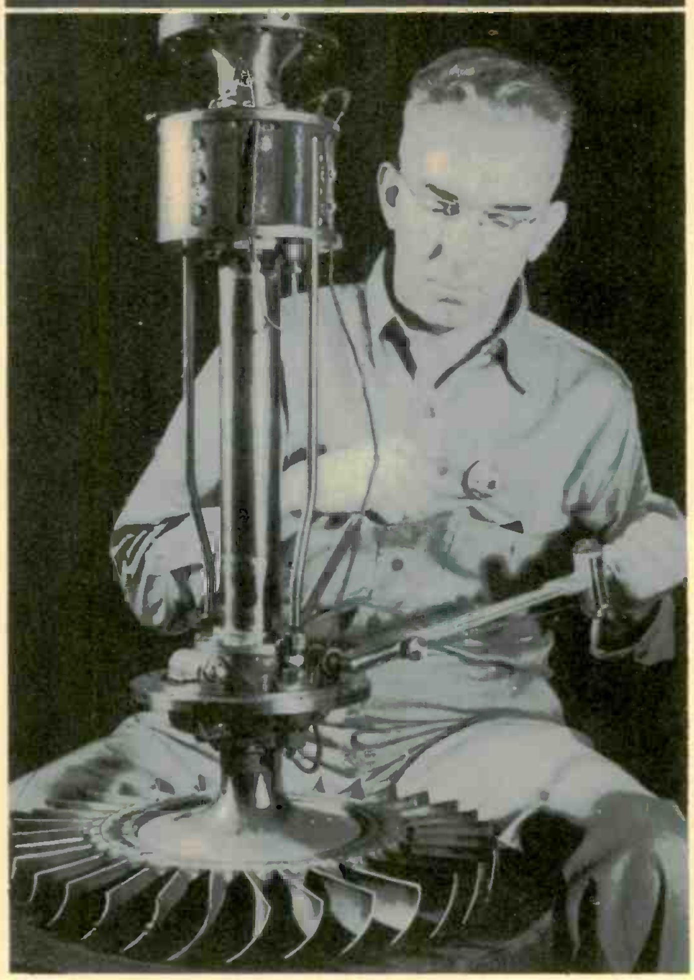


A jet-engine test operator (top center) sits by his desk in the soundproofed control room. Through the heavy, double-glass windows is visible one of the 19-inch engines in its cradle ready for a test run . . . Because gas turbines run at high speed—18 000 or 34 000 rpm depending on size—precise balancing is a must. In the electronic Dynetric balancer (top left) is an axial-flow compressor for a 19-inch jet unit . . . Sections of stationary blading (at left) for one of the 19-inch axial-flow compressors.

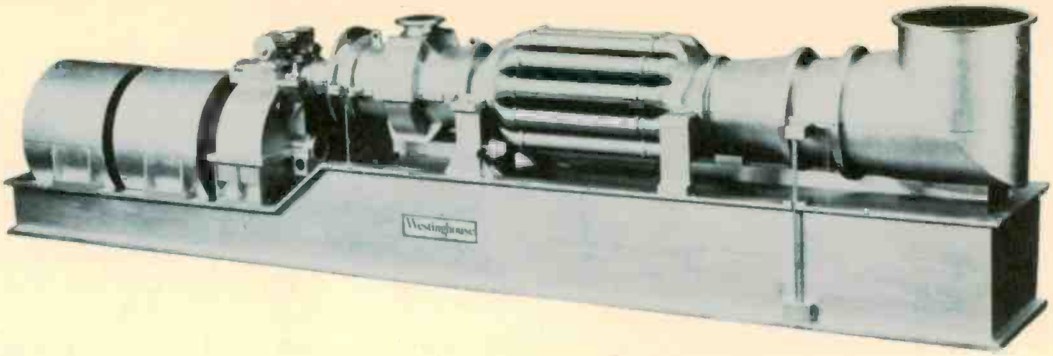




(Left) These are production units of the first two types of jet units in their assembly cradles. They are identified by their external diameters, 19 and 9.5 inches respectively . . . The man hólds one of the 9.5-inch jet engines, that, at 375 mph, would have a power output of approximately 240 hp. . . . The rotor of a gas turbine for jet propulsion (right) consists of a single stage of blading. Because turbine-inlet temperatures reach 1500 degrees F high-temperature alloys, as Refractaloy, are required.



A 2000-hp, open-cycle experimental gas turbine has been built. At the right is a scale model. Below is an experimental gear to link a turbine and a plane propeller.



must also be considered. One pound thrust at 375 mph equals one horsepower.) The $9\frac{1}{2}$-inch engine weighs only 150 pounds but produces 260 pounds push at standstill and 235 pounds at 400 mph, with an operating speed of 34 000 rpm.

The small diameters of each are particularly important as this means small frontal area, which, at the high speeds these jet-propulsion units must travel for acceptable fuel economy, results in greatly reduced drag. The small diameter of the Westinghouse engines results from use of axial-flow compressors.

The most serious metallurgical problems in a gas turbine are those of the turbine. Blading for turbine stages is made from the new high-temperature metal called Refractaloy (see description elsewhere) which has acceptable creep rates even at as high as 1500 degrees F, 500 more than steam-turbine temperatures.

Gratifying as is the performance of these two engines, particularly considering the youth of the jet-propulsion turbine, they are already obsolete. They have been superseded by two other types, the performance of which, while still restricted as to detail, is far superior to that of the earlier j-p engines. These newer models weigh less than one half pound per pound of thrust, which is less than one half the weight of piston engines. In diameter they are but one half that of comparable engines. This means that whereas the ordinary aircraft engine must spend about one third of its total power output to drag itself through the air, in overcoming "barn-door" effect, the gas turbine must devote but a tenth of its power against drag. It is believed that these new engines are the smallest in size and weight for their power in the United States.

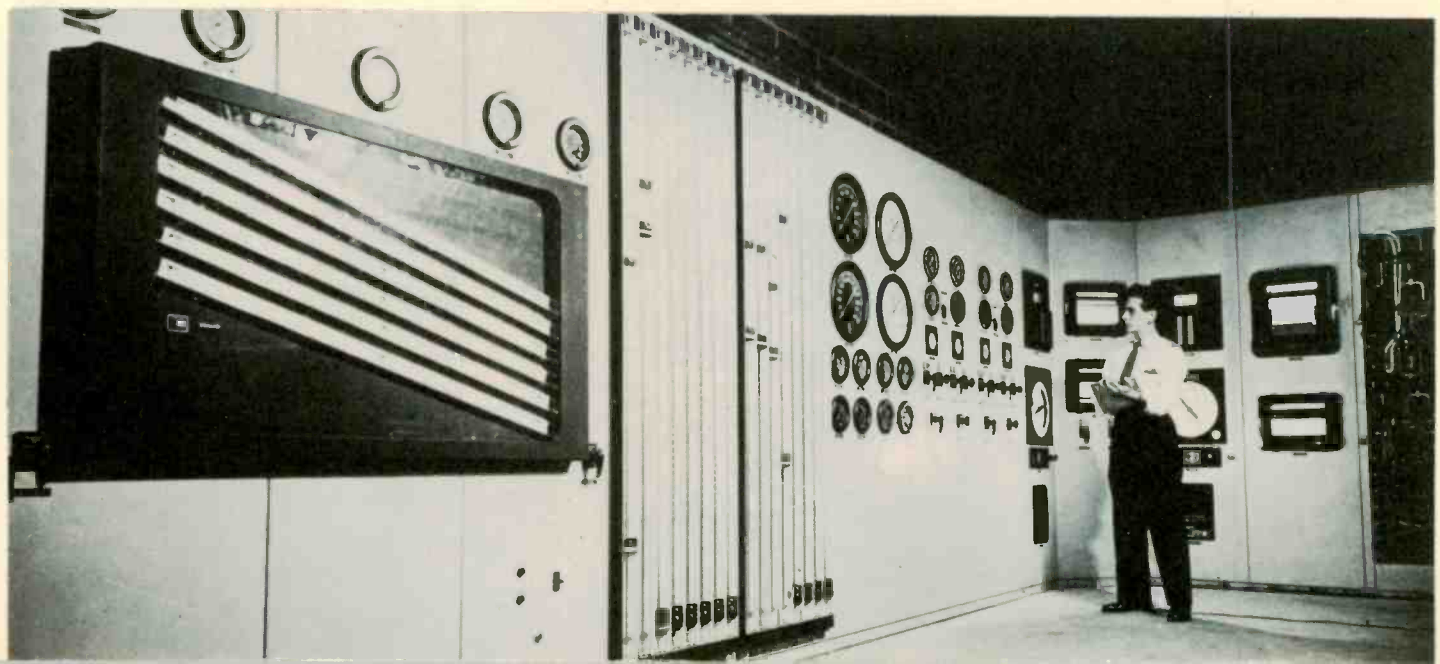
In addition to the several types of engines for jet propulsion already built, under construction, and still on the drawing boards, an engine is being developed for a geared-propeller drive. This engine will have an output about equal to the present most powerful reciprocating engine, but will have but one third the frontal area and but three fifths the weight. An experimental gear for connecting the engine to the propeller has been tested, with very favorable results.

The first large-quantity use of gas turbines was as engine superchargers. Westinghouse does not build superchargers, but has had an intimate part in their development, largely in connection with the high-temperature metallurgy involved. Many tons of special high-temperature alloys have been produced for supercharger blading.

Parallel to the development of gas-turbines for aircraft is one for land and marine service. A 2000-hp experimental gas turbine was assembled late in 1945 and is now undergoing tests. This unit is remarkable on two counts. It burns low-grade fuel (Bunker C) because it uses no heat exchanger or regenerator, which tends to clog up with such fuels. The other factor of note is its compactness. It occupies—overall—less than 500 cubic feet (90 square feet of floor space). The turbine alone occupies but 150 cubic feet. The unit operates on the open-cycle principle, with 1350 degrees turbine inlet temperature.

As a new type of motive power, primarily for the field of transportation—in the air, at sea, and on the rails—the gas turbine stands at the threshold. It has an assured future in the field of power development.

A section of the control room of one of the gas-turbine laboratories.



mostly for radar. From the Westinghouse plant that before the war was proud of a maximum annual production of 150 000 distribution transformers came, during the last two years, over a half million of these small and entirely new units. So great was the military need for radar and radio transformers that one and three quarter millions of the wound cores (type C) of grain-oriented Hipersil were provided to other transformer builders.

Radar as a business will continue to be sizable. In addition, the experience gained with radar is a valuable legacy to television, railway-signalling, power-line carrier, and electronic heating.

The types of transformers built for radar are multitudinous, but a few serve to show their diversity and the ingenuity required in their creation. One, for an airborne radar set, was no larger than a cigar box and weighed but four pounds, yet it delivered 225 kw during the pulses that lasted from one half to five millionths of a second and were repeated between 200 and 800 times per second. The unit was hermetically sealed, completely oil filled under high vacuum. To keep the unit full of oil at all times, a sylphon bellows (of thin corrugated alloy) was built into it to absorb changes in oil volume caused by variations in temperature or barometric pressure. Much credit for the small size and weight goes to extremely thin (two thousandths of an inch) grain-oriented Hipersil wound-type cores.

Not only did the unit contain the pulse transformer but also a filament transformer. This transformer, contained in a porcelain well on top of the metal case (to reduce electrostatic capacity with the pulse transformer), had a voltage ratio of 115 to 12.6 volts but had to be insulated for 15 000 volts to ground.

Sylphon bellows have become very useful to transformer builders. In fact one radar transformer used a bellows as most of the external case, thus saving valuable space in an airborne set. It weighed but three pounds complete, yet its pulse unit delivered 180 kw during pulses as short as one fourth of one millionth of a second and repeated 2000 times per second.

A three-phase, 400-cycle transformer of abnormally large capacity, 3.9 kva, weighed but 69 pounds, largely because of the high flux densities possible with thin-gauge Hipersil cores. Crammed into a case measuring only 8 by 6¼ by 17½ inches were the three independent phase cores and windings, a sylphon bellows, and insulating oil, inserted under high vacuum for maximum strength.

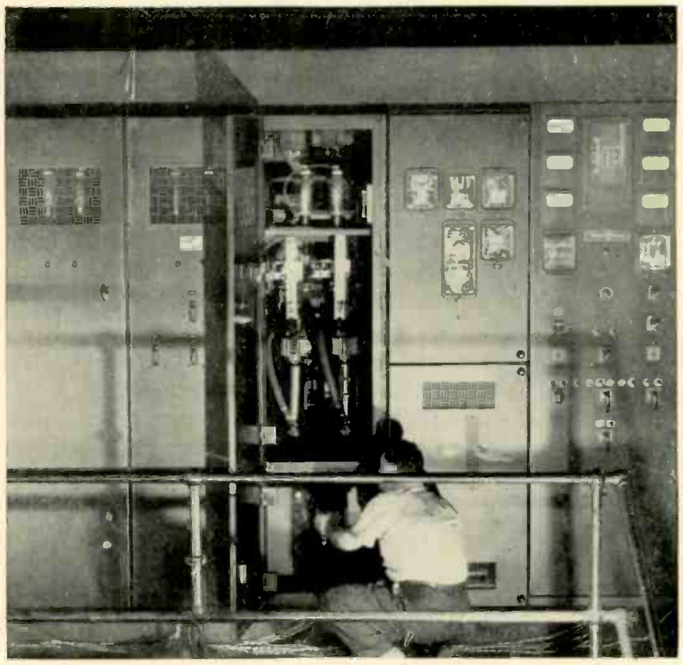
One radar equipment required as filament supply a transformer of low capacitance, something less than 40 microfarads. To obtain this and to secure the 50-percent reactance necessary to hold short-circuit current down to twice normal current, the primary and secondary windings were placed on opposite ends of a wound Hipersil core. To assist in the matter of high reactance, another wound core with controlled air gap encircles the primary and the portion of the main core enclosed by it. The problem was further complicated by the fact that the secondary had to be insulated for 15 000 volts to ground, although only five volts appeared across its terminals.

Electronic Field Supply for Generators

The powerful generators of a central station would be valueless if the constant transfusion of life-giving strength from their exciters were to cease. Yet exciters too must be stopped at intervals for brush maintenance and the usual repairs necessary for rotating machines. Electronics with its lack of moving parts and its sturdy reliability is being considered for many roles such as these.

In its latest assignment, it will supply complete field excitation for an 81 250-kva turbine generator at the Springdale generating plant of the West Penn Power Company. Exciters of this type have been used before for synchronous condensers but never for such a large installation in which continuity of power is so vital. It is expected that time out for repairs or maintenance will be reduced to new lows by the electronic means of field excitation.

Six ignitron tubes will be energized from a six-phase diametrically connected rectifier transformer. This in turn is supplied directly from the generator buses themselves. Primer excitation to be used in starting will be obtained from a separate motor-generator set. Depending upon the conditions at individual locations, other sources for starting might be a-c power taken from station buses and introduced into the ignitron system or battery voltage applied directly to generator field.



The electronic tubes mounted in these steel cubicles will supply the entire field excitation for an 81 250-kva generator at the Springdale generating plant of the West Penn Power Company.

Regulation of the generator-output voltage is fast and sensitive with electronic-field supply. Line-to-line voltage between all three buses is stepped down by potential transformers and converted to direct current through Rectox units to operate Silverstat regulators. These in turn vary the bias on thyratron tubes to control the firing time on the main ignitrons. A constant a-c voltage is superimposed on this variable-bias voltage. As the d-c component is increased, the a-c wave rides higher to cut the critical curve of the thyratrons earlier in each cycle, thus making the ignitrons pass current over longer portions of time. This increases the main-generator field current to raise the generator-output voltage.

The usual maintenance problems attendant upon rotating equipment are lacking since the only moving parts are leaves of the Silverstat regulator. Ignitron tubes can be replaced while the unit is in operation, in fact, any two diametrically opposite tubes can be removed simultaneously and the unit will continue functioning while new tubes are being installed.

Blade Tips—Approaching 1000 Mph

In one sense, in a steam turbine the last shall be first. The limit to volume of steam flow, and hence to economical capacity, is set by the length and diameter of the blades in the last row. As the blades get longer, the centrifugal forces tending to pull them out by their roots become enormous. Also the velocities of the blade tips at high turbine speeds become very large—which emphasizes the need for the best airfoiling.

Heretofore, the longest blade for the 3600-rpm turbines has been 20 inches. The new blades, soon to undergo tests, are 23 inches long. At 3600 rpm this will mean a blade-tip velocity of 1520 feet per second—one third greater than the speed of sound. They will make possible steam turbines that can deliver 40 000 kw from a single-cylinder 3600-rpm condensing unit or 80 000 kw from a tandem 3600-rpm condensing unit. These outputs compare with 30 000 kw and 65 000 kw of the present largest 3600-rpm machines.

Aircraft Power Generation at Wider Speeds

Electric generators on airplanes are now being asked to provide full power over a speed range of three to one instead of two to one. The top speed remains about the same—9000 rpm. But full output is expected at speeds down to 3000 instead of 4500 rpm. This trend results from a desire to supply more of the loads during taxiing, landing, and cruising from the generators instead of from the battery. This changed requirement increases the difficulty of providing good voltage regulation, particularly at the high speed. Mechanically the generators have been improved to make them easier to mount and dismount. A new mounting flange has been designed so that holding bolts can now be put into place before the generator is slipped into its operating position.

Single-Element Distance Ground Relay

Distance relays have long been used to provide protection against phase-to-phase faults. This type of relay, however, has not been used extensively for ground faults. The ground fault is quite different from a phase-to-phase fault, and generally produces higher values of fault resistance. This requires a reactance element to measure distance accurately. But a reactance element may operate improperly on normal load conditions and, therefore, a supervising impedance element is required. The impedance element can't "see" far enough to let the reactance element exercise its full capabilities of accurate distance measurement. Furthermore, a selector function is required to discriminate between single-phase-to-ground and two-phase-to-ground faults because on the latter fault the reactance element may often come up with the wrong answer.

All of these difficulties are surmounted in a new type ground-relay system wherein only one distance-measuring relay is required instead of three.

The negative-sequence selector relay previously developed for single-pole tripping is used to connect the distance-relay potential circuits to the faulted phase. This same selector relay discriminates between single-phase and two-phase-to-ground faults. The distance relay is energized by residual current and consequently the impedance supervising element is not required and no limitation is placed on the reactance element.

A Telemeter without Commutator

A robot, referred to as a telemeter, reposes quietly in some isolated part of a power system, counting the kilowatts at that spot. It reports to some common point the sum as a set of impulses, perhaps to be totalized with the reports of similar instruments. This telemeter has heretofore consisted of a commutator driven at a speed proportional to the quantity being measured. The rate of interruptions or pulses produced by the commutator is the transmitted indication of that quantity. But brushes drag on a commutator with varying amounts of pull. As the speed decreases, the drag becomes more pronounced. Also this braking action differs in the two directions of rotation.

A photoelectric scheme removes troubles from the telemeter transmitter. Two discs with holes are rotated, one at constant, fixed speed, the other at a speed proportional to the quantity measured and in a direction depending on the direction of power flow. A lamp shines upon the rotating discs, casting light, when the holes are coincident, on a photoelectric tube on the other side. The result is a series of light impulses that are noted by the phototube, amplified, and transmitted. As the metering disc changes in speed or direction due to fluctuations or reversals in the flow of power, the number of pulses transmitted changes accordingly. If no power is being transmitted, light impulses of the standard or base rate are produced. The resulting signal can thus be interpreted both as to direction and magnitude of the power flowing.

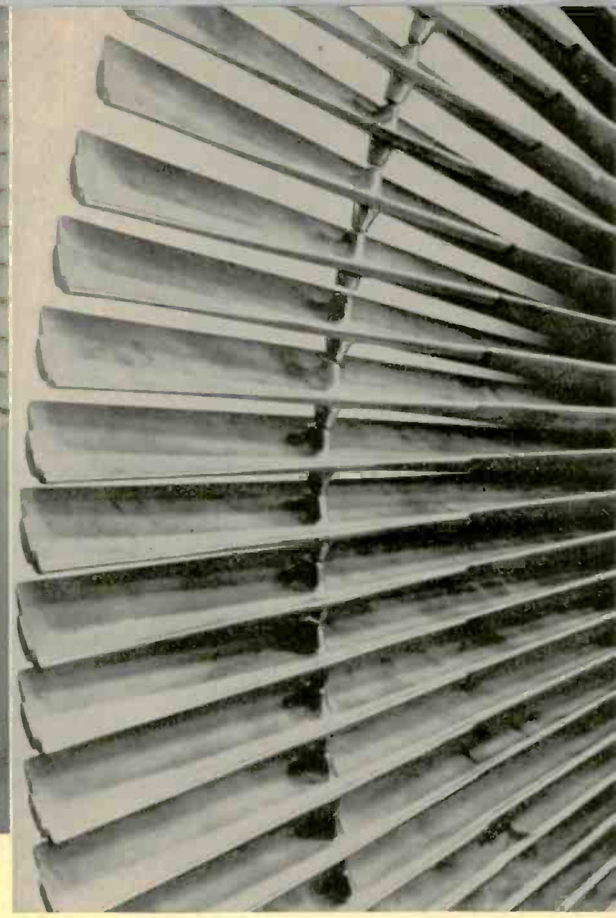
Power-Line Carrier Channels Doubled by Single Sideband

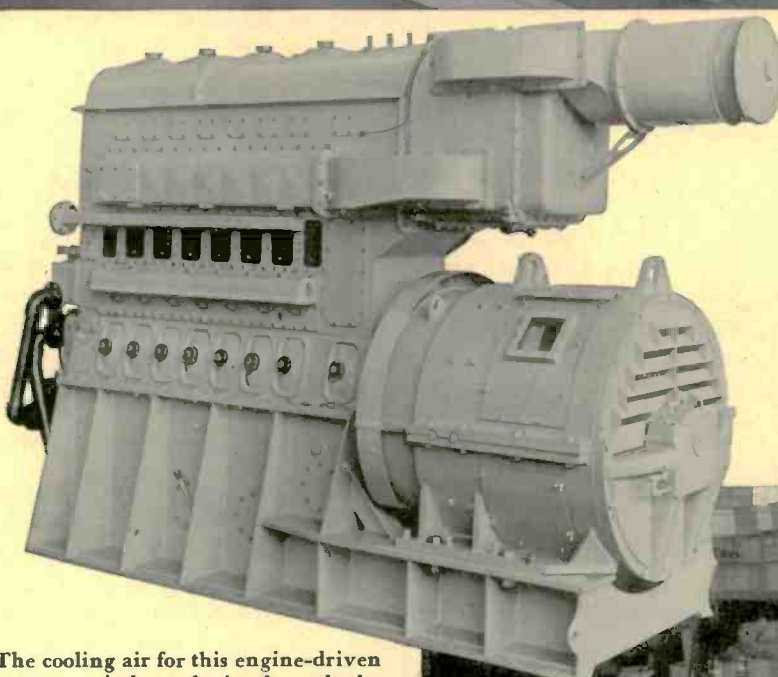
The solutions of many problems are obvious after they have been discovered. Single-sideband carrier transmission over power lines has been one example. Its principles were well known twenty years ago, and it has been applied almost exclusively to telephone circuits. But for general use on transmission lines the equipment was too bulky, too complex. Furthermore, the system was not needed. Its greatest single advantage is its economy of frequency width. Only recently has the crowding of the frequency spectrum by carrier services become acute. But the problem of how to provide more channels for power-line carrier is now before the engineers of some systems. Designers of carrier apparatus have risen to the demand and have produced a novel single-sideband scheme of the requisite simplicity.

The conventional single-sideband system has been to generate a carrier frequency and to modulate that frequency with the signal to be transmitted. The result was the carrier frequency and the two sideband frequencies (the carrier plus the signal frequency, and the carrier minus the signal frequency). Then for single-sideband transmission, the carrier and one sideband had to be eliminated. This required elaborate filtering.

The new system neatly circumvents these complications by generating only the desired single sideband, creating nothing that must be eliminated later. The crux of the scheme is to use two sets of small dry-type rectifiers and some phase-shifting impedances, all connected in such a way that only one sideband of frequencies appears in the output with no need to cancel out other frequencies.

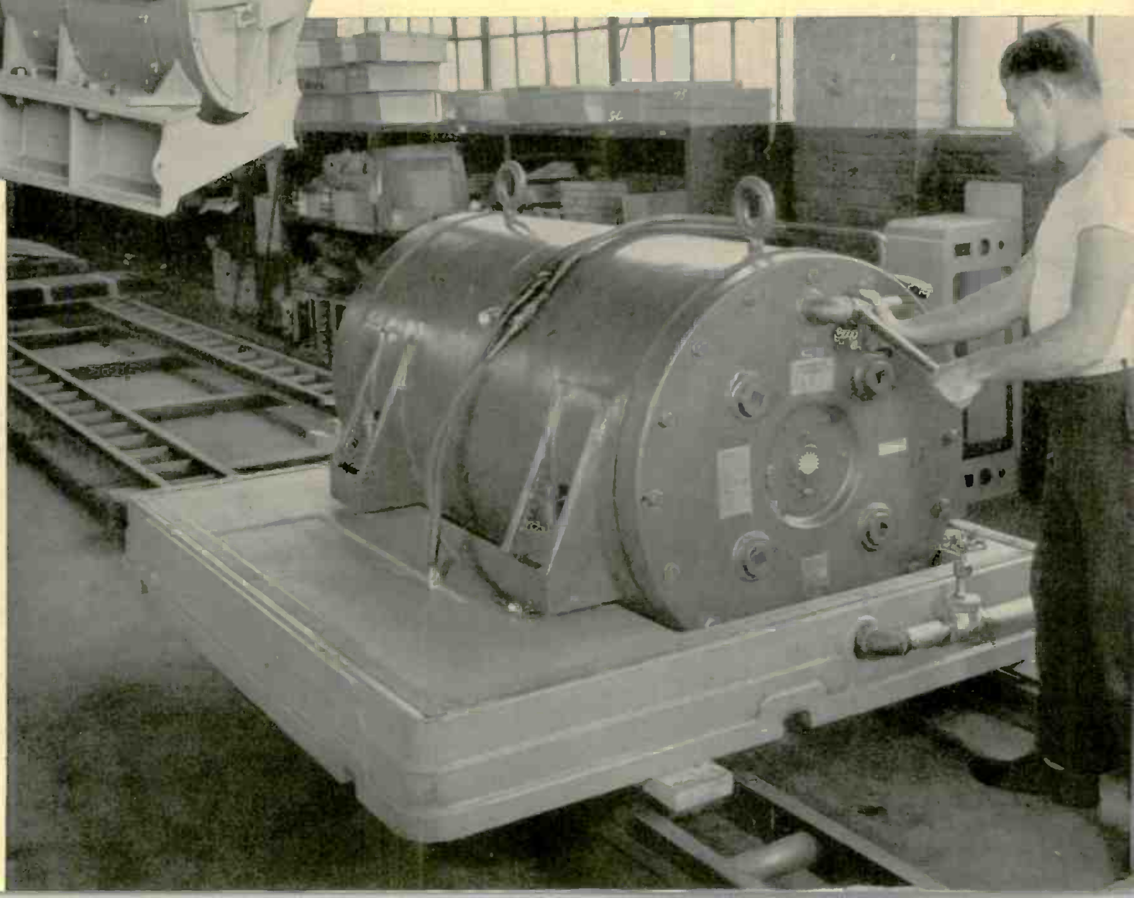
In addition to having the effect of doubling the frequency spectrum available for power-line carrier (sometimes the gain is more than two to one), the new single-





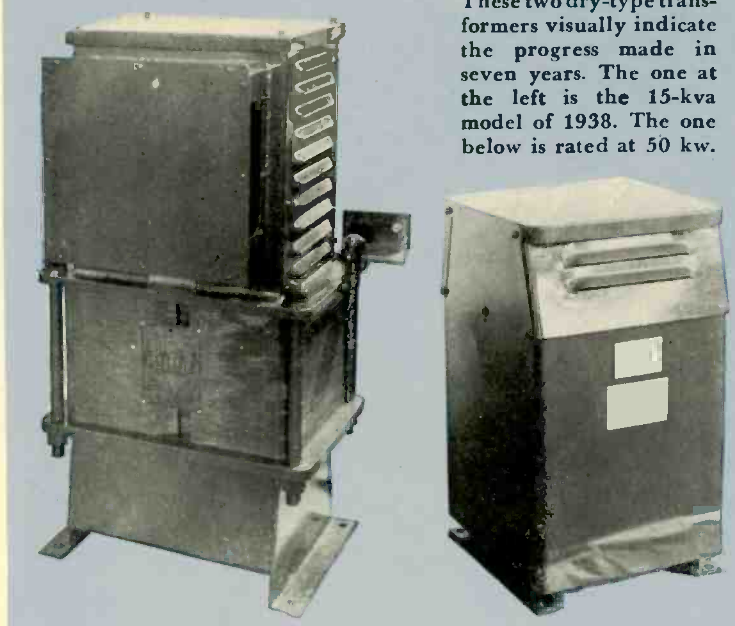
Selenium rectifiers of improved performance are made in this air-conditioned plant (upper left). On the basis of two years' life, this new selenium rectifier has a low rate of aging, can withstand heat, is extremely small, and is light in weight. It permits certain uses for dry-disc rectifiers not met by the copper-oxide variety.

The long turbine blades in the exhaust-end rows must be lashed together near the midsection. This was done formerly by welding to the blades themselves. New forging techniques make it possible to form bosses on the blades to which the welding can be performed without adversely affecting the blade structure itself.

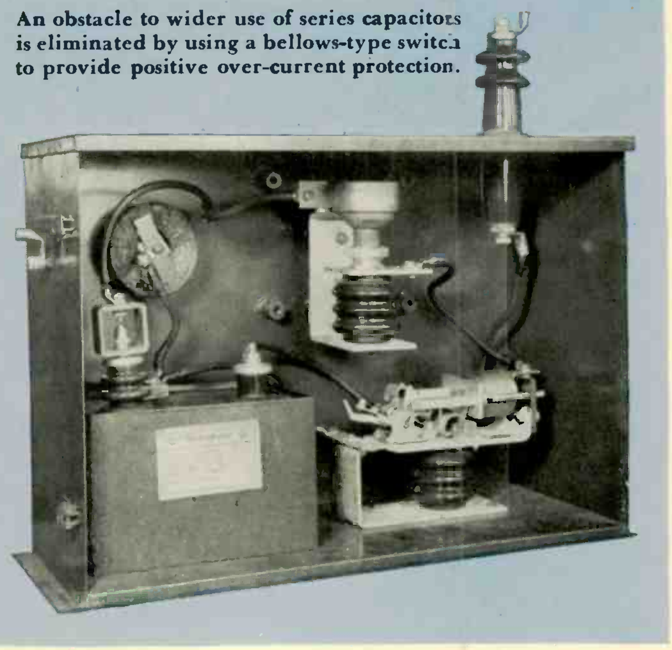


The cooling air for this engine-driven generator is brought in through the collar next to the engine, reversed by a fan, and expelled through the louvres over the commutator. This solved the requirements of bringing in the air from the end opposite the commutator and not drawing in oil mist.

High-frequency rotating generators for induction heating have always had a troublesome heating problem. The inherently high core losses at these frequencies require lots of cooling air. Because of the many poles, small teeth, and high speed, these hurricanes of ventilating air produce an ear-crippling shriek difficult to deaden. A low noise level is important. In a new generator, the noise problem was solved by enclosing the machine and cooling it with water. The enclosed, water-cooled machine is no larger than the air-cooled one. (Photo courtesy of Ohio Crankshaft Company.)



These two dry-type transformers visually indicate the progress made in seven years. The one at the left is the 15-kva model of 1938. The one below is rated at 50 kw.



An obstacle to wider use of series capacitors is eliminated by using a bellows-type switch to provide positive over-current protection.

sideband carrier provides a gain in signal-to-noise ratio of nine decibels. The single-sideband system can be added to modern Westinghouse amplitude-modulated equipments, or A-M systems can be installed with the thought of adding the sideband equipment later when more channels for carrier are needed for expanded operations.

Air-Cooled Marine-Distribution Transformers Grow Smaller

A REVIEW of progress during the war years in dry-type distribution transformers such as used on naval vessels shows constant improvement in performance and weight at a rate almost unparalleled. The present 50-kva unit weighs less than the 15-kva model of 1938, and is considerably smaller in occupied space. Performance has been improved and weight has been reduced by use of special Hipersil-core materials, specially developed class-B insulation, and operation at the higher temperatures permitted by them. The latest units have been standardized to the point where their mountings and connections are interchangeable among all manufacturers.

Keep the Oil Clean

GEARS are in some ways like people. The large majority of the citizens of the gear world are healthy and perform normally with only occasional minor distress. Then local epidemics of trouble appear. Sometimes the cause is readily diagnosed and a cure easily effected. In a few cases, the ailment—usually well isolated and extremely local as to occurrence—defies analysis.

Engineers operate on the logical premise that, as among humans, there is always a cause for every malady. Last year they ran to earth the reason for a most mysterious but annoying local epidemic of excessive gear wear. As so often the case, the cause was a simple one. Fly ash or other abrasive dust was getting into the lubricating oil.

That hard dirt particles in gear lubricant are not good is not a new idea, of course. But it had not been generally appreciated how little abrasive dust—fly ash, ore dust, or even log-bark dust—need be present for consequences to be serious. In one case, gears of a turbine-driven induced-draft fan were wearing and becoming noisy in a matter of days. Analysis of the lubricating oil indicated a small amount of fly ash. Applying adequate oil filters completely solved the trouble.

Higher-Voltage Indoor Switchgear

AN installation of switchgear in South America late last fall marked a significant increase in voltage of metal-enclosed, air-insulated switchgear used indoors. This switchgear is for 34.5-kv service at a hydroelectric station. It makes use of the newest developments in compressed-air circuit breakers, which have a current rating of 1200 amperes and an interrupting capacity of 1½ million kva.

Improving the Appearance

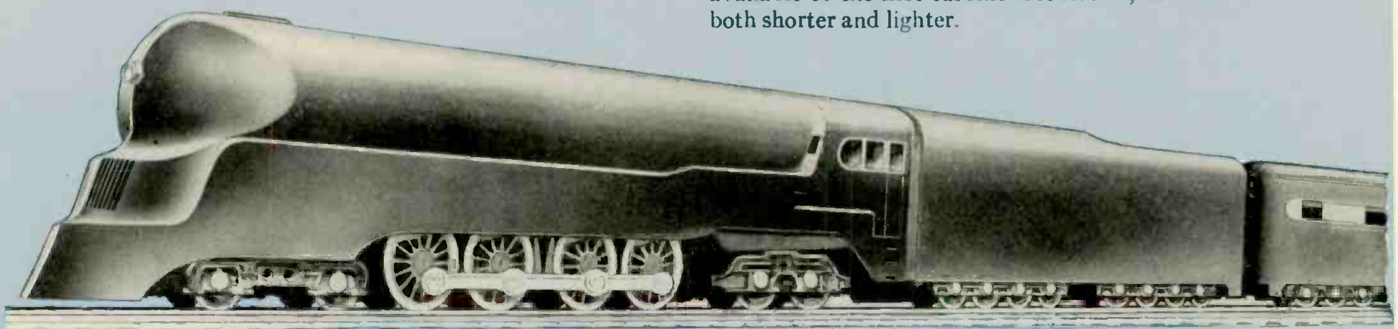
In the construction of new homes, appearance gets a high rating. This is carrying over to the power lines that serve them. Therefore, much attention is being given to an economical means of carrying the wires and equipment underground. Westinghouse is studying this problem in conjunction with several utility companies, and a practical solution has been developed. This involves mounting the transformer in a two-thirds buried

Geared-Turbine Locomotive Proves Itself

In the past twelve months the geared-turbine locomotive, although a radically new railroad motive-power unit, has given convincing evidence that the hopes of her creators—Pennsylvania Railroad, Westinghouse, and Baldwin engineers—were justified. After a few trial runs in revenue service in eastern Pennsylvania the geared-turbine unit began making regular runs in high-speed passenger service between Crestline, Ohio, and Chicago, pulling such blue-ribbon trains as the Broadway Limited and the Trail Blazer with a high record of "on time" performance. By last December first the locomotive had rolled up a total of about 43 000 miles in revenue service.

Early in the year work was begun on three turbine-electric locomotives for new streamlined Cincinnati-to-Washington trains of the Chesapeake and Ohio. Each locomotive will have one 6000-horsepower steam turbine driving four d-c generators. Each of eight axles will be separately motor driven.

The next edition of the geared-turbine locomotive is expected to be a 7000-hp unit completely streamlined. Because it will use alloy steels and other war-restricted materials not available to the first turbine locomotive, the new one will be both shorter and lighter.



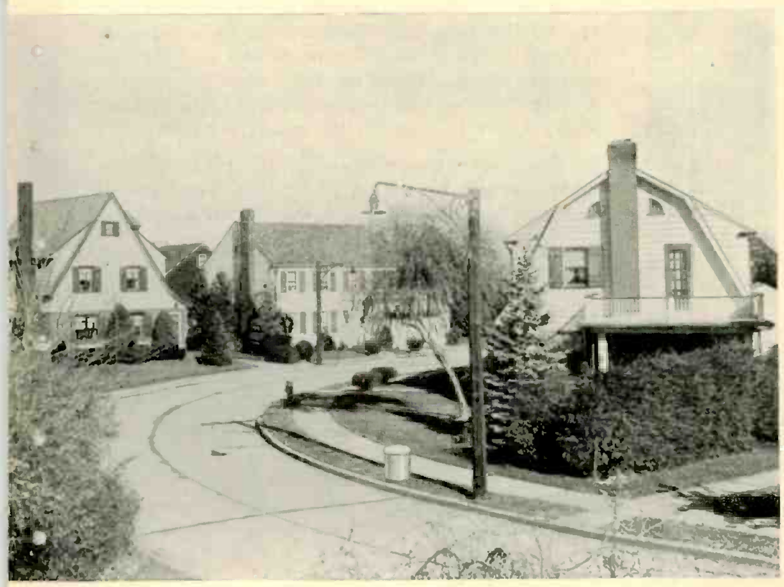
Extension of the metal-enclosed, air-insulated construction to these voltages for indoor service continues a trend that has been apparent for several years. The application of these breakers results in space saving, seals the apparatus from weather, results in better and simplified maintenance, and in general helps in realization of the economies inherent in these higher distribution voltages.

More Capacity for Railway-Electrification Breakers

Circuit breakers have had to grow in interrupting ability as the systems behind them grew in capacity. Breakers for use on 11-kv, 25-cycle railroad-electrification systems illustrate this well. Twenty years ago railway breakers were required to interrupt only 15 000 amperes. Then as the generating units and interconnections grew, breakers capable of interrupting 50 000 amperes were called for. To achieve this, the then new De-ion air circuit breaker was employed. Last year in anticipation of further 25-cycle system growths, two breakers capable of handling short-circuits of 65 000 amperes were built and installed. These were improved, compressed-air breakers capable of extremely rapid operation of the mechanical parts, resulting in high speed of arc interruption.

of the Street

concrete-and-steel, dome-shaped cell, open at the bottom for drainage. Particularly suitable because of their small dimensions are the Hipersil distribution transformers. Projects now under consideration involve 15- and 25-kva transformers, but ratings as high as the standard 50-kva Hipersil unit can be mounted in a cell with 30-inch overall outside diameters. Enclosure involves sacrifice in capacity of not more than 10 percent.

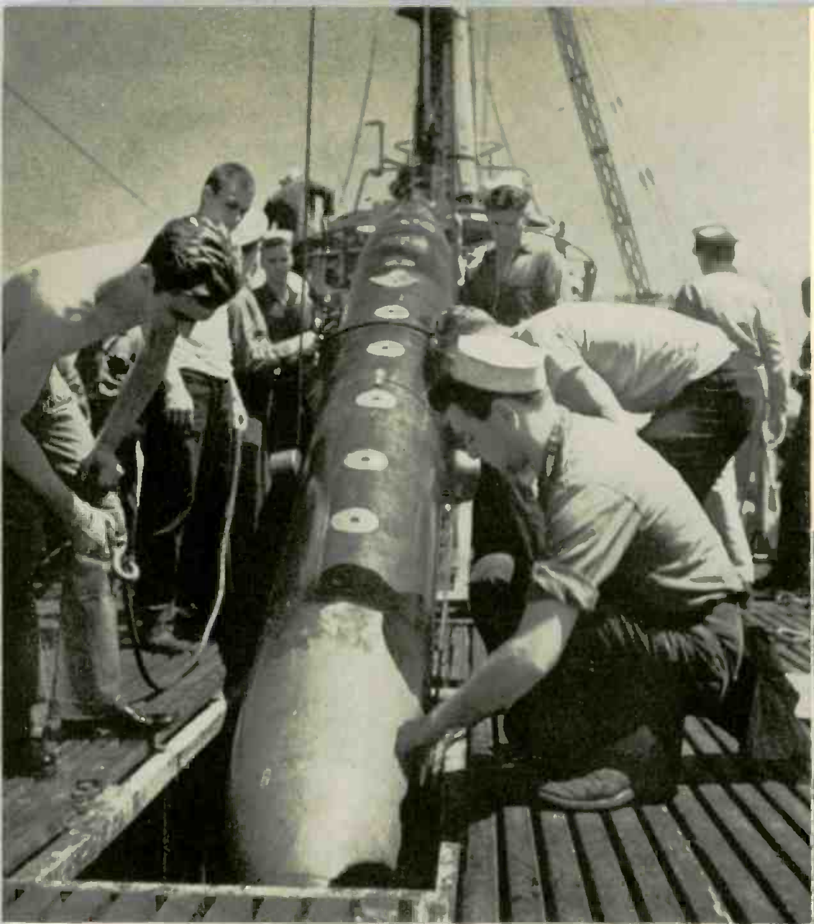


Greater Kva for Breakers

The interrupting ability of high-voltage circuit breakers has been increased again. A number of 230-kv breakers (196-kv insulation) capable of interrupting three and a half million kva in 3 cycles and reclosing in 20 have been built recently. Operation of the breakers is by pneumatic mechanisms that reverse the contact movement during the opening stroke, for a reclosing operation. The interrupting elements of this breaker, the multi-flow De-ion grids, the new mechanism, and a new auxiliary grid—all have made it possible to extend the use of 20-cycle (1/3 second) reclosing up to 230-kv systems, with gains in system stability and with extremely fast interrupting times.

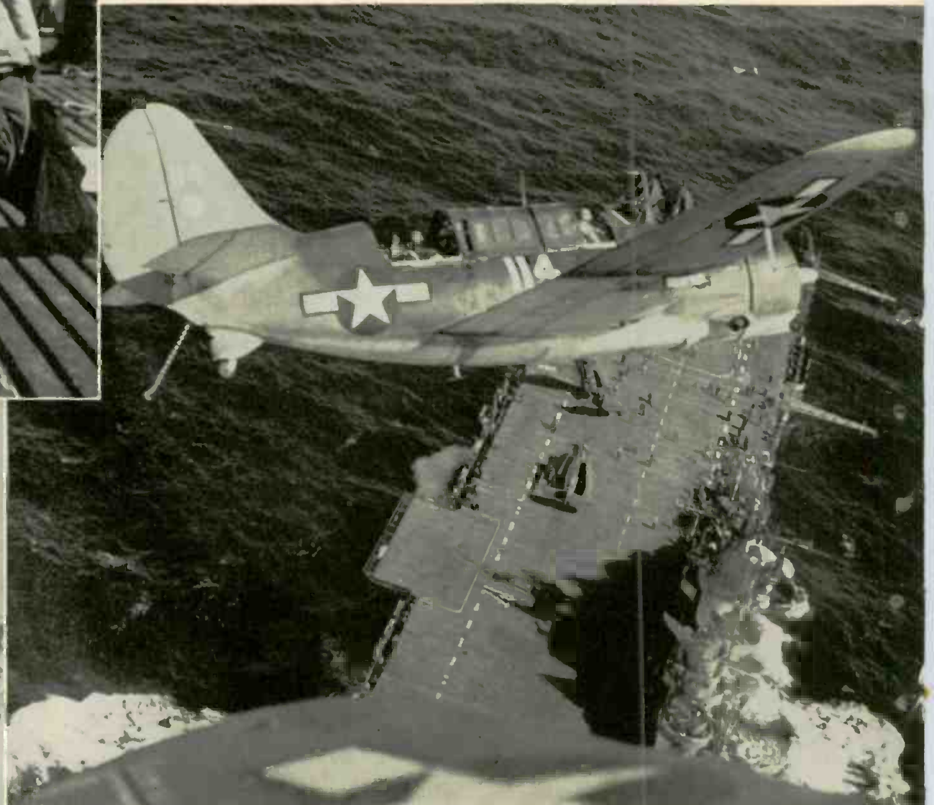
Smaller Network Protector

The benefits of the secondary network for power distribution have been extended to the edge of towns by the development of a new network protector for light duty. It is smaller and lighter by one half than the previous light-duty protector, which now becomes a medium-duty unit. Simplifications have been possible because of the relatively light demands made on it by the service intended. For example, no phasing relay is required because the protector does not need to be sensitive to small power reversals. The unit is rated at 300 and 600 amperes, 250 volts. It can be mounted on poles adjacent to existing transformers or on new installations as an integral part of the transformer itself.



Aids to

Stories of the engineering behind the weapons that helped achieve victory would fill volumes. But a few that were so potent on the battle lines as to require complete secrecy throughout the war are due special note.



The electric torpedo stands well up in the list of the Navy's most successful weapons. Although its use began in September, 1943, by V-J day it had sunk nearly 400 Japanese ships, totalling nearly two million tons. The electric torpedo, having no tell-tale wake of bubbles, permits a completely surprise attack. All electric torpedoes were made by Westinghouse in its transformer factory. The view, upper left, shows one ready for test.

Jutting from the carrier's midsection is the deck-edge elevator by which planes can be shuttled between hangar and flight deck with dispatch.

As our fleet closed on Japan, proximity fuzes played a big part in stopping the suicide attacks.

The Essex, first of her class of aircraft carriers to be commissioned, established a remarkable distance record. She covered a quarter of a million miles of ocean—averaging 240 miles a day for every day since commissioning, including the very few days in port, until the war's end. This is more mileage than would normally be expected in the entire lifetime of a capital fighting ship. To the immense satisfaction of the Navy and of the Westinghouse men who designed and built her propulsion machinery, the turbines and gears have required only routine maintenance.

Victory

Saving Seconds Aboard the Carriers

IN the closing months of the fight with Japan the Navy did many things "not in the book." Big carrier fleets approached closer to Japanese-held land bases than had been considered possible—and got away with it. One thing that contributed mightily to this is the ability of a big carrier of the Essex class to get its planes up into the air quickly. The elevator system for shuttling planes between hangar and flight deck is a key factor. The dispatching and landing of planes from an aircraft carrier must be performed with almost split-second timing of crews, pilots, and the ship itself. A few wasted seconds may cost the lives of pilots, the loss of planes, even damage to the carrier or jeopardy to the mission.

On the older type carriers, each time the midship elevator carrying airplanes left the flight deck for the hangars below, a large hole appeared in the middle of the flight deck. During this time planes could neither take off nor land, which clearly was a serious matter. Furthermore there was always the possibility that the elevator might be so badly damaged while in the lowered position that it could not return to the flight deck, making the runway unusable. An elevator near the middle of the ship was absolutely essential to facilitate hangar operation as well as for strategic reasons. The Navy was posed with the problem of transporting airplanes between hangar and flight deck without creating a gaping hole in the landing and take-off area.

The solution was to hang the elevator over the side of the ship—in short, a deck-edge elevator. Several factors greatly complicated this problem. A platform 60 feet long by 34 feet wide, an area on which a thousand people could stand, and capable of lifting an 18 000-pound load, must be overhung from the side of the ship with no chance for counterweighting and operated by a driving mechanism within the ship. Furthermore, the platform and supporting structure must be collapsible against the side of the ship when not in service to enable the ship to pass through the Panama Canal. In heavy seas the ship may roll to such an extent that the platform and supports are submerged. When this happens, with the carrier knifing through the water at high speed, the structure is smacked with a tremendous force that must be absorbed without injury to itself.

For this deck-edge elevator, a radically different type of hydraulic drive was created. This not only provides means for braking the load, but also returns to the system about one fourth of the energy required for the next lift. Use of a hydraulic mechanism provides an energy storage and partial recovery system by which the peak load on the aircraft's electrical plant is reduced by nearly three fourths.

Many safety features are built into the elevator. Should the steel hoisting ropes be shot away, the platform is gripped tightly by a spring mechanism at the guide rails to prevent a load from being dumped into the sea. Ordinarily the elevator is controlled electrically by an operator at the flight-deck level, but in the event of any electrical failure, it can be operated manually from the hangar deck. All of the aircraft carriers of the Essex class are provided with Westinghouse deck-edge elevators amidships. The performance has been such that many of these features are being applied to the conventional airplane elevators.

A 75-Foot Miss Is as Good as a Hit

BEATING an enemy by increasing his effective size is a stroke of genius. That is essentially what the radio-operated fuze for rockets and bombs accomplishes. With these fuzes, the explosive is fired when the missile gets close to the target; shell and target do not have to make physical contact. What this does to accuracy in anti-aircraft work or to the devastation of anti-personnel bombs must have been astounding, because the radio fuze was credited by the services as being second in effectiveness "only to the atomic bomb."

Several types of proximity fuzes, as they are called, were developed and used. Two of the most interesting and the most deadly were a fuze for use with such missiles as anti-aircraft rockets, and one for use on bombs. The control features of the first fuze are included in the nose of the projectile, and the assembly is no larger than a pint milk bottle. In it a tiny radio set establishes an electric field about the flying missile. As the fuze is advancing, distortion of this field by proximity of a metallic target, say an airplane, is detected by it and the explosive circuit triggered. Thus a rocket can be set to explode as soon as it gets within some desired distance of an enemy plane—say 75 feet—sending a shower of high-velocity shrapnel in all directions.

The second type of fuze cannot arm itself until after the bomb has been dropped and reaches a certain speed. The source of electrical energy used supplies suitable voltages for filament heating and plate potential for acorn-size radio tubes. A continuous wave is transmitted, which is reflected by the approaching earth. This reflected wave, by Doppler effect (the varying pitch of the whistle of a passing locomotive is an example) creates a beat note. When this reaches a preselected strength, a thyratron tube suddenly discharges, the current actuating the firing mechanism. The fuze can be set to operate the detonator for various selected heights above the ground to give the most effective coverage.

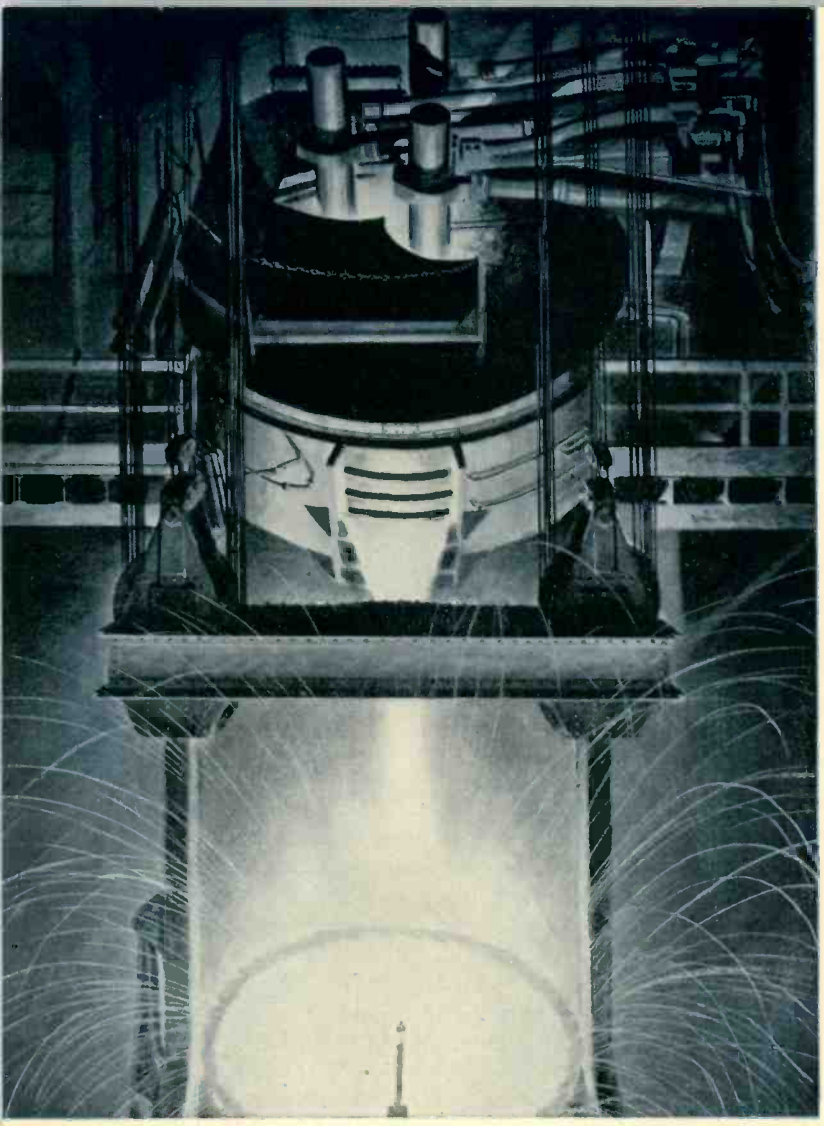
A Motor with a Life of One-Fifth Second

POSSIBLY the strangest request ever made of designers of small motors was for a machine to use with the Navy's long-secret and deadly weapon, the electric torpedo.

The small gyroscope of the control mechanism must be brought from standstill to full speed of 12 000 rpm in 0.2 second. The best universal motor available for the job had been doing it in 10 seconds—50 times too long. Calculations showed the desired motor would have to be 1200 times more powerful. And in a torpedo, space is anything but plentiful. Furthermore the motor was required to declutch or disengage itself from the gyro instantly at the end of one-fifth second, and disconnect itself from the power supply. This was so the motor would not itself introduce error in the operation of the gyroscopic control.

To the credit of the designers of small motors, these difficult requirements were fully met. The motor, which has an instantaneous rating of 22 hp, can be held in one hand. It weighed 8½ pounds, only 1½ times more than the original motor.

If the motor were allowed to run just a small fraction of a second longer, it would reach a rotating speed that would produce centrifugal forces of hundreds of pounds—so great that the motor would fly apart—literally explode!



For the electric-arc furnace new controls have been devised.

Uses

Some phases of the applications of electricity have not yet fully recovered from lack of engineering time available for them during the war, but, in the aggregate, engineers are finding interesting new ways of employing electric power and improving its well-established uses.

New Types of Arc-Furnace Controls

Two additional types of arc-furnace regulators have joined the first—the balanced-beam regulator, which for two decades has had the field pretty much to itself. These are a rotating regulator of the Rototrol type, and an electronic control.

No one had any particular quarrel with the performance of the balanced-beam device. It has done a creditable job of holding under tight rein the electric-arc furnace, the most demonstrative of electrical machinery. But each of the three types has some particular characteristics that make it more suitable in a given case.

All three controls do the same fundamental job. All maintain arc energy as the operator wishes by causing the motor-driven electrodes to raise or lower as the activity of the thawing charge, usually scrap, and turbulence of the subsequent liquid dictate. Likewise they adjust for electrode wear. All three controls start with a measurement of arc voltage and arc current, whereupon they achieve their common goal by different means. Of the two new regulators, the rotating one appeared first. It is an adaptation of the Rototrol principle, which got its start in life a dozen years ago by controlling the speed and accurate landing of elevators and which has since been applied to the control of position, speed, voltage, current and other quantities in literally dozens of applications. Basically it consists of a small three-machine, motor-generator-motor set with special interrelated magnetic fields that cooperate to give an enormous amplification of the control indication and great precision of control over the quantity in question (in this case, electrode position). The variable-voltage control of the electrode motors provided by the rotating regulator is advantageous when there is much activity of the electrodes.

The electronic regulator does its work by using dry-type rectifiers to obtain a measure of arc current and voltage. These outputs are amplified and impressed upon thyratron tubes, the d-c output of which controls the electrode motors. Like the Rototrol, this regulator responds rapidly to actively moving electrodes. The electronic control has no moving parts and provides instantaneous response.

Twin-Motor Drives for Sheet Mills

Several years ago steel mills were built with one d-c motor on each roll. It was a twin-motor drive, one motor driving the top roll and the other the bottom roll. The system worked very well indeed. But that was on blooming mills, where the ingots are enormous rectangular chunks of steel several feet on a side. Whether one motor tended to turn a trifle faster than the other mattered little.

But now two big mills are being equipped with twin-motor drives that are to roll steel sheet down as thin as five thousandths of an inch. Tin-can stuff! Here no difference in motor speed can be tolerated; perfect synchronism is essential.

Furthermore the speed characteristic of each machine is flat, i.e., there is substantially no variation in speed with load changes. Getting two d-c machines with flat characteristics to share load is a very different thing than with those having drooping characteristics.

This feat is being accomplished on four twin-motor drives for two cold-strip mills by an adaptation of a scheme developed years ago for securing parallel operation of two or three d-c generators furnishing power to reversing blooming mills. As its principal element it employs a zero-voltage generator with two fields, each in series with the series field of one of the twin-drive motors. The voltage of this little generator remains zero until one of the twin motors takes more load than its mate, whereupon a correction voltage of the right magnitude and polarity is created to effect speed recovery.

Reactor Control Permits A-C Hoists

The hope of factory owners to eliminate need for a direct-current distribution system around their plants is in fair way to being fulfilled. The last stronghold of constant-voltage d-c motors in most factories is for overhead cranes, where wide speed ranges and dynamic breaking obtainable with series machines are desirable. But a new system by which a large variation in speed at different loads and improved lowering characteristics are possible with induction motors has been developed. It is accomplished by doing just what electrical engineers generally seek to avoid—unbalancing the voltages of a polyphase system. By the use of a reactor in

# of Power

one primary line, the voltages applied to the terminals of a three-phase wound-rotor motor are deliberately unbalanced, causing the motor to operate at increased slip for reduced hoisting, and for better control of lowering speeds. With a saturable-core reactor the amount of inductance inserted can be varied from a little to a lot. When a small amount of reactance is applied to the circuit, the motor operates in the usual manner. The more reactance that is introduced into one primary line, the more nearly is single-phase operation approached. Because the reactor is continuously variable and because its impedance varies with speed as well as with the switch position selected by the hoist operator, flexibility of power and speed are available while handling a load or a hook carrying no load at all.

Wide Speed Variation from D-C Motors

ASK any engineer what speed variation can be obtained by field adjustment of a standard d-c motor. He'll tell you the ratio of maximum speed to slowest speed is about four to one. It has been that ever since the first d-c motor was built, a half century ago. Greater speed variations have required some additional complicating feature, such as variable-voltage control with attendant changes in horsepower output.

But now, four-pole d-c motors that are essentially standard are providing twice the speed range—or about eight to one—with no change in rated output at any speed. Essentially this is accomplished by separate control of two of the four field coils. Two adjacent poles are energized in the usual manner to supply a nearly constant magnetic flux. The remaining two poles, by a special resistor, are varied in flux strength from maximum, down to zero, and finally reversed. Thus the combined field flux can be changed from a value representing the sum of all the fields to the much smaller total of their difference. Since the armature voltage does not change throughout this entire range, the horsepower output remains essentially constant as the speed varies.

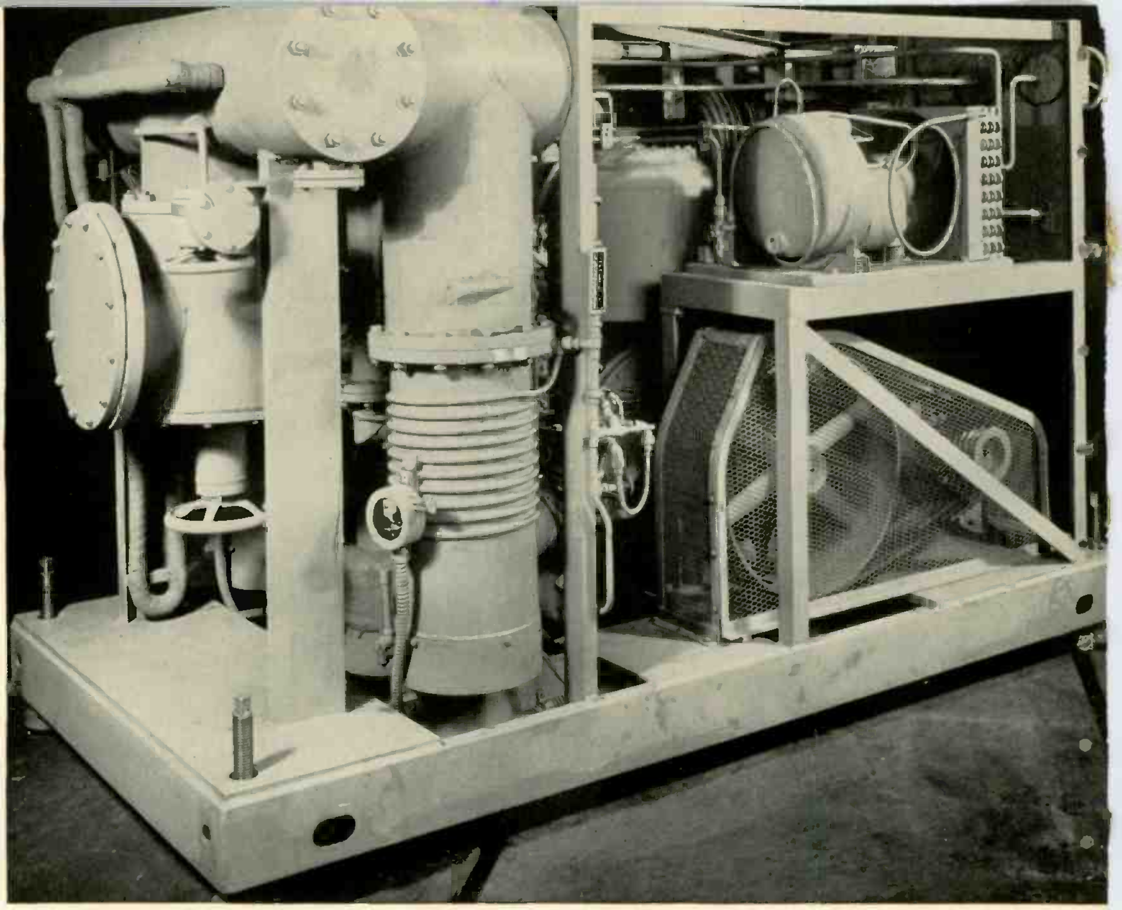
The wide-speed-range motor is extremely useful on many machine-tool applications where constant horsepower output is needed over wider and continuously adjustable ranges than have heretofore been available from a four-to-one motor. It will eliminate in these cases the need for many of the gears previously required.

Molecule Pump

THE ether—in which there is supposed to be a complete absence of matter—is an interesting hypothesis. It is unobtainable—but engineers have come surprisingly close to it. In the laboratory, with refined equipment, vacuums of one millionth of a millimeter (10^{-6} mm) of mercury have been drawn. Sea-level air pressure is 760 million

An invisible and harmless barrier of electrical impulses keeps fish from swimming out of bounds in this channel by a device made by the Electric Fish Screen Company of Hollywood, Calif.

Extremely low vacuums are obtained by diffusion-type pumps. Above are the internal cones of two sizes of diffusion pumps.



times greater. Pressures down to one hundredth of a millimeter of mercury (ten microns) are commonly obtainable with rotary-type pumps. Such pressures, regularly maintained in vacuum tubes and mercury-arc rectifiers, have been generally low enough for industrial purposes, before the war anyway. But certain war-production processes—still secret—demanded much lower pressures, and in enormous volumes. Huge pumps capable of drawing vacuums of one millionth of a millimeter of mercury were required in quantity.

No rotary pump can do this job alone. Engineers fell back on a pump principle previously known only in laboratories and in very small, special industrial units. It is a pump operating without moving parts on the diffusion principle.

The pump consists of a vacuum-tight cylinder with water-cooling coils on the outside, inside of which is located a jet assembly consisting of one or more jets in series. A pool of oil at the base of the cylinder is heated and the oil vapor passes up through a central pipe in the jet assembly and, on reaching the top, is deflected downward by the jet as a cone-shaped spray against the wall of the cylinder. This wall of downward moving oil vapor traps and carries out the gas molecules from the region above. The oil vapor is then condensed by the water-cooled wall of the outer cylinder and returns to be used over again. The gas has now become concentrated sufficiently so that it can be pumped off by a good rotary pump. Rotary pumps and diffusion pumps are used in series, the rotary pumps doing the large-volume portion of the task while the diffusion pumps increase the vacuum to the desired degree.

Locating a Fault after Proving It Exists

One of the problems in making a high-voltage test of any electrical insulation is, having proved a weak spot exists, to locate exactly where the spot is.

Formerly it was the practice when a fault was indicated to remove the high-voltage excitation and connect a relatively low-voltage, high-current transformer to burn the insulation noticeably around the fault. The relatively low voltage of the fault-burning transformer often was not sufficient to re-establish the arc in the fault. In the new set, a fault-burning transformer is connected across the fault immediately after the breakdown at high voltage occurs and before the tiny arc initiated by the high voltage is extinguished. In addition, a high-frequency arc-stabilizing current is used to maintain the arc during the successive current zeros of the 60-cycle power wave.

The high voltage is continuously adjustable from zero to 3000 volts or zero to 6000 volts depending on which range is selected. The high-voltage test circuit can be used without the fault-burning feature when desired simply by the operation of a two-position toggle switch.

Constant Speed from a Variable-Speed Motor

There seems to be a perversity about engineering needs. Sometimes a variable speed is desired from a basically constant-speed machine. Then again a constant speed is sought from one that operates at different speeds. Worthy of note is one ingenious method of achieving from a d-c motor of fractional horsepower a speed held closely constant regardless of normal changes in load, voltage, and temperature.

On the motor-shaft extension is a smooth drum. Surrounding this drum is a cage with lengthwise slots. Resting in these slots and riding on the motor drum are carbon blocks, held in position by garter springs. The cage is connected to the driven load. The motor is arranged so that at all times its speed is above that desired, but the blocks and springs are so adjusted that at the correct rotation, the centrifugal forces lighten the pressure of the springs and the carbons lift by an infinitesimal amount and thus slip on the motor-shaft cylinder.

The resulting speed regulation is remarkably constant. On a motor-generator set serving a torque meter, the 400-cycle output is held within one cycle for motor speed changes from 8400 to 11 000 rpm. The output of this set is entirely an instrument load and does not vary widely. At constant load the variation for all atmospheric conditions of temperature, altitude, and humidity is approximately one quarter of one percent of the rated speed.

The device is flat compensated for wear, but tests show barely measurable change in the surface of the friction members in 2000 hours of operation. These carbons, however, must be carefully chosen for constancy of friction characteristics with temperature and durability at high altitude.

This type of drive is not intended for use with large outputs (it has been built in sizes up to one kw) nor for wide load variations. A 50-percent change in load produces a speed change of a little more than one percent.

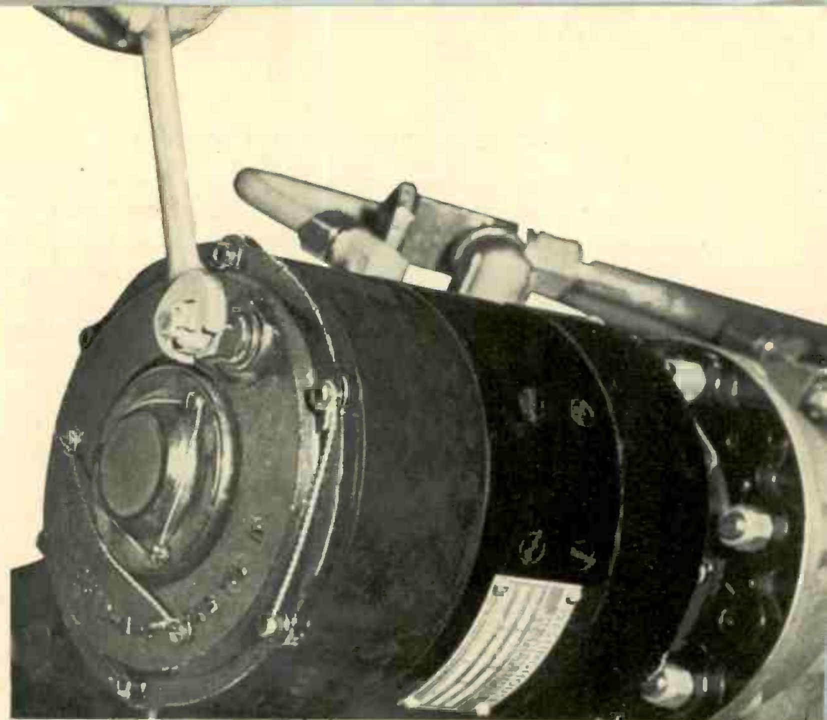
Larger Engine Dynamometers

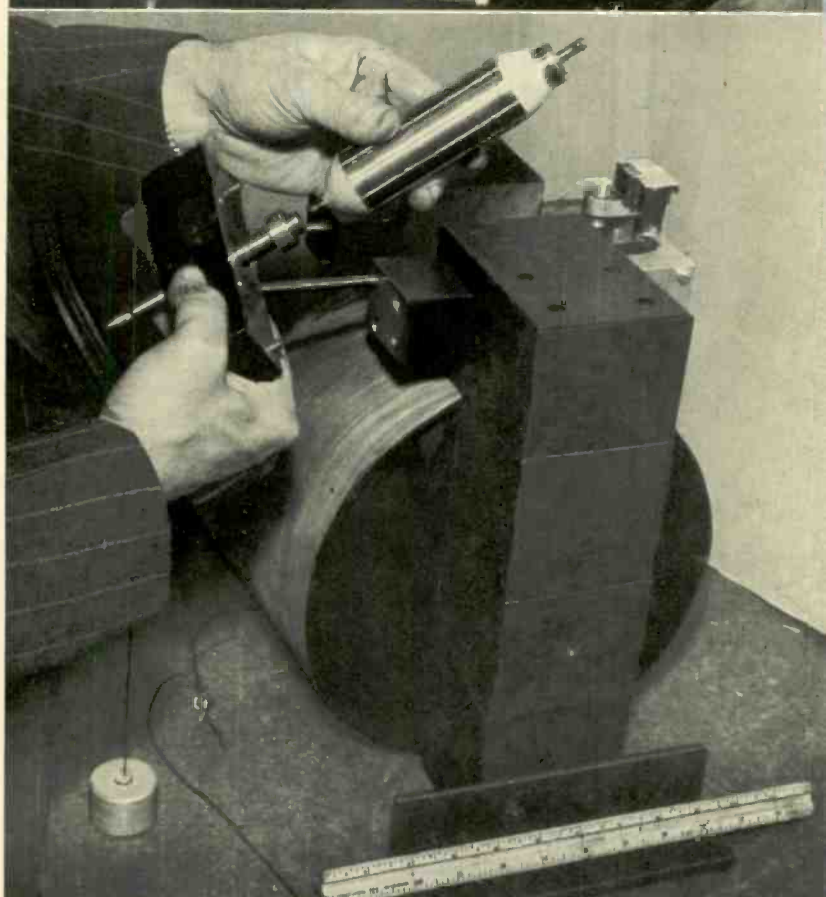
THE rapid increase in horsepowers available from aircraft engines is graphically displayed by the history of the dynamometers used to test them. It is customary for engine builders when purchasing dynamometers to order them twice as large in horsepower rating as the largest engine available at the time. This allows for future growth in engine capacities. With the exception of two 4000-hp dynamometers, at the war's beginning most of them were capable of absorbing about 2000 hp. The newest one, well under way when the war closed, will be good for 7700 hp. To obtain so much energy-absorption ability this big one uses the same basic machines, but instead of a single d-c generator and a single eddy-current brake, it uses two 850-hp d-c generators and two 3000-hp eddy-current brakes. All four machines are coupled together on one shaft, although the d-c generator on one end can be disconnected from the other three and used for independent testing of small engines. Instead of the usual weight scale to measure torque, pneumatic indicators are used in which torque is measured by air pressure.

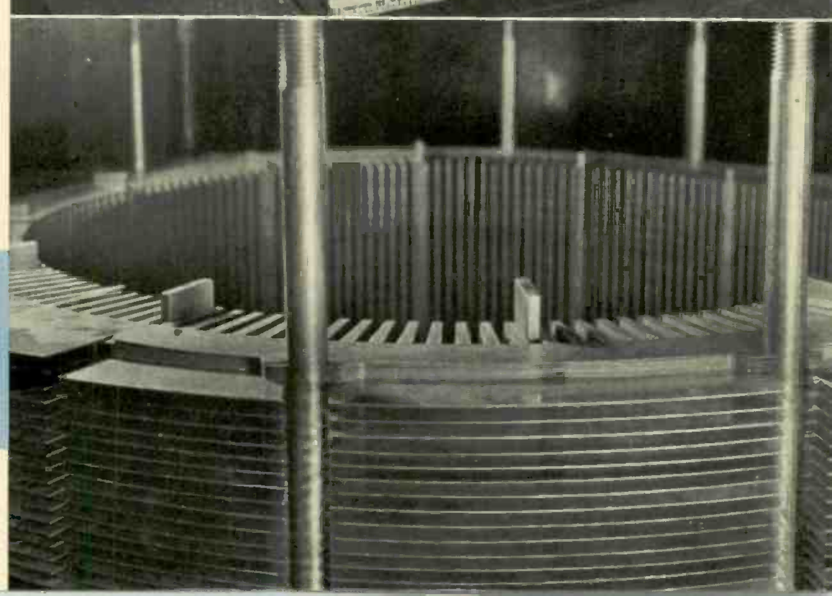
Copper Sandwich Aids Motor Cooling

GIVING proof to the idea that anything can be improved no matter how old, is the appearance of a novel scheme for cooling the stators of large totally enclosed a-c motors. It is a simple thing, but effective. It depends on the fact that copper conducts heat ten times better than iron. Stator punchings are made of thin copper sheet exactly like the magnetic-iron punchings except they are about two inches longer at the back. These copper punchings are spaced at intervals with the steel punchings, giving in effect circular fins projecting beyond the stator iron. Because these copper discs are in intimate contact with the iron, where the heat is generated, they are able to conduct heat to the back of the stator, where it can be removed by the air recirculated by the fan on the rotor shaft. Because the copper laminations go into the spaces previously occupied by the slots to allow for passage of cooling air the total length of the rotor is not increased but is actually reduced in size.

This copper-fin cooling system is particularly applicable to large, totally enclosed, fan-cooled motors where the ratio of exterior surface to volume of iron is small. In small machines the ratio of surface to volume is large (on the basis that the ratio of surface to volume of a sphere decreases as the diameter increases). Undoubtedly this development will mean that totally enclosed, fan-cooled induction motors of larger size can be built.







(Top) Gas turbines require starting motors. This one weighs but 31 pounds and develops 18 hp peak. It brings turbine and compressor rotors to 2000 rpm from standstill in 15 seconds. (Center) This motor armature must withstand 500 degrees F in a high vacuum. (Bottom) Cooling of this stator is aided by including in the stack of iron extra-long copper laminations at regular intervals.

Fluorescents Make Progress

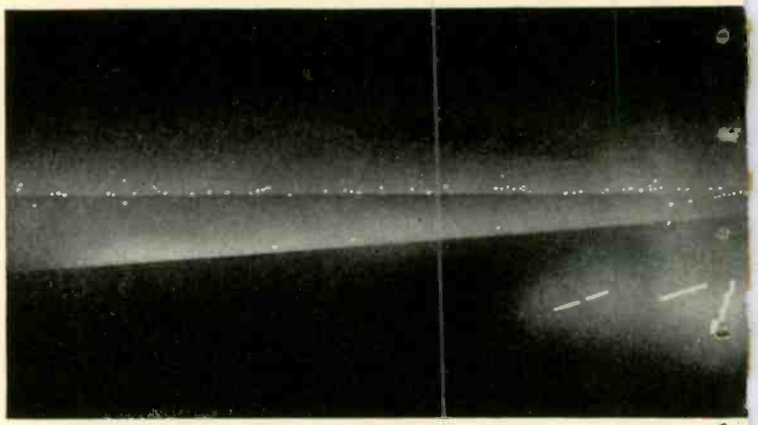
Developments continue to appear in the fluorescent lamp family at the high rate consonant with still young devices. The fluorescent lamp is less than ten years old. Yet the fact that about forty million of them were made last year is indicative of their popularity.

The first important variations from the familiar cylindrical shape of fluorescent lamps have appeared. A circular lamp has been developed. It is an even foot across and is rated at 32 watts. Because of the high light output in a small space and its symmetrical shape, it removes the principal obstacles to use in portable lamps in the home. It is now appearing as the light source in floor and table lamps and in other specially designed household lighting units.

New fluorescent lamps are longer and slimmer. Four lengths —five eighths and one inch in diameter—are standard, from 3½ to 8 feet long. Their special place in the lighting picture is for showcase and decorative lighting where long lines of low brightness are required. The electrodes are designed for instant starting on high voltage. Long lamps present a starting problem in humid air which is overcome on the "slimline" by painting a narrow silver stripe along the outside of the glass to within a short distance from each end. This metallic stripe acts as a capacitor facilitating starting.

The slimline lamp is slightly more efficient in turning watts into lumens than the regular lamps. This is because a large proportion of fluorescent-lamp losses occurs at the ends, and with the slimlines, for a given length, there are fewer ends.

The specific effect of starting on fluorescent lamp life is better understood. As a result, fluorescent lamps are now rated in terms of the number of starts. For example, the 40-watt lamp has a life of 6000 hours if it burns 12 hours per start. But if the lamp burns 6 hours per start, the life is 4000 hours; for 3 hours per start, the life is 2500 hours. The efficiencies in percent of initial lumens per watt when the lamp reaches 70 percent of its rated life are 70, 76, and 84 percent under the three conditions above.



New neon markers give pilots positive indication at night of which of several runways is to be used for landing of their airplanes.

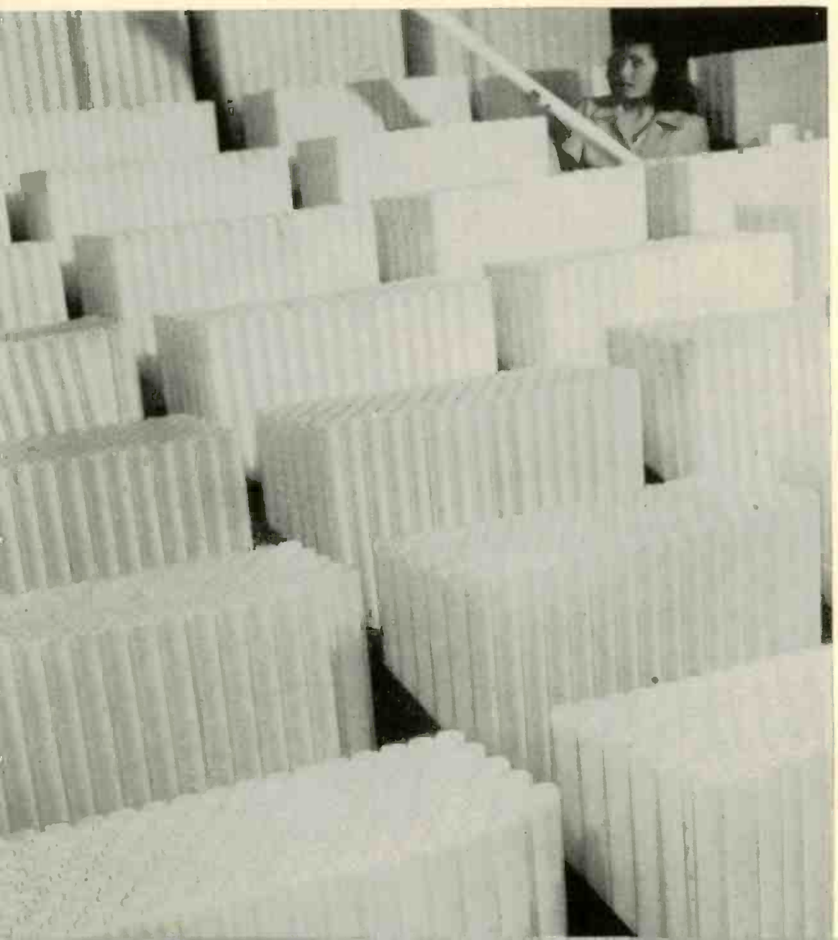
Fluorescent lamps decline about 15 percent in efficiency during the first hundred hours and then at a much slower rate for the remainder of the lamp life. This initial decline has been a matter of much concern and some mystery to lamp engineers. Various theories have been set forth, such as a sort of poisoning of the phosphors by mercury vapor. Research at the Westinghouse Lamp Laboratories now definitely fixes the blame at another source. It is caused by the low wavelength (mostly 1850-Ångstrom) radiation of the mercury-vapor discharge. This short radiation has a damaging effect on the ability of phosphors to convert invisible to visible light. The cure is still not known, but knowledge of the cause must precede.

Lighting Tailored for the Small Airport

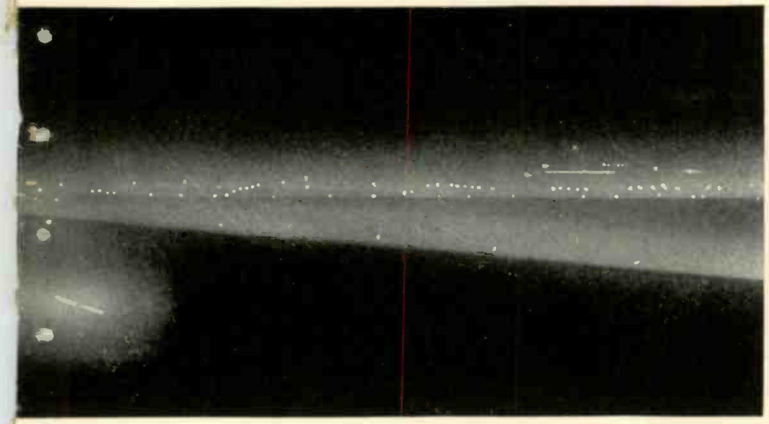
Large commercial airports are spectacular and command wide attention. But hundreds of other airports, which have no regularly scheduled operations, are vital in the national aviation program. Their requirements for lighting and other equipment, although less rigid because all-weather operation is not involved, are important. These are: no sacrifice in safety under the conditions of flying done at these ports, unqualified reliability, and low initial cost and maintenance during operation of the field.

The equipment must be engineered for these special needs and cannot be simply a cut-down version of the high-powered apparatus for the commercial-line airports. Representative of what is being done is a new wind cone and a new rotating beacon. The wind cone employs four 50-watt lamps instead of four 200-watt lamps, but it can be seen as far as necessary in any type of weather for which the airport is used.

The rotating beacon delivers 100 000 cp instead of 2 000 000. Rather than using an elaborate lamp-changing mechanism to insure continuity of service should a lamp burn out, the new one has two separate lamps and two separate, but much simpler, lens systems. Instead of a powerful turning motor, a 1/100-hp motor and gear provides beacon rotation. All rotating mechanisms are enclosed; hence the unit is free from ice troubles.



These fluorescent lamps presage a better-lighted world. Outlined is an approach-angle indicator to aid plane landing.



In On the Color Beam

One of the most interesting and at the same time most valuable devices that has come along to assist a pilot to land his plane at night is termed an approach-angle indicator. To those who enjoy ingenious engineering, this device is a delight. It enables a pilot literally to glide in on a beam of light—colored light. This unit (two of which stand at the end of each runway) projects three colored beams toward the approaching plane. The top beam of the color sandwich is amber, eight degrees thick. It indicates the plane is above the proper approach angle. The middle one is a two-degree green beam, indicative of correct approach. The bottom one—six degrees through—is red, significant of the danger of too-low approach. All beams are 16 degrees across or wide.

The striking thing about the beams is their extreme sharpness. The overlap is so slight that at 100 feet, if a person inclined his head sidewise he would see one color—and only one—with one eye, and a different color with the other eye. Even at one mile the zone of color transition is only about four feet wide. The secret of such remarkable color-beam fidelity is the lens system. The unit comprises a reflector, a 100-watt, single-plane filament, and a series of five clear lenses and three color filters. The lens system not only provides sharp color separation but also achieves a ten to one light magnification.

To prevent mistaking the red or the green beams for obstacle markers or other airport markers, the beams are flashed. The mechanism to accomplish this has the beauty of simplicity. A vane is tipped across the light beam to cause the interruption. But instead of rotating the vane by a motor and a gear (which would require space for complete vane rotation and would of necessity involve equal portions of light cutoff and transmission), a tiny high-speed motor drives a cam, which forces the vane to move 90 degrees into the light path against a light spring. By variation of the cam, proportion of light on and off periods can be controlled. Actually it is arranged to produce a darkness period only one-third of total. This is ample for unmistakable interruption, and allows a longer period of light-on, providing the eye effect of greater brightness. Furthermore the transition is extremely rapid, which also is important.

The new-type approach-angle indicator made its debut on the three initial runways at the huge Idlewild Airport.

Better Landing-Strip Identification

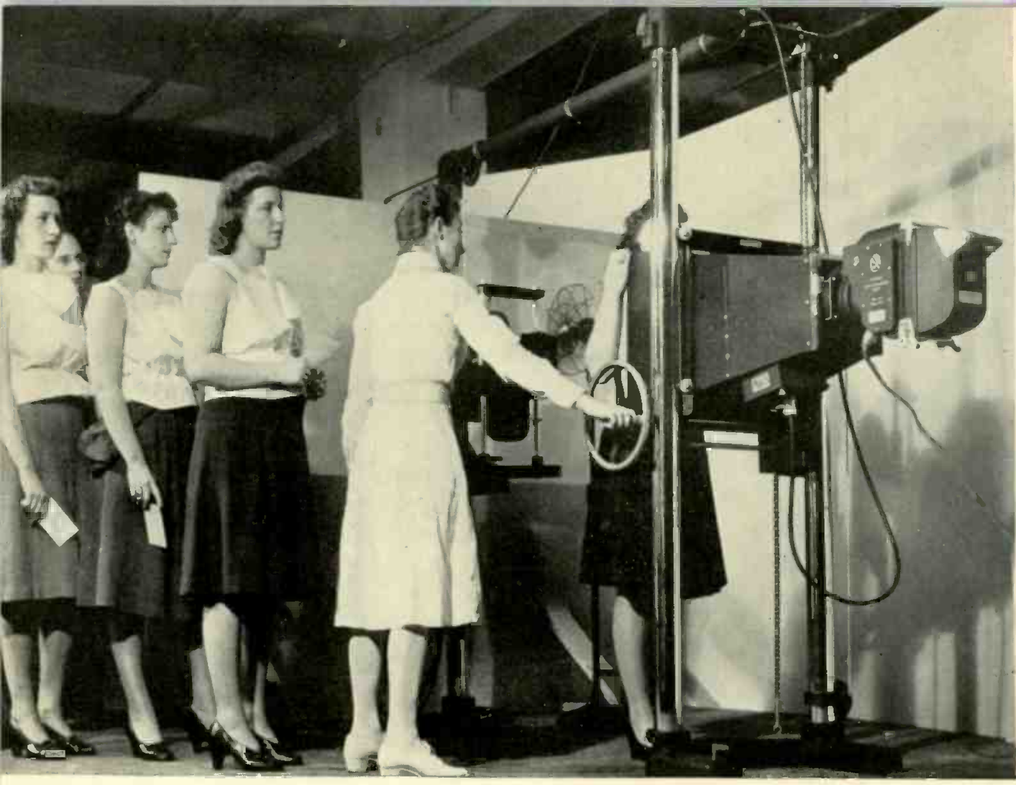
The pilot of a plane approaching a busy airport needs unmistakable guidance as to which runway and in which direction to land. Lack of clear signals may spell disaster. Illumination engineers have supplied the answer with a unique "traffic light" that employs a large × and → outlined in bright colors at the end of each runway. The cross, of which each diagonal is 90 feet long, is outlined in neon lamps. The arrow, 100 feet long from end to point and 35 feet across the head, is made of zeon (green) lamps. When a landing is to be made at night, all the red crosses are set to flashing while the green arrow at the landing end of the strip in use is lighted. Each cross consists of twelve pairs of high-intensity cold-cathode lamps physically similar to the new, long fluorescent lamps. Each arrow consists of ten pairs of lamps. Each pair of lamps consumes 225 watts, so that sufficient light is produced to make the markers visible even under extremely adverse atmospheric conditions.

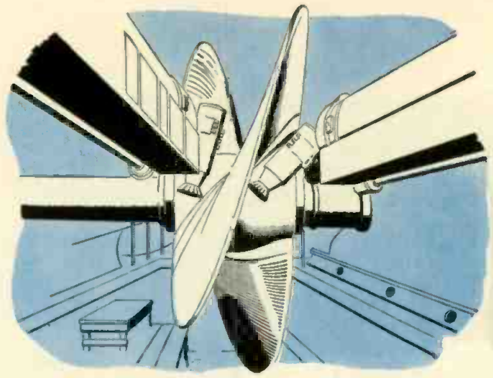
More Light on the Street

The problem always before the street-lighting engineer is how to get a larger proportion of the light produced by the lamp onto the road. Considering that illumination engineers have been working on this problem for fifty years, an increase of five percent in efficiency in one year, i.e., from 66 to 71 percent, represents a sizeable accomplishment.

Such an improvement could be made only by making an entirely fresh start. The new unit is the result of calculation. Based on present knowledge of pavement reflectivities, specularity under wet and dry conditions, a curve of ideal light distribution was prepared. Then by differential equations the reflector shape necessary to provide it was plotted. The shape thus arrived at came out, quite understandably, to be something most unusual. It called for a compact light source, i.e., incandescent or horizontal short-arc mercury-vapor lamp

A new type of street lamp casts a higher proportion of available light on the road.





(Left) Rapid chest examinations of groups of people are possible with the miniature film x-ray. (Above) Electrical fingers, riding on a model, guide cutting tools as they machine the complex surface of a ship's propeller.

held in a polished reflector shaped as a long, solid oval.

The reflector made as a result of these calculations is extremely effective in directing the available light to the street surface. The enclosing glass lens below the lamp also is shaped to contours determined by mathematics. It controls the light that comes directly from the reflector and provides the proper amount of diffusion at every elevation. Even the light that would ordinarily be wasted by the edge, where glass and reflector join, is recovered and directed onto the street by auxiliary or booster shields.

Translation of the mathematically derived design into a practical unit without sacrifice in efficiency presented problems. For example, it is necessary to make the aluminum reflector in one draw because past experience has shown that a second time through the press results in light-destroying scratches. It was a great source of satisfaction to the creators to find that the light-output curves, from data provided by photometric tests on the first unit, coincided almost exactly with the original calculated curves.

Better Secondary-Street Lighting

THE open-type street lamp, with bare bulb projecting from a plane or radial-wave reflector, has done a job of sorts for a long time in alleyways, highways, and streets where traffic density is small. It has now been supplanted by a fixture that is superior in many ways.

The reflector is of enameled porcelain and consists of a circular flat disk in which is a deep oval indentation. The lamp, instead of projecting below the plane of the reflector, is mounted up in the oval hollow, so that no light is thrown above the horizontal. Thus there will be less need to provide the unit with a special shade to keep light out of someone's bedroom. Also the glaring bare bulb cannot be seen by a motorist more than 200 feet away. When he is closer than that the light becomes so high in his field of vision that glare is not serious. The reflector is so shaped as to capture a high proportion of light and to cast it where needed, i.e., on the road. About 60 percent more light falls on the actual roadway than with previous open-type lamps. Contributing to the high utilization factor is scientific use of the specular reflection of porcelain enamel.

Supersensitive Electrical Fingers Sculpture in Metal

CURVES are fascinating things. Many people spend their lives trying to produce them—pin-up girl artists, sculptors, baseball pitchers, and workers in metal.

Propeller blades, for example, haven't a straight line in them. To carve out of a large hunk of bronze the exact contours of true streamlining required for most efficient propulsion is a very difficult task. The curves are compound and continuously changing from point to point. No two lines on a truely formed propeller blade are alike.

Machining propeller blades has been a tedious, time-consuming procedure—extending over a period of weeks for the screws used on large merchant and fighting ships. Even then only the front surface is correctly contoured; the back is formed to approximate shape by hand chipping and grinding—with some small loss in propulsion efficiency.

A set of electrical fingers far more sensitive than those of a blind man or a safe-cracker now do this work. With this new system an exact scale model of the curved part is made out of any convenient, easily worked material. This replica is set up near the milling machine so that the probes of the electronic tracer mechanism can move over it in the same successive paths to be followed by the cutting tool. The position of the probe each instant is translated into an electrical quantity by means of a sensitive multi-contact regulator (Silverstat). This current is then used to position the cutting tools so that they follow exactly, in scale relation, the contours of the model.

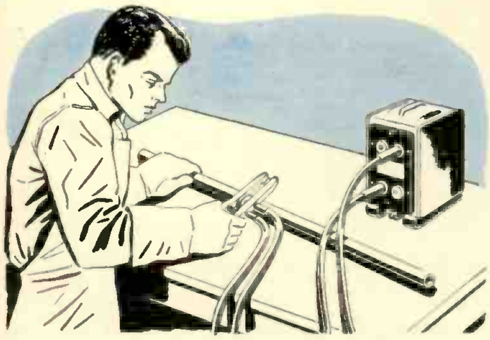
As actually applied by the Morton Manufacturing Company to the milling machine for large propellers, two models and two tracer mechanisms are used, one for each side. Appropriately designed machines mill both sides of a propeller accurately at the same time.

The amount of time saved is enormous, in addition to an improvement in product. Rough machining plus laborious hand finishing that previously required two or three weeks can now be done automatically in as many days.

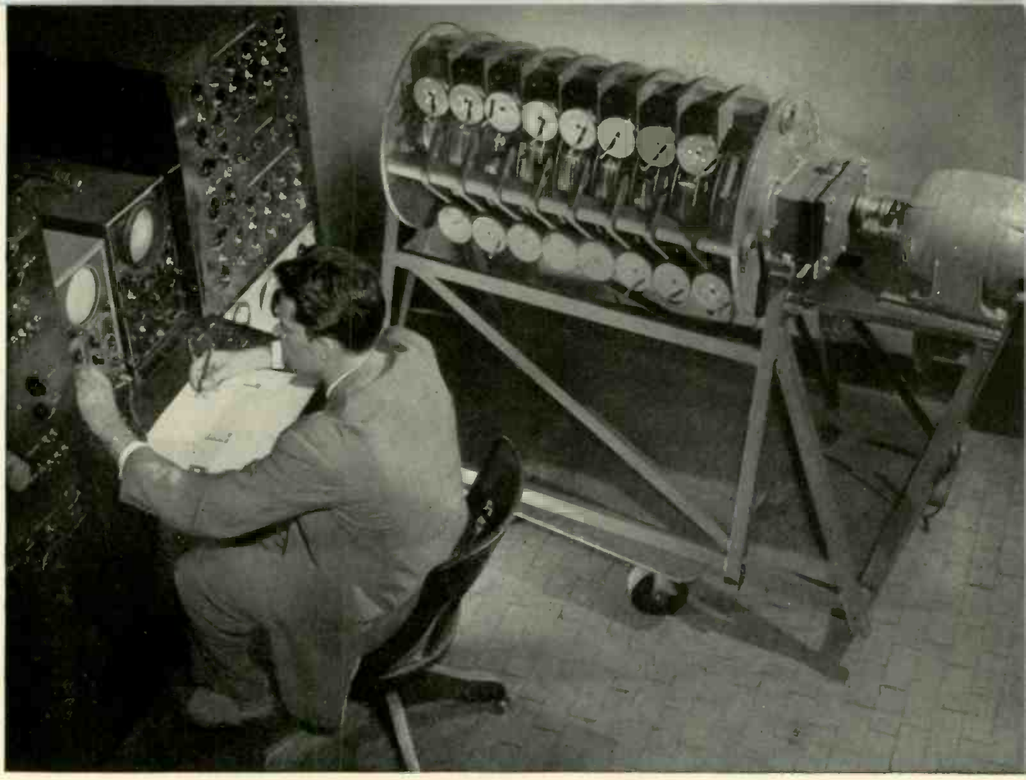
The contour system of machining under tracer control is of course not limited to ship propellers alone. Nearly any odd-curved part can be accommodated by this system.

Brazers That Go to the Work

BRAZING is an old but still not too generally used method of joining members of copper, brass, bronze, or various alloys. One handicap has been the lack of brazing apparatus that can be readily taken to the job, as in shipyards, railroad



(Above) A compact tong-type brazer can be readily taken to the work location. (Right) Extremely complicated mechanical problems can be solved electrically in short order by the mechanical-transients analyzer.



shops, etc. For the production lines of factories, the well-developed brazing furnaces are in much demand, but there has been a need of portable units for joining wire cables, strap connectors, pipe, etc. This need is met by a self-contained family of brazing sets that require only a connection to a 220-volt power source. These sets consist essentially of a transformer for providing high currents at low voltage, suitable voltage selectors, controls, and carbon-tipped tongs that can be clamped over the pieces to be joined. The high currents flowing through the carbons bring them to incandescence, quickly raising the material to brazing temperatures, which are from 1200 to 1500 degrees F.

Three sizes, 5, 10, and 20 kva, comprise this group of mobile brazing elements. The 5- and the 10-kva units are air-cooled. The 20-kva unit is fan-cooled and has a self-contained water-cooling and recirculating system used to cool the brazing cables and tongs. This cooling system permits the use of a small-size portable unit for medium brazing work. The smallest unit weighs but 30 pounds, the middle-size one 100 pounds, and the 20 kva, 250 pounds. The corresponding secondary currents are 625, 833, and 1667 amperes.

Shortest Air-Cooled Transformers, for Thin-Seam Mines

For coal mines where the seams are thin a 150-kva transformer has been created that is only about two feet high. Low height, however, is but one requirement placed on transformers for mining service. Often long runs of low-voltage cables are extended from mine-slope entries back to the hill where conveyor motors are located. In many cases, the voltage drops at the load by as much as 60 percent.

To improve cable voltage drop, a dry-type air-insulated transformer has been designed so that it can be located in the mine relatively close to the working face. This transformer is semi-portable and suitable for skidding through passages of low height by means of a common hoist. The unit is a complete power center having high-voltage plug-entrance cables and low-voltage De-ion circuit breakers. High-temperature silicone-bonded insulation is used on the windings. The case, bushings, and fittings are made tight by metallic seals.

This transformer is designed for location in the common horizontal-entry mine without expensive vaults for which space is seldom available. A 150-kva, three-phase, 2400- to 240-volt power center is only 25¼ inches tall and weighs 3600 pounds. The use of plugged-type cable connections makes it easy to move the unit from one location to another as required by the various operations in the mine.

Super Problem Solver

How heat flows through a turbine blade, the shocks to a vacuum-tube grid when a crate of tubes is dropped, the torques developed in a generator shaft during short circuit, and complicated problems in hydraulics—all almost impossible of solution by mathematics—can now be solved in a few hours or days by an electrical analyzer. The great diversity of problems that can be solved electrically is a manifestation of the orderliness of nature. The worlds of mechanics, thermodynamics, hydraulics, and electricity are each governed by their own sets of laws. But the laws in one field are analogous to those in another. In mechanics, force is equal to mass times acceleration or expressed mathematically $f=Ma$. In electricity, exactly similar relationships are found.

The mechanical-transients analyzer is built on these analogous behaviors. Combinations of resistances, inductances, and capacitances are connected in proper circuit arrangement. Then flashes of voltage or current are applied to this circuit repeatedly and at a high rate by a set of rotating contacts. These voltages or currents correspond to the disturbing or initiating phenomenon in the analog, i.e., the bump, the temperature gradient, the water pressure, or what have you. The output voltage or current from the electrical circuit is applied to a cathode-ray oscilloscope, and because it is repeated so rapidly, it appears as a standing wave that can be photographed or studied at leisure. In this wave lies the desired answer to the problem.

The time saved is astounding. In the first six months that the mechanical transients analyzer has been in use, the number of problems solved that could have been done by conventional mathematical analysis would have required two mathematicians working for a period of at least fifteen years. In addition, several important problems have been analyzed that could not be done at all by conventional mathematics.

Refinements in Design of Store-Type Air Conditioners

Air conditioning for the small shop, shoe store, delicatessen, or dining room was fast becoming a must before the war sidetracked the growing application. The air conditioning of these establishments is usually done by cabinet-type units,

These electric-range units are being tested by repeatedly pouring salt water over the elements, both with power on and later when they are cold. The insert shows how easily the reflector pan can be removed for cleaning.

the general sizes of which are from one- to five-hp capacity.

With this experience to build on, these units have been redesigned with several resulting benefits. Commercial artists have had their say as to exterior appearance, a matter of importance in postwar shop remodeling.

This self-contained unit, especially designed for use within the space to be air conditioned where floor area is held at a premium, has been reduced in size by 15 percent. The weight of the five-hp size is reduced 20 percent. These reductions make for much easier installation in a store's limited space.

Like a day at the beach, with none of its disadvantages, this combination heat-lamp sun-lamp unit provides heat rays for drying hair or for any of the many uses of heat applications. By simply turning the lamp holder over, end for end, the benefits of ultraviolet sun rays can be enjoyed.

All component parts are mounted on a rigid structural chassis with panels readily removable to facilitate easy inspection and servicing without the necessity of moving the entire unit to get at the required parts.

The air-supply grille that distributes the conditioned air throughout the space is interchangeable to permit either vertical or horizontal air flow. This feature eliminates duct work in many installations and provides a choice for better air distribution throughout the area.

The blower-type fan that circulates the conditioned air incorporates features of both the propeller and centrifugal fan and requires less power from the fan motor.

The hermetically sealed refrigeration compressor has been completely redesigned for the two-, three-, and five-hp models. The cylinders are now arranged in a 90-degree vee and the rotating parts dynamically balanced for smoothness. Quieter operation is obtained by the increased use of cast iron in place of the steel shell which previously enclosed the compressor.

In two of the prewar models, two compressors were used. Now only one of the newly designed higher capacity compressors is necessary to produce the same effect.

Robot Fresh-Drink Mixer

You pause for refreshment, step up to a red and white cabinet, push a coin into a slot, and see a paper cup slide down a chute behind a glass window. Streams of refrigerated syrup and charged water pour out, filling the cup exactly to the brim. Fresh, precisely made Coca-Cola is mixed before your eyes in about six seconds. If a dime or a quarter is used instead of a nickel, the change tinkles down into a metal cup. The robot drink mixer can serve 1000 people as fast as they can step up, before the machine runs empty of cups or syrup.

It all seems very simple. But like most things that look simple, a whale of engineering lies behind it. Several kinds of engineering—electrical, mechanical, hydraulic, and, not least of all, psychological.

Getting the cup from the 1000-cup magazine into position was not simple. It was fairly easy to make the cups slide down smoothly and land right side up almost every time, but to do it every time required precise shaping of each part.

Filling the cup with charged water and adding an exact amount of syrup presented other problems. A mechanism for charging water was devised which consistently maintains the extremely high absolute carbonation of six to seven volumes of carbon dioxide to one of water. This was achieved by injecting the water into the gas as an extremely fine fog.

A Sterilamp maintains a sterile atmosphere in the cup station and at the same time discourages the collection of flies and other insects that would be attracted by the syrup.

Elaborate controls make the machine automatic. They were designed to eliminate customer annoyance with failures to get a drink, perfectly mixed, properly chilled, clean, and without mishap. Appearance of the machine, simplicity of operation, ease of cleaning, and absolute reliability were all made part of the engineering program.

ENGINEERING PROFILES

Simplified Color Photography—Amateur color-photography fans have had to use one type of film for daylight pictures and another type for shots indoors with artificial light. The camera seemingly is always loaded with the wrong kind of film, and if the photographer should make a mistake or forget which film is being used the results are sad indeed. This nuisance has been eliminated as far as flash pictures are concerned by a blue photoflash bulb that can be used with daylight color film. Hence, daylight film can be used either for outdoor pictures or

for interior photoflash pictures. The new photoflash bulb is not suitable for use with indoor-type color film. The new lamp provides better color balance and 40 percent more light output as a result of an improved blue dye in the lacquer coating. This new bulb also makes possible pictures with mixed daylight and artificial light illumination.

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Large-Scale Tuberculosis Safari—The largest, most thoroughly organized microbe hunt in history is on. Plans are well under way to locate every tuberculosis victim in the United States. Under the general direction of the United States Public Health Service and with federal financial aid, various agencies in different states are organizing comprehensive programs to canvass literally every citizen for incipient tuberculosis infection.

The trick in combating tuberculosis is to discover it early—long before its victim is aware of its presence. If found in that early stage, cure is fairly simple and sure, and the risk of infecting others enormously reduced.

The principal instrument in tracking down tuberculosis is the x-ray. But obviously taking chest x-rays of any large proportion of 140 million people on the standard 14- by 17-inch individual film is out of the question. Film costs, developing facilities, technicians' time, storage of film, etc., make such a prospect hopeless.

A simple, rapid, compact x-ray system offering extremely low cost per examination is required. It must be a mass-production x-raying scheme. And x-ray engineers have provided the answer. Using the principles of the miniature x-ray, Westinghouse engineers have developed a unit that takes chest pictures on standard 70-millimeter roll film (slightly less than three inches square), hence using only eight square inches of film instead of 239 square inches. Several hundred exposures can be made (and simultaneously developed) on one roll of film. Exposures can be made as fast as people can step into position and away again, or about ten per minute.

Even the length of exposure, which must be different for chests of different thicknesses and bone structure, is automatic. Based on the system developed by Dr. Russell H. Morgan at the University of Chicago, a photoelectric exposure meter actually measures the amount of light falling on the film during exposure. The meter then takes action to stop the exposure at the right film density. Considering that the phototube must allow for ensuing relay time and that the total length of exposure is sometimes as short as one thirtieth of a second, some nice engineering problems in timing compensation were introduced.

The photo-fluorographic x-ray unit (PFX), as the miniature x-ray equipment is called, clearly must be portable. It is arranged for easy dismantling into a few parts such that two men can readily carry the largest case or the equipment can be carried dismantled in a truck, or permanently erected in a bus or a trailer. In the bus and trailer types, dark-room facilities, technicians' quarters, independent power plant, and other facilities can be provided to suit the area it is to serve.

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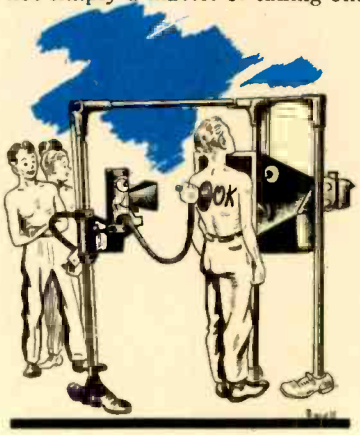
The Home Takes a Heating Tip from Industry—Use of lamps in the home for purposes other than reading continues to increase. The infrared lamp, long a familiar tool in industry for multifarious quick-drying jobs, has become domesticated. It was not simply a matter of taking one of



several industrial heat lamps and marketing it for home uses. For safety it had to be provided with a hard-glass bulb, one that would not shatter should water be spattered on it. Also the glass is colored a most eye-appealing red, which serves to filter the visible light down to a pleasing glow, distinguished from other lamps.

One no longer need be faced with the hard choice in chilly fall or spring mornings of either foregoing that invigorating shower or enduring the unpleasant goose pimples that result. With a splatter-proof heat lamp, in a ceiling or wall fixture above the shower, directing the long, penetrating warm rays onto one's back, the chilling effect of low room temperature is nullified.

The heat lamp is equally useful for quick drying of fingernail polish, shampooed hair, silk stockings, or on cool mornings to provide a zone of warmth on the floor of the baby's playpen.

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A Motor That Runs in a High Vacuum at 600 Degrees F—Motor engineers were asked during the war to build special d-c armatures that could operate continuously in a temperature of 600 degrees F, and in a high vacuum of but a few microns pressure. Furthermore, under these "impossible" conditions, the armatures must give off no gases to contaminate the vacuum system, which is higher than is used in most vacuum tubes. To add to the rigors of the problem, the armatures must turn at 1200 rpm without noticeable vibration and without the addition of any balance weights.

The armatures are wound with glass- and silicone-insulated wire. Although machine-wound, the coils are wound on both sides of the shaft to maintain weight symmetry. After winding, the armatures are placed in an oven at about 500 degrees F to burn out any organic materials and to drive out all other volatile matter. The entire armature is then subjected for hours to a filling of sodium silicate and mica dust under alternate vacuum and pressure. This ordeal is followed by another bake and removal of surplus impregnating material.

Arc-Proved Materials

From research laboratories come new plastics and new metals that mean more durable, improved devices. Here an insulating panel of glass melamine is being deliberately flashed to prove its endurance under the heat of arcs.