WESTINGHOUSE

Engineer

JANUARY 1947

Engineering Today

ADVERTISING copy and wishful thinking to the contrary, engineers last year returned to no "brave, new world," with dream products crowding the market, materials plentiful, and all the wartime secrets released for their benefit. To be sure, the war left a great and valuable legacy of new materials, improved manufacturing techniques, new tools and new processes. But the first peacetime year since 1941 was primarily one of reconversion—not only of plants, but of engineers and engineering as well. And in that process, many a notion conceived during the recent years has been rudely jolted.

The engineer hoped or expected he could turn from the distasteful job of building for destruction to the adaptation of new ideas and fresh viewpoints into new and better kinds of things. The months just gone have been directed instead to aiding in the production of a fairly modest amount of the familiar goods. Dreams of things different and better have by no means been abandoned; only distressingly delayed by a necessity for clearing of decks.

Also, the engineer on V-J day breathed a sigh of relief that soon he would not be plagued with material substitutions, and substitutions for substitutions. Good old iron, or steel, or copper, or varnish, or what have you would be available again in quantity. But not so. He has been confronted with more material shortages than ever. And the end is not yet—not even in sight.

Again surprise! Termination of hostilities and censorship did not release an avalanche of secrets embodying new ideas, new knowledge, new technical principles that would greatly alter the familiar equipments of engineering or their use. There are, to be sure, a few thrillers, such as guided missiles, proximity fuses, radar and associated ultra-high-frequency techniques, nuclear fission, supersonic flight, and reaction propulsion devices. Yet, close examination of these discloses no new basic principles that will affect or obsolesce the long-established equipments. For example, there seems to be no prospect or need for major change in the generation, transformation, transmission, distribution, or use of electric power. The familiar steam turbines, generators, transformers, switchgear, protective devices, motors, lamps, and furnaces will mostly retain their familiar forms and be used in familiar ways. Unquestionably many new things will come—nuclear-energy power plants, radar navigation aids, supersonic flight, television, and so on—but it appears that mostly they will occupy new fields and will compete only slightly with the old. That's one of the fortunate characteristics of science and technology. It is an ever-expanding component of civilization. It inevitably leaves a trail of obsolescence, but the new more than compensates for that which is outmoded.

The engineers find themselves with enlarged responsibilities. Their shop organizations lean on them, far more than a half decade ago, for guidance in turning their creations into goods. Instructions must be more complete. The engineer must have fuller understanding of materials and how they are processed into products.

While the actualities of 1946 required modification of some notions, a review of where we stand shows much that is good, that heralds technical progress. The long recess from normal activities, while it produced not too many startling principles, did provide the basis for innumerable improvements. The designer of 1947 models finds at his disposal dozens of new or improved materials, a bevy of improved manufacturing techniques, interesting new trends and demands, new tools, new concepts—and more unsolved problems than ever. These comprise the subject for this year's review. In short, we find in an inventory of engineering the most salient fact is that technology is evolutionary, not revolutionary. Great things lie ahead.

WESTINGHOUSE
Engineer

VOLUME SEVEN | JANUARY, 1947 | NUMBER ONE

On the Side

The new general-purpose induction motor being smaller, lighter, more rugged, and less needful of attention summarizes well the numerous gains of the last few years in new knowledge, new skills, new tools, and new production techniques. The motor is described at length on page 22.

• • •

Giant projects call for giant machines. Associated with the Grand Coulee hydro-electric development on the Columbia River in the State of Washington is one of the most stupendous of irrigation projects. Construction has begun on four electric motors of 65 000 hp each, which will drive pumps to lift water from the river level to the storage basin.

• • •

Stratovision, it has recently been announced, will soon enter its second phase, which is the broadcasting of actual television and frequency-modulated programs from an airplane antenna. A pressurized airplane is being equipped with television and F-M transmitters for experimental operation this year.

• • •

Another war-built plant is being converted to peacetime production. The plant at Vanport in western Pennsylvania, which was operated by Curtiss-Wright Corporation for aircraft parts' manufacture, will soon be converted to the production of small De-ion circuit breakers, motor starters, safety switches, and kindred switching apparatus. The enormous peacetime demand for small air switches far exceeds the capacity of the present Westinghouse manufacturing plant at East Pittsburgh, Pennsylvania, and has led to the establishment of this new manufacturing center.

Editor
CHARLES A. SCARLOTT

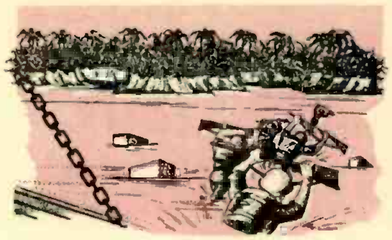
Editorial Advisors
R. C. BERGVALL
T. FORT
G. EDWARD PENDRAY

In This Issue

The *Westinghouse* ENGINEER is issued six times a year by the Westinghouse Electric Corporation. Dates of publication are January, March, May, July, September, and November. The annual subscription price in the United States and its possessions is $2.00; in Canada, $2.50; and in other countries, $2.25. Price of a single copy is 35c. Address all communications to the *Westinghouse* ENGINEER, 306 Fourth Ave., P.O. Box 1017, Pittsburgh (30), Pennsylvania.

THE WESTINGHOUSE ENGINEER IS PRINTED IN THE UNITED STATES BY THE LAKESIDE PRESS, CHICAGO, ILLINOIS

Engineering Lessons and Gains of the Recent Years



". . . The recent period of engineering activity under altered objectives has given engineers a vast fund of detailed know-how that will be valuable in unsuspected ways for years to come for improvement of the old and development of the new."

On one of those grim days in August, 1942 a landing vessel drew up on the sands at Guadalcanal and men began pitching packages overboard to be towed ashore. Among them were portable marine radio receivers in sealed-metal cases, which, upon being fished out of the surf, could be quickly set up to provide vital communication for the landing operations. The metal cases of three of these radio sets were punctured by Zero strafing, so they promptly sank. But they were not given up for lost. Because every bit of radio equipment was desperately needed, the marines retrieved the three sunken cases. After the salt water was emptied out, the radios were laid in the bottom of a fresh-water creek for several hours for further washing, following which they were placed over a slow fire under a tent and dried. The three sets were placed in operation and worked satisfactorily.

The proximity fuze, one of the most successful of our ordnance developments, by which the shell would explode when in the neighborhood of its target, contained thimble-size radio tubes that had to function even under accelerations of 10 000 times gravity. The fuze contained a wind-driven turbine generator the size of a man's fist that, almost independent of shell velocity, turned at a constant speed of 40 000 rpm.

To bring the control gyroscope of the electric torpedo up to speed required a super-special motor. It could never run longer than one-fifth of a second, in which brief time it had to accelerate the gyro inertia wheel from standstill to 12 000 rpm. The motor weighed less than nine pounds but developed 22 peak horsepower. To achieve this the materials were worked to the utmost. Current densities in the armature copper amounted to 63 500 amperes per square inch and nearly that in the field winding. The motor would have melted in a second or two of operation.

Much useful information has accumulated from the construction of military communication equipment, electronic devices, and similar apparatus for high-altitude service. For example, small, readily cooled, pressurized housings were required in the rare atmosphere. Extensive use was made of such new high-temperature insulation as glass wire, the synthetic enameled wires, ceramics, micas, etc. Better use was made of blowers, fins and drafting means. Glass-to-metal seals have come to a high peak of perfection. Most of these lessons will be carried over, for example, to equipments for frequency-modulation and long-wave broadcasting transmitters, train-to-train radio sets, and power-line communication equipment. Although equipments sealed or otherwise protected against ambient conditions are more expensive, they result in longer life, and greater reliability, which are very important in communication and signalling service.

These episodes are but three of thousands of like kind. They are interesting in their own right, but more important they indicate the kind of thing engineers were called upon to perform. The general fact is that until about 1941 the considerations that guided a product-engineer's hand were life, reliability, performance, and cost—especially cost. At the onset of conflict these were replaced by a new combination of objectives: maximum rate of production; ability to operate at high altitudes, in extreme cold, in great heat, and high humidity; to withstand shock and corrosion; to operate at phenomenal speeds or outputs or both; be both small and light weight; and be transportable with rough handling literally to the ends of the earth. Life became a matter of weeks, hours, or even fractions of a second. Cost came at the bottom of the list.

Specific Lessons

Engineers have returned to a normal regime in which the ruling factors are, again, cost, reliability, performance, and life. One would expect them to bring along a body of new information, bought at high price and under tremendous pressure, but a portion of it useful in the engineering ahead. They have indeed. It is much too early to measure the true value of these lessons; this knowledge will show up in apparatus for many years to come. However, a variety of case examples show the nature of the useful technical information. Take corrosion for example.

Protection for "Tin Fish"—Electric torpedoes became the business of transformer engineers. Not the least of their problems was how to protect the thin steel shell of the torpedo body (conventional torpedoes have thick walls) from the corrosive action of sulphuric acid on the inside and salt water on the outside. "Insulation" against these vigorous corrosion agents came, surprisingly enough, from a highly specialized electrical insulation

The materials engineer in charge, a man with chemical training and electrical-research experience, contemplated the highly resistive qualities required for both acid and salt water. To his surprise he found they coincided well with those of high-grade electrical varnish (Thermoset). The steel torpedo shell was Parkerized, given but a single dip in varnish of the same sort used in transformers, and baked. The result was a treatment that gave, in one operation, corrosion protection to both the inside and outside—and at low cost and slight expenditure of labor and time. Furthermore, the baked synthetic-varnish surface was remarkably abrasion-resistant, a desirable attribute, considering the rough handling to which a torpedo is subjected. The ultra-protection of the "armor" coat was indicated when a torpedo was fished out of the sea after nine months' immersion and found to be in perfect condition.

Protection for Black-Oxide Treated Parts—Corrosion protection for splines and gears sometimes presents a special problem in that whatever is done to the surfaces must not change the overall dimensions. Hence plating is taboo because it adds to the thickness and would wear off because it is relatively soft. A designer of electrical apparatus for aircraft was posed with the problem of how to remove oxidizing salts from small recesses of steel parts subjected to black-oxide treatment. A bath in chromic acid was tried. This worked well enough, but more important, it was discovered that the oxidized parts thus washed withstood the standard salt-spray test several times longer than before. This was not too surprising as chromates are well-known corrosion inhibitors. The chromate, however, is not permanent, as continued exposure to water removes it. It seemed that if some protection could be given the chromated surface perhaps it would be more permanent. The chromate-washed nitrided parts were then treated with one of the well-known corrosion inhibiting oils that have the ability to displace moisture from a surface. The parts were thereupon able to undergo the salt spray 200 hours instead of two hours for plain oxidized parts. A test at 100-percent humidity was stopped after 50 days, as it appeared it could go on indefinitely without appearance of corrosion on the triple-treated surfaces.

Cathodic Protection for Water Tanks—The life of the usual galvanized-steel electric water-heater tank is greatly influenced by the character of the local water. Some 20 years' service can ordinarily be expected from a properly galvanized steel tank, which is by all odds the most economical tank construction now available. In a few areas—curiously enough these are the areas in which the water is soft rather than hard—galvanized tanks corrode in a small fraction of 20 years. Sometimes a water tank in a house on one side of the street lasts indefinitely, whereas across the street, served by a different water system, a tank fails in two or three years. The difference seems to lie in the lack of lime or carbonates in the water, which partially protects the tank wall. Corrosion is largely the result of electrolysis.

Inasmuch as corrosion cannot be eliminated, at least the attack can be diverted to something less objectionable than the zinc surface. Favorable results have been obtained experimentally by the fairly simple expedient of suspending inside the tank a magnesium-alloy electrode electrically grounded to the tank. Galvanic currents are such that ions flow away from the magnesium electrode instead of the tank wall, thus destroying the magnesium instead of the zinc. When the magnesium electrode is well disintegrated it can be readily replaced by a new one.

This manner of preserving the interior follows the well-known principle of cathodic protection, long applied to pipe lines, water tanks, and other buried structures that are subject to galvanic earth currents.

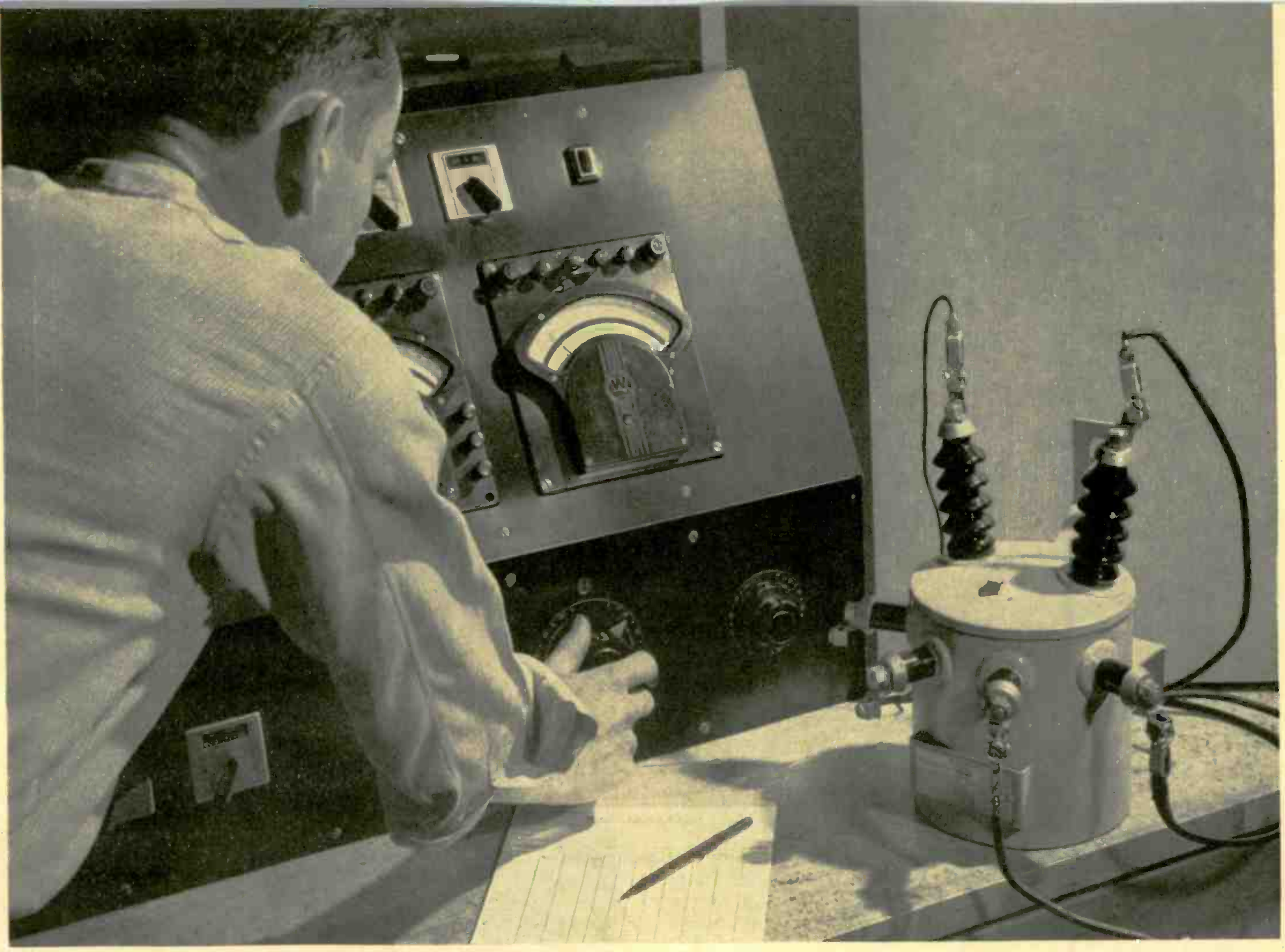
Corrosion Promotion—Corrosion is not always undesirable. In one spectacular instance a means of creating and maintaining a surface film is essential. This is on the commutators of aircraft generators. When airplanes began operating significant periods of time at altitudes above 30 000 feet, the life of carbon-brushes diminished to a few hours. In the substratosphere the thin copper-oxide film normally present on the commutator surface at ground level is lost. This oxide film acts as a lubricant for the brush face. Without it the carbons ride on raw copper, and are quickly ground to dust at the high speeds at which aircraft generators turn. Also, the absence of the film decreases the brush-contact resistance, which has an adverse effect on the electrical characteristics of the generator. The high temperatures at which the commutators operate nullify conventional methods of lubrication.

Armed with this information, research engineers developed a special treatment for brushes that creates on the commutator the necessary oxide film as rapidly as it is worn away. Essentially the treatment is an impregnation of the brushes with certain halide compounds, which work to the carbon surface as the brushes get hot. Brushes treated in this manner are proving superior for certain other non-aircraft applications where commutating conditions are severe.

Painting with Molten Metal—Another big gun in the ever-present campaign against corrosion is the molten-metal spray. Frames and panels of radio-communication equipments have been protected in this manner, in which the steel was first shot-blasted and then "painted" with a film of molten zinc.

This method is being applied regularly to the protection of shunt capacitors for pole mounting where ordinary paints have seemed inadequate, because the handling during installation often scores the surface, paving the way for early corrosion. It is being applied also to transmission-line protector tubes and may be extended to other communication equipments, train-radio sets, and broadcasting equipments located in certain localities. Metal-spray protection will be

A synthetic electrical-insulating varnish gave torpedo engineers the answer to a salt-water and acid corrosion problem.



What appears to be a midget power transformer is actually a transformer built to meet the special requirements of high voltage and low current for railway-signalling service.

useful for other apparatus that must be subjected to corrosive atmosphere such as salt air. It has been reported that the upper structure of the *Normandie*, for example, was protected in this manner.

Particular merit of the metal-spray idea is that the coat can be made as thick as desired, whereas, with galvanizing, the zinc, is more limited in thickness. By molten-metal spraying, surfaces up to eight mils have been applied readily to capacitor surfaces. Even if the sprayed metal is scored all the way through to the base steel, corrosion is less likely to ensue because of the more favorable relationship of zinc and steel in the electromotive series—oxidation of steel being in part a galvanic phenomenon. Sprayed metal requires no time to dry whereas conventional baking methods require both furnace equipment and time. The coating is complete and has its final durability as soon as it is applied.

Protection from Shock—Undoubtedly more has been learned in the last half dozen years about the effect of shock on apparatus than in any previous two decades. Mostly this is because so much equipment has been subjected to the effects of gun fire. The attention of engineers generally has been focused on the problem, which inevitably leads to a better-directed and more concentrated approach to the solution. For example, methods of making shock tests and specific shock-test equipments were developed, which permits comparison of shock-test results made in different plants.

Until the recent emergency period there was no standardized method of shock testing or machines for shock tests. At the Navy's request several types of shock machines were developed. The outstanding and largest of these were shock stands equipped with a 3000-pound hammer, which could be dropped six feet giving an 18 000 pounds-feet blow. Five of these of identical design were built and have been used extensively in the plants of three electrical manufacturers and in two of the Navy's laboratories. Among the special shock machines was one developed for the testing of switchboard-type instruments. These various machines make it possible to test a variety of machines and have the results correlated throughout the industry.

Equipment built to resist shock is generally more expensive than equipment that has to endure only normal service, hence it is not logical to expect that all apparatus will be so constructed. However, some improvement of regular apparatus will result even though the extreme methods of shock proofing may not be applied. For example, engineers learned that the heaviest and most rugged switching devices don't necessarily stand up against shock resistance as well as lighter equipment that can be better balanced. This knowledge will have an effect on non-military switchgear equipments, particularly the smaller devices.

In the construction of radio equipment for use on shipboard, it was found that mountings made of cast aluminum were quite superior because of their high damping characteristics. Electronic devices generally will be improved because of the need for protecting them against shock. It is now possible to protect large tubes and to isolate contactors that cause vibration, using isolators of various types such as springs and damping pads. This knowledge will be specifically of benefit in building radio equipment for Stratovision. Also, some of this knowledge has been applied to the improvement of medical x-ray tables.

The method of sealing metal to glass, using metals of the Kovar type that have virtually the same coefficient of heat expansion as glass, provides as well as an excellent seal substantial improvement in the ruggedness of tubes. As compared with the feathered-edge types of metal-to-glass seals that had long been used by the industry, Kovar can be applied in thicker sections, resulting in an attachment much more rigid and shock resistant. This sealing method is being extended generally to the manufacture of electronic tubes for F-M and A-M broadcasting, train radio, Stratovision, and radar, as well as the vacuum tubes for the frequencies used in induction and dielectric heating.

Shock Lessons from Miniature Lamps—Miniature lamps of the 6-, 12-, and 28-volt variety were used literally by tens of thousands mostly on vehicles such as tanks, jeeps, and airplanes. Characteristic of all this service was extreme vibration and shock, which is the worst enemy of lamps with their precision and intrinsically fragile parts. As one might expect during the early part of the war the record of lamps applied to tank service was discouraging. Here the life was measurable not in hours but in miles, frequently fifty miles being the absolute maximum life. As experience accumulated, general improvement in shock and vibration resistance was achieved with miniature lamps which will be of benefit to this type of lamp generally.

Perhaps even more important, however, was the focussing of attention by manufacturers of all lamps in general on the problem. With this need for an aggressive attack on the problem came a better understanding and coordination of shock testing and the effect of rough service of small lamps. Out of this will inevitably come an improved construction for all types of vehicle lamps such as those used on aircraft, Diesel trucks, and railroad passenger cars.

Newer, Better Lighting—Numerous lamps developed for special purposes in these recent rugged years will have almost direct carry-over. One of the most spectacular of miniature lamps—that for aiding pilots downed at sea and shipwrecked seamen—will have an appeal to every motorist. This so-called sea-rescue lamp, developed for operation from a hand-turned generator, provided a long-range beam to attract searching parties. The lamp is a small, walnut-size bulb with an internal silvered reflector and a precision-located filament. This combination provides a strong, sharp beam of nearly 1200 candlepower.

The lamp will have various more ordinary uses, possibly becoming the basis for an automobile emergency or trouble light located on the end of an extension cord that plugs into the cigarette-lighter outlet on the instrument panel. The convenient lamp can be used for under-the-hood operations, to provide light for changing a spare tire, or reading a road sign or house number, or for giving an emergency signal in case of an accident along the road at night. The lamp utilizes its seven watts of energy so efficiently that with it a road marker 100 feet away can easily be read under normal conditions.

Another type of miniature lamp utilizing the glow principle carries over to a lamp for use in domestic electric refrigerators for the control of bacteria and mold spores. This lamp, slightly smaller than a golf ball, irradiates the air in the refrigerator as it circulates past the lamp, giving a reduction in bacteria and mold spores, and a consequent reduction in food spoilage. In addition, the ozone produced in the cabinet's air destroys odor-bearing vapors.

Construction of the refrigerator Sterilamp as a miniature of the conventional Sterilamp was not practicable with reasonable efficiency. Engineers, casting about for a suitable bactericidal lamp for refrigerator service, took note of the glow type of lamp originally developed for fliers and sailors forced into life rafts during the war. By altering the glass and making minor modifications in the electrodes, an extremely efficient refrigerator Sterilamp has resulted.

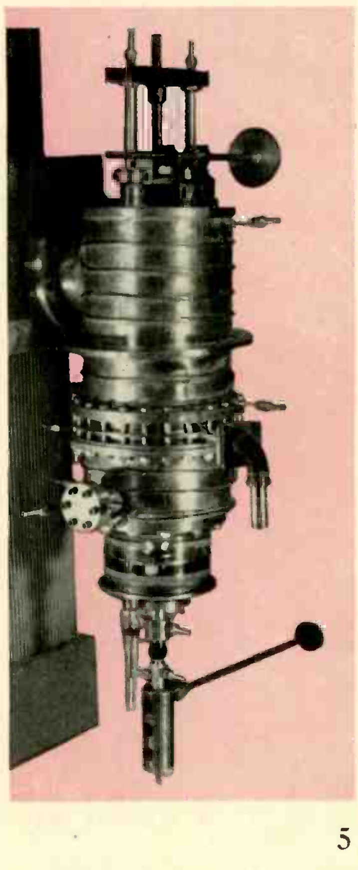
Mercury-vapor lamps are being built in new forms and larger sizes to provide a better answer to the problem of lighting industrial areas, particularly those with high ceilings. Most recent of this growing family of high-efficiency lamps is the 1000-watt high-pressure, air-cooled unit, which, although about the size and shape of a fountain pen, provides a concentrated, high-power source for factories, particularly those with high ceilings. This lamp will continue to serve its original purpose, but in addition it appears to have application in photochemical processes where the reactions are expedited or controlled by ultraviolet and visible-light radiation.

General Changes in Engineering

Whether the "good old days" were really good or just seem so at a distance is always an open question. In either case, to crave their return is only wishful thinking. This is fully as true in engineering as in any other field. Although engineering has resumed its more normal activities, it is by no means the same as before the interruption. The last few years have left permanent marks on the profession, mostly good, some not so good—but anyway, marks. There are many such marks, most of them vague and intangible. Frequently, one feels strongly that this is so without being able to cite specific evidence.

In numerous plants engineers became much better acquainted with factory men and methods. And vice versa. With production paramount, the usual model-shop, pilot-plant steps, by which difficulties of large-scale manufacture are avoided, had to be side-tracked or telescoped. Every difficulty with a new design—or for that matter, with an old one—with a material substitution, or from any one of a score of other sources, required instant attention by the design engineers involved. This urgent production necessity resulted in many more personal contacts between design and production departments instead of the usual indirect routines. Frequently design-factory liaison engineers were placed in the shop itself. The outcome has been a better understanding by technical men of shop problems, methods, and men. Likewise production people have an appreciation for the initial creative phases of products and machines. This interchange has large but intangible benefit in the aggregate.

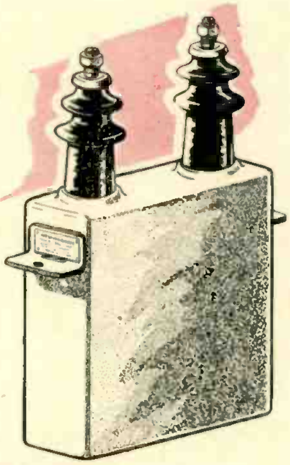
Being Critical of the Accepted — The great pressure for unheard of production rates had



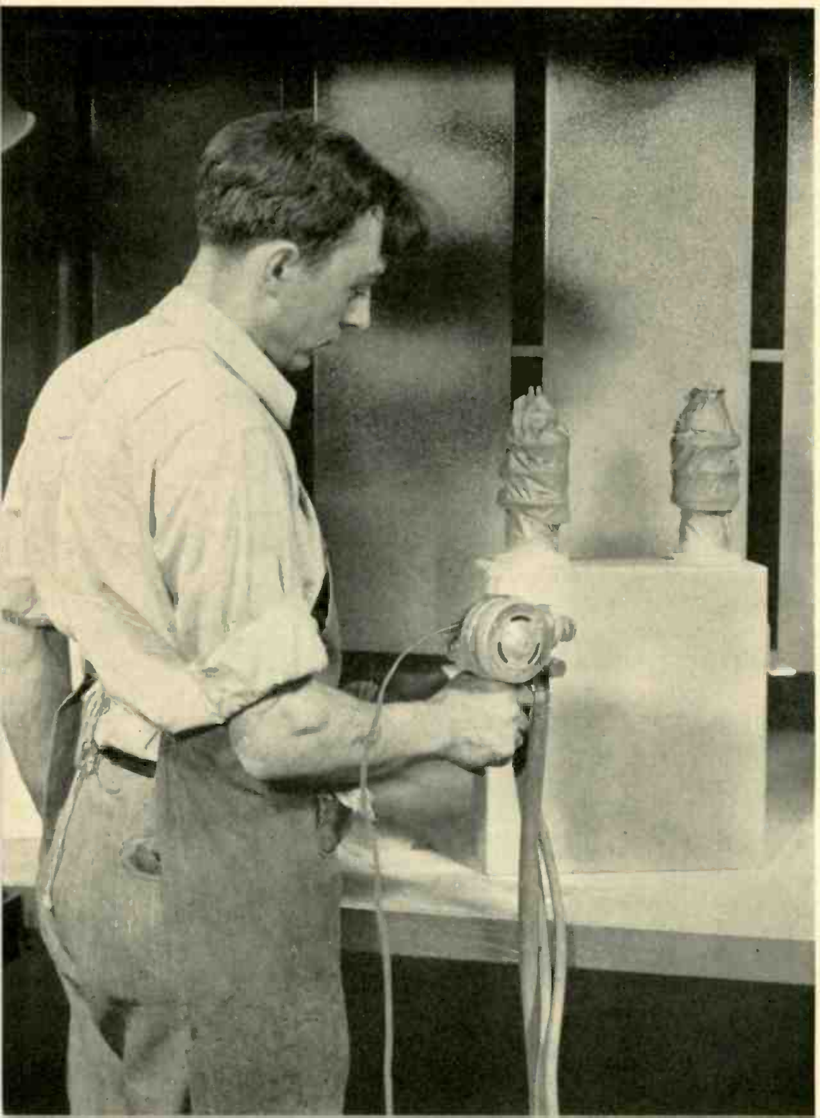
This is a tube. It is a resnatron, a high-power tube for generation of microwaves.

another incidental good. It forced examination of many time-honored ideas and methods, sometimes with astonishing results. It not only resulted in specific benefits but also taught the general lesson of the value of frequent critical examination of the conventional.

The Westinghouse electronic tube plant soon found itself with the problem of manufacturing several times more large tubes than it had ever before provided. Furthermore, the physical arrangement of the plant was such that further expansion of facilities was not possible. Somehow the greatly stepped up production would have to come from the existing space. This led the design and production engineers to re-examine every step in tube manufacture for ways of increasing output. The traditional method of sealing glass to metal was in horizontal lathes. This resulted from the fact that the men who performed these sealing operations had been machinists before the skyrocket rise of electronics. They brought with them, naturally, their previous experience which was with horizontal lathes. One harassed production engineer, however, considered that time and space might be saved by using vertical machines. For trial some old drill presses were found and the chucks rearranged so that the glass portion of the tubes were held in the upper member and rotated around a vertical axis during the fastening operation to the metal member held on the fixed bed below.



Painting with liquid metal to impede corrosion. Steel cases of power-line shunt capacitors are sprayed with a thick coat of molten zinc to make them weather resistant.



The results were astonishing. The vertical machines occupied only a fraction of the space of the horizontal ones. Furthermore gravity now worked in favor of the joining operation instead of, as in the horizontal machines, attempting to distort the seal. These and other advantages brought about an eight-fold improvement in electronic-tube production from the given working area. The idea has been so beneficial that it has been generally adopted for manufacture of all types of large tubes such as those for x-rays, radar high-frequency heating, F-M and A-M broadcasting.

Such experiences have taught engineers in many plants that there is nothing sacred about ways of doing things just because they have been long accepted. This is indeed a wholesome attitude and for a time will have many engineering and product benefits.

Design and production engineers find themselves equipped with machines and test setups that normally would not have been available. These result from the need for such vast quantities of products that literally demanded machines, tools, and setups. In the normal course of events many of these machines couldn't be justified but now that plants have them they will be put to good account. The result is more accurate devices produced at less total cost.

The greater diffusion of technical knowledge that comes as a by-product of conditions of recent years acts as an accelerator for many lines of development. The freer interchange of knowledge, the necessity for standardization of mountings, physical dimensions, etc., the more frequent contacts of technicians with other plants are positive gains. As a single example, the importance of vibration and machine design is now much more extensively appreciated, as is indicated by the fact that electronic machines for producing continuous vibration for test are now being sold in numbers. Ten years ago vibration-test programs were rare.

Greater Responsibilities for Engineers—Design engineers in many plants find themselves with more responsibilities than when they last produced the normal kind of things. In general, drawings are much more elaborate, much more detailed and more numerous. There are many reasons for this. Apparatus, particularly in the electronic and control field, is becoming much more complex. Also, during the years of large quantity ordnance production many people with limited shop experience had been brought into production organizations. Also, the greater use of incentive systems, and greater segregation of time rates require that less freedom of discretion be given the production worker. Processes, dimensions, treatments, and assembly methods must be specified in more detail. All this can hardly be counted on the plus side of the engineering ledger but is a fact to be reckoned with in many lines of technical endeavor.

Also, hardly to be counted an advantage is the fact that engineers had a tendency when the emphasis was on production to lose their cost consciousness. This is particularly true because many young engineers have come into organizations who have had little or no experience with the normal ways of doing things where expense is a major consideration. This return to a keen awareness of cost considerations in design is made the more difficult because of the natural and commendable trait of engineers to like to do the best possible job, which frequently of course is not always compatible with practical considerations of economy.

Designers of high-power tubes for use at radio frequencies have found that engineers' experience in ultra-high-frequency tubes of the radar class can be of great aid to them in explaining previously baffling phenomena. For example, certain radio-frequency tubes have demonstrated a tendency for local heating unexplainable except on the basis of resonant-cavity effects, which is the underlying principle of such tubes as the magnetron and klystron.

Material Scarcity Spurs Ingenuity

The shortage of materials that plagued engineers throughout the war took a curious turn at the end of hostilities. Some materials that had been scarce became plentiful and others that had been reasonably plentiful became difficult to get. For a long time aluminum was among the most scarce of war-needed materials but with the sudden decline in aircraft manufacture aluminum became relatively plentiful, and its place on the shortage list in certain types and shapes was occupied by steel.

Problems of Steel—During the middle and latter part of 1946, engineers found it increasingly necessary to reduce their usage of steel, in order to keep the production line in action. Engineers have displayed the same ingenuity evidenced during the emergency in these matters of substitution. A study of the electric range disclosed that it would be possible to make 27 substitutions of aluminum for steel, eliminating a total of 38 pounds of steel per unit. Aluminum can be substituted in many places where strength is not a consideration, such as for baffles, traps, and other non-load-bearing parts. No change resulted in any compromise with quality and some were definitely advantageous.

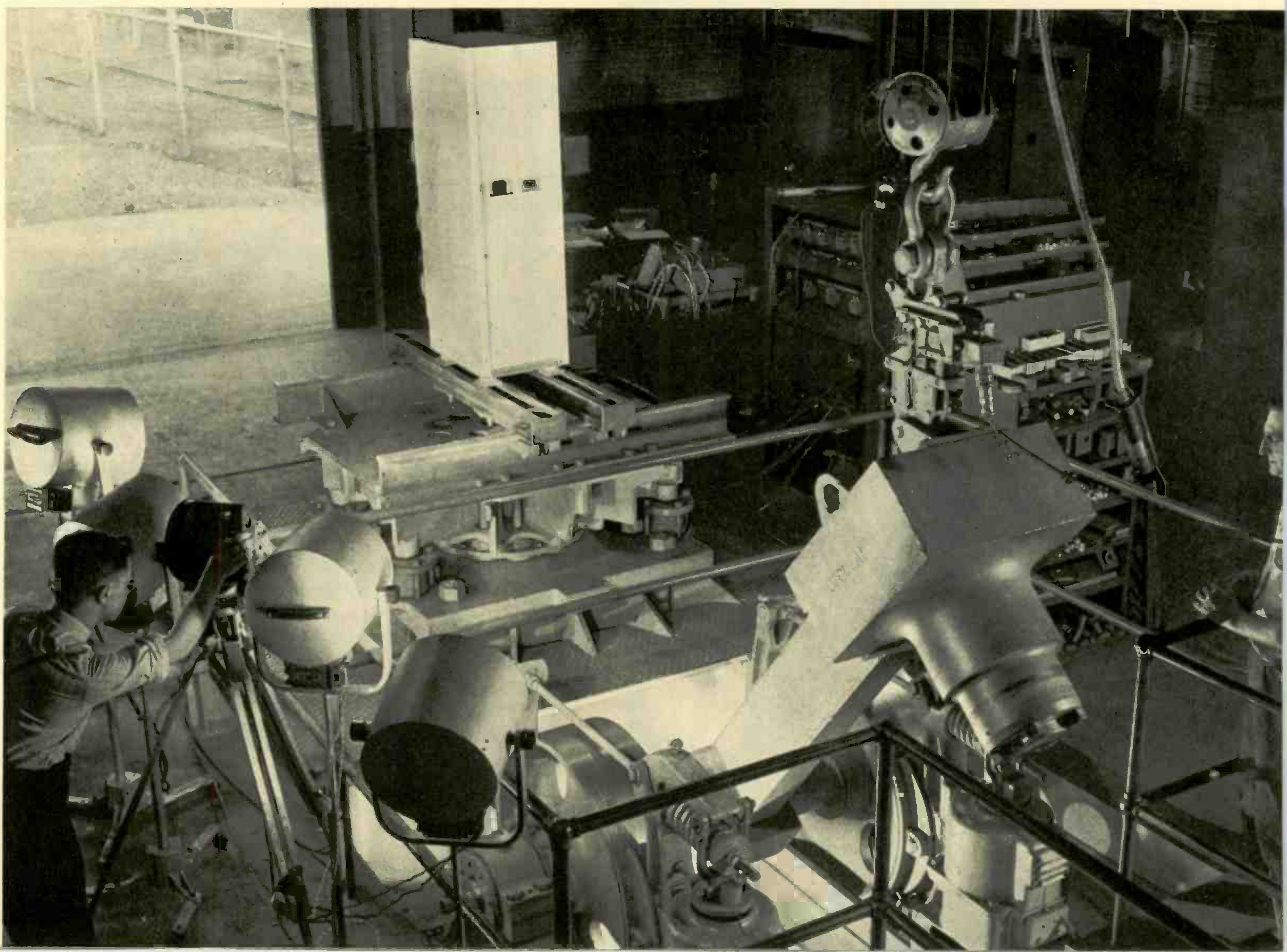
The cover or exposed upper part of electric irons is now made from aluminum, with definite advantage. The new aluminum surface requires less finishing time and a few ounces are cut from the iron's weight. There is no chrome surface subject to injury, and rejects are reduced.

Even cast iron has at times become strangely short. In one product requiring about 65 pounds of mass for a balancing function the customary cast iron could no longer be readily obtained. As a substitute, thick sections of a boiler plate were bolted together. This change proved to be not only an actual economy but also was easier for workmen to handle.

Because steel rivets became difficult to obtain, aluminum rivets have been substituted in some cases where shock is not encountered. In certain lighting fixtures aircraft-type aluminum rivets have been used for screws.

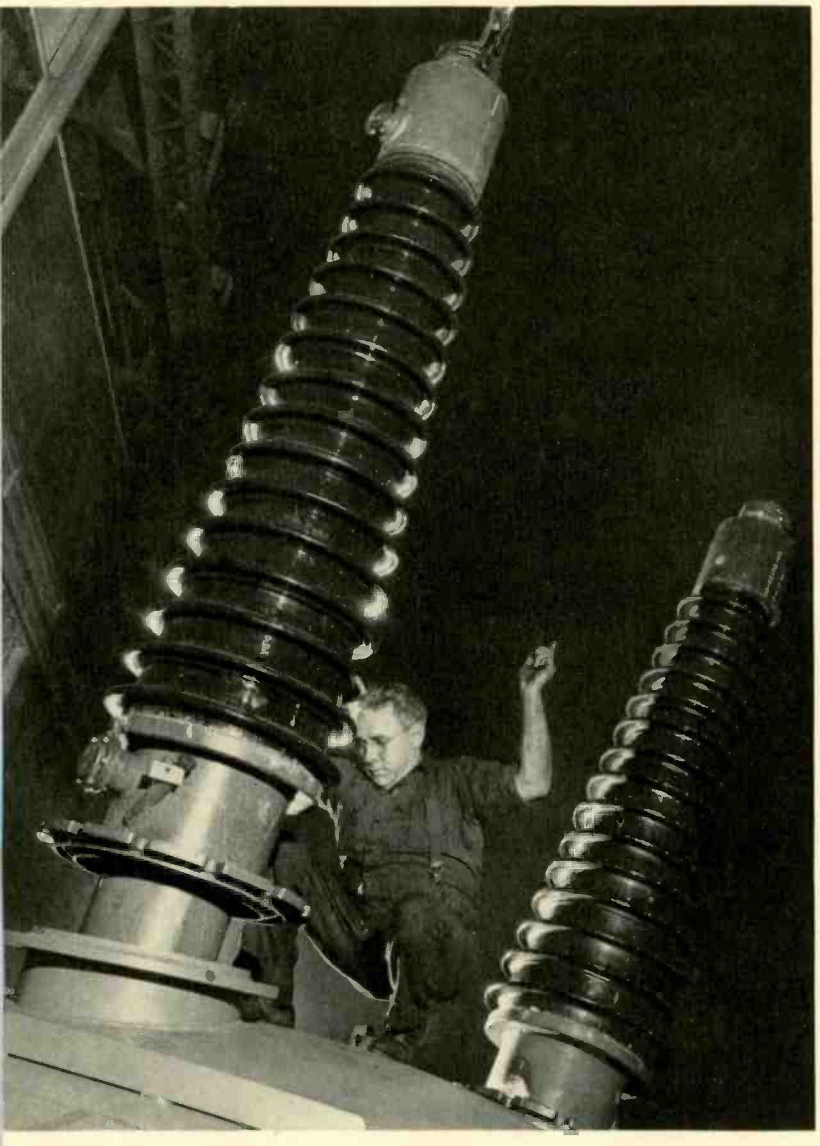
Control wires with coverings of different colors simplify assembly, but lately it has not always been possible to secure wire in a desired color. Thereupon, it became necessary to devise a means for coloring the available wire inasmuch as the

Vibration resulting from shock on this 18 000 pounds-feet test stand can best be analyzed with high-speed cameras.



white cotton-covered wire is more readily available. On short wires this was done by using a wrapping of colored scotch tape, or by a short piece of colored insulating tubing over the cotton. On longer wires, and where space factor was a problem, the wires were racked and sprayed with colored lacquer.

When the supply of sapphire jewels from Switzerland became strangled in 1941, engineers turned again as they had 25 years ago to other types of bearings for instruments, which not only were absolutely indispensable but were demanded in many times larger quantities than ever before. On this occasion, experiments with glass jewels have proved more successful, so much so that they will unquestionably live for certain applications. Glass is not as hard as sapphire, and, therefore, wear and friction of a steel pivot and glass cup are less than with the steel pivot and sapphire. Up to a certain



Stemming in part from shortage of a shellac, the new condenser bushings are constructed by a method that does not require it.

point of stress, the glass is superior, but beyond that the sapphire is still preferred. Glass will continue to be used in some applications where the bearing loads are lighter.

Better Grids for Tubes—A permanent improvement in electronic tubes comes about because tantalum became scarce. This forced electronic engineers to seek an alternate material for use as the grid wires on high-powered tubes. This was a particularly stubborn problem inasmuch as tubes were being built for larger and larger capacities and grids were being exposed to greater concentration of cathode power. It was recognized that platinum would be ideal in some respects, inasmuch as it has a high work function (i.e., it does not tend to give off electrons even when hot). However, platinum softens and weakens mechanically when high temperatures

Switchgear that only a few years ago was barely able to meet the 150-pounds feet shock test successfully passes the 18000 pounds feet test. Furthermore, this heavy blow is given three successive times to each of three sides. While most of the construction in design improvements that have made this possible are too expensive for ordinary applications numerous facts about shock and ensuing vibration and movements of parts will permit engineers to avoid many pitfalls from vibration. Numerous improvements will ensue, such as better latches on contactors, spring mountings, etc.

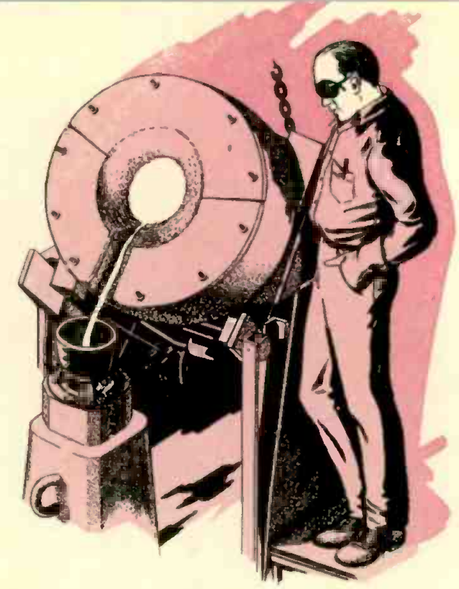
are reached. The problem was solved by making grids out of molybdenum wire coated with platinum. The moly retains its strength at high temperatures and serves to support the platinum. This combination has another advantage, as platinum has the fortunate property of absorbing the thorium given off by the cathodes during operation. Without this property, thorium would accumulate on the surfaces and greatly lessen the tubes' capacity to function properly. This construction, which began as a substitute measure, has proved successful and will be extended to commercial tubes such as tetrodes for F-M broadcasting.

Bushings without Shellac—Shortage of shellac has resulted in a major improvement in condenser bushings. The new construction requires only a small amount of shellac and therefore permitted uninterrupted production of badly needed high-voltage bushings and at the same time released large quantities of shellac for other uses. The new bushing is superior electrically and has entirely replaced the previous construction in the high-voltage class.

The new condenser bushing consists, as before, of layers of high-grade paper, wound under tension on the copper conductor, which is a copper tube or stud. In accordance with well-known condenser-bushing principles, sheets of metal foil are inserted at intervals. Except for an adhesive to bind the first turn of paper to the conductor, the paper is wound dry, with no binder between layers, as in modern transformer practice. There is, likewise, no subsequent varnish treatment of the insulator surface to interfere with oil penetration. After the winding has been made in this manner—usual except for the absence of the shellac between layers and the final varnishing—and is machined to proper dimensions, the structure is placed in its porcelain housing. In the new bushing, the condenser is completely enclosed by upper and lower porcelains connected at midsection by a steel sleeve. Thus the condenser projecting down into the tank is encased in porcelain as is the upper end.

In this bushing the mechanical and electrical functions have been entirely separated. The condenser no longer assumes any of the mechanical load. All stresses are carried by the porcelain in compression. Completed bushings of this design have been subjected to severe shock and vibration tests with results that proved the porcelain and steel structure to be entirely adequate.

The Legacy of New Materials



". . . Machines will be built better because of new, improved, or cheaper materials and because engineers have a fuller understanding of the nature of materials and just what can be expected of them."

THE designer of the 1947 model of something finds at his disposal an array of materials not available to him in 1941 or 1942. Some are wholly new, others are new only in that previously they were of academic interest because of size, shape, or cost limitations. Others have been significantly improved, giving them a new order of importance.

The new materials form a prodigious list, including plastics for structures and for heat and electrical insulations, metals for high temperatures, magnetic alloys, lubricants, glasses, enamels, and many more. Some are the direct result of new needs for which previous materials were inadequate. Others are sturdy and worthy survivors of critical material shortages, i.e., substitutions made good.

Something Better than Mica—In 1942 when it appeared that the Japanese might overrun the whole of the South Pacific, engineers were alarmed lest the supplies of indispensable mica be cut off. Although this did not happen, a frantic search began for a substitute for mica, something long assumed to have no alternate. Without mica or an equivalent electrical insulation the electrical industry would have been in a bad way indeed.

A material quite equal to the requirement—and in some ways better—was created. Asbestos paper was impregnated with a thermosetting synthetic binder of the Fosterite family (see p. 11) molded to the desired shape, and cured under heat. The resulting insulation, while by no means a complete substitute for mica (a new material seldom wholly replaces an old one), has some superior qualities that dictate its use even with mica readily available. It is much less affected by water than is mica and hence does not deteriorate in storage even under conditions of moisture. It does not delaminate. It has good arc-resisting qualities and excellent dielectric strength. Furthermore, it can be formed easily into complex shapes, can be machined, drilled, and punched.

It has been used extensively as pole cell insulation on a-c motors and is now being regularly used for commutator bar spacers for small motors, class B coil-support channels, and miscellaneous insulating structures which are difficult or impossible to fabricate from conventional materials. The material is limited to applications where high voltages are not encountered, because asbestos does not have as high dielectric strength as mica.

Famous Silicones—Silicones are gradually infiltrating many avenues of electrical apparatus. Best known to electrical men is the use of silicones as a high-temperature varnish for motor windings. The cooperative Westinghouse-Dow Corning motor tests begun in 1943 have verified the fondest hopes as to the performance of silicone varnish. For example, a railway motor after 1700 hours of operation at 260 degrees C (500 F), including 46 high-humidification cycles, was torn down for inspection. The motor could have continued to operate indefinitely. The windings were in excellent condition and withstood the standard voltage tests.

While as yet the costs of silicone varnishes preclude their wholesale use on rotating machines, they have demonstrated superiorities for high-temperature conditions. They are, accordingly, being used experimentally on railway motors, on certain totally enclosed industrial motors, on magnet coils, for transformers used in street-light fixtures and similar applications. The field for silicone varnishes is definitely growing and will accelerate as costs decline.

Silicone rubber or gasketing material has proved useful as a cover seal for searchlights where the temperatures created by the electric arc became exceedingly high. This ability of silicone to withstand high temperatures without hardening may be utilized in the electric steam iron. A paste of this rubber seals the cover plate to the main base casting. Because the paste conforms to the surface of the metal parts better than the previous sheet metal, fine machining of the mating surfaces can be eliminated, yet obtaining even better, longer lasting seals. Washers of silicone rubber in sheet form also find other uses, such as gaskets in electric irons, arc lights, and oil circuit breakers.

Nylon, High-Pressure Gasket Material—Valve seats and packing for high-pressure valves have long been a source of difficulty. Ordinary materials become hard and eventually lose their ability to hold against the stiff pressures.

When transformer engineers turned to making electric torpedos they found their old gasketing problem awaiting them—in aggravated form. Valves had to be seated against a pressure of 3000 pounds per square inch. The answer to the old problem lay in a new material—fabulous nylon. Washer-like valve seats were made from a hard, milky-white form of nylon. They performed perfectly.

Nylon can be molded and machined readily. It is chemically inert and changeless with time. It is tough and highly resistant to mechanical abrasion.

Transformer engineers, returning to their normal pursuits, took their nylon valve-seat material with them. It has already been applied as the sealing gland on switches of network transformers where, after hundreds of thousands of operations, it is negligibly changed. It will show up, of course, in many other places where metal parts must be seated against pressure. Already it shows indication of going beyond the electrical industry as interest is being shown in it for valves of high-pressure gas cylinders.

Thermal Insulation—Glass fiber has proved its superiority in several respects as a heat insulator in electrical appliances. Organic material such as the redwood-tree fiber has heretofore been used. However, the new glass fiber exhibits better thermal efficiency, which reduces the radiation loss by ten percent. For example, this advantage can be readily realized in the water heater where such a loss is continuous 24 hours a day.

Then, too, glass fibers are longer and more resilient than those of the organic materials. A glass blanket does not sag or settle under vibration or action of water. In a tall vertical column, as in the water-heater, this is particularly useful. To offset the higher cost of synthetic fibers, an economical means of machine-forming the blanket into half cylinders was devised. This glass blanket can be built up in about one third the time previously required for the organic-fiber insulation and it provides a more uniform thickness.

High-Temperature Lubricants—Operation of machines at high temperatures imposes grave burdens on lubricants as well as on metals. Two materials, still inadequately known, show much promise as lubricants for parts that move when hot.

One is the molybdenum sulfide family. Moly-sulfide molecules are polarized and have the property of attaching with tenacity to clean metal surfaces, forming a bond that ordinary friction cannot remove. The coefficient of friction of moly-sulfide heated surfaces is remarkably low and permanent. Also it is temperature stable. It has been used successfully as a lubricant at 700 degrees F. Because the moly-sulfide film is lasting it is useful where low starting friction is required after a long period of idleness.

Glass fibers make better heat insulations for electric water heaters than do organic materials. Furthermore they are less adversely affected by moisture or water and sag less.

Moly-sulfide can be applied as an impalpable dust, as a grease, or in a solution. One of its first uses was to lubricate the high-speed rotating anodes in the high-vacuum of x-ray tubes. It is useful also to lubricate the leader pins of forming dies, the temperature-adjusting screws of electric irons, and the stainless-steel shaft and cast-iron bearings of motors that are confronted with the intense heat of electric-arc searchlights. Its uses, the best methods of its application, and its limitations are still imperfectly known.

Color certainly has nothing to do with the qualities of a high-temperature lubricant. Moly-sulfide is metallic black. Another new material of absorbing interest for the same kind of job is whiter than the whitest chalk. It is boron nitride, curiously enough at one time a nuisance by-product of igniter manufacture. An observant materials engineer, faced with the problem of disposing of the "worthless" material, noted the extreme smoothness of the white dust, and, because it is created in the arc furnace at 3250 degrees F, it must be temperature stable. These properties suggested its use as a high-temperature lubricant. Mixed with silicone grease it has proved a superior lubricant for ball bearings of searchlight motors, and certain aircraft motors exposed to heat. Other uses are in prospect.

Molybdenum Is a New Material—Moly is moving from the field of academic to practical interest. For all its attractive qualities it has been beyond reach as a structural material because it has been available only in small sizes, simple shapes, and at high cost. All three of these bottlenecks have been broken, curiously enough as a result of research on materials for lamps and electronic tubes. Now moly is available in slabs as large as a desk top, in complex shapes, and at a cost per pound roughly half that of five years ago.

The 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.

The most important characteristics are its high melting point and great wear resistance at elevated temperatures. Also it has a higher modulus of elasticity, superior strength when hot, and better thermal conductivity than any steel. Its specific heat and coefficient of expansion are less. As to corrosion resistance it compares favorably in many media with tantalum, palladium, and platinum, each costing many times more than moly.

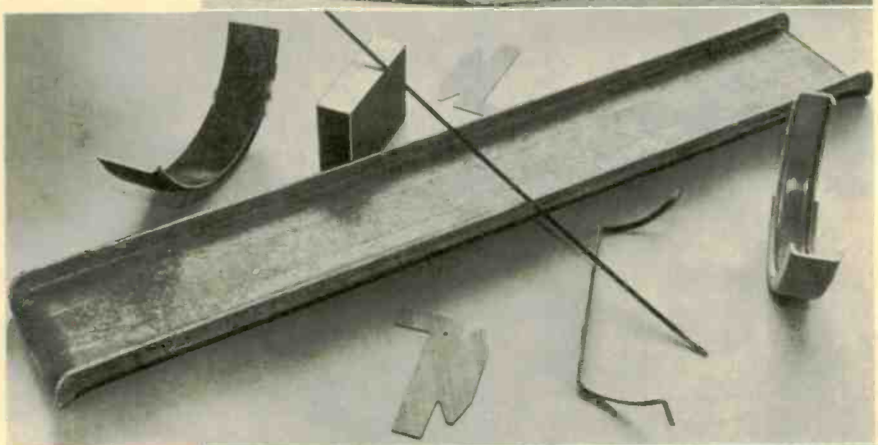
Moly is now proving valuable in the form of crucibles, electronic tube parts, electrical contacts, electrodes for resistance heating of glass, welding tips, thermocouple tubes, and for electric-furnace heating elements for high-temperature work in a vacuum or protective atmosphere. It is expected to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

Electrical Glass—The designer of bactericidal lamps is much concerned with transparency of glass to invisible radiation. Of greatest interest is the ability of the glass to pass the principal mercury-vapor spectral line—2537 Angstroms. Also important is the much shorter and ozone-producing wavelength, 1850 Angstroms. Depending on the application, the 1850 radiation may be desired or undesired. Now a glass is available that is far superior, considering cost and workability, to previous materials for work with these invisible radiations. It is called Vycor.

This glass has three interesting properties. Its transmission of the principal bactericidal wavelength—2537 Angstroms—is nearly half again better than that of the glass previously available at acceptable cost. Also, Vycor retains this high ultraviolet transmission ability throughout its life far better than other glasses. This means that bactericidal lamps of the Sterilamp type can be built without necessitating allowance for a fairly large decline in ultraviolet transmission during the first few dozen hours of its life. Furthermore, by the addition or absence of certain minor constituents of the glass at the time of its making, the ability to pass the ozone-producing wavelength can be controlled over an extremely wide range. Thus, for example, Sterilamps, for use in food storage areas where a modest amount of ozone is desired to combat food odors, can be made of Vycor which has a fair transmission of 1850 Angstroms. On the other hand, Vycor of another type transmits little or no radiation of 1850 Angstroms and hence can be used in buildings occupied by people where ozone is not desirable because of its toxic quality.

As seems to be true with all new materials, Vycor is not without certain disadvantages that prevent wholesale substitution for other glasses. It has a fairly low coefficient of thermal expansion which means that the conventional seals to lead-in wires can't be employed. Instead, graded glass seals or other schemes must be developed for bactericidal lamps using Vycor.

A molded material that favorably takes the place of mica for numerous insulating jobs is formed of asbestos fiber impregnated with a synthetic binder molded to shape and set by heat. Upper right is a sheet before curing. Right is various shapes formed of this material. Lower right demonstrates a wide range in physical sizes of Kovar-glass seals.



Manufacturers of glass and engineers who apply it have taken a cue from powder metallurgists and have produced an essentially new material, called Multiform. It is made by grinding glass to a fine powder, mixing it with an appropriate amount of synthetic binder and molding it to the desired shape while applying heat. In this way, complicated shapes having all the desirable properties of glass, but stronger and not so brittle as glass, are achieved. Coil forms, insulating spacers, and other nonsymmetrical shapes are being readily made in this fashion to accurate dimensions.

Water-Impervious Insulation—Since the first electrical machine was made engineers have sought an insulation that is both electrically and water resistant. Conditions in the Pacific made such a material mandatory.

Radio equipments, particularly, were subjected to rapid and severe temperature changes, as in aircraft service, where the temperature might drop between take-off and high altitudes as much as 150° F in a few minutes. The cycle of frosting and melting quickly wrecked ordinary insulations on transformers and other wound apparatus. Frequently the life of equipment was reduced to a matter of a few days and in some cases even only a few hours.

The problem was presented to a research engineer who reasoned that most varnishes failed because they consist of a small portion of solids carried in a volatile solvent subsequently evaporated in processing. This leaves a surface porous by the amount of the solvent driven off. It appeared that if an insulation could be made without volatile solvents it would have no voids for destructive moisture to enter. Acting on this reasoning he created a synthetic varnish in which the solvents react chemically under heat to form the solid insulation. Hence, if all air is first evacuated from the device to be insulated before Fosterite is applied there can be no voids because nothing is lost in the subsequent treating processes.

Tens of thousands of transformers for radar and radio communications have been protected both internally and externally with the Fosterite treatment and have turned in an excellent record of moisture resistance even under the high humidities of the tropics.

The treatment, while it is not intended to compete with hermetic sealing, does have the advantage of providing extremely good moisture resistance without the extra weight of metal cans and sealing compound. Fosterite is an organic insulation and has the limitations of such. Also it is incompatible with certain substances, of which, unfortunately, bare copper is one. Hence it must be applied with discretion.

Fosterite has many interesting applications to normal electrical products. The full extent of these is not yet explored although Fosterite has much promise as an insulation for coils of certain motors that have restricted air passages. Coils impregnated with Fosterite and baked have a hard, tough exterior surface that is highly resistant to mechanical damage and to moisture.

Better Enamels—To solve the problem of excessive corrosion of exhaust manifolds of engines in airplanes and tanks, an enamel was developed capable of withstanding much higher temperatures. This new enamel, of the aluminum-oxide type, has been applied with benefit to panels of electric ovens, and to the heating units. This finish is able to withstand 200 degrees F higher temperatures than the zirconium-type enamels previously used. This allows the heating coils to be made smaller and to be held closer to dimensions, leaving more usable oven space. It is an example of the general tendency to work materials harder.

When antimony and zirconium enamels became scarce, a search was made for other enamels suitable for the exterior finish of electric appliances, such as electric ranges, subjected to high temperatures. From that search came a titanium-base enamel that, without additional cost, provides an acid-resisting finish and one that is more shock resistant than the previous enamel because it can be applied in thinner layers. Also, its color does not vary with its thickness, which simplifies the color-matching problem when repairs are to be made.

Low-Loss Magnetic Materials—Grain-oriented silicon-iron (Hipersil) has gone a long way since its introduction about ten years ago. It was first employed in standard gauges —about 13 mils—as core material for distribution and power transformers. In order to make the most of the favorable magnetic properties in the rolling direction (the permeability is about one third better than non-oriented silicon iron) all but the very large cores are wound, like adding-machine tape, sawed in two for entry of the coils, and reassembled. The smaller cores permit smaller coils, which means less surrounding oil and tank.

The seemingly endless demand for communication transformers, particularly at the very high frequencies, even up to thousands of megacycles, called for thinner and thinner Hipersil, to hold the eddy-current losses within reason. Rolling and heat-treating techniques have been improved, successfully permitting production at practical cost of 7-mil, 5-mil, 3-mil, and now 2-mil Hipersil. Tens of thousands of transformer cores, some of them as small as a single peanut, were made for communication equipments. These thinner gauge Hipersil cores are continuing to be used for high-frequency service, as for radar, television, and F-M radio where the service justifies the higher cost.

When the designer of a motor or other device requiring a soft magnetic material finds himself under pressure to decrease its size or weight, he can consider Hiperco. Hiperco is a magnetic material high in cobalt. It can be forged, pressed, or rolled into desired shape. It has the fortunate property of permitting a higher flux density, obtained with a lower magnetizing force, than ordinary materials. In aircraft generators and motors, for example, it permits up to ten percent overall reduction in size and weight. After annealing, Hiperco is somewhat more brittle than ordinary materials and hence requires care in assembling. At present at least, it costs more than conventional materials, hence its use is determined by the worth of the benefits it provides.

New techniques in manufacture and combinations of new ingredients have resulted in new types of porcelains, many of them suitable for high electrical strengths and duty at high frequencies. Among these are the zirconium-type porcelains that have excellent heat-shock characteristics as well as merit at high frequencies. Several new families of the porcelain enamels have been developed that will lead to improved electric appliances. Some are better adapted to high heat shock while others are chosen for easier application, superior appearance, high mechanical strength, or low electrical loss.

High-Temperature Alloys—Metals are now available with considerably greater strength (for the same creep) at gas-turbine temperatures than were had in 1940. This, of course, has come about because of the demands for high-temperature metals for gas turbines, jet engines, and superchargers. There are already several of such high-strength, high-temperature alloys—or more correctly, several families of alloys. K-42-B and Refractaloy 26 are examples of titanium-hardened materials. Stellite, which is not a new metal, is representative of another family. This material is so hard as to defy forging and machining processes. Its use as gas-turbine blade material had to wait for development of appropriate casting methods, such as the so-called lost-wax method (described on p. 15).

D-C Capacitors for High Temperature—Although chlorinated hydrocarbons such as Inerteen have excellent general properties, the combination of sustained high d-c voltage stress and high temperatures results in definite limits of life due to cumulative electrochemical activity. Addition of chemicals called inhibitors in the impregnant has increased the life at high temperatures, such as 150 to 175 degrees F, by as much as thirty times. Frequently, a d-c capacitor in a radio rectifier or in an electronic equipment may be required to operate at high temperatures due to ambient temperature or proximity of transformers or tubes. Prior to the use of these inhibitors, it was necessary to derate d-c capacitors drastically on high temperature applications or use mineral oil capacitors, either of which expedient increased the size by a factor of one and one-half to three. This problem is not encountered on a-c capacitors because designs are limited by other factors and the stresses are well below the level where electrochemical reactions are a problem. The inhibitors are used, however, on a-c capacitors as a protection under abnormal operating conditions involving temperature and high local stresses.

Silver-Bearing Copper—Recently it has been shown that copper containing a small amount of silver (a fraction of one percent) evidences larger creep strength. Certain types of copper as mined contain this necessary quantity of silver. Thus in choosing this type for use in the manufacture of electrical machines a much greater creep strength is obtained, with correspondingly longer life. There are also other metals and alloys that can be smelted into the copper to produce similar properties. The process of cold-working copper to lessen plastic deformation has been used in the preparation of conductors for large a-c generators. This cold-working process combined with the use of silver-bearing copper greatly reduces the seasoning time.

Steel manufacturers have provided a new trump card useful in the endeavor to build a-c generators with larger outputs but with little or no increase in physical dimensions. Steel forgings of 85 000 pounds per square inch yield strength, as compared to about 75 000 pounds available a few years ago, permit a significant increase in the maximum rating of high-speed, turbine-generators.

As a result both of scarcity and unusually severe requirements new enamels of greater heat and shock resistance and better appearance are available for electric appliances, particularly those such as ranges and roasters where relatively high temperatures are encountered.

New Production Skills

". . . Like the leader of a larger, more talented orchestra, today's designer has at his command new materials, improved materials, and less expensive ones. Furthermore, he now better understands them and what they have to do . . ."

Good design is harmonious and economical usage of technical principles, materials, and manufacturing methods. The way something is made has important bearing even on the initial concepts of a product. The apparatus engineer of today has many new and vastly improved shop practices at his command. They run the gamut from fabrication, machining, joining, finishing, and assembly. A few representative examples best show the evolution under way in factory aisles.

More Welding, More Forming, More Furnace and H-F Brazing—Blanket statements that one method is replacing another are hazardous because to say, for example, that fabrication is fast replacing casting is misleading for while it may be true generally, it is not in certain isolated cases. However, the trend away from castings and to welding, begun a dozen years ago, is more conspicuous. The new squirrel-cage motors, for example, (see p. 22) is wholly of welded steel; no castings are employed. The motor at the same time illustrates the greater use of deep drawing. The feet, subsequently welded to the circular frame rolled up of steel plate, are deep drawn, calling for the last word in this technique to effect such deep draws of heavy steel sheet. The end bells are likewise deep drawn from heavy-gauge steel.

Casings for steam turbines have customarily been cast. A beginning has been made to fabricate certain of them. This was done on the turbine for the 5000-kw package power plant (see p. 28). This means better production schedules, as there have been occasions with castings when flaws have appeared after machining was well along, necessitating a whole new casting. Some overall saving in weight has been effected in the turbine casings designed for fabrication thus far.

Resistance welding is edging in on some jobs formerly done by arc welding. This is conspicuous in construction of metal-enclosed switchgear, where spot welding is being used with benefit and savings. To realize these to the fullest, considerable standardization, greater tooling, and more expensive welding setups are required.

Furnace brazing, particularly with controlled atmospheres, reached major-league stature in the past half dozen years. It is being employed for myriads of connecting jobs, often replacing soft solder. As a single example can be mentioned brazed flexible shunt connectors for use with switchgear.

In the production of large electric appliances more stampings are being used, with a tendency to greater use of combination dies. Bases and covers for electric water heaters, 18 by 27 inches in area and several inches deep, are formed with rubber dies instead of being welded together with the necessary flat pieces. The result is a more consistent, more accurate product.

The same trend is manifest in construction of radio-transmitter frames. They are being made out of sheet stock instead of fabricated from structural shapes. In the new construction the outer walls become the frame, strengthened by appropriately placed ribs. Weight is saved, design and shop practices are simplified, and allowances are not necessary for minor dimensional variations in angles and other sections.

A method of making compound shapes in the aircraft industry, called stretch bending, has been borrowed for the production of the curved tracks for electric stairways. The structural sheet or shape to be bent is gripped by the arms of a special machine. The arms are rotated, stretching the metal beyond

Wiring of switchboards before the assembly with apparatus, where possible, offers economy of time and reduces chance of mistake. The new F-M transmitters below are simpler and lighter because of new production methods.

Serve Product Engineers

its elastic yield point. The part permanently retains the compound curvature thus given it.

Squeezing Copper—Magnetrons for radar are electronic tubes essentially simple in construction, albeit generators of ultra-high-frequency power. However, they presented one of the most rugged of manufacturing problems. A magnetron body consists essentially of a short cylindrical block of copper in which the resonant cavities must be precisely formed because the circular walls form the inductors and the gaps act as the capacitors, giving the L to C ratio for frequency determination. These cavities generally consist of a central hole (for the cathode), surrounded by perhaps eight other holes. A slot connects each of these surrounding cavities with the central one. In the beginning of magnetron manufacture these cavities were formed by machining methods. This was extremely time-consuming and, because the cavities must be accurate to one mil or better, the percentage of rejects ran high, even up to 85 percent, which was intolerable.

Magnetrons were demanded in prodigious numbers, hence some better, faster way of forming the complicated pattern of holes in copper stock had to be found. The way finally chosen was literally to press the desired configuration into a solid block of copper. The cylinder of copper is gripped in a hydraulic press. With a pressure of about eight tons, a die is forced an inch and a half into and nearly through the metal. The copper cold-flows upward to the top of the confining cup. The cavities are formed to the desired dimensions and all that remains is to cut off the bottom of the copper block so the cavities extend through, and to face off the top surface. A magnetron body can be made in this fashion in a few minutes —and rejects were reduced to a percent or two as compared to the conventional machining methods.

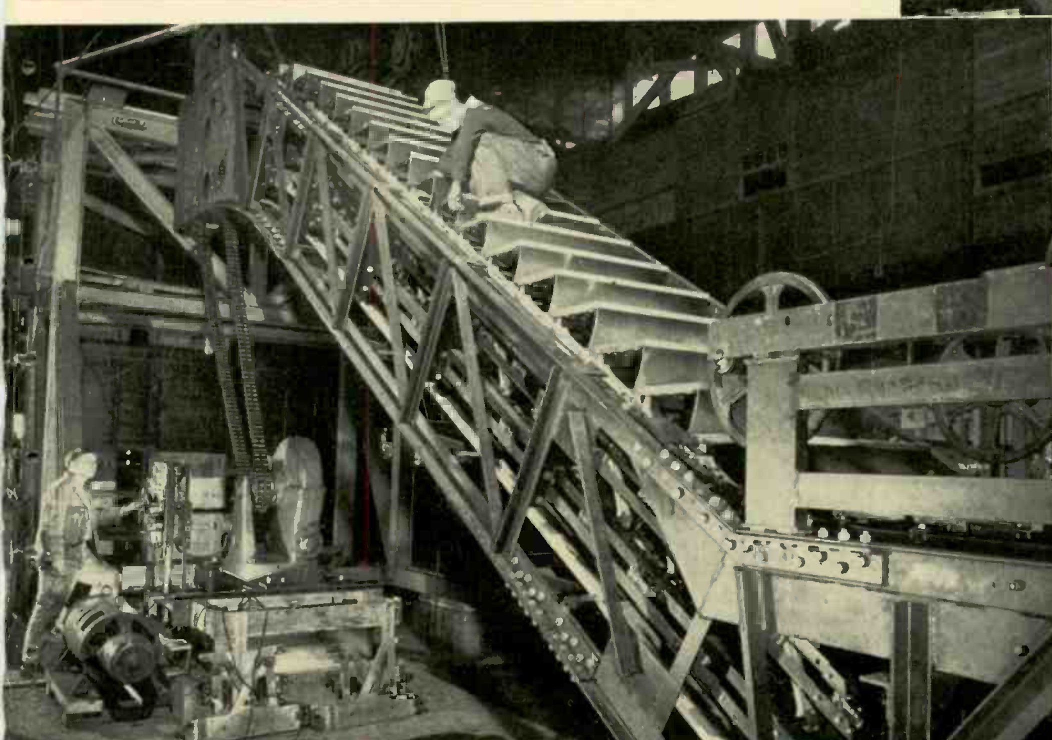
Stouter Gears—The loads that can be carried by reduction gears of the spur-tooth type are approximately proportional to the hardness of the tooth material. Steel of virtually any hardness can be obtained but the catch comes in forming the teeth. The conventional hobbing process is suitable for hardness up to about 350 Brinell. Answering the present demand, engineers have devised a means of forming teeth in harder material by grinding. The pinions for the 6500-hp geared-turbine locomotive, for example, were formed in this manner and have a Brinell of between 450 and 500. This cut the weight and bulk approximately in half.

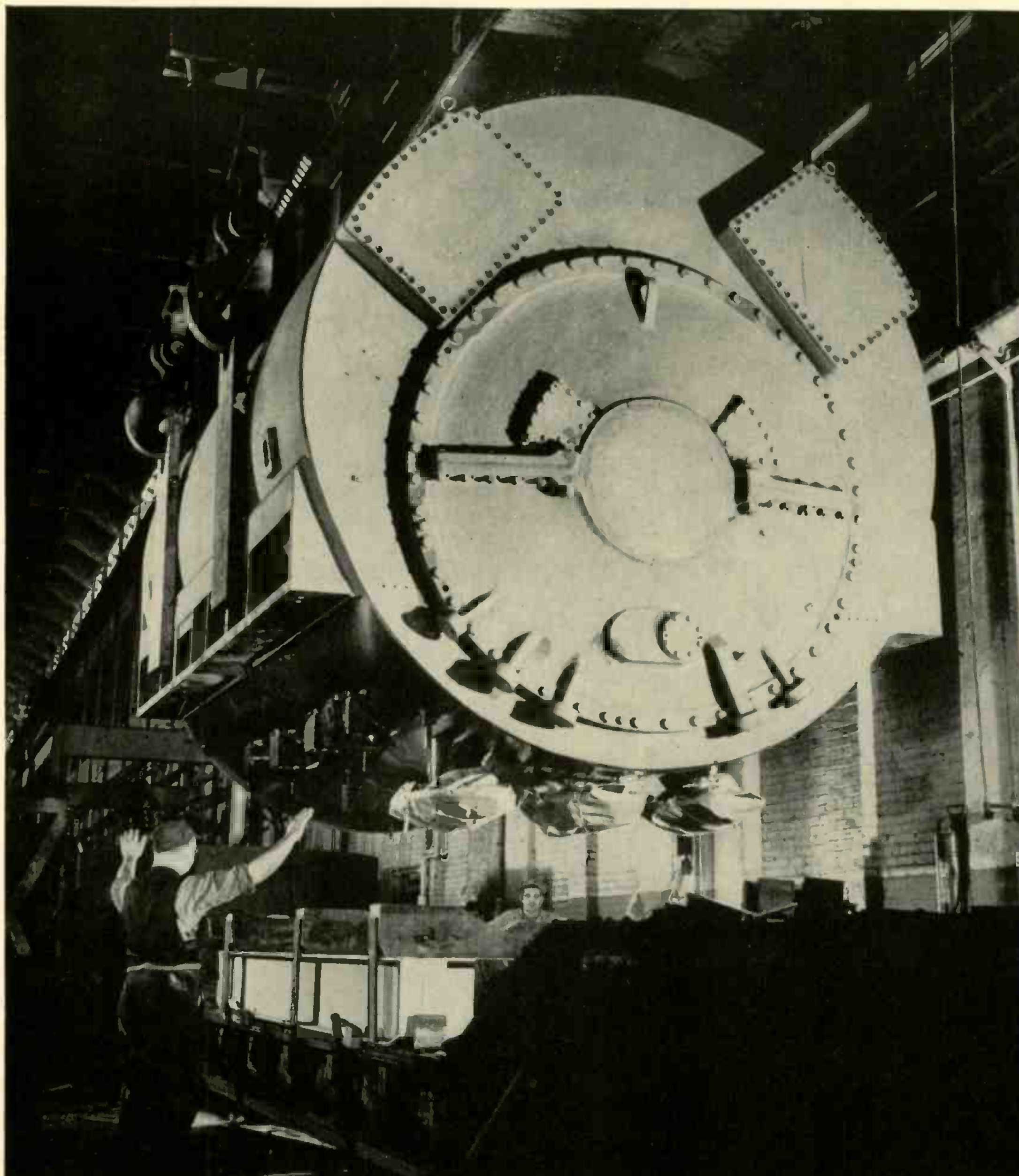
The secret of the new method, compared to previous methods of gear grinding, lies in the fact that the heavy gear blank is rotated slowly and continuously during grinding and is not subjected to starts, stops, and reversals that limit other processes to lower power or speeds. This new method has no serious size limits and it is expected that where light weight or compactness merits it, the process will be applied.

From Cellini to Gas Turbines—The craftsmen of yore guarded their secrets jealously. Cellini, master of masters, used the process, old even then, of creating a pattern of his masterpiece out of wax, investing this in a plaster-like material, then forming a subsequent casting. The result was, for example, the famous saltcellar presented to the Pope. In this process the original pattern was melted, hence "lost." Thus there was assurance that there could be no more than one of that particular creation.

Curious enough this same "lost wax" process has become a part of modern quantity production methods. This casting technique, widely used by manufacturers of dental structures, has been applied to the manufacture of gas-turbine blades, small pieces of complex shape for circuit breakers, etc., where the metals or shapes involved are not readily forgeable or machineable. In the gas turbine, for example, forged blades

Stretch bending, in which curved members are formed by stressing structural shapes beyond the elastic limit, simplifies manufacture of electric stairways (below). Improved pre-babbitting cleaning makes stronger bearings.





America needs more power. Som t
of additional generating capacity ar
factories of the company. Several mil
actively studied and much of it
Nearing completion is this 25
generator of latest design with

From the humble begin
calculating board we h
opment of the mathema
The a-c board was a gre
ly came the transient ar
with two engineers is sl
boundaries of electric
of hydraulics, mechani

Available now is a host of mini
precise light control and e2ce
Lamps for rescue at sea, for inter
sights, etc. will find a wide va

Black light intrigues the fancy and has had specta
Also it has many workaday functions. These small bu
aircraft service, providing a high proportion of invi
for illumination of fluorescent instrument dials of

Down the line come
precipitators utilizing th

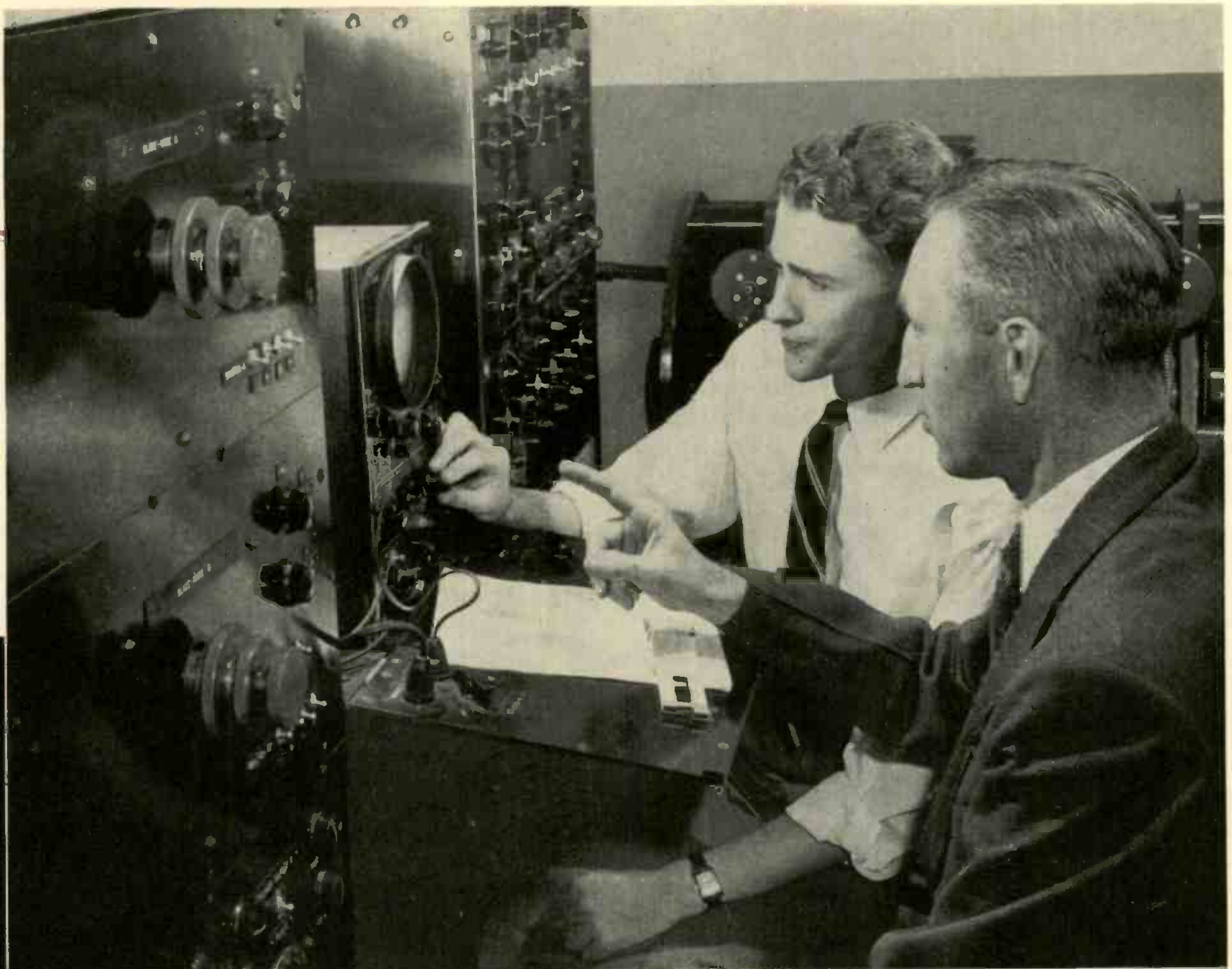
million kilowatts
w in the several
more are being
be purchased
-kva, two-pole
izontal coolers

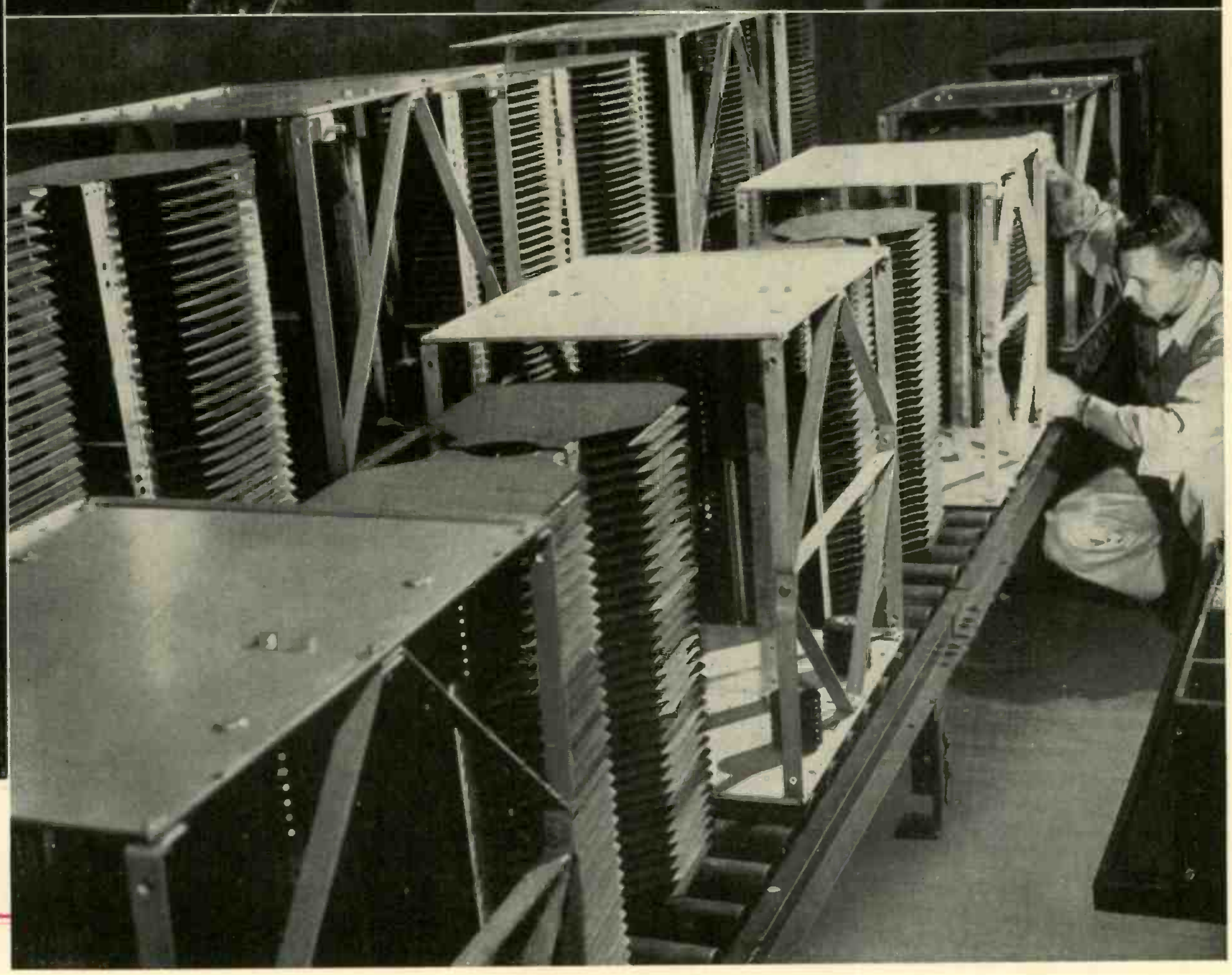
gs of the direct-current
seen the steady devel-
l-problem laboratory.
milestone. More recent-
zer of which a portion
n. It steps beyond the
and into allied fields
and thermo-dynamics.

te lamps providing
nt beam efficiency.
illumination of gun
y of peaceful jobs.

ar uses.
s are for
le light
planes.

st-traps, electrostatic
recipitron principle.





can't be used because service conditions are approaching those corresponding to actual forging—that is, high stress at high temperature. This lost-wax casting process furthermore lends itself to relatively high precision, as it is possible to hold dimensions to three or four mils.

Super-Cleaning for Better Bearings—In the production of babbitted bearings, cleanliness is next to godliness. A good journal bearing requires that the babbitt be applied to an absolutely clean oxide film-free surface. In the production of bearings for steel turbines and gears during the war it was found possible to adopt a new cleaning method (Kolene Corp.) that has resulted in a superior bearing. With war production methods of producing bearings by the hundreds, immediate babbitting was not always possible so that some oxidation of the machined surface was inevitable. The bearing shells are shot-blasted to remove all scale, then dipped in an electrically heated Kolene bath, which removes all greases and alkalies. Next, they are given a water wash and immersed in a second Kolene bath which dissolves the ferric oxide produced and left on the shells by the first salt treatment. Another water wash follows, after which the shells are submerged in a hydrochloric acid bath to neutralize any remaining alkali. They are then fluxed and tinned. The whole process takes from 10 to 25 minutes. The setup consists of a hooded and ventilated chamber, about 40 feet long, in which the various baths and rinses are arranged in continuous flow. Electric clocks control the timing of the various baths. The result has been a much tighter bond between the bearing surface and the steel or cast-iron shell, that is not only less likely to give trouble in service but also carries off heat much better.

Shaving Makes Better Gears, Quicker—Marine-gear engineers have taken a lesson from automotive and aircraft-gear people and used gear shaving as a method of providing a better finish on the gear teeth. The idea of taking a thin slice (a few thousandths of an inch) from the surfaces of teeth after they have been formed by hobbing had worked well on small gears but had never been applied to the big gears eight feet in diameter and capable of transmitting several thousand horsepower, such as those used for aircraft carriers.

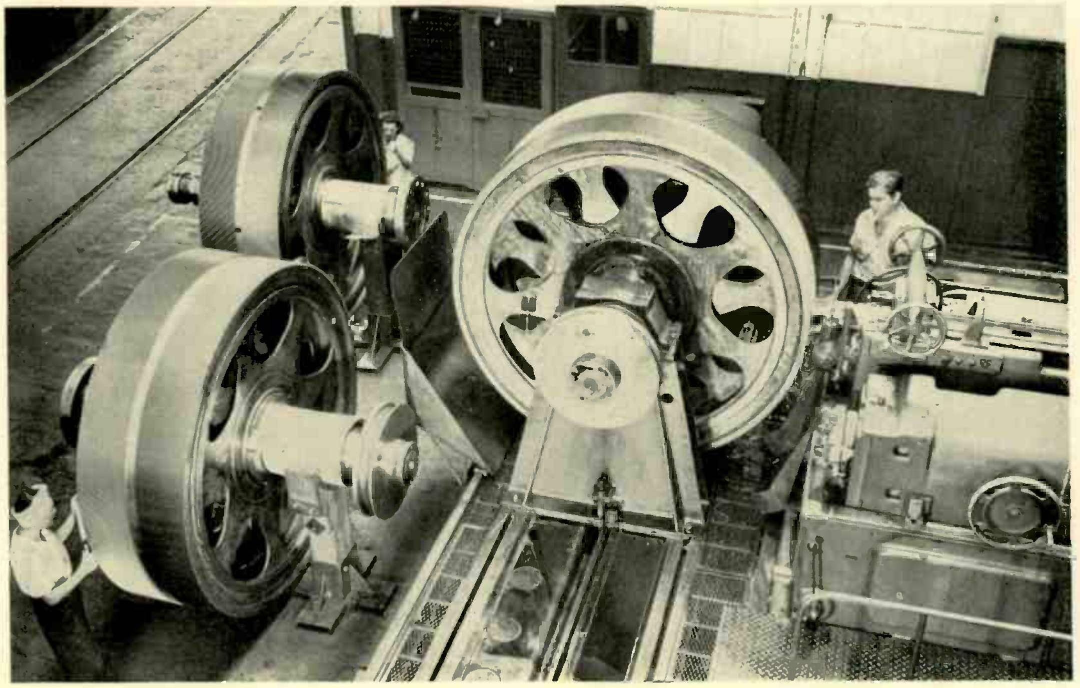
Gear shaving removes feed marks and other surface imperfections left by the hobbing machines. After considerable development of the shaving technique it became possible to obtain full-face contact without recourse to lapping or other means. Furthermore, hobbing feeds and speeds could be increased as much as 50 percent without sacrifice of accuracy but with a somewhat rougher surface finish that could be corrected by shaving. The resulting shaved tooth surface has about twice as fine a finish as the best hobbed surface, even at slow hobbing speeds.

Gear-hobbing machines are large, costly and time-consuming to build. They were for a time the bottleneck to ship-propulsion manufacture. The development of the shaving process for these big gears resulted, therefore, not only in better gears but raised very considerably the productivity of the available hobbing machines.

Preformed Wiring—Radio receivers are often completely wired before the parts are assembled. In this preformed wiring technique the conductors are arranged in the pattern they are to have when connected to the equipment. This permits the job to be done in the open quickly and with less risk of error. But the process generally has been limited to high-production items such as radio sets. However, identical power switchboards were made in such quantities for the services that the preformed wiring idea became practical. As the idea of standardization of factory-built switchboards increases, it appears that preformed wiring will be one of the devices by which they can be built faster, better, and with less expense. Also, this system can be used in the construction of network calculators. Although mass production is not obtained in building calculators, the unusual complexity of the wiring warrants the use of preforming.

The system of preformed wiring is merely a method of giving the worker a visible pattern to follow. A large plywood board is provided, upon which various colored lines are drawn that trace the path the wires are to follow. Small pegs and eyelets in the board are used as guides and supports for the wires and the many strands of wire are tied together with cord to give further stability. Thus a three-dimensional wiring set-up is converted into an accessible two-dimensional job.

Crush Grinding—An interesting new manufacturing technique, termed crush grinding, is used in many industries, but applied by Westinghouse to the shaping of the root of cast gas-turbine blades. The surfaces must be ground to dimensions. This is done with a grinding wheel of Carborundum in which the pattern is accurately formed by running the wheel at slow speed and at high pressure against a master die. The desired grinding wheel shape is formed literally by crushing the impression into the abrasive stone. The wheel is then used for grinding blade roots until it wears slightly, whereupon its profile is reformed by running it slowly against the master die.

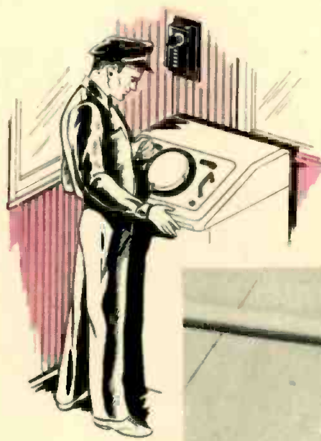


Tooth surfaces of big marine gears are "shaved" after hobbing, thereby eliminating all tool marks.

New and Improved Industrial Tools

". . . Tools, tools to make tools, instruments of study, instruments for control, new machines, new components for old machines—all these move in a steady parade across the engineering horizon . . ."

IMPORTANT additions have joined the engineers' slide rules, calculating machines, instruments, meters, oscillographs and other paraphernalia of the trade. These are tools that aid him in his creations of useful equipments, or, having little value in themselves, are adjuncts to those equipments. Most spectacular of the tools are those of nuclear physics. These are usable only by the specialist and for purposes not too clearly understood by the lay engineer. These generally are the devices popularly referred to as atom-smashers but have such names as cyclotrons, betatrons, synchrotrons, and linear accelerators. These are important tools of far more than academic interest, with which engineers generally need to acquire a degree of familiarity. Most of these do not as yet touch upon the engineer's daily life, but there are many that do.



Seeing Inside at High Speed—A device of major importance that takes its place alongside the high-speed camera is the microsecond x-ray. Together, they give the engineer the opportunity of actually observing the behavior of machines in action. This incredibly fast x-ray takes pictures of a machine's insides in a millionth of a second.

The high-speed x-ray, termed the Micronex, is actually simpler than the conventional x-ray. Essentially it consists of a "lightning generator," i.e., a bank of capacitors charged in parallel and suddenly discharged in series, and a special tube for generating the short-lived but extremely penetrating x-rays resulting from dumping large quantities of energy through it. The peak amount of this energy is staggering: 600 000 kw. The tube is a special sort, one built to enhance and capitalize on a phenomenon considered a weakness of ordinary x-ray tubes.

The obvious ideal use for the high-speed x-ray is in ballistics work for the study of guns in action, projectiles as they bore through a target, the behavior of armor plate under impact, and so on. For such it has been extensively used, as well as being an important tool in the initial design of the atomic bomb. It holds possibilities, however, as a useful tool for more peaceful research. For example, it might be used to study welding of all types, particularly the formation of heat cracks and the flow of metal in arc welding. Others include valve actions, behavior of electric-contact mechanisms hidden from ordinary cameras by the arc, turbulence of liquids and gases. The Micronex has already proved useful for flash photography as well as for fast x-ray exposures by the discharge of the stored energy in a sudden open flash.

Vibration Super-Sleuth—As more machines are made to operate in the stratosphere of speed, the need for balancing becomes more acute and more sensitive balancing machines are demanded. Electronic balancers of the Dynetric type that can detect and locate rotating-machine vibrations of twenty millionths of an inch seemed adequate ten years ago. But gyroscopes for bombsights, navigational aids, and numerous "civilian" activities of the future run at 10 000 rpm commonly, and some of them twice that fast. This has demanded a new order of sensitivity in high-speed machine balancing. This is provided in the Microbalancer.

To meet the 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

With the "eyes" of radar, the pilot of a coastwise or lake vessel can operate his ship with speed and safety in times of poor visibility. Below is the radar antenna on the *William G. Mather*, an ore boat.

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 tiny piece of lint or a moist fingerprint easily weighs that much.

Mechanical Mathematicians—Recent years have brought an enormous increase in the use of machines for solving difficult and complicated engineering problems. The electrical industry began using calculators of the d-c board type for solving simple network problems over two decades ago. This expanded into an a-c calculating board able to solve more complex problems of the a-c circuit and to this family of calculating machines has been added one recently called the mechanical transient analyzer. This device, based on the analogs between mechanics, hydraulics, and electricity, is able to tackle almost all problems in the mechanical, hydraulic, or thermal field by its reduction to an electrical equivalent and solution on the analyzer as an electrical problem.

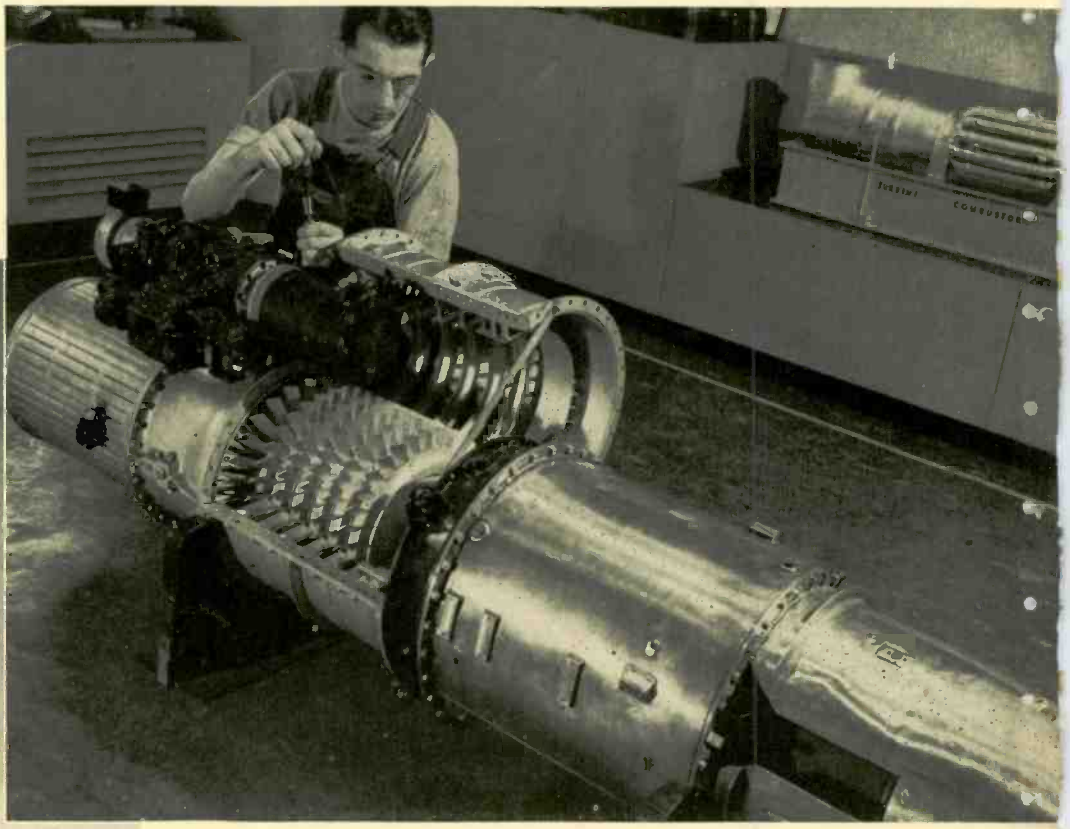
This makes possible the solution of numberless problems that previously could be only estimated or solved by tedious and costly experiment. Problems of shaft stresses in machines can be solved in two or three hours, whereas they previously required that many weeks. The analyzer has also been put to a variety of problems such as transient voltages on systems, servo-mechanisms, voltage regulators, traveling waves, speed and voltage controls, jet propulsions, heat flow, hydraulic mechanisms, and stresses resulting from mechanical shock.

The complex non-electrical problem of tomorrow will not be a chore for an engineer with a slide rule and hand calculating machine, but will be delivered to an air-conditioned and dust-free laboratory equipped with d-c and a-c calculating board, mechanical transient analyzers of various sizes and types, and with computers. The day of the problem laboratory has arrived!

High Vacuum, an Industrial Tool—Except to the lamp and electronics-tube engineer, high vacuums were something that existed only in the laboratory. The events of the past few years have changed all that. Probably the atomic-bomb project is responsible for the development of the truly industrial version of a high-vacuum pump. Oil diffusion pumps, while by no means new, were produced in sizes up to 32 inches in diameter, which could pump 600 cubic feet of gas per second at suction pressures of 10^{-5} to 10^{-4} mm of mercury and thereby produce high vacuums. These oil diffusion pumps do their work without benefit of moving parts—in itself a great benefit. Oil is heated, caused to rise as a vapor up a central chimney, and then forced downward in a cone shape, trapping gas molecules and carrying them to the exhaust below. After the oil is condensed it is returned to the evaporator and central flue to repeat the process.

Reconversion of Radar—Everyone expects big things of radar. And rightly so. Of all the military developments, radar is unique in that it had no previous commercial background and yet reached a high point of development and actual use. On V-J day, although radar was not more than five or six years old, except as to idea, radar sets were being produced by the thousands and for literally scores of different functions. Radar emerged from its military use already full grown.

That does not mean, however, that radar can immediately and with practically no engineering development, be swung over to civilian use. The two conspicuous uses of radar are for



Navy's fighter craft powered by jet engines similar to the one above have made flights to and from the decks of aircraft carriers. The Life-line motor (p. 21) is a smaller and lighter, but no less capable, squirrel-cage induction motor designed for general-purpose application to any of industry's tasks, as in the pump drive shown.

marine and for aircraft navigation and safety. Military types of radar cannot be translated to either of these uses without major change. Certain basic important aspects of radar for military use became of lesser importance when applied to ordinary vessels or aircraft. Furthermore, the element of initial cost again becomes a major consideration.

All this is resulting in a period of development of military radar to these regular uses. Under way are designs for families of radar equipments to meet the wide range of needs both on sea and in the air. Certain members of the family have already appeared. Installations have been made on coastwise vessels and on lake boats, and during the present winter a trial installation is being made on a river vessel. Because vessels that operate close to the land and marker buoys require a high degree of safety in the frequent operations to and away from docks, the emphasis is on the short-range detecting ability of radar. The sets built for this purpose emphasize these characteristics. For the larger coastwise vessels and ocean-going steamers, where the major part of the operation is in open water, the requirements differ. Furthermore, larger investments are there possible, which means that more of the de luxe features can be employed.

A new device has almost unanticipated uses. One of the first peacetime applications of radar was for fishing vessels and trawlers. Here it is used, among other things, to enable the fishermen to locate their net marker buoys after fogs obscure them. Often they have had to wait for days for fogs to lift before their fishing nets could be found.

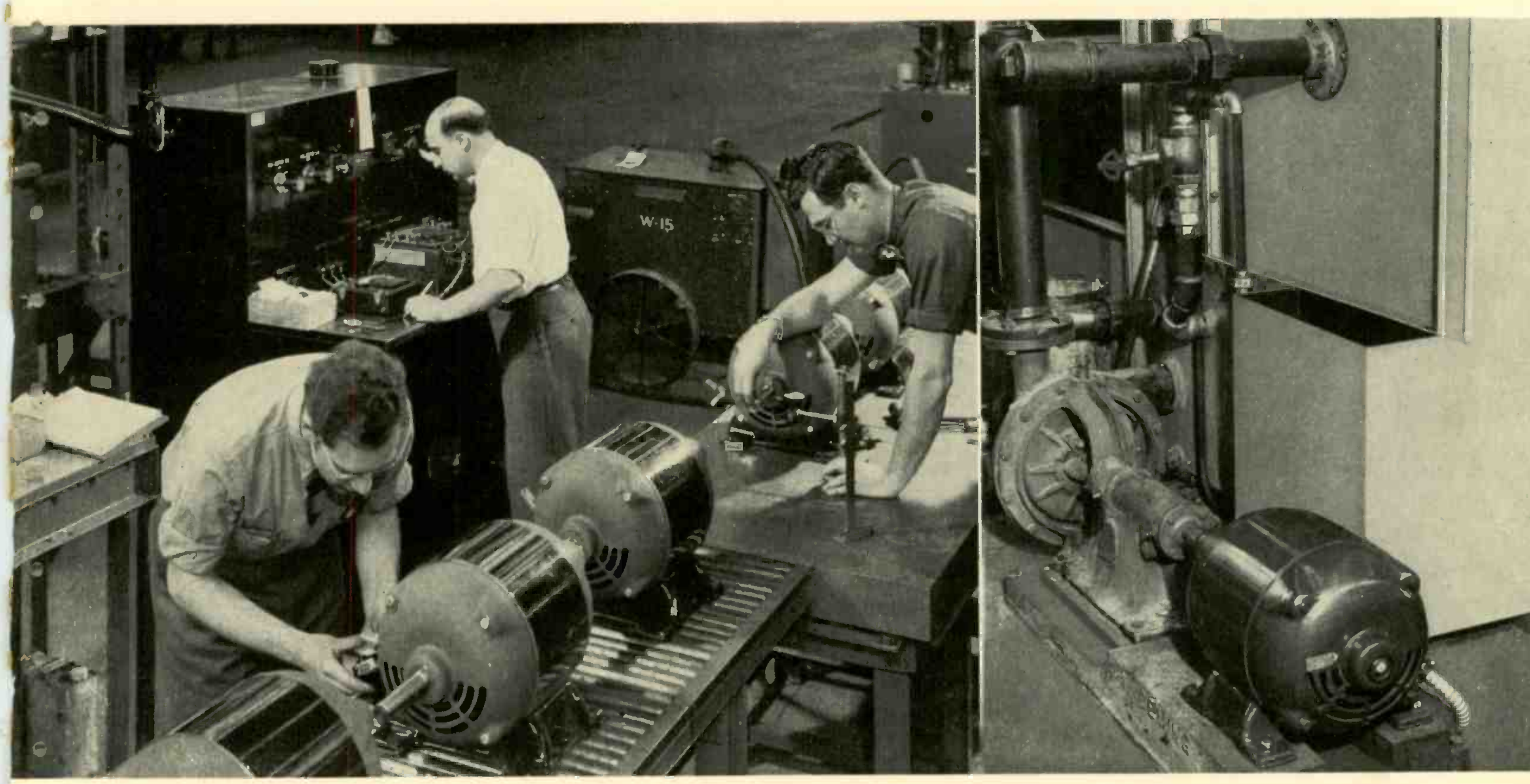
• • •

It was tried at the Altoona, Pa., test plant in midsummer and the early fall. Here the locomotive was given "the works" and no major difficulty in the drive became evident. The locomotive delivered without distress the anticipated load. Close measurements fully supported the expectations of its fuel economy. Prior to these dynamometer tests, the locomotive had rolled up about 50 000 miles in revenue freight and passenger service on various parts of the Pennsylvania Railroad system.

Since the dynamometer tests the locomotive has entered the third stage of its proving. It has been returned to regular service to accumulate the mileage in day-by-day railroad operation which is the final and conclusive proof of the merits of a new type of prime mover. The locomotive is now gathering this experience at the rate of several thousand miles weekly. There is, at the point of this writing, every indication that the drive will provide long-continued operation under the most rigorous of railroad conditions with low maintenance.

The next appearance of the steam turbine on rails will be the three turbine-electric locomotives for the Chesapeake and Ohio. These locomotives are expected to enter service this year. Each of these locomotives has a single 6000-hp steam turbine geared to two d-c generators which supply power to eight axle motors in the manner commonly employed with Diesel-electric locomotives.

Engineers expect that the steam-turbine type of drive is here to stay and will appear in other forms. For example, studies have been made of a 9000-hp geared-turbine locomo-



Steam Turbines on Locomotives—The events of the past several months have pointed to the soundness of the geared-steam-turbine idea for locomotives. The 6500-hp geared-steam-turbine locomotive, designed by engineers of Westinghouse, Baldwin, and the Pennsylvania Railroad, met with marked success in its road trials and shop tests.

tive. This one will employ two 4500-hp steam turbines set longitudinally with the locomotive frame and each driving four axles through a longitudinal shaft and gearing instead of side rods. Also studies are being made of the most appropriate boiler and steam conditions for use with a turbine. The theoretically attractive higher steam pressure and temperature

which are somewhat better suited to the steam turbine are being actively studied for locomotive application.

Jet Propulsion—Gas turbines for powering aircraft are here to stay as turbo-jets, turbo-props and auxiliary power plants. Originally promoted by the military services for high-speed interceptor aircraft, turbo-jets will soon make their appearance in bombers and commercial planes.

Greater efficiency and swept-back blades have given the propeller a new lease on life. It is expected that propeller-driven planes based on aircraft carriers will be capable of speeds up to 650 mph. The tremendous power required to drive these planes at near sonic velocity will be provided by gas-turbine power plants.

New giant airliners must have greater electrical capacity to provide for electrical auxiliaries—air conditioning, lights, retractable landing gear, etc. Generators will be driven by an auxiliary gas turbine.

Many of the details surrounding jet-propulsion gas turbines are still restricted. Only slightly more than a year ago announcement was made of two sizes of jet-propulsion gas turbines, one 9½ inches in diameter and the other 19 inches in diameter, which is the power plant in the Navy's Phantom (XFD-1), recently given trial runs on the aircraft carrier *Franklin D. Roosevelt*. Within the past half dozen months figures have been released on a new nineteen-inch unit, which shows the rapid progress being made in this field. The first 19-inch engine announced produced 1365 pounds thrust. The more recent model weighs 11 percent less but develops 1600 pounds thrust. Thus on a thrust per pound basis there has been in approximately a year's time a 30-percent improvement. Also the fuel consumption is less. This is indeed an engineering achievement, as the new engine has the smallest diameter and is the lightest for the power produced by any engine built in this country.

The same engineering skill which produced the small diameter high-speed axial flow compressor and annular combustor, peculiar to Westinghouse turbo-jets, is going into a combination turbine-propeller type of drive.

A Major Step in Induction Motors—One does not expect to find the general-purpose induction motor included in a list of new developments. It is the oldest of alternating-current devices, even antedating means of generating the a-c power for it. Logically it should now have experienced the major steps in its development and further improvement should be a matter of refinement. It is a tribute, therefore, to engineering skill, and deeply significant of the never-ending possibilities of technical advancement, to observe a new squirrel-cage motor that is a full one third smaller and lighter, but with somewhat better starting and pull-out torque, and no sacrifice in overload capacity. Appearance, likewise, has been markedly bettered; its ability to withstand severe mechanical handling is improved, and the need for service and repair substantially reduced. No new principle is involved; it is difficult to see how there could be. But the motor is the result of complete redesign integrating all improvements of the past decade in materials and manufacturing, and particularly capitalizing on the greater precision resulting from special machines that high-quantity production justified.

The motor is all steel. That is, it uses no castings. The frame is rolled up of a slab of steel and welded. The feet and end bells are deep drawn of heavy-gauge steel. Stator punchings are stacked, held between thick end-plates by locking bolts whose ends are tapped to receive end-bell bolts. Punching insulation is provided, instead of by conventional water glass, by surface oxidation obtained as part of the sheet annealing. Slots are more open, have rounded bottoms. New winding techniques were developed by which windings are inserted with less physical damage to insulation. The completely wound stator is treated with a synthetic varnish that both insulates the coils and is the primer coat for the steel.

The exterior surfaces, being steel, are smoother than the cast frames heretofore used. This, with the fact that sharp angles and corners have purposely been eliminated, enhances the motor's appearance. The ball bearings are sealed and require no addition of lubricant for at least five years.

The motor is the product of special precision machines. The machining and assembly procedure is entirely new and has been planned to provide a far higher degree of concentricity than normal. The air gap is much more uniform and is held to much closer limits. As compared with its predecessors, the motor is a much more precisely built machine. This tends to inherent quietness.

A degree of interchangeability of parts never before achieved is obtained. The more common varieties—open, splash-proof, open-protected, totally enclosed fan-cooled, etc. —are made from the same basic parts, with the appropriate external components. The great reduction in total number of parts simplifies stocking of spares and reduces the time between purchase and delivery.

The economical dimensions are of high importance for those applications where the motor must be shoe-horned into almost impossibly small space. The machine-tool field is rife with such situations. Specifically the new 7½-hp open motor is 83 percent as large in diameter and 94 percent as long as its predecessor. The corresponding reductions for the totally enclosed type are 83 and 82 percent respectively.

The rather remarkable features of the new motor are the outgrowth of remarkable conditions. Seldom—with any old-line apparatus—is there opportunity for completely new electrical and mechanical design unhampered by considerations of previous tool facilities, construction in an entirely new plant arranged specifically for motor design, and the use of high-production, specialized precision tools.

Electric Slingshot—Speaking of motors, probably the strangest one in physical form of all time was "unveiled" last year. It is a motor a third of a mile long. It is called an Electropult and was developed for assisted take-off of heavily loaded planes. It is essentially a squirrel-cage motor with the cage unwound and laid out as a long track. The primary is a flat car only six inches high, to which the plane is harnessed. This car has wheels that ride on rails in slots below the surface of the "cage." Under the action of the moving magnetic field in the track or cage, this car is accelerated smoothly but at a high rate, giving the heavy plane the necessary assist for a short take-off run.

The amount of power transmitted across the air gap during a launching run is about 10 000 kw. To collect the high current required at the maximum speed of 225 mph (about 7000 amperes during acceleration and 10 000 amperes during dynamic braking), twelve shoes per phase, made of sintered copper graphite on a copper base, are held against the submerged collector rails by spring pressure. The resistance of the secondary winding is progressively decreased in four steps, giving a wound-rotor effect that enables the tractive force to be held substantially constant as speed increases. The car is stopped at the end of its run on the track by a combination of dynamic braking and the application of direct current.

This was developed originally for use on small islands of inadequate size for runways, but has since been used by the Navy for experimental work and the launching of target planes. The Electropult is able to bring a 10 000-pound airplane in a 340-foot run from standstill to 117 miles an hour in 4.2 seconds. This seems fast. It is. However, the rate of increase of acceleration is much smaller and more uniform than with mechanical and hydraulic catapults; the take-off is smooth and comfortable. Pilots are enthusiastic about its take-off performance. Consideration is being given to the Electropult for aircraft-carrier application.

The Electropult illustrates the ways in which well-known principles can show up in entirely new forms. This unique launching aid utilizes the true rotating-field principle of the squirrel-cage motor.

Bearings without Lubricant—Dozens of motors have been built without a lubricant—at least without the ordinary kind. A layer of gas provides the necessary separating film that prevents sliding metal surfaces from tearing each other apart. These particular motors run at high speed—above 10 000 rpm and deliver several horsepower. The shafts of these motors are vertical. The thrust is taken by a plate-type, gas-lubricated bearing. The shoe-type guide bearings likewise are gas lubricated. These motors and the pumps they drive are completely enclosed in large chambers. The bearings are lubricated by the gases being pumped. The thrust and sleeve bearings are constructed to favor drawing in between the sliding members the molecules of the ambient gas that provide the necessary thin lubricating film. The loads that can be carried are sizable but depend on the kind and pressure of the gas, rotational speed, etc. Engineers feel they can build motors of 75 hp or more lubricated in this fashion, should the nature of the job make it desirable.

The gas film is adequately maintained as long as speed is high. However, at slow speed or when the motor stops the metal surfaces come into intimate contact. To permit starting without damage to the thrust bearings the rotating member must be lifted until the gas film is established each time the motor is started.

Sealed-Beam Automobile Spotlights—The trend, begun several years ago, to the more general adoption of the sealed-beam construction for lamps, most notably for automobile headlamps, is being extended. This construction is now appearing for automobile spotlights. With the precision filament and reflector permanently sealed in a glass housing, high efficiency is assured throughout the entire lamp life. This is not the case with the usual spotlight, consisting of a bulb and reflector in a unit exposed to the elements.

Anti-T. B. Gun—A man who should know recently remarked that in ten years tuberculosis will be virtually unknown in this country. That sweeping statement was to a large extent predicated on the expectation that all citizens will be x-ray examined as a matter of routine, thereby catching this disease before it gets a firm grip on unsuspecting victims. With tuberculosis, early detection is far more than half the battle. In the early stages of the disease physicians are masters of the situation; it is only when it becomes well seated—which can readily happen without notice—that it becomes difficult or impossible to root out.

The need has been for a means of detection. It must be something that can be used with large masses of people—whole schools of children, employees of companies, communities of people—and hence be inexpensive, convenient, simple, and fast. The military service had a similar need, which led to the photo-fluorographic x-ray using small inexpensive film. With this unit a chest is x-rayed, the image being presented on a fluoroscopic screen instead of the conventional 14-by-17-inch film. A photograph on 35-mm or 70-mm film is taken of the fluoroscope image, using conventional camera equipment. Because the film is small the cost per exposure is but a penny or two instead of more than a dollar. Chests can be x-rayed at a rate of 100 or 200 per hour. The equipment is physically small. The entire outfit, including power supply and dark room, is readily contained in a truck-drawn trailer.

The miniature chest pictures by no means prove the presence of the disease. They simply provide means of locating the few out of many who should have more careful check. It offers a way of locating those with the very early stages of tuberculosis when it can readily be cured.

These mobile x-ray equipments are being built in quantity for federal, state agencies, county, industrial concerns, and others so that soon everyone in the land will have the service brought to him. The attractive prophecy of tuberculosis eradication is not too much to expect.

Ignitrons for Excitation—The ignitron is reaching out in new directions. For several years it has been used to provide the direct current for excitation of synchronous condensers, but last year it was extended to the much more exacting task of serving a main generating unit. A sealed-tube ignitron exciter has for several months been in operation with a large unit at West Penn Power Company's Springdale Station. Previous factory tests and actual service indicate the ignitron can perform satisfactorily with respect to meeting the genera-

Extensive experiments have been conducted with trains of the Southern Pacific lines equipped for radio communication between the front and rear of the trains, and between crews and wayside stations as an aid to train operation.

Truck trailers equipped with the photofluorographic x-rays are being used in a nationwide campaign to stamp out tuberculosis. The chest x-ray equipment uses small and inexpensive film, and is equipped for quick handling of large numbers of people. It also contains darkroom facilities.

tor's needs during switching and transient conditions and is sufficiently free from arcbacks as to cause no concern. Although the ignitron represents a higher initial cost, it carries the favorable characteristic of a brushless non-rotating device.

Sealed ignitron tubes are becoming larger in maximum capacity. Last year a 400-ampere permanently sealed tube became available, the previous largest being 200 amperes. There seems no insuperable technical barrier to the manufacture of sealed ignitrons in any size desired, and the trend is to the larger sizes, as experience has shown. It is entirely possible that eventually all ignitrons will be permanently sealed. However, the larger tubes are always applied in larger power applications where higher maintenance skill is available for other reasons, and this makes maintenance of vacuum-pumping equipment nominal. Modern vacuum pumps have given an excellent account of themselves, and it might be that the permanence of pumped tubes and the opportunity of on-the-spot repairs will prove more attractive than the replacement or exchange of tubes in the larger sizes. However, at the present time the upper limiting rating of sealed ignitrons is still increasing as is the upper rating of pumped tubes. The probable result will be that the border-line rating between the two types will increase and each will continue to have its field of service.

Functionalized Resistance-Welding Controls—Over a period of years, resistance-welding control units have been designed to meet specific needs as they arose. Each unit was suited to its job without particular reference to common physical forms or dimensions. All these controls have been coordinated into one family of units with resulting convenience of operation, maintenance, and versatility. It consists of a few subassemblies of standard basic dimensions and several standard cabinets to house them. The various functional subassemblies are combined in a hinged frame, and are plug-connected for quick replacement. Thus, all control apparatus is mounted in one cabinet affording easy accessibility for installation and convenient maintenance.

The most commonly used subassemblies are heat control and ignitron firing panel; spot timer; spot pulsation and seam timer; fully electronic seam timer; electro-mechanical seam timer; two types of sequence timers; non-synchronous heat control; and voltage and current regulators. All control apparatus needed is mounted in one standardized cabinet, 20 or 24 inches wide, that can be mounted on the floor or on the side of the welder. The overall result is a unified design permitting many improvements in welder operation.

Airport Lighting—The present serious obstacle to growth of aviation itself is the inadequacy of airport facilities. The congestion of planes trying to land and take off, resulting during periods of impaired visibility, threatens to choke the young industry. Two electrical developments are under way to relieve the situation. One employs radar in various forms. The other is better lighting of the landing areas.

Events of the past couple of years have brought the realization that previous methods of lighting runways are wholly inadequate. It is recognized that the bad-weather problem is complex. No single type of runway-marker light can hope to do an adequate job for all combinations of fogs, storms, and darkness. The degree of darkness, the height of fog, fog density, type and amount of precipitation all have bearing on the proper illumination of runways. The traffic director at a busy airport must have at his command a variety of lighting methods and intensities.

A beginning has been made in the direction of providing the necessary lighting tools from which can be selected the methods required to meet the spread of weather conditions that prevails at a given airport. The so-called contact lights, installed as buttons at intervals along a runway which cast out a flat, horizontal fan of light across the runway surface, have been enormously improved in the past half dozen years. The unit, although interchangeable physically with its predecessor, can withstand loads of 200 000 pounds, or nearly ten times more. The light output of contact lamps has been stepped up from 60 cp to over 2000 cp.

For some types of obscurity, such as occurs at New York's Idlewild Airport, upward curtains of light along each side of a runway are desirable. For this condition a special unit has been built, having a dual lens system. One part gives light output similar to a contact light, the other part throws an intense fan-shaped beam on low-hanging thin clouds to show the location of the runway to pilots approaching from above such thin cloud layers.

For runways, a new high-intensity contact light has been developed. Used with a simple control system, ten steps of brightness are available to the traffic director, ranging from intensities as low as 10 cp to a high of over 100 000 cp. This enables pilots to stay within the confines of the runway in the heaviest fogs without being blinded by glare on occasions of unlimited visibility.

An approach-angle indicator, recently developed, will in some cases allow pilots to bring in their planes literally on beams of light. Three colored beams (red, green, and yellow) are sent upward at the proper angle from the end of the runway. By a novel and extremely efficient optical system, the three beams are narrow in vertical angle and sharply differentiated. The pilot "slides" down along the green beam. Should he approach along the bottom or red beam his plane is too low; if the yellow beam is visible, he is too high.

These illumination aids will be supplemented by others, now being developed. What final form they will take is not too clear. It is possible that some type of light source a hundred or more times brighter than anything now in use will give the answer. Perhaps a modification of the high-intensity discharge lamps, such as have proved useful in high-speed photography, can be used. As one engineer expressed it: "We will have to find some simulated strokes of lighting so bright that the pilot can see his strip through the worst pea soup that ever develops. We believe it can be done."

Lessons from the Circular-Scale Instrument—To meet the requirements of the Navy, compact high-quality meters were provided with 250-degree scales. Most significantly, however, it was found possible to use iron-core electromagnets instead of the conventional air-core type.

While extension of the iron-core construction to other lines of instruments in general will require an extensive period of development, there are numerous obvious advantages that make such a move ultimately desirable, now that much of the basic development has been done. For example, it can be estimated that accuracy will be improved all the way down the scale, particularly at very low power factors because it will be possible more effectively to use the copper, thus providing a much greater overload capacity. Furthermore, with cores formed from punchings rather than relying on variable air gaps, the uniformity between instruments will be greatly enhanced. Torque will be much higher for the same energy consumption. As a result, the instruments should be much more sturdy and more nearly out of the delicate class. Engineers hope that it will be possible to disassemble and reassemble the core and coils without necessitating recalibration. The long-established air-core electrodynamometer type of instrument may well be largely superseded by instruments of a new type.

Railroads Go for Electronics—Operation of trains with the aid of radio, long-a-coming, is here—at least in the sense that the technical difficulties have been resolved. More than a year ago, radio equipment was demonstrated to provide high-quality voice communication between engine and caboose of long freight trains and between trains and wayside stations of the New York, New Haven, and Hartford, even under adverse ambient noise conditions. Since then the channels allotted by the Federal Communications Commission for railroad service have been shifted to a much higher frequency, necessitating major electrical design changes. A re-test of the new high-frequency equipment on the New Haven Railroad over the same terrain as the low-frequency equipment has shown that the higher frequencies, because of their increased ability to "bounce," actually give better performance under the most unfavorable conditions. Tests on the high-frequency equipment have since been made by the Southern Pacific Lines under most rigid conditions with pleasing results.

Not quite ten years ago the air-cooled distribution transformer made a somewhat hesitant appearance. This has blossomed into a full-grown major business, as indicated by the fact that now approximately three out of every four factory or plant indoor transformers are of the air-cooled type. Behind this trend lies, of course, the desire to eliminate oil coolants with their attendant problems of handling and potential hazard. Engineers now freely predict that shortly, virtually all indoor transformers will be air-cooled.

Railroad operating regulations will have to be accommodated to this new tool and maintenance and operational procedures must be worked out before wholesale adoption of radio for railroading is possible. However, the technical obstacles have been hurdled.

Experts guess that radio will find its first use in expediting the handling of cars in "humps" and classification yards. This, perhaps, will be followed by application for communication between the ends of long trains, and finally for use between operators at wayside stations or dispatching points and the crews at the head and rear end of the train.

Important Trends in Power Production

"... Ten million kilowatts of additional generating capacity are on order in this country. This and the several million still under consideration, added to the fifty million now in service, are expected to give the country at least sixty-five million by 1950. In 1935 the figure was but thirty-six million . ."

A review of the electric power industry, as to what it has been through and where it is going, reveals immediately a salient fact: there is nothing much wrong technically with the way electric power is produced and handled. The power industry has been sorely tried, in an unforeseen severe test of electric-power systems as a whole. It has been called upon to carry unheard of loads. Many generators and transformers of advanced age ran for long periods fully loaded, and frequently were overloaded. Replacements were few; additions almost none. Yet at no time was there a serious breakdown and never was there a power shortage. Had there been any technical weakness in any phase of the business—generation, transformation, transmission, or distribution—the demands of the past half dozen years would have made that weakness conspicuous.

The technical problems of the industry are those of replacements for tired equipment, extensions of existing plants, and improvements that reduce cost of delivering kilowatts to the customer. In the twelve months after August 14, 1945 the Westinghouse Company alone received orders for 45 central-station type generating units, totalling 1 600 000 kw. Inspection of the ratings and steam conditions discloses certain interesting points. These 45 units are divided as follows: 10 000 to 15 000 incl., ten; 20 000 to 35 000 incl., nineteen; 40 000 to 65 000, eleven; 65 000, one; 75 000, two; 80 000, one; and 105 000, one. As compared with the last major generating-unit buying period (1937-1941) the swing to the high-speed unit has become almost complete. Only the two 75 000-kw units are for operation at 1800 rpm. The average size of unit has significantly increased, as indeed has the maximum rating. The largest single-shaft, high-speed (3600 rpm) machine previously was 81 250 kw, while now a 105 000-kw unit is under construction and one of 150 000 kw has been studied and could be built.

Steam conditions have, in 1946, moved to the next higher plateau. With two or three exceptions the top had been 950-degree, 1250-pound steam. The 105 000-kw unit for the Sewaren Station of the Public Service Electric & Gas Company of New Jersey will operate with steam at 1500 psig and 1050 degrees F. The rise of 100 degrees in inlet steam temperature is particularly significant as the amounts of fuel consumed to produce a kilowatthour is reduced about four percent; however each few-degrees rise in temperature greatly increases the severity of the metallurgical problem. Turbine engineers are now willing to take this next really big step in inlet temperature because by using a method of construction that confines the high-pressure, high-temperature steam to parts which can be made from the newer and better alloys, developed for high-temperature service, the accustomed degree of turbine reliability can be maintained.

Trends in Power Transformers—The kilowatt capacity of power transformers is increasing. This denotes two things. First, power companies are no longer reluctant to entrust so much to a single unit, a confidence that reflects the high order of reliability of the modern power transformer, which dates from the inception of impulse testing a dozen years ago.

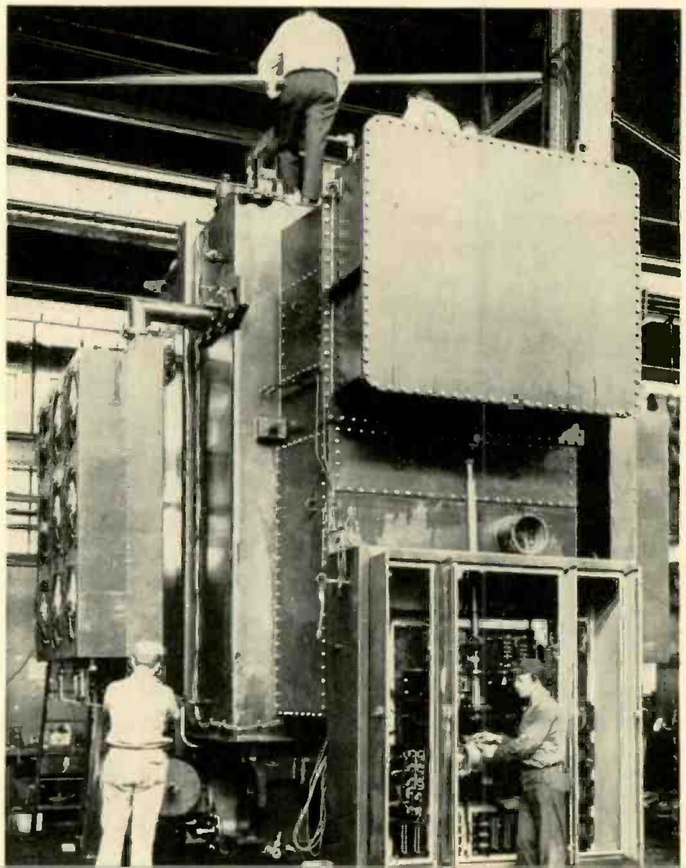
Also, the steady growth in the "biggest" power transformer signifies that transformer design is now based on a well-understood theory. Transformer designers feel confident of their ability to make a rational design for any voltage or current one might propose. The limits are not those of unknown performance of materials when applied beyond present boundaries. They are, instead, those of cost and transportation.

The present largest (electrically) are two 100 000-kva, 3-phase, 69-kv units for Philadelphia Electric Company. They are forced-oil cooled. They were shipped completely assembled with tap changer, but without radiators or bushings, and were shipped lying flat.

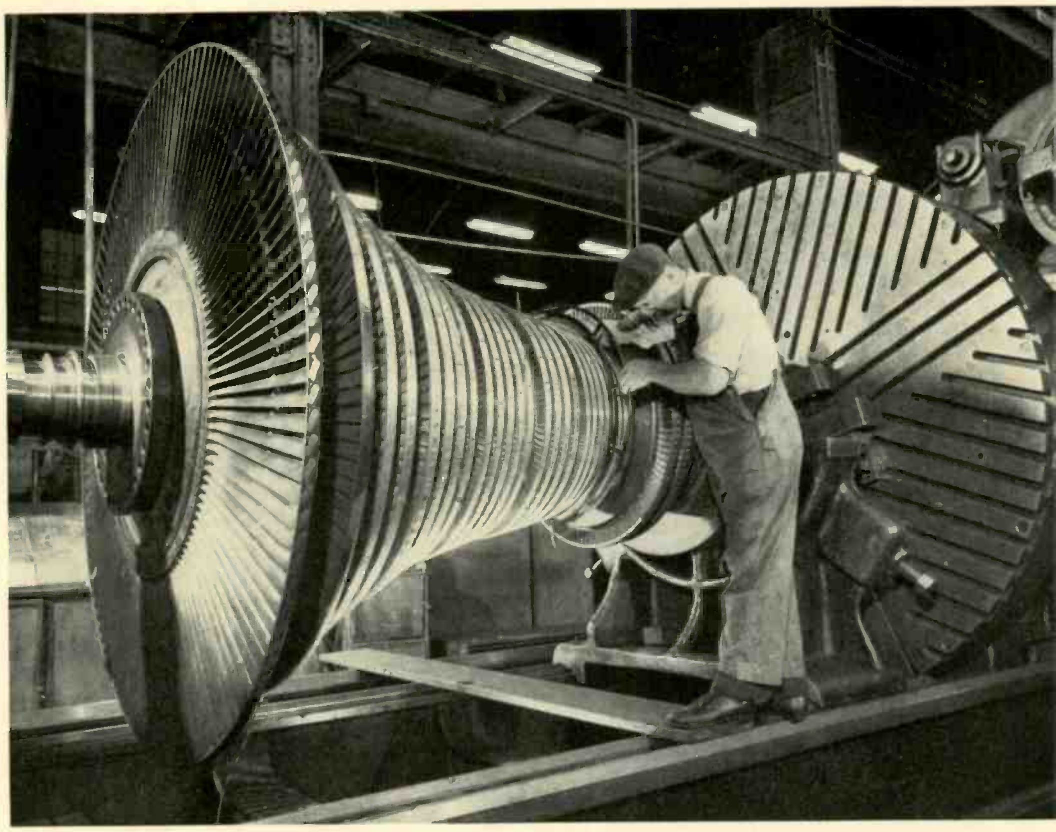
The transformers for the experimental one-half-million-volt line—now proved by test—entailed no basically different principles or construction. They are simply logical extensions of lower voltage designs.

These high-voltage transformers do, however, incorporate something distinctly new in high-voltage metering. Corona considerations require a cap on the upper end of the bushings larger than is necessary simply for mechanical reasons. This cap is made to serve the additional purpose of housing the

Being assembled here is a 100 000-kva, 3-phase, 69-kv transformer. The unit is turned on its side for shipment.



Being built is a low-pressure spindle for a 150 000-kw cross-compound turbine.



metering equipment. The metering system so located uses the bushing porcelain as its insulation thereby eliminating need for a separate ceramic housing.

Transmission and Distribution—The period of production of goods for the military services meant the addition of great blocks of loads to power systems. Some of these were connected to already established lines. The system serving them was not basically changed, only strengthened. Frequently, however, shiny new plants sprouted in more isolated sections, in rural sections remote from urban areas and therefore distant from generating centers. This required all sorts of expedients. More power lines had to be tied together and more taps were added to existing lines. Multi-terminal lines greatly increased. This has resulted in greater use of power-line carrier, pilot-wire relaying, telemetering, supervisory controls, and has accelerated the development of distance relays. Unattended stations became more popular because of man-power shortages. With the favorable experience with this type of equipment, its popularity has materially increased in the last several months.

Power Circuit Breakers—Power systems have expanded in size and more interconnections have been made between systems. As a result the interrupting duty on high-voltage power circuit breakers exceeds the ratings available a few years back. This has led to the development in the high-power laboratory at East Pittsburgh of larger grids for oil breakers and interrupters for air breakers. The new De-ion grid, termed the Multiflow, can interrupt three and one-half million kva. Two and one-half million was the previous top limit. Before these words appear in print, it is expected that a Multiflow grid will have been tested at five million or better. And that is no final limit as consideration is being given to breakers with even considerably greater interrupting ratings.

The Multiflow type of De-ion grid differs from the older forms in that extinction is accomplished by forcing several jets of oil under pressure across the lengthening arc. This differs from the previous method for high-voltage interruption in which the arc is pulled magnetically into the oil. This results in faster arc interruption, and also a much smaller gas bubble. Because of this latter it has been possible to reduce the physical size of circuit-breaker tanks by as much as 50 percent. This has been important as it resulted in a much smaller consumption of steel and insulating oil when both were critically short. There was also, of course, the added advantage of requiring less space in the switchyard and simplification of provisions for handling and purifying oil.

These same power-system changes during the emergency period required also that the interrupting time be speeded up. Changes in design have made available five-cycle breakers in the higher voltage classes where eight- or twelve-cycle interruption was acceptable not many years ago.

The performance of the Multiflow grid as demonstrated in the high-power laboratory shows that these breakers can be used for fast reclosing times of twenty cycles or better. An increasing proportion of breakers are being built with this in mind. Automatic reclosing on high-voltage transmission lines is increasing in popularity and as many as one third of the breakers now being installed are provided with mechanisms suitable for fast reclosing.

The desire for faster reclosing breakers led to the development of the pneumatically operated mechanism. With this apparatus, it is now possible to obtain closing and reclosing speeds on oil circuit breakers as much as one half or even less the time necessary with the former standard solenoid operating mechanisms.

Improvements in indoor, low-voltage, high-capacity power circuit breakers have taken a somewhat different turn during the past five years. The development of the compressed-air circuit breakers has been carried to a point that several hundred of these breakers are now in satisfactory service. In the range of 15 to 34.5 kv the compressed-air breaker has largely superseded the oil breaker for indoor service. Not only is the interrupting performance considered superior, and the oil-fire hazard reduced, but oil handling is eliminated and the apparatus can be kept in service with appreciably less time allowed for maintenance.

The extent to which the compressed-air breaker will be used for high-voltage outdoor applications is still a question. In its favor is the ever-present desire to eliminate oil. However, tests indicate that other hazards are introduced. All designs considered thus far have limitations in the manufacturing cost, because it is difficult to install current transformers and potential devices in this breaker as easily as with a conventional dead-tank breaker. Other factors are mechanism complication, insulation, and weather-proofing. Space limitations also make this apparatus less desirable, and in many cases may be a deciding factor. Experience shows the oil hazard to be negligible, especially with the smaller quantities used in the new breakers. Further, the difficulty of securing strength and rigidity with a structure composed largely of porcelain makes it all the more difficult to produce a compressed-air breaker competitive with oil circuit breakers. The issue is not settled, however. Experimental compressed-air outdoor units are continuing in operation, one for 138 kv having been in operation four years. Study and development with this class of breaker are being continued.

Design work has been under way leading toward the production of apparatus for voltages above 287 kv, the present maximum operating voltage. Power systems in the United States and also other countries will soon require apparatus with a voltage rating of the order of 400 kv. Recent studies have proved that this is quite feasible without fundamental changes in interrupter design. Applications of this higher voltage apparatus are likely within the next few years.

The popularity of automatic equipment and remote control of industrial processes increases by leaps and bounds.

Networks—The secondary network, which for 25 years has steadily grown as the preferred method of giving high-quality service to concentrated urban loads, has become a favorite distribution system for factories. At least 60 new industrial plants have secondary networks.

The trend to adapt the secondary network to lighter density urban loads continues. The heavy-duty network protectors normally used in underground secondary networks was supplemented many years ago by a line of medium-duty protectors. These medium-duty protectors, with ratings of 200, 300, 450, 600, and 800 amperes, are suitable for use in either underground or overhead systems. They extended the economic use of the secondary network into areas of lighter density load than was possible when using heavy-duty protectors. The practical use has recently been further extended by the development of a light-duty network protector (known as the type CM-88). It is designed for pole mounting in an overhead network system, and is available in ratings of 75 and 150 kva.

Last year saw the introduction and rapid adoption of a new method of secondary banking, i.e., the inter-connection of secondaries of transformers connected to the same primary. Although the new system was announced only a few months ago, before year end more than 20 power companies had purchased equipments to give the system a trial.

The idea of secondary banking is by no means new. Its advantages have long been recognized but the system has been handicapped by lack of adequate commercial equipment. Tying together the secondaries of several distribution transformers permits advantage to be taken of the greater load diversity existing among a much larger group of consumers. Loads are shared by several transformers, and at least a two-way secondary feed is provided to consumers' services. Banked secondaries result in improved service reliability when compared with radial secondaries.

In short, most of the normal-operation merits of the eminently successful secondary network system are gained without the network protectors required with secondary networks supplied by more than one feeder. A banked-secondary installation, however, is supplied by a single primary feeder. Hence the banked-secondary system cannot offer the same high degree of service reliability under feeder fault conditions as is provided by the secondary network. Because of its lower cost it can be used in lightly loaded areas when the secondary network would be too expensive.

Installed transformer capacity may be reduced compared to the radial system; secondary conductors can be one or two sizes smaller. Fewer changes in secondary circuits are necessary to accommodate load growth. Voltage flicker on the secondaries is reduced by half.

The hitch to the idea has mostly been in the lack of economical protective measures that function properly on fault or overload conditions to prevent cascading. This has been solved by the development of a completely self-protected transformer (CSPB) with two built-in circuit breakers.

More in a Package—The package idea, while not at all new, is more important than ever. The closer a machine or product approaches a single physical unit, permanently assembled and tested at the factory and shipped as one piece, the less installation labor is required. Assembly and test on the site is accomplished with less adequate equipment and frequently unfavorable conditions. Also the unit construction generally entails less maintenance; to some extent because there are fewer things to go wrong.

Numerous examples of the packaged idea have appeared. Even power producers are being built as units. Several 1000-kw and 2000-kw turbine generators were built for emergency service in China. Eight-car power trains of 5000-kw, consisting of boiler, turbine, condenser, generator, switchgear, auxiliaries, and repair shop, were provided for devastated areas in Russia. Power units of 1000 kw on a skid-type base were built as emergency power units. Each was made up of a Diesel-engine, cooling system, and an a-c generator. Power plants for 128 troopships were built, shipped, and installed as units. In these the condenser served as the base for the 3500-hp steam turbine and a-c generator.

A central-station type 5000-kw steam power plant was built last year for service abroad. Again the condenser became the bedplate for turbine, generator, pumps and other auxiliaries. The entire unit occupied but 31 by 13 feet of floor space and stood 17.5 feet high.

Engineers are giving consideration to the possibility of making auxiliary power plants for ships in packaged form. Conceivably a 500-kw power plant could be built as one unit with the turbine, generator, and condenser combined. Possibly some of the experience gained with 400-cycle systems for aircraft could be utilized for a shipboard system. This would permit utilization of the high efficiency and small size attendant to high-speed steam turbines. If central-steam conditions of 1000 pounds pressure and 1000 degrees were adopted instead of the 650 pounds and 850 degrees currently used aboard ships, weight and bulk of the auxiliary power plant might be reduced by half.

Prewar, the packaged power transformer had proved successful in voltages up to 5 kv. The logical extension of that idea to higher voltages, although considerable development was entailed, has been accomplished with units suitable for 15 kva. These units contain all the functions of a modern substation coordinated in one case, and are proving useful in reducing distribution expense through smaller first cost, lower operating expense, and simplification of provisions for relocating to meet load growth. Availability of the power package in voltages up to 15 kv will not only permit servicing new rural loads but also will find use in more densely populated areas in which a pronounced trend toward higher voltage distribution is apparent. The first of these units will go into use early this year.

Less Weight—The lighter the weight, the better the product. While this is not without its exceptions, the feeling is growing among engineers that apparatus can and should weigh less. This results in part from better knowledge of materials, more rational disposition of materials in a product, and often from better materials. In some, cost reductions result. However, more often than not, weight reductions are sought for other reasons. The cost may, in fact, actually rise. In any case the tendency to peel weight out of designs of almost all kinds of power apparatus is quite widespread.

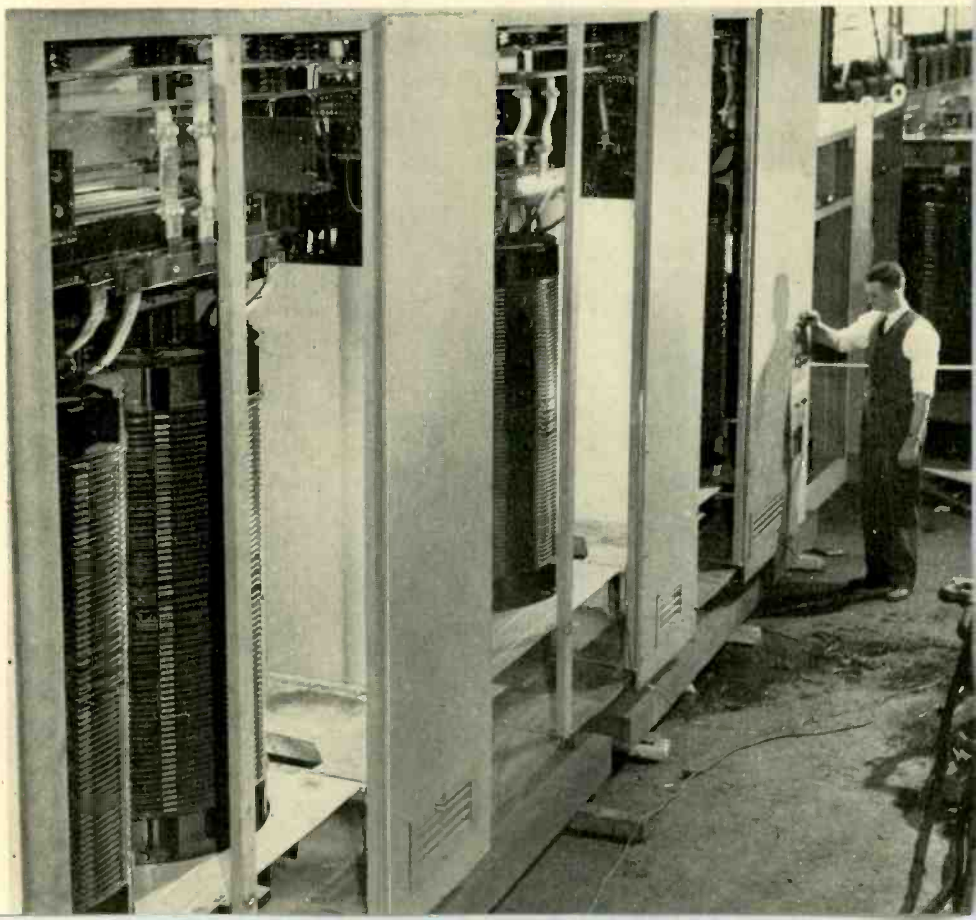
To reduce the weight and to eliminate the castings required in the cases of marine gears, an entirely new construction has proved satisfactory. Instead of a heavy welded or fabricated stress-carrying housing, the gear case now consists of a skeleton of steel beams to carry all bearing loads. This skeleton is encased in a light-gauge housing of aluminum alloy, which serves satisfactorily to house the oil and to enclose the rotating members. This construction of 1/8-inch aluminum sheet replaces a 3/8-inch steel sheet. Approximately ten percent of total weight is saved.

In 1920 a 10 000-kva, single-phase, 138/13.8-kv transformer weighed 100 000 pounds. The 1946 model weighs 62 000 pounds. This new one weighs even 19 000 pounds less than the "modern" power transformer of 1940—a decline of 23 percent. Largely accountable for this striking reduction in weight is the use of the construction logically named form-fit, in which the tank consists of a fabricated, low-height lower portion, into which the core and coils are set and around which is placed a cover and upper portion having a shape that closely fits the working parts. The upper portion of the tank is then welded to the lower member making a sealed unit. This construction supersedes the round or rectangular tank in which the transformer core-and-coil assembly is located. Because the form-fit tank has relatively little space between it and the working parts the oil to fill it is much less, 14 500 pounds as against 21 000 pounds for the 1940 unit, or 28 000 pounds for the 1920 unit. Because the case is small, it and its fittings weigh 18 000 pounds instead of 23 000. The core and coils now weigh 29 500 pounds instead of 37 000 in 1940, largely because of the use of Hipersil steel. With the form-fit tank goes, of course, less floor area. As compared with the 1940 unit, the new one occupies 94 by 136 square inches as compared with 110 by 152 square inches, or nearly 25 percent less.

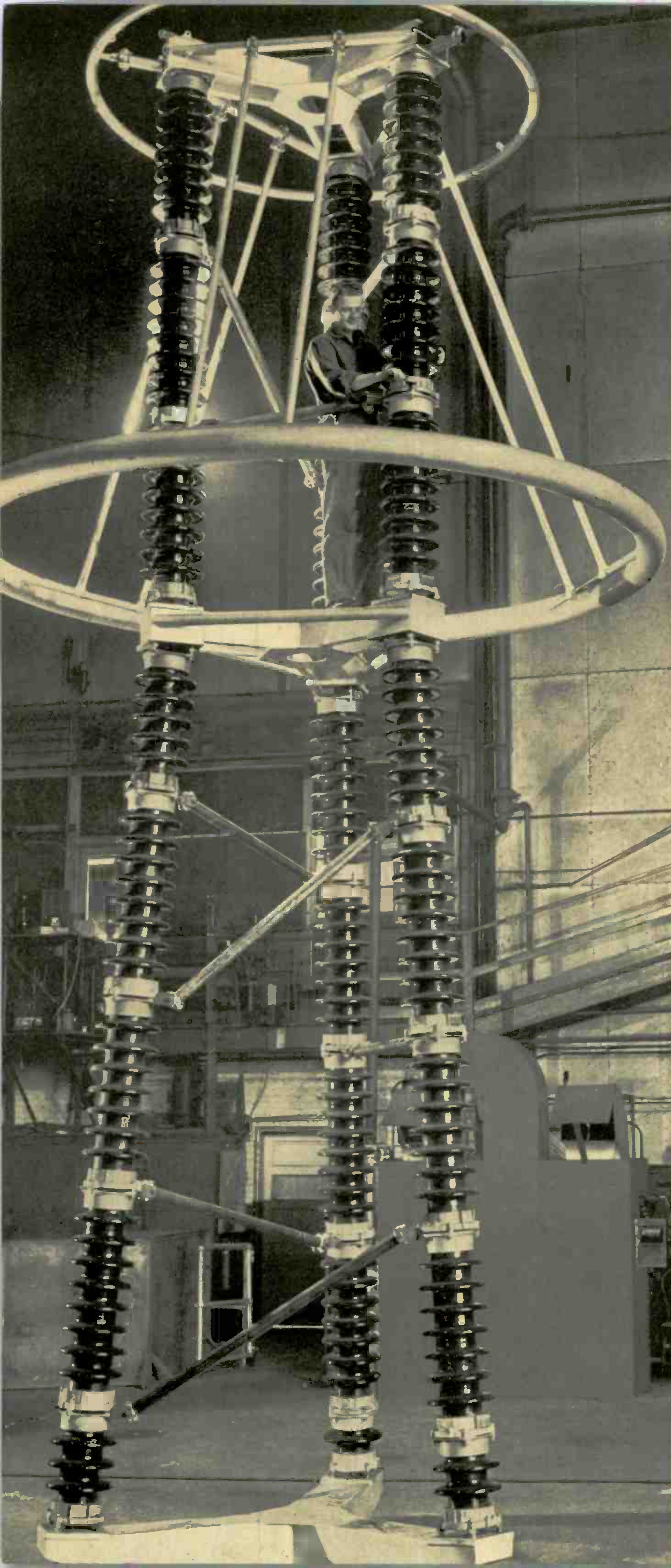
In 1940 a 25-kva dry-type distribution transformer weighed 670 pounds. The Navy's stupendously expanding fleet began to require large quantities of such transformers—but with weight and dimensions reduced to the minimum. Insulation was changed from class A to class B; grain-oriented steel (Hipersil) replaced hot-rolled silicon; wound cores replaced stacked punchings; pancake coils were changed to cylindrical coils with end ducts; end frames were made of steel instead of castings, and castings were otherwise eliminated. At the war's end the Navy was using a 25-kva air-insulated transformer that weighed 270 pounds, (a 53-percent reduction) that occupied less than half of the original 12 900 cubic inches.

This same transformer is being supplied in large quantities for use in factories. Thus, to a large extent the result of the Navy's emergency need, the 25-kva dry-type transformer of 1947 has a few percent lower losses, weighs less than half as much, is 43 percent as large as its prewar predecessor.

Weight has also been taken out of broadcast transmitters. A one-kw A-M transmitter built only a few years ago weighed about 3500 pounds. The new F-M transmitter of same rating weighs 1600 pounds. This comes about from greater use of aluminum, simplification of the frame structure, use of lightweight sheet stock and reinforcing ribs.



Air-cooled power transformers are becoming larger. This is a 10 000-kva, three-phase unit.



A Glance Ahead

"The encouraging thing about the future of engineering science is that so little has been done, so much remains to do."

THE full value of a great man or his works cannot be immediately set forth in his lifetime. Similarly it will be some time before the significance of the past few years to engineering can be judged. The mass of detailed information, skills, methods, and concepts will require years for full absorption and utilization. New apparatus appearing for the next decade will be better for the lessons learned.

On the Brief Side—The engineer and scientist find, in the leftovers of war, tools they do not yet know how to employ fully. But give them time. For example, it was possible in 1940 to measure, with cathode-ray oscillographs and such, events happening in times as brief as a few millionths of a second. That was pretty good. But, as a by-product of microwave techniques and devices, phenomena with life spans as short as one thousandth of a millionth of a second can be studied. Perhaps this will be useful in research on arcs and ionization. Anyway, a tool for probing beyond old limits is at hand.

The high-speed x-ray (p. 19) that provides one-millionth-of-a-second snapshots of action hidden within metal has thus far been used mostly for ballistics and armor-plate studies. Many fields of engineering have problems to which the super-fast x-ray will help provide answers.

Electronics, par Excellence—The engineer of today has been bequeathed a whole family of microwave devices. These are magnetrons, klystrons, resnatrons, TR switches, synthetic crystals, etc. Until radar became something more than just an idea the best generators of microwave power could produce only a few milliwatts. The application of the resonant-cavity principle to microwave power generation has resulted in magnetrons that can produce power pulses of 2.5 megawatts or more at frequencies of thousands of megacycles. Klystrons, used as local oscillators, develop continuously a few dozen watts at these high frequencies, while the resnatron—used to provide radar jamming power—produces 85 kw. Engineers commonly agree that these are but beginnings in ratings at microwave frequencies. They see no reason why, given development money and time, a practical 50-megawatt microwave generator cannot be produced.

What such quantities of ultra-high-frequency power will be used for is not altogether apparent, nor does it need to be. The tool precedes the use just as frequently as the application awaits the need. Having one, the other is bound to follow.

One of the greatest possible future uses of microwaves is radio relaying. This will probably be done with klystrons or magnetrons with a power output

Lightning arrester as built for the experimental 500 000-volt transmission line.

of about one watt. Relaying stations will probably be approximately 25 miles apart and will replace expensive lines and cables for telegraph, toll telephone, facsimile relaying of radio and television programs.

The resnatron tube has already been mentioned for possible use as a high-frequency generator for television. Commercial radar will probably be able to make good use of these high-power generators. Guided missiles, with their ominous connotation, will call for the best that designers of microwave generators can devise. High-power radar quite likely will have meteorological research value. Astronomers may find it a useful tool. Guided rockets for peaceful purposes and space ships can no longer be dismissed with a smile. For them high-power generators of high frequencies will be essential. Uses of microwave frequencies for dielectric heating, as for food sterilization or processing or for heating or curing of extremely thin films, are still unexplored because engineers simply have not yet had time.

Developments in older electronic generators, while not so spectacular, are equally significant. Tubes are being built for frequency-modulation radio-broadcasting in capacities that could not have been attempted a few years ago. For example, tubes of 7.5 kilowatts, producing frequencies of 100 megacycles, and with plate efficiencies up to 80 percent, are now attempted without question by tube designers. Only a few years ago, 20 megacycles would have been about the limit for tubes of such capacities.

Super Cathodes—But much more remains to be done. For example, the best cathodes emit electrons at the rate of about one or two amperes per square centimeter. Engineers dream of emitters that can do ten to twenty times better than that. "Freakish" emissions of such magnitudes have been observed in the laboratory. Scientists work on the theory that if such a phenomenon occurs even rarely the factors causing it can eventually be discovered. A ten-fold improvement in electronic-tube thermionic emission would be revolutionary and would have ramifications affecting every phase of industry.

Television—Television has emerged from this past period of electronic super-activity the beneficiary of many technical improvements. In fact, high-quality televised programs are now possible. In fact, the remaining problems of black-and-white television are no longer technical ones but largely commercial and financial. Already color television is coming hard on the heels of black-and-white television—so hard that in the opinion of some it should be adopted as the standard without taking the intermediate and expensive step with installations for black and white. Color television has been demonstrated (by Columbia Broadcasting System) and several studio equipments for further experiment are being built by Westinghouse. These employ synchronized rotating color-filters at the studio and the receiver. While the color screens cut down the light intensity, this is more than made up in optical effect by the presence of all colors. The system and apparatus are simple in principle and admittedly will require a period of development—how long is the industry-disputed point.

High-Altitude Broadcasting—Stratovision, the system of broadcasting and relaying television and F-M programs from flying antennas, has completed its first stage of flight testing. A modified bomber during 1946 made flights with high-frequency signal generators between Baltimore, New Haven, and Detroit with Federal Communications Commission and Westinghouse engineers making signal-reception measurements.

This plane was equipped with an F-M transmitter and a high-frequency pulse transmitter, which permitted measurements of field strengths under varied conditions. These tests definitely confirm the calculation of signal propagation.

How the Wind Blows—Wind tunnels have assumed surprising stature and importance in the industrial scene. Until the late thirties there were a few isolated tunnels requiring a few hundred or a few thousand horsepower. In the intervening years Westinghouse alone has installed, or will have in service, 225 000 horsepower in wind-tunnel drives. The country probably has of the order of 400 000 hp of installed capacity in wind tunnels, of which the largest single-motor drive in operation is the 40 000-hp tunnel at Wright Field.

But all this is but peanuts compared with what is being contemplated. The following quotation from a national publication* gives a clue as to what engineers are considering:

". . . Several months ago, a representative of NACA (National Advisory Committee for Aeronautics) asked (the Bonneville Power Administration) for "a block of power." Bonneville inquired how much was wanted.

The answer: "Two million kilowatts."

The Bonneville man scented a misplaced decimal point. "You mean 200 000?"

"No, we want two million."

"There isn't that much power anywhere."

. . . Last week NACA came fairly clean to a *Time* correspondent. It was considering the reports of two committees on a projected cluster of gigantic supersonic wind tunnels."

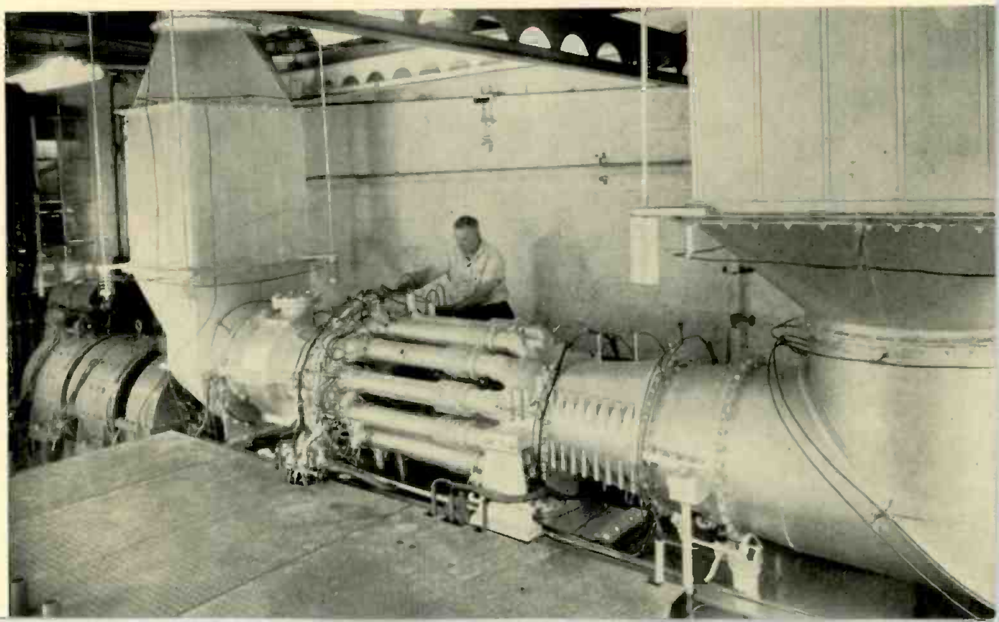
It appears that we may see a single wind tunnel requiring more than a million horsepower to create a supersonic wind for research. Those agencies concerned with high-speed aerodynamic research freely speak of "smaller" tunnels with power inputs of two and three hundred thousand horsepower.

Whether and when these materialize cannot yet be said. Such thinking, however, indicates the nature of requirements for exploration of flight at speeds far above that of sound. Air speeds of 2500 miles per hour are being seriously considered. Only a bare beginning has been made in aerodynamic research. It is one of the truly big things of the future that will have major effect in many industries.

Gas Turbines—Paralleling the development of gas tur-

*Time Magazine, October 14, 1946.

Testing continues on the experimental 2000-hp gas turbine.



bines for jet propulsion and aircraft propeller drive is the intensive development of the gas turbine for surface use. An open-cycle unit of 2000 hp was tested in the early fall. At the time of this writing the unit had been tested up to 60 percent of full power at all speeds. The machine starts quickly and maneuvers well from one speed to another and has demonstrated no mechanical weakness. This unit is the sort that might be installed on a locomotive, as it is but three feet wide, six feet high, and (including geared d-c generator) 26 feet long.

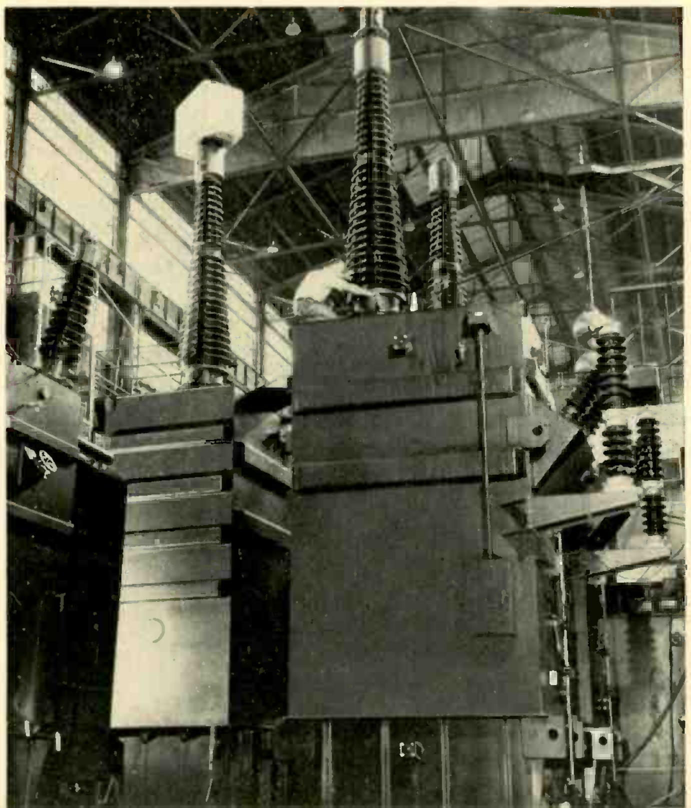
This 2000-hp unit was built to burn liquid fuel, such as bunker C oil. Intensive efforts are under way to enable gas turbines to burn coal instead of liquid fuel. This development is still in its early stages but eventual success appears likely.

In general there are two approaches to the use of pulverized fuel in a gas turbine. One is to pulverize bituminous coal to the same degree of fineness employed in powerhouse boilers, and burn it under about five atmospheres pressure. The combustion products then are cooled with excess air to a turbine inlet temperature of not more than 1350 degrees F. These hot combustion gases are then led through numerous cyclone separators of small diameter in an endeavor to separate erosive ash before passing the combustion products through the gas turbine. This system is simple in concept but bulky in execution as about 100 cyclone separators are required for each 1000-hp capacity.

A second approach is to pulverize the coal to face-powder fineness—down to about forty microns or 1½ thousandths of an inch, in maximum dimension. Coal crushed to that degree may result in combusted particle sizes so small that they follow the law of gases more than the law of solids. Although hot enough to be fluid they will flow around the blading on the inevitable microscopic film of gas that surrounds the fast-moving blades and thus not impinge on the blade structure. In effect, the ash then would pass out the exhaust without eroding the turbine components.

Higher Transmission Voltage—A new assault is being made on the limits to high-voltage power transmission. Nearing completion at Brilliant, Ohio, on the property of the American Gas & Elec. Service Corp., are two lines a mile and a fraction long. For it Westinghouse provided transformers, lightning arresters, and metering equipment suitable for voltages as high as one half million. No circuit interruption on the transformer secondary side is being provided initially and the line will carry charging current only, no power.

The three transformers for the experimental high-voltage line are here undergoing factory tests.



Experiments with this high-voltage line are expected to provide a mass of information essential before the next step beyond the present 287-kv top in transmission voltage. High on the list of unknowns is the phenomenon of corona at high voltages. The nature of corona is such that extrapolation from known data is unreliable. The tests will provide experience on conductor characteristics, divided conductors, performance of bushings, transformers, and lightning protection over a long enough period of time so that various kinds of weather, aging of conductors, etc., will be considered. This year should see the accumulation of data that will promote a rational design of lines of voltage higher than anything heretofore attempted, paving the way to transmission of power economically over long distances when this becomes desirable.

Sources of Power—What of the most fundamental thing of all—our sources of power? A look into the next few years does not disclose any radical change in our sources of power or methods of their utilization. However, several factors are at work that may affect power production in the more distant future. One of these is depletion of reserves of liquid fuels and the long-term increasing costs of solid fuels. Cost of coal has been rising steadily, and, although developments will make it possible to mine coal with less human effort, it is entirely reasonable to expect that the costs per Btu will continue to rise. To a degree, coal production is a social problem. There is evidence, particularly in Europe, that as the standards of living rise, there is less willingness on the part of men to engage in this activity, which in turn is reflected in increased cost of fuel.

As coal costs rise and underground liquid reserves decline, more thought is being given to the utilization of oil shales of which the United States has ample stocks and good quality. Various unique methods of extraction of energy from oil shale have been proposed. It is yet too early to say which will be successful or at what cost per unit.

Atomic power looms as a possibility. Many studies have been made in an attempt to predict to what extent it will compete with liquid or solid fuels as a producer of electric energy. All these studies are based on various assumptions, including as yet inadequate knowledge of the cost of nuclear fuel. As a result the estimates of nuclear-produced energy as compared with that of conventional power plants extends over a wide range of values. The situation is changing with such rapidity that quotations of specific figures are soon out of date.

As matters stand now one can make the general conclusion that the cost of nuclear-produced power will not differ greatly from that of present power. Further discoveries, of course, may alter the situation. However, aside from cost considerations there are many formidable problems in connection with the nuclear-energy plant. These problems will take years of mechanical, chemical, electrical, metallurgical, and nuclear engineering to solve.

The magnitude of the problems ahead of nuclear power production does not at all dim its undeniably bright future. Engineering thrives on problems. Nuclear development holds great promise for engineering skill, imagination, resources, and employment.

Views in Review

In gathering information for this annual survey some sixty managers of engineering sections at Westinghouse were asked their opinions of what the past half dozen years have done to the profession. The written replies contained dozens of succinct, thought-provoking views that show the engineer to be not only a technical man but a philosopher as well. We have room for but a few.—*Editor.*

Shortages impressed upon everyone the fact that material supplies are not limitless and that it is necessary to conserve material resources. . . .

Many of the problems solved during the war had been studied long ago, but solutions were delayed because of lack of money and manpower. . . .

We have learned to do more with what we already had. This is particularly true in the case of aircraft apparatus where we were forced to do things that we hesitated to attempt in the past. . . .

The war period very definitely shortened manyfold the time involved from the inception of a new idea until its appearance as a marketed product. . . .

We are beginning to understand that virtually all costs are labor costs. What is one man's material cost is simply someone else's labor. . . .

We are able to produce more apparatus per foot of manufacturing floor space and per man-hour of labor by the use of more, new and improved machines. . . .

The trend in the shop is to more expensive tools, less expensive workers and an incentive or piecework basis of pay, so it is becoming more and more necessary to make better than average drawings. . . . It is almost necessary to include enough information so that a drawing cannot be read wrong. . . .

The war advanced, by many years, the development and introduction of new devices, materials and manufacturing techniques that could be used advantageously for the useful purposes of destroying the enemy and thus assuring our own national supremacy. While many of these ideas and developments can be used effectively in peacetime activities, it would not be economically (or politically) possible in a normal peacetime economy. . . .

The war taught us that young engineers could accomplish more than we thought they could, provided they were given proper coaching and instructions. . . .

Because of the pressure of getting things done, engineers learned to rely more and more on their theoretical knowledge, and reduced the amount of "cut and try" methods. . . .

There is a definite attitude among engineers that practically anything can be done if time and money are available for the specific job. This is a healthy condition, especially since our position in world trade will be directly dependent upon our abilities to design and sell against foreign competition. . . .

On the bad side of the war ledger and due to the fact that satisfactory characteristics and fast deliveries had top priority, engineers had a tendency to lose their "cost consciousness." . . .

The war forced the engineers to follow their product through and into the factory until production was underway. This gave them a better understanding of manufacturing problems. The same urgency that brought this about also brought them in contact with the application engineers so that they know more about the use of their product. . . .

The war has hurt engineering a great deal through the loss of four or five classes of engineering graduates in colleges during the war years. Our "young" engineers are now 27 and 28 years old instead of 22 years old. . . .

Engineers must be more technical, and at the same time, more practical than they have been in the past. This applies as well to the research scientists, who are dealing with the fundamentals of physics, chemistry, and engineering. . . .

While theory can guide us, it can also misguide us. Theory offers the explanation of many phenomena, but we sometimes look so hard at an accepted theory that we miss the true answer. . . .

The principal lesson taught by the war is that we must never have another one. . . .

These transformers are members of a high-voltage, fact-finding program. They are built for operation at voltages up to a half million.