WESTINGHOUSE

Engineer

SEPTEMBER 1948

World Radio History

Engineering Development Is a Long, Expensive Road

On a hot sultry night last June members of the press gathered in the lounge of a country club in Zanesville, Ohio, to see by television the nomination of Republican candidates in Convention Hall, Philadelphia. This was not ordinary television—it could not be, for Zanesville is far outside the range of the New York-Philadelphia-Washington link of telecast stations. It was a Stratovision program—the program telecast from a Washington station was picked up by the experimental Stratovision plane circling 25 000 feet in Western Pennsylvania (160 miles away) and relayed on a new frequency over a circle of some 250 miles radius, which included Zanesville, 130 miles farther west. This was a demonstration of another of the several steps necessary in the course of this spectacular television development.

* * *

Stratovision illustrates in uncommonly clear fashion several important and fundamental aspects that characterize major engineering developments: the time span from birth of an idea to widespread commercial utilization is several years; large sums of money expended without hope of early return—in fact, without positive assurance of any return; and close essential cooperation between companies, often working in dissimilar fields.

* * *

To peg the genesis of the idea of a "sky-hook" antenna for transmission of ultra-high-frequency signals (as are used in radar and television) to a particular person or time would be difficult, if not impossible. As these frequencies have much the directional characteristics of light, the merit of a high antenna has long been apparent. However, the birth of Stratovision does date to a specific day in December in 1944 when a young electronics engineer —C. E. Nobles—flew from Mexico to his office at the Westinghouse Industrial Electronics headquarters in Baltimore. His wartime duties involved him in development of air-borne radar, which gave him good background for his reflections. "Why," he thought, as the airliner droned along over the plains of the Southwest, "couldn't an airplane serve as a flying antenna for commercial television and f-m, receiving the signals from a station below and recasting them over an area many times larger than can be 'seen' by a ground antenna?"

* * *

The idea persisted. He could not shake it. The more he considered it the better it looked. He kept turning it over in his mind for technical flaws but found no serious ones. Arriving at his desk he made some preliminary calculations and discussed the aircraft problem with aviation friends of his. This only confirmed his belief in the soundness of the idea. He proposed the idea to his superiors, who rightfully pointed out several objections, not the least being economic. But Chili Nobles was not one to take "no" easily. He met each argument with further analysis and computation, always stressing his belief that here lay the answer to the outstanding weakness of television—the short range of land-bound transmitters. Finally he won his point, Westinghouse management agreed to support an exhaustive mathematical analysis and preliminary discussion of the flying portion of such a scheme with the nearby Glenn L. Martin Company. This took time, weeks in fact, because any fundamental weakness in the scheme had to be found before more costly research could be undertaken. No such weakness developed.

* * *

The next step—to demonstrate that carrier signals could be broadcast from a flying antenna—would involve a sizable sum of money and man-hours of technical talent by both Glenn L. Martin and Westinghouse. The companies elected to back the equipping and operating of a plane carrying tone-transmitting apparatus. Months were required to obtain a suitable plane, strip it of non-essential apparatus, build by hand special high-frequency signal generators and install them, make many flights in different areas in all kinds of weather, at various times of the day, and record the results with test receivers distributed over several states. Many obstacles appeared. None were fundamental; they were those troublesome ones that always dog any undertaking in uncharted fields. They had to be met, one by one, each levying its charge of time and expense. But, in September, 1947, the engineers—aircraft and electronic—became convinced of the complete success of this step and so reported to their managements.

* * *

Their work was far from done. Stratovising a tone or carrier wave, while successful and strongly evident of the feasibility of telecasting, was not the same as relaying pictures. This could be done only with a larger plane, capable of flying much higher and carrying much heavier loads. Something like a B-29 was indicated. The ship would have to be pressurized to enable the crew to work six miles in the air. Special television transmitters, of shape and weight suitable to be carried aloft would have to be designed, built by hand, thoroughly tested and installed in the extensively modified airplane. An entirely new television antenna system had to be devised. Scores of incidental but tough problems, such as cooling the plane while the television apparatus is at work and heating while it is off, had to be solved. Numerous experts in many fields had to be consulted.

* * *

The steps were getting bigger now. So were the sums of money required for each further venture—and always the next step might disclose some hidden basic defect that would necessitate abandonment of the whole program. Managements again found the possible end result attractive and approved the organization and cost of the next critical move, which had its demonstration last June 23 in Zanesville.

* * *

That Stratovision is technically feasible can no longer be seriously questioned. But that does not bring Stratovision into being. Attention must now be given to other matters—reliability of planes and telecast equipment over long periods of time, during high winds, and under all types of storm conditions. And the economics of Stratovision as compared with other television systems must be demonstrated.

Possibly the next step will be—the Federal Communications Commission approving—to equip planes and establish a regularly scheduled but limited commercial service in some chosen representative area. But this will involve more time. A plane designed solely for this special purpose and with economical manufacture in mind must be planned and built. So, too, the telecasting equipment. How soon can all this be? No one can say for sure. Certainly a year. Probably longer. And cost? Large, six-digit sums will have to be added to the investment already made by the two cooperating companies.

* * *

It is a saga of American technical skill, private initiative, venture capital at work. It differs from scores of developments—radio itself, the airplane, Nylon, and scores of others—only in that it is somewhat more spectacular, its divisions and phases a little more clearly discernible. It is, in short, illustrative of the American system at its best.

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WESTINGHOUSE

Engineer

PROPERTY OF
WILLIAM P. FISHER
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On the Side

The Cover—Dick Marsh, the artist, symbolically portrays the manufacture of plywood, a product typical of new schemes of wood utilization.

• • •

Although the experimental 2000-hp gas turbine was built principally for test purposes, it has proved so satisfactory as to be suitable for actual service. The machine will be used to drive an Ingersoll-Rand centrifugal compressor at 8750 rpm to boost pressure in a natural-gas pipe line. When installed it will be the first complete gas turbine (incorporating a compressor, combustors, and turbine in a single unit) in industrial operation in the United States. Because of its light weight and accurate balance, a simple, inexpensive concrete mat will be the only foundation required.

• • •

The recently displayed, 132-foot-wide water-fall over Broadway in New York is lighted as brightly as Niagara Falls by Westinghouse mercury-vapor lighting. The mercury spectrum adds a bluish-white color to the sheet of water that contrasts with the golden glow of the lettering in the mammoth sign.

• • •

The oldest full-length industrial movie ever made was recently uncovered in the archives of the Library of Congress, where it was filed for copyright purposes in 1904. Produced by Westinghouse just after the turn of the century, the movie was at that time the second longest in existence, the only longer one being "The Great Train Robbery." The movie was used to demonstrate manufacturing operations at the East Pittsburgh Works.

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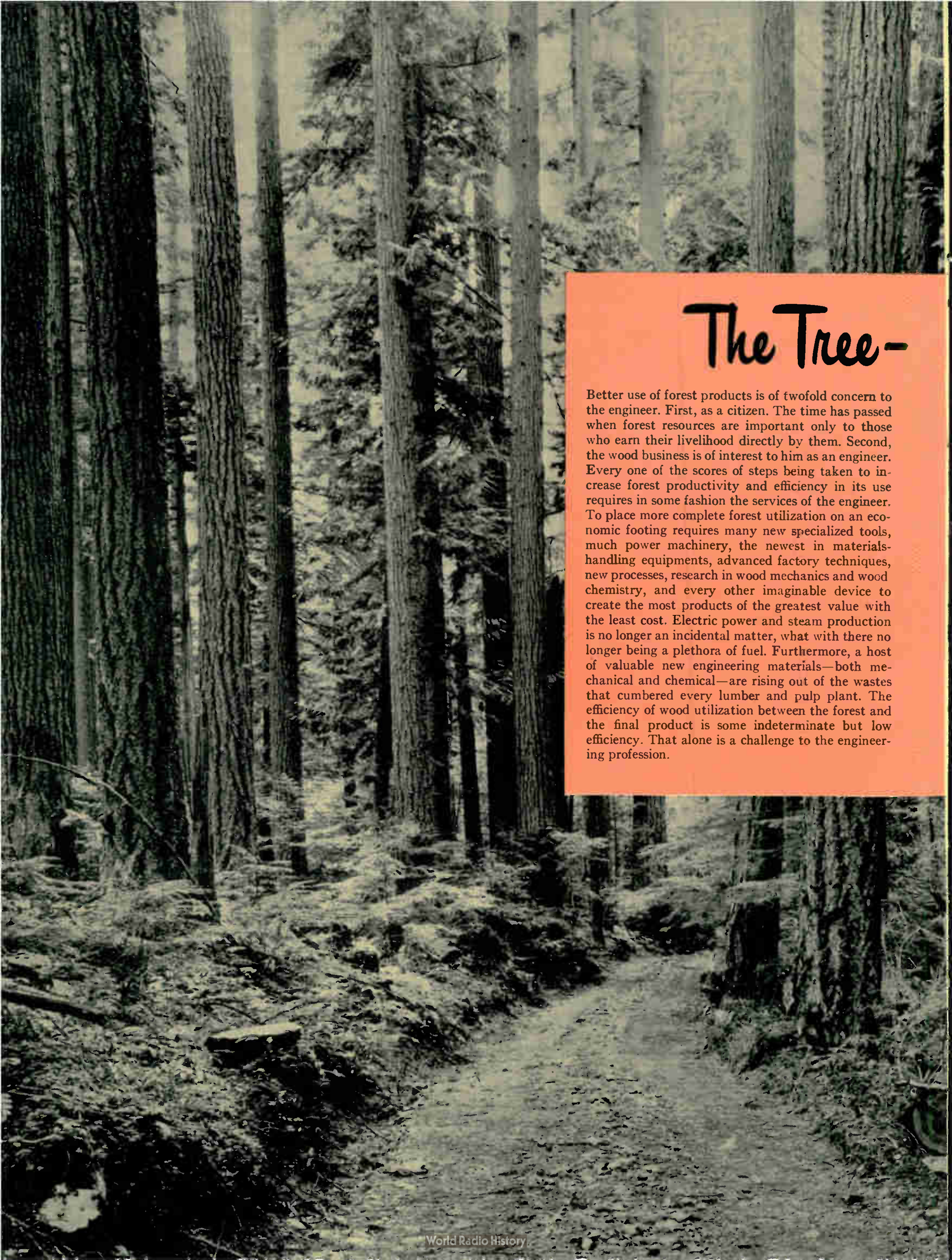

The Tree-

Better use of forest products is of twofold concern to the engineer. First, as a citizen. The time has passed when forest resources are important only to those who earn their livelihood directly by them. Second, the wood business is of interest to him as an engineer. Every one of the scores of steps being taken to increase forest productivity and efficiency in its use requires in some fashion the services of the engineer. To place more complete forest utilization on an economic footing requires many new specialized tools, much power machinery, the newest in materials-handling equipments, advanced factory techniques, new processes, research in wood mechanics and wood chemistry, and every other imaginable device to create the most products of the greatest value with the least cost. Electric power and steam production is no longer an incidental matter, what with there no longer being a plethora of fuel. Furthermore, a host of valuable new engineering materials—both mechanical and chemical—are rising out of the wastes that cumbered every lumber and pulp plant. The efficiency of wood utilization between the forest and the final product is some indeterminate but low efficiency. That alone is a challenge to the engineering profession.

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The tree, for too many generations, was simply a weed to be cleared from the land, or something to be chopped down, its trunk hauled to a sawmill and the central portion cut into lumber, the remainder—much of the total—going to the trash burner. That concept has pretty well passed. Economic good sense promotes it. Necessity dictates it. Ways of increasing the amount of merchantable wood grown on an area and brought out to the mills, and of elevating the milling and processing scraps that do occur into products of value are of surprising variety and number. They herald a new concept of wood.

More Wood, More Products

"WASTE wood is becoming scarce!" Thus spoke an executive of a large modern lumber company in the Pacific Northwest. He continued: "Until recently we had so much sawdust, bark, and miscellaneous mill slab and edgings during lumber manufacture that we had to burn most of it to get rid of it. Now we don't have enough to supply our demands for steam and electric power. We are purchasing thousands of barrels of oil yearly to supplement the fuel obtained from milling leftovers for our boilers." As he spoke, the dismantling of two trash burners could be seen and heard outside his window. These silo-shaped structures with wire-screen domes have been a conspicuous element of every lumber-mill skyline, evidence of prodigal use of wood.

The dismantling of wood-waste burners is significant—significant not so much of something that has already happened, but is beginning to happen. A good start has been made on the long road to more complete and better use of trees. Some would emphasize that it is only a bare start, but the fact that it is a start is a hopeful sign. In some quarters the progress in this desirable and essential direction is considerable; in others, it is non-existent.

The Status of Our Forests

When the Pilgrims landed, probably one third of the total land area was virgin forests. Pioneer settlers had never seen forests the equal of America's timber stands. These primitive areas proved a curse to land settlement. Lumber was not a product of an organized forest industry, but a by-product of land clearing. The forest was pushed ever westward as man's quest for land quickened the tempo of his axe strokes.

Development of the railroad hastened the use of forest lands, as did the beginning of paper making and the increased use of wood in mining and the settlement of the prairie states, whose development required tremendous amounts of lumber from outside sources because of the treeless land. It took 250 years for the logger to come from Massachusetts to Michigan, but only 75 years from there to the southern pineries and then to the Pacific Coast. From 1860 to 1910 was the golden age of wood. Frontier days had passed and the country teemed with industrial development and settlement. Wood was the universal building material; the forests were marshalled to nurture the growth of a nation. From 1890 to 1910 over 800 billion board-feet of standing forests became the framework and walls of a growing nation, the wood that made America an industrial empire.

Many of the forests became the victims of an economic system, socially condoned, which as yet had little thought of perpetuating natural wealth. Complete liquidation of forest areas—in some cases necessary to provide needed farm land, in others by firms interested only in immediate return—was accepted without question. Fire protection was virtually non-existent, in fact, the loss resulting from fires was hardly given a passing thought unless life or property were involved. Tax laws lent no encouragement to perpetuating forest productivity. The public at large was apathetic.

It was not until about 1870 that the concept of the forest as a renewable resource was born, and even then it developed slowly. In fact, most of the change has occurred since the turn of the century and most of the real gains have been made since World War I.

According to United States Forest Service surveys the country has 461 million acres of land capable of producing timber of commercial quantity and quality (or approximately one half of the original forest area of the country). Of these 461 million acres of commercial forest land, 75 million are virtually non-productive as a result of destructive cutting and fire. This leaves 386 million. Of this all but about 45 million have been cut over from once to four times, and most of this is producing considerably less than the amount of which it is potentially capable.

Of the commercial forests, 345 million acres or nearly three fourths are in private hands. Most of the remaining 117 million belong to the national government (89 million) while 27 million belong to the states, counties, and municipalities.

Class of ownership of the forest lands has a great deal to do with the problem. Of the 345 million acres in private hands, 261 million (76 percent) are held by slightly more than four million owners in tracts up to 5000 acres but which average about 65 acres. The medium-size holdings—of 5000 to 50 000 acres—comprise 33 million acres, which have about 3000 owners. Only about 400 single-ownership tracts are larger than 50 000 acres, which in the aggregate total 51 million acres or one seventh of the privately owned forest lands.

It is significant that the treatment accorded the forest varies widely depending on class of ownership. According to a recent (1946) reappraisal of the forest situation the U. S. Forest Service classifies the percentages of cutting practices as: high order, good, fair, poor, and destructive. The figures given for the small, medium, and large tracts respectively are: good or better, 4, 8, and 29; fair, 25, 31, and 39; poor or worse, 71, 61, 32. Taking private holdings as a whole, 8 percent are classed as good or better; 28 percent, fair; and 64 percent, poor or worse.

These figures indicate the importance of the owners of small forest tracts. Infrequently do these have both the understanding and incentive to operate their holdings on a perpetual cropping basis. Too often the cutting is determined by pressing demands for ready cash, the temptation of high immediate prices, or complete indifference to needs of future generations. More progressive forestry is in general being practiced by the large holders, equipped with ample capital and equipment and the determination to be in business 50 and 100 years from now, drawing from the same lands now being worked.

Some headway is being made with the enormous program

Prepared by Charles A. Scarlott from information supplied by numerous sources including the following: the engineering departments of Westinghouse; several branches of the United States Forest Service including the Forest Products Laboratory; College of Forestry, University of Washington; Puget Sound Pulp and Timber Company; the Douglas Fir Plywood Association; Weyerhaeuser Timber Company; the Simpson Logging Company; National Lumber Manufacturers' Association; American Forestry Association; the Forest Products Research Society. Certain firms and products are cited as illustrative of progress toward better wood utilization. Space limitations only, however, prevent mention of many others.

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of education and planned help and cooperation required for these several million small owners. One such is the tree-farm program sponsored by private forest industry. A tree farm is an area of privately owned forest land devoted primarily to the continuous growth of merchantable forest products under good forest practices. Tree farmers maintain a specified area of land for growing forest crops, protect it from fire, insects, disease, and excessive grazing, and harvest timber in a manner that assures future crops. A tree farm is a practical business venture and is expected to pay its own way.

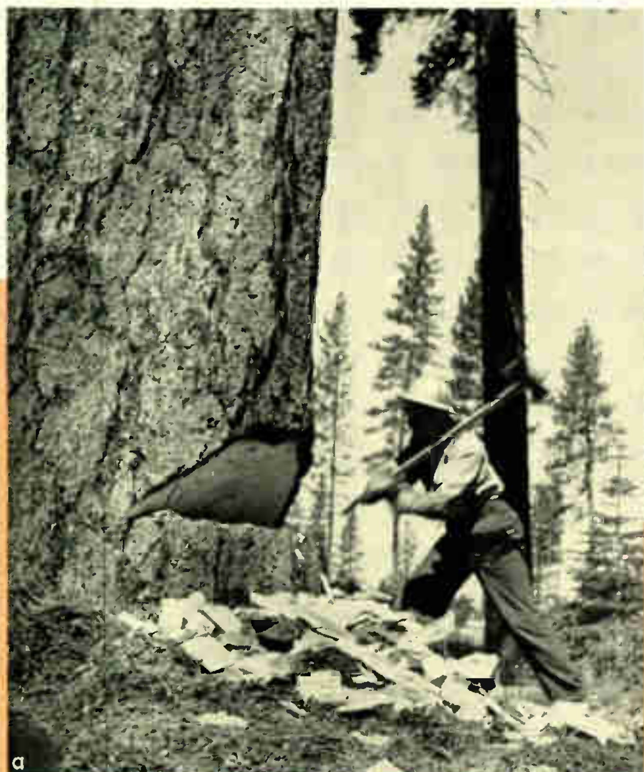
On the 1400 tree farms totaling 15 million acres now certified in 19 states, since the first tree farm was certified in Washington in 1941, private owners are investing their own capital to permit the greatest possible harvest on a permanent basis. Most of these (1129 farms with 9½ million acres) are in the Southern states, but the program is spreading, particularly in the Pacific Northwest. While the total number of tree farms is small their influence is great, because they serve as the best possible educational medium for their neighbors.

Testifying to the interest with which private industry is engaging in this tree-growing program is the fact that the total of private industrial foresters now employed throughout the nation exceeds 2500. This number is six times the total so employed in 1930.

One cause of poor utilization of the forest has been single-purpose cutting. When a tract is harvested for or by a small concern or one interested in a single product, such as lumber in general, cooperage stock or cross ties, the proportion of waste in the forest and in manufacturing is high. A few well-integrated and—of necessity—large operations have become established in the Pacific Northwest. To cite a single example, the Weyerhaeuser Timber Company at its Longview, Washington, plant is equipped to produce lumber, to process bark into salable products, to make plywood, to manufacture kraft pulp, to make pulp by the sulphite process, to utilize the waste liquors from both pulp-making operations for conversion to chemicals and to convert sawdust and planing-mill shavings into a high-quality domestic fuel. All the operations are properly interrelated to make maximum use of all the logs coming to the plant. The unused residue of wood from one section of the mill becomes a highly desired raw material for another section. For example, the cores left in a plywood plant after logs have been "peeled" down to the minimum diameter of about ten inches, are just the ticket for the pulp-making plant across the street, so to speak. Lower grades or smaller sizes of fir logs that might scarcely pay their way through the sawmill can be diverted to the kraft-pulp mill.

Douglas-fir bark is carefully ground off mechanically in the plywood plant and sent to the bark-processing plant where it finally appears in several trade-name products, such as a vehicle for insecticide, a soil conditioner competitive to peat moss, molding powders, extenders for phenolic glues, fillers for linoleum, and cleaning and buffing compounds. One of these bark products is returned to the plywood plant where it originated as a leftover and becomes an ingredient in the glue used to bind the veneer into plywood panels.

As a result it becomes profitable to harvest all kinds and sizes of trees in an area, perhaps even limbs, as those not suitable for one part of the operation may serve ideally another. The tremendous investment required for such a plant is a powerful force to maintain the cutting operation on a sustained production basis. It cannot do business on the "cut and get out" basis that for generations contributed to forest destruction. This plant, incidentally, is one of those no longer self-sufficient for Btu's, because the volume of hogged fuel is not enough to meet power demands.



A Douglas fir (a) begins its long journey to become useful products. The tractor (b) has been a big factor in increasing the amount and quality of the wood brought from the forest. At (c) is a trash burner, familiar lumber-mill landmark, used to dispose of the accumulating mountains of hogged fuel (d).

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From a purely conservation point of view the arguments for the large-scale forest-products operation are very strong indeed. However, well-integrated operations by groups of small owners have been accomplished.

The total efficiency of forest use is still at a low figure. This is not to say that great strides of improvement have not been made by progressive, far-seeing industry managements. The improved forestry operations, milling techniques, and research activities of some are truly impressive, and give large hope for the future of our forests. However, according to Forest Service estimates, only 43 percent by weight of the wood cut appears in products other than fuel. Thirty-five percent is not used at all while the remaining 22 percent is used as fuel, much of it ineffectively. In tonnage the unused portions bulk very large. In logging, the loss amounts to 49 million tons yearly, in addition to the bark. Of this only 7 percent is used as fuel. In converting wood into products like lumber, wood pulp and paper, veneer, etc., the loss is 53 million tons annually, of which slightly more than half is burned as fuel. In secondary manufacture, i.e., conversion to final articles, another 7 million tons are lost, virtually all of which are burned. For lack of a better term this loss is called waste, which is understood to include the inevitable losses, those for which there is no economic way at present to avoid, as well as those resulting from wasteful methods.

As yet the drain on the forests is greater than the growth. Saw timber is currently being cut one and a half times faster than it is growing—although the ratio exceeded five to one only 30 years ago. This improvement comes about not because of reduced lumbering but because of increased growth. The annual growth of saw timber has risen steadily from about 10 billion board-feet in the 1909–1918 period to 35 billion four years ago. Improved forestry practices and replacement of static old-growth forests by rapidly growing young forests account for some of this. Much credit, however, goes to reduced fire losses. As a matter of fact, more wood is lost now to insects and disease than to fire. The passage of the Clarke-McNary Act in 1924, which permitted pooling of federal, state, and private funds and efforts to prevent and fight fire has been a great factor in the steadily improving fire record.

The picture with respect to all timber (not just saw timber) is somewhat better. The annual drain has declined from 26 billion board-feet annually 30 years ago to 14 billion in 1944 while growth rose from 6 billion to 13 billion—almost bringing total growth and drain into balance as far as quantity (but not quality) is concerned.

More Wood from the Forest

There are several approaches to the problem of bringing growth and use into harmony. One is to increase the amount of wood grown; another is to use the trees available to better advantage, i.e., with less waste. Both begin in the forest. Logging practices are being improved. Instead of "clear cutting" of large areas, which deprives a forest of means of reproducing itself, practice now in some areas is either to leave seed trees standing at frequent intervals or to clear cut but leave untouched patches of trees here and there, which, with an assist from the wind and birds, can reseed the cut-over areas. Also, modern good practice includes in some areas, such as Douglas fir, pre-logging by which certain species or smaller trees are taken out before the larger trees are felled, thus salvaging a crop that would otherwise be damaged or lost. Also, selective cutting is practiced in some areas with benefit generally in forests where all sizes and ages of trees are present. It consists

Credits: Photos (a), (b), (c) American Forest Products Industries; (d), (f), U. S. Forest Service; (e) Douglas Fir Plywood Assn.; (g) Weyerhaeuser Timber Company.

e

g

Plywood (e), with greatly improved glues and new curing techniques, contributes much to better utilization of some woods. At (f) is shown salvage logging using equipments designed for that job, while (g) illustrates prelogging of small trees to prevent their destruction when big ones are felled.

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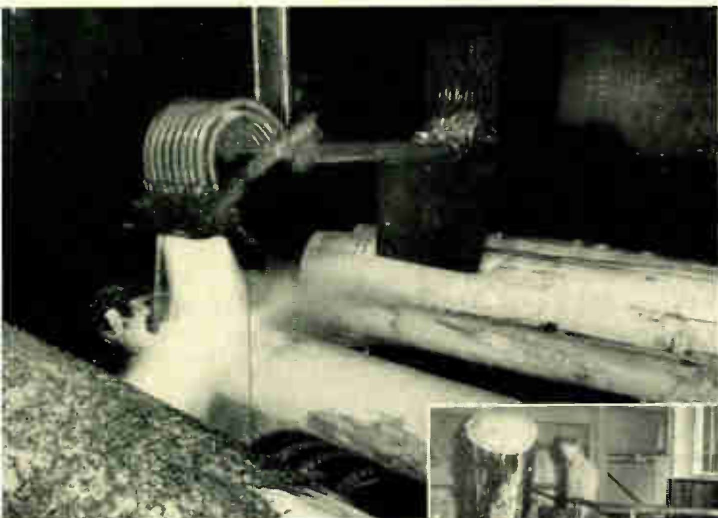

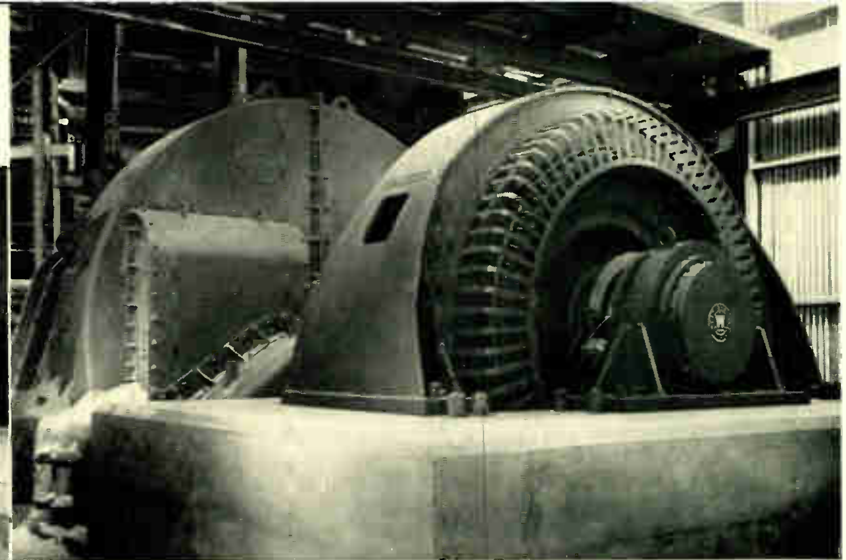

Westinghouse has been a leader in providing apparatus to assist forest-products industries to increase wood utilization and lower costs. Among them is the specially rugged 1500-hp chipper motor, above, at the St. Regis Paper Company. Logs are shown, at the left, entering a modern chipper of the Weyerhaeuser Timber Company. Estimates place the saving made by big-log hydraulic barkers and whole-log chippers at approximately 20–25 percent.

Bark on large logs is "tooled" off by jets of water at about 1300 psi, such at the Puget Sound Pulp and Timber Co., Bellingham plant above. Hydraulic barkers are faster and are responsible for less damage to wood.

of taking out of a forest only the mature or inferior trees, leaving the remainder to grow more rapidly to maturity, and to reseed the area. Relogging or picking up the chunks and low-grade logs left over from the primary harvest is another form of greater utilization.

The contribution of the engineer and industry to production of more wood per acre must not be overlooked. The small wheel-mounted power saw has been helpful in some classes of forests. It is being used, particularly in the South and West, to cut trees almost at ground level with a consequent large increase in the pulp-wood per acre. Hand-carried, two-man power saws in the big timber of the West have permitted a greater utilization of the stump section, which contains the most valuable wood. Gasoline and Diesel tractors by their power and mobility have greatly reduced the breakage that occurred when only steam winches were available, although some forest terrains are too rugged for their use.

Tractor logging, in general, has had the effect of reducing the investment necessary to harvest large trees. Tractors and heavy-duty trucks have permitted access to areas where, formerly, railroads were necessary. Good timber has been passed over because the investment to handle it made it unprofitable to attempt a harvest. Now, tractors and other special equipment make it economical to harvest such trees.

The Drive Against Waste

When the log arrives at the mill the problem is to convert as much of it as possible into products of the greatest combined value relative to cost of doing so. Here a great deal of ingenuity has been displayed. The ways developed for utilizing "all but the squeal" are far too numerous to relate here. Regrettably, only a representative few that indicate the scope can be selected.

Many things are being done to improve the oldest type of wood utilization—lumber. A wide variety of techniques in wood handling, sawing, and curing is resulting in more lumber and better lumber from a given tree. Pieces, edgings, and slabs that once were cast aside are sawed into salable pieces.

Making lumber has been a matter of cutting the pieces desired out of larger pieces, i.e., reducing big pieces to smaller ones, and holding the waste to the minimum. Now the process is sometimes reversed. Lumber—boards and timbers—is being built up of smaller pieces. The development of new glues, including waterproof resin glues, has been making this possible, and the process is being given a further spur by the introduction of radio-frequency or dielectric heating as a means of setting the glue. High-grade pine boards 40 inches wide are being made out of 16-inch logs by edge-gluing of narrow strips, such as might come from the outside slabs of the log, which has been (and mostly still is) simply hogged fuel. Eight-foot two by four's are being made out of 30-inch pieces of scrap. The resulting product is in some ways superior to a single piece. The individual small pieces can be more thoroughly seasoned. Dimensions are not limited to the diameter of the tree. High-strength, high-grade pieces can be teamed with inferior stock to provide an engineered structure of maximum strength and best appearance.

Solid oak beams and timbers have traditionally been considered to be without substitute for keels and other principal members of boats. The enormous demand during the war and the growing scarcity of the big white oak fostered the development of superb laminated oak timber, which was used in building thousands of vessels in private plants and United States Navy shipyards.

Such construction for marine work appears to have an extremely valuable by-product advantage. Toredos and other marine borers hesitate to cross certain types of glue lines, which suggests the possibility of small-boat construction highly resistant to such pests. Built-up members can be better seasoned in less time and with greater assurance of freedom from concealed defects.

Curved beams used as rafters for barns and small industrial buildings also are being made by gluing the surfaces of several narrow slats. The assembly is bent to the desired arc and passed between the electrodes of a radio-frequency generator. The induced heat sets the glue rapidly. Long, curved beams are thus made by this process at a high rate of production.

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Curing or seasoning in air or in dry kilns has always been a time-consuming process in which some wood is spoiled by checking and warping. An important development with prospects of effecting a large reduction in seasoning losses is the use of chemicals for seasoning. The wood is in contact with the gas or liquid chemical long enough to permit diffusion into the outer zone of the wood surface. The chemical solution lowers the vapor pressure at the surface, while the normal vapor pressure of the moisture is maintained at the center of the piece. Thus, moisture moves rapidly from the interior to the surface where it evaporates more quickly.

While still in its infancy, this method holds much promise. In use during the war, seasoning losses in some of the large timbers, which formerly ran from 40 to 60 percent, were reduced to less than 5 percent. Drying time is also reduced.

Numerous mechanical developments have effected savings in wood by permitting stronger structures to be built with less wood. Among these are the many types of connectors for simplifying and making stronger joints, such as the Teco Timber Connector.

Many processes have been developed for improving certain qualities of wood. Among these are "impreg" and "compreg" originally developed at the Forest Products Laboratory at Madison, Wisconsin, the research laboratory of the U. S. Forest Service, Department of Agriculture, operated in cooperation with the University of Wisconsin. To make impreg, wood, preferably thin veneers, is impregnated with chemicals that form resins when heated. The product has several advantages over unimpregnated wood, the principal one being the greatly reduced response to moisture. Swelling and shrinking over a wide range in humidity are permanently reduced by about 70 percent, which means, for example, the virtual elimination of checking surfaces as a result of stresses imposed by dimensional changes. The treated wood also is resistant to termites, decay, and to the effect of acids. Electrical resistance is increased 10 to 1000 times depending on the humidity and, in addition, is nearly constant. Compressive strength and hardness are significantly improved, at the expense of a considerable decline in toughness.

If pressure is applied during impregnation and heat-forming of the resins within the wood cellular structure, a still different product—"compreg"—obtains. Depending on the pressure used, which varies with the kind of wood and result desired, the density and hardness are increased. Swelling, even under prolonged immersion, is reduced to about five percent. Resistance to termites and decay is further increased. Strength factors are likewise improved, accompanied by corresponding drops in impact strength or toughness. Compreg is made from a great variety of woods, including normally inferior species such as cottonwoods. Compreg takes a beautiful, high polish, which is strongly resistant to organic solvents such as alcohol that normally ruins wood finishes.

Indicative of the ingenuity being displayed by firms bent on banishing waste is the effort of the Weyerhaeuser Timber Company to salvage certain kinds of decayed wood of which a certain amount is present in all stands and which even most conservationists would accept as waste. The decayed wood is cut into lumber, nicely finished, and sold as "Driftwood Panels" for basement playrooms, summer cottages, and even commercial establishments desirous of achieving a quaint, attractive atmosphere.

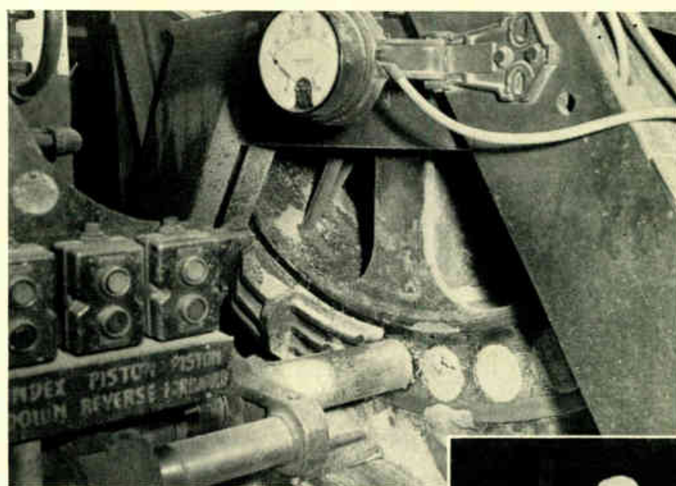
Plywood achieved many spectacular headlines during the war, doing many jobs commonly considered as definitely jobs for metals. Bulkheads for the fascinating and effective PT boats were formed of plywood. So were some training planes. The famous Hughes' eight-engine flying boat—largest in the world—is constructed largely of plywood.

The greatest single boon to plywood was the development and commercial use of synthetic, heat-setting resins about 1934. These are of two general types: those that are completely waterproof, used for marine and other outdoor applications and others that are less costly but are highly water resistant and are used in less severe exposures. Hot presses likewise have been improved. The introduction of dielectric heating, still in its infancy, is making possible more rapid setting of glues, and permits plywood to be built up to a thickness of several feet.

Plywood is principally of two types: softwood and hardwood. Douglas fir (a softwood) plywood is far the most common, comprising probably about two thirds of all plywood made. A small amount of plywood is made from pine. It is always made in flat sheets, which can be very large. (Single sheets as long as 80 feet have been made by scarfing panels together.) Plywood utilizing veneers from many of the beautifully grained hardwood trees of the United States and elsewhere is used in furniture manufacture and wall paneling.

Plywood is an extremely important phase of better utilization of trees. For a given weight a plywood structure has its strength properties better distributed than one of solid wood. The inner plies and one surface can be made of wood that has a number of defects. The West Coast Plywood Co., for one, is making a plywood in which an exterior type (i.e., waterproof) of plywood base is surfaced on one or both sides with a coating mixture of synthetic resin and wood-flour made from mill waste and synthetic resin. It provides a material with smooth, uniform, waterproof surface, suitable for painting or other finishing. It permits use of lower grade veneer, and, for some thicknesses, increases by one fourth the volume of panels that can be produced from a given amount of logs.

Much has been done to create built-up structural sections that are strong and utilize but a small amount of wood. The Simpson Logging Company manufactures flush doors consisting of beautifully grained plywood laid on a ladder-like structure, made from scraps, to give it rigidity. The joining is done with moisture-resisting resins set by r-f heating. Here good appearance, combined with light weight, is obtained



Fireplace logs are being made artificially. Sawdust and mill shavings are compressed at 50 000 psi to form dense logs four inches high by twelve long.
Photos by Weyerhaeuser Timber Company.

World Radio History

with minimum amount of high-quality and expensive wood.

Improved ways have been found to bond plastic, paper, and metals to plywood. These processes have resulted in wider use of new materials consisting of surfaces as required for special purposes on a strong, light body. Some entirely new constructions have been developed. These have great possibilities for home building and commercial furniture. The paper-covered plywood, for example, conceals surface defects in the wood (permitting lower grade wood to be used) and provides a uniform, smooth surface for painting.

Another interesting member of the plastic-surfaced plywood is one which a layer of aluminum foil is imbedded just below the outer layer. Because it provides excellent heat conductivity this type of plywood makes an essentially "cigarette-proof" table-top material.

Bark has been, and for the most part still is, a nuisance to lumber and pulp makers, because it comprises from 10 to 20 percent of the total volume of a log and soon accumulates to a very large quantity unless disposed of. Considerable research is being done to find more valuable uses for it, thus far only partly successful. The composition of bark is not fully understood but it is possible, when more is known about the chemicals in lignin, that important uses will be found for it. At present most bark is burned.

Numerous types of insulating board and wall boards are being made from one-time waste wood. The operation of the Simpson Logging Company is indicative. Integrated with its lumbering operation is a plant in which 300 000 square feet of insulating board is made daily from log trimmings formerly used as fuel. The wood is chipped, cooked, and formed into a board on a special continuous machine. Masonite, made from wood cooked, "exploded," and the wood fibers compressed, is another example.

Chemicals from the Forest

The brightest future in better wood utilization perhaps lies in wood as a source of chemicals. Already there are numerous aspects of this, of which representative examples can be cited. For example, the liquors remaining from the cooking processes in pulp paper have not only been a waste but also a stream-pollution nuisance. The Puget Sound Pulp and Timber Company uses the cooking liquors from its sulphite pulp mill in an adjacent plant to produce 8000 gallons of alcohol daily. The residue or "waste" from the alcohol plant is mostly the original lignin of the wood. This becomes the raw material for another process in which most of the water is removed. The final product—which might be termed a by-product of a by-product—is marketed as an experimental plastic extender, for the hydronization of cement.

The Forest Products Laboratory has found that yeast can be grown on the bottoms of the alcohol stills, to produce about 200 pounds of fodder-yeast per ton of dry wood entering the pulp-making plant.

Weyerhaeuser is investigating another interesting approach to the waste sulphite pulping liquor. In this the base for the cooking liquor is a magnesium sulphate instead of the usual calcium sulphate. This magnesium-base liquor, after cooking, is evaporated and burned (the heat content of dry cooking liquor is about 7500 Btu). The highly caustic magnesia that forms the main portion of the resulting ash is collected from the flue gases, made into a slurry, and advantageously used to absorb the sulphur dioxide in the flue gases to form fresh cooking liquors. Thus, instead of dumping the waste liquors into the streams, steam and kilowatts are obtained, cooking chemicals recovered, and a troublesome stream-pollution problem greatly mitigated to the pleasure of local residents.

In the sulphate process of paper making, practiced particularly in the South using yellow pine, turpentine and tall oils are being recovered to a limited extent. The yield of tall oil, useful in drying oils and soaps, runs as high as 100 pounds per ton of pulp.

Plants using other processes of producing alcohol have been in operation—certainly with enough success to prove that it is feasible—although the economics are as yet undetermined. A government sponsored plant has operated experimentally at Springfield, Oregon. After a shutdown it is expected to reopen, equipped to produce some four million gallons of ethyl alcohol per year.

By the use of a dilute sulphuric acid solution, the cellulose component of wood (which is more than half of the total) can be converted into a sugar solution. From this four main products can be obtained: (1) sugar, largely glucose, commonly called as corn sugar, which might serve as a raw material for further chemical processing; (2) molasses, as high as 85 percent glucose, which might be used directly as a source of carbohydrate in stock and poultry feed or as a source of crude sugar; (3) alcohol, which may be produced by the fermentation of molasses or of the crude sugar as at the Springfield, Oregon plant; and (4) a high-protein yeast feed grown upon the sugar solution. The wood molasses has been tried experimentally as a preservative for grass silage. The result appears to be a superior feed for cattle that warrants a reduction in more expensive grain feeding.

Much research by federal and private agencies is in progress. Some successes have been made. For example, the lignin resulting from soda-pulp manufacture (a small proportion of the total, however) is simple to isolate and has excellent plastic-making properties. Lignin from the other (and major) pulp-making procedures is now mostly used as fuel, but better uses may be found. The rewards would be considerable.

One interesting bit of lignin research is under way at the Forest Products Laboratory. Brown powdery lignins are reacted with hydrogen at a pressure of about 4000 psi and temperatures of 480 degrees F to produce a liquid. This liquid has been fractionated into methyl alcohol, neutral oils, and phenolic compounds. These show promise as plastic solvents, anti-knock agents for motor fuel, and toxic agents.

The laboratory has found that starting with wood chips instead of a lignin solution, the cellulose can be converted to glycerine and sugars. With the lignins being converted to alcohols, this means that the entire wood is converted to liquid products. It is still too early to define the future for these techniques.

Behind this whole matter of forest productivity, waste reduction and conversion stands—as always—the problem of economics. To demonstrate that a waste can be converted into a usable product does not mean, ipso facto, that it will be done. In our society the economics must justify it, although the more progressive companies are accepting a longer time scale than formerly.

The tree is now regarded as something more than requiring only the axe, the saw, the veneer lathe and the paper machine for conversion to man's uses. The tree is an amazingly complex product of nature from which can be obtained structural materials of far greater variety for serving many new purposes than heretofore imagined, and a host of chemicals. The wood in a tree is not necessarily a finished product as nature made it; it is now being considered as something to be improved upon, as the starting point for the many new and superior products.

World Radio History

Stratovision—Over Another Hurdle

STRATOVISION has successfully met its proof-of-the-pudding technical test. A pressurized B-29 modified for the purpose by the Glenn L. Martin Company, equipped by Westinghouse with f-m and television apparatus, and manned by a crew of Martin and Westinghouse engineers has, during the past several months, made frequent flight tests over a wide area along the eastern seaboard and as far west as the Ohio-Pennsylvania line. It has on numerous occasions demonstrated its ability to pick up a telecast signal from a station below and place in receivers 250 miles distant pictures of quality and strength comparable to those delivered by primary telecast stations within its limited range. The fact that television and f-m signals can be picked up by a moving antenna at altitudes of 25 000 feet and rebroadcast on different channels with good coverage in a 500-mile diameter circle was indicated by earlier calculations and flight tests.

The essential objective of Stratovision is to increase the area in which signals on the customary f-m and television bands can be received. The approximate limit to an earth-bound antenna operating at these ultra-high frequencies is a line-of-sight of approximately 50 miles. A Stratovision plane flying 25 000 feet has a practical reach of some 25 times greater area than its primary transmitting station below. Another fortunate technical advantage holds for the Stratovision antenna, and that is, much less broadcast energy is required. A Stratovision plane at 25 000 feet with a 1-kw transmitter can place in a 500-mile circle a signal equal in strength to that of a 50-kw land transmitter in a 100-mile circle.

While a modified B-29 has been adequate for experimental work thus far, it is expected that a commercial Stratovision system would call for a type of plane designed specifically for large loads, low cruising speed, and for continuous flying in a pattern, which, viewed from the ground, is essentially a circle regardless of wind conditions. For this purpose the Glenn L. Martin Company contemplates using a two-engine airplane similar to its 2-0-2. Seven thousand pounds of equipment, including four men to operate the receivers and transmitter, will be needed in each airplane.

Although at present operation of only one Stratovision station has been requested, a coast-to-coast network linking New York and Hollywood, broadcasting four television and five f-m network programs and requiring only eight planes flying about 400 miles apart, has been projected. By adding six planes to this system for more coverage in the Southeast and Northwest, service would be provided over 50 percent of the nation's area, which includes 78 percent of the population. A network of ground stations spanning across the country, but covering a much smaller area, would require more than 100 different relay points.

The B-29 experimental Stratovision plane is crowded with 7000 pounds of electronic apparatus and its operators. In the view above, C. E. Nobles, who conceived the Stratovision system, is at left.

World Radio History

Dielectric Heat—Wood-Fabrication Tool

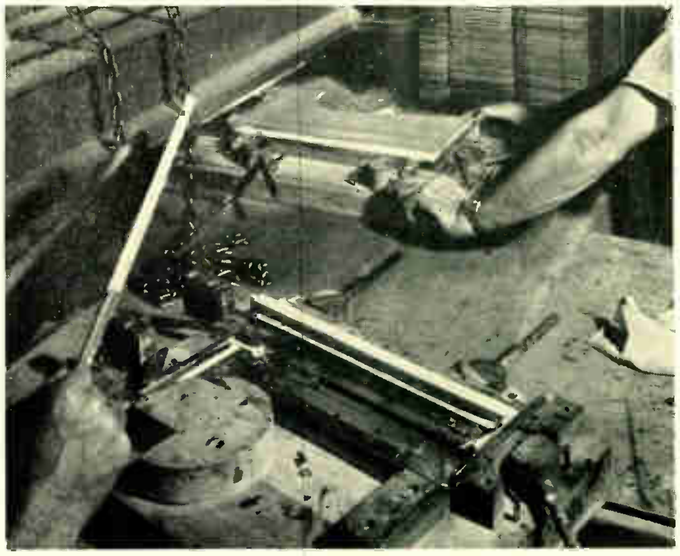
Two nonrelated but simultaneous developments—resin glues and dielectric heating—form a team that is making possible improved products of wood, an increase in production rates, and the transformation of low-grade woods or wood wastes into articles of market value.

T. P. Kinn *and* R. E. Kirby, *Industrial Electronics Division, Westinghouse Electric Corporation*

If your favorite brassie has a laminated head, if you rode home from the golf club in a station wagon, if your new radio has a wooden cabinet, or if you had dinner last night on the new dining room table—radio-frequency heating is a factor in your life. Today, radio-frequency heating is playing a major role in the fabrication of practically all types of articles made of wood. This is a companion development to the introduction of superior glues of the resin type, which are highly resistant to heat and moisture and which develop a strength greater than that of wood itself. These glues are synthetic, being compounded from basic raw materials. Unlike the earlier wood glues, which are mostly of animal origin and set by evaporation of solvents, these glues set through a chemical change that is accelerated by heat. They do not depend on the evaporation of water or other solvents for setting.

For many years, the electrical engineer had been striving to perfect dielectrics (the separating material between the plates of a capacitor) that would not heat when alternating voltages are applied. For dielectric heating the goal is exactly reversed. The plates of the capacitor are the electrodes and the dielectric is the material to be heated. The rate of heating is proportional to certain electrical characteristics of the material called the loss factor, the frequency, and the square of the applied voltage. To achieve rapid heating requires frequencies in the megacycle or millions-of-cycles-per-second range because the voltages must be held below certain limits to prevent breakdown or flashover of the material being heated.

This form of heating is a revolutionary departure from most previous methods. No longer is it necessary to apply heat to the outside of solid materials and wait for the heat to flow into the material, which generally has a low thermal conductivity. With radio frequencies, heat energy is established within the material itself by friction between molecules stressed by the swiftly alternating voltage. The heat is there-



This table-model radio cabinet has 28 joints, all glued and cured by r-f heat. No pins, nails, or fasteners are used. The side panel is assembled in a simple wood jig in two operations as shown above. Five blocks are placed in the jig in the foreground, glue applied, and the side panel of the cabinet placed into position with cam pressure then applied at the top. The complete assembly is then placed between the pressure heads of the ram, and the r-f power applied. The electrodes are copper strips adjacent to each glue line and are built into the jig. The heating time is 20 seconds. Because the jig-loading time is about equal to the heating time, by using two jigs and a transfer switch, the generator is in almost continuous operation. Three 5-kw and two 2-kw r-f generators are used, giving a production of 400 cabinets in eight hours.

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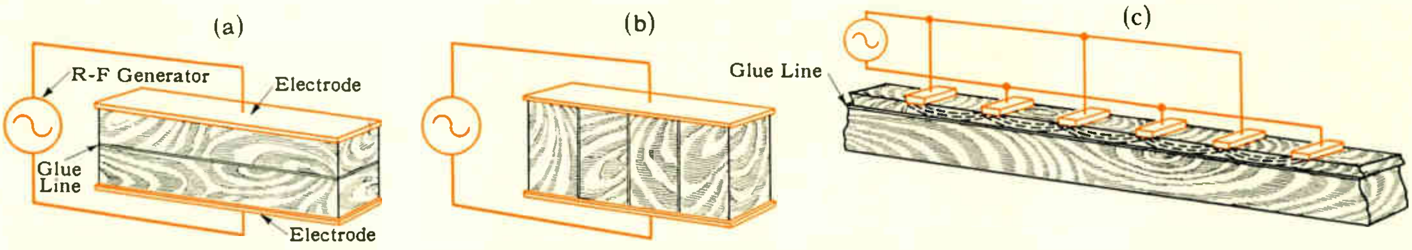


Fig. 1—Arrangement of electrodes for (a) through-type r-f heating, (b) glue-line r-f heating, and (c) stray-field, r-f heating.

fore generated in each particle of the mass, and no actual transfer of heat between two points is necessary.

Types of R-F Gluing

To apply radio-frequency heating to wood bonding with resin glues, it is necessary only to locate the electrodes strategically so that the power is delivered to the desired section. This has led to the application of power by three techniques:

In *through-heating*, illustrated in Fig. 1 (a), the glue lines are parallel to the electrodes and the dielectric mass heats uniformly. This method, most widely used, is applied to mold laminated plywood sections, to form plywood, to glue some types of panels and doors, to glue special assemblies, and to remove moisture from wood.

In *edge-gluing*, Fig. 1 (b), the glue lines are perpendicular to the electrodes. The large difference in effective conductivity between the wood and the glue line causes most of the power to be absorbed by the glue lines. This method is used for assembly gluing, core and open-face stock production, lamination of narrow glue-line assemblies, and veneer splicing. In general, it is faster than through-heating because heat is generated directly in the glue line.

Stray-field heating, Fig. 1 (c), utilizes the fringing or stray field between adjacent electrodes and is used for heating inaccessible joints where edge-gluing is not possible and where through-heating is not economical. It is used for patching of damaged or knot-hole sections in plywood, some assembly work, and for laminating outsides of thick assemblies.

Types of Glues

Resin glues, which have been found to be the most satisfactory for radio-frequency gluing, fall into three general classifications: phenolic, resorcinol, and urea. Joints made with phenolic glues are the strongest and most durable, and can stand alternate soaking in water and drying and continuous boiling in water without appreciable loss of strength. They are not affected by fungi, bacteria, most chemicals, or by heat even beyond the charring point of wood. They usually require a high-setting temperature. They are not normally used in edge-gluing techniques but are generally confined to special applications such as exterior-grade plywood and exposed parts of boats or airplanes.

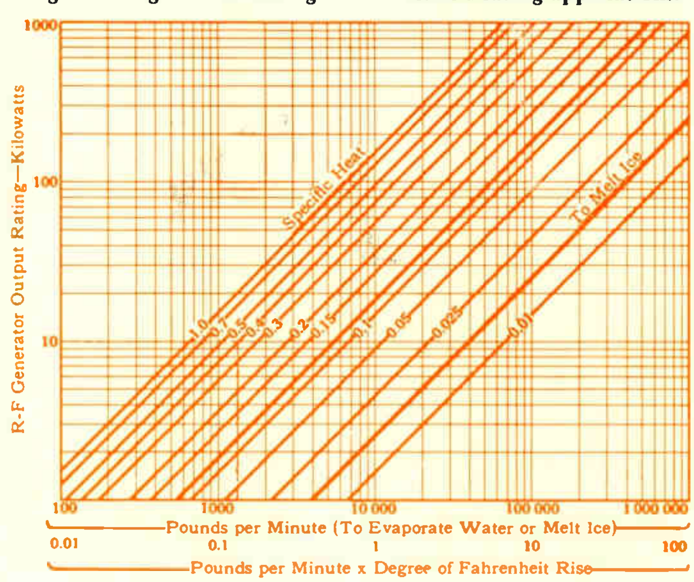
Resorcinol glues have the same heat-, chemical-, and moisture-resistance properties of the phenolics without the high-temperature disadvantage. They set at room temperature and curing is accelerated by radio-frequency heating. They are a fairly recent product and their cost is relatively high compared to the other types.

The most satisfactory glues for general purposes are the urea glues. These glues have water and moisture resistance far in excess of the animal-type glues, but not as good as the phenolics and resorcinals. They are satisfactory for all indoor uses regardless of ambient temperatures and extreme changes in temperature and humidity. Urea glues are available for setting at high or at room temperature. Low temperature glues, where setting can be accelerated by heat, are preferable for use with radio-frequency heating. As an example of the acceleration, at room temperatures some ureas require six to eight hours to set, but at 200 degrees F only twenty seconds. Because of the wide variety of these glues on the market, many of them designed for special uses, the glue manufacturer should be consulted for his recommendation as to the most suitable glue for specific applications.

Advantages of R-F Gluing

The combination of the radio-frequency generator and the resin glues provides the industry with the proper tools for production at a high level. A uniform, high-quality product results because automatic processing can be used. The moisture content of the wood is not affected because moisture is neither added nor removed. Because the panels or assemblies are ready for immediate further use after the heating, storage space ordinarily required for time setting is eliminated. In many applications the brute strength and physical labor of operating hand clamps are eliminated and the productivity per man-hour is greatly increased. This process permits maximum utilization of materials in the face of diminishing supplies of virgin timber, since panels of any width can be readily built up from boards of random width, providing a strong, finished stock with low-cost materials. Stacking of stock on separators to remove moisture from glue is eliminated, since no air flow is necessary after the radio-frequency treatment. Tongue-and-groove joints are unnecessary because a resin-glued joint is stronger than the wood itself. In assembly work, pins, nails, and fasteners are eliminated, and, with them, the attendant problem of rendering them invisible. In

Fig. 2—R-f generator rating for dielectric-heating applications.



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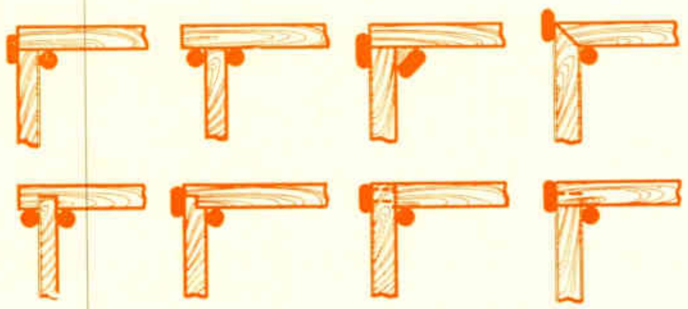

Fig. 3—Electrode arrangements for various types of joints encountered in assembly gluing. Production rates vary, depending on the efficiency of electrode location; for estimating, 100 square inches per kw per minute can be assumed for generator power requirements. A minimum heating time of 20 seconds should be used to insure proper curing of the glue.

molding curved sections, the costly steam or electrically heated dies are not needed, only wooden dies with thin metal faces to act as electrodes. The working conditions are clean and cool, since production-line techniques are used, and the curing process gives off no external heat. This is high-speed production at low operating cost, producing a stronger and more uniform product.

Application of R-F Gluing

To analyze a radio-frequency heating application for time and power requirements, it is first necessary to determine the type of heating to be used. In through-heating, the time and power requirements are calculated as in any heating problem:

$$T=\frac{0.0176\times M\times c\times(T_2-T_1)}{\text{Kw}}$$

Where T = time, minutes
M = mass to be heated, pounds
c = specific heat of mass
T_2 = glue setting temperature, degrees F
T_1 = initial temperature of mass, degrees F
Kw = kilowatts of power into mass

Curves calculated from this equation for different specific heats are given in Fig. 2. For wood of approximately 6 to 10 percent moisture, which is normal, specific heat of 0.4 should be used. For example, if a 50-pound load of plywood is to be cured with a 10-kw generator, the pounds per minute times degrees F rise, by Fig. 2, is 1400. If the glue used is fast-setting, it will require a final temperature of 180 degrees F, so the rise is from room temperature (80 degrees F) to 180 degrees F or 100 degrees.

$$\text{Pounds per minute}\times\text{degrees F rise}=1400$$

$$\text{Pounds per minute}=\frac{1400}{100}=14$$

It will require, therefore, 50/14 = 3.57 minutes (3 minutes and 34 seconds) heating time. If the amount of glue used is more than 10 percent of the total mass, it should be calculated as additional water.

The moisture content of the wood should always be calculated separately if the final temperature will exceed the boiling point of water. In wood-drying calculation, the conversion of water to steam represents the major portion of the power requirements.

In edge-gluing, the problem is calculated on the basis of the number of square inches of glue area to be cured per kilowatt per minute. This basic number varies from 35 to 750, depending on a number of factors: the number of glue lines per inch of width, the kind of wood, the preparation of the wood joint the type of electrodes, the pressure, the type of glue, and the amount of glue used.

As the glue lines per inch of width increase, the square inches of glue line cured per kilowatt per minute increases, because less wood area is exposed per unit length of glue line and less power is lost to the wood; this reaches an extreme when thin veneers are bonded to form laminations, as in the manufacture of tennis rackets.

The denser the wood, the more power it absorbs and diverts from the glue line. More area of glue line is cured per kilowatt per minute when soft woods are glued.

The quality of the preparation of the joint, the pressure, and the amount of glue used are interdependent. Smooth, parallel board edges permit the use of lower pressure, less glue, and eliminate stresses that necessitate a more complete cure of the glue to hold the panel together when removed from the press. These techniques result in a higher rate of production. Excessive glue squeeze-out causes a loss of heat energy from the glue line and lowers production.

The rate of heating is affected by the type of electrodes. With flat-plate electrodes, as in Fig. 1 (b), the glue line is heated uniformly. An electrode arrangement widely used is a staggered arrangement of bars, as shown in Fig. 4, which gives a zigzag cure pattern if the panel remains stationary while

The three-ply curved front is molded as two-ply birch or poplar with a face mahogany veneer, and formed in the press. The electrodes consist of flat aluminum sheets facing both parts of the die. A heating time of 120 seconds for complete cure is obtained with a 5-kw generator. After forming, the section is cut by a gang saw to obtain four curved cabinet fronts from one large piece.

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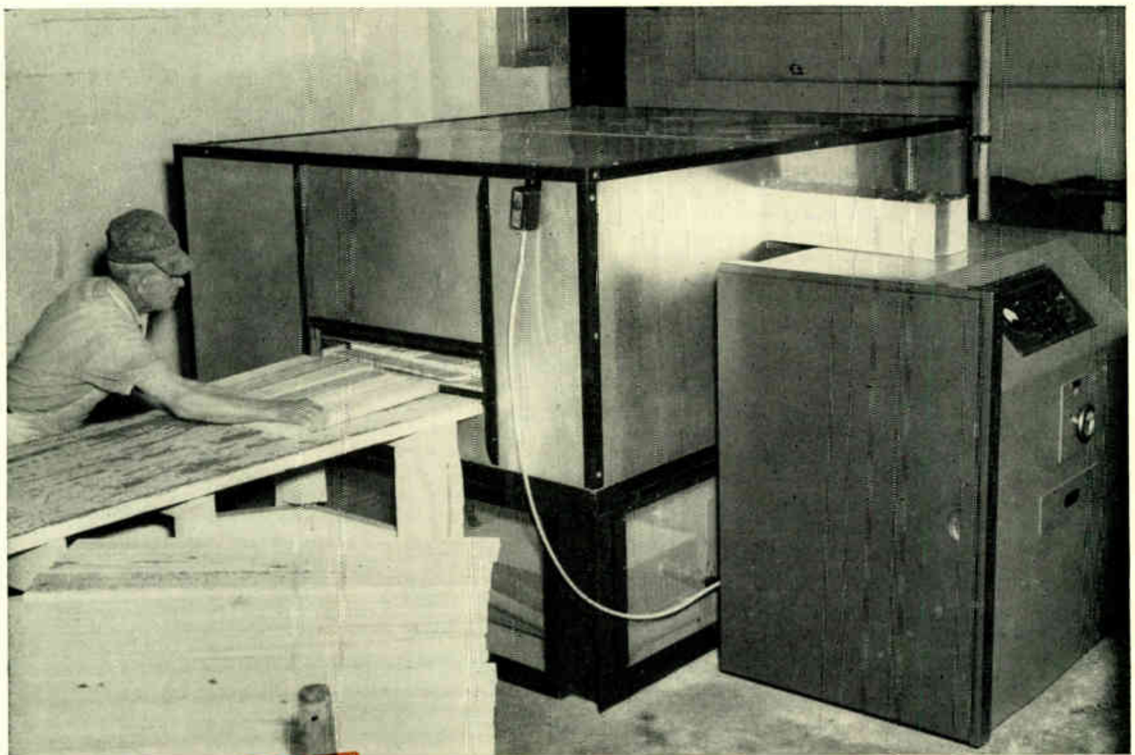
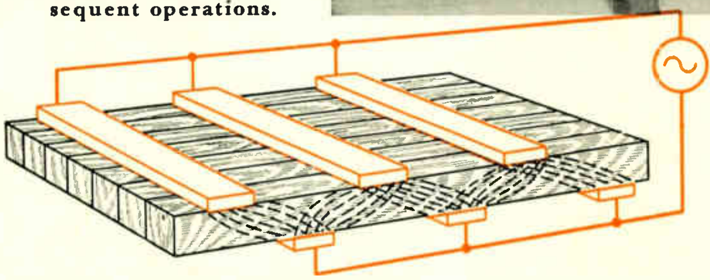


R-f heating applied to an edge-gluing batch operation.

Fig. 4—Staggered arrangement of electrodes produces zigzag glue cure pattern, for partial curing of glue-line area. Area cured immediately is approximately one third of total glue-line area, providing sufficient strength for subsequent operations.



being heated. The area cured is from one third to one half of the total glue-line area with the remainder curing from the residual heat in the adjacent sections of the glue line a short time after removal from the radio-frequency field. The bond is sufficiently strong to withstand immediate, subsequent operations such as sawing or planing.

Other factors, such as the length of time the glue has been mixed and ambient temperature have only a small effect on the heating rate. For purposes of estimation, when using the staggered-grid electrode, urea-formaldehyde glue that cures at room temperature, and well prepared boards with an average width of three inches, the rate of heating for soft wood can be taken as 250 square inches of glue line per kw per minute. For hard wood, the figure is about 125. Thus to cure a 36 by 96 inches by 1 inch panel of soft wood with 11 glue lines, using a 10-kw generator, requires:

$$\frac{96\times11\times1}{250\times10}=0.42 \text{ minute (25 seconds)}$$

Types of Applications

The ways in which r-f heating can be applied to setting of glue in wood-working operations have already become numerous. Its use in assembling complicated and curved products, replacing the conventional fastenings, is shown in the illustrations on page 140 and above. These, however, illustrate that to take maximum advantage of these new tools the product and assembly procedures need to be designed with them in mind.

The formation of panels from narrow boards has developed further than any other r-f application, largely because it was one of the first problems attacked. Today press-generator combinations that require small floor space, are easy to operate, and speed production from three to five times over the old glue reel or hand clamp system, are sold as a completely assembled unit to the woodworker.

Basically, there are two types of presses, batch and continuous, both of which are illustrated. The batch-type press is operated by pushing the pre-cut panels into the press where, automatically, side pressure and top pressure are applied. The r-f generator is turned on at the right moment, also automatically, and is turned off at the end of the curing cycle by a process timer. The glued panel is then removed and a fresh panel started through the cycle. Production rates on these presses run up to 15 000 board-feet of soft-wood panels per eight-hour day and up to 10 000 board-feet of hard wood, where the average board width is three inches.

These presses are equipped with adjustments for side and top pressure so that many different types of stock can be handled. The largest standard-size press accommodates panels up to 50 by 100 inches, but special presses for larger sizes have been built. Most presses are equipped with 10-kw generators which permit heating times from 20 to 40 seconds. With previous equipment the time was four to eight hours. Time for loading and unloading requires about one fourth of the complete cycle. The generator is operating, therefore, about three fourths of the time, or on a 75-percent duty cycle.

Continuous-type presses have a 100-percent duty cycle for the generator, and are capable of turning out an average of up to 20 000 board-feet of panels per eight-hour day. The stock is fed onto clamp carriers which exert side pressure as well as carry the panel through the press. Top pressure rolls are located at the feed end and apply the proper pressure to produce flat panels. After leaving the top pressure rolls, the panel passes under the electrode where the heating of the glue line occurs. Due to the movement of the wood, the high-voltage electrode is separated from the top of the panel by a small air gap. This has no effect in the efficiency of the heat-

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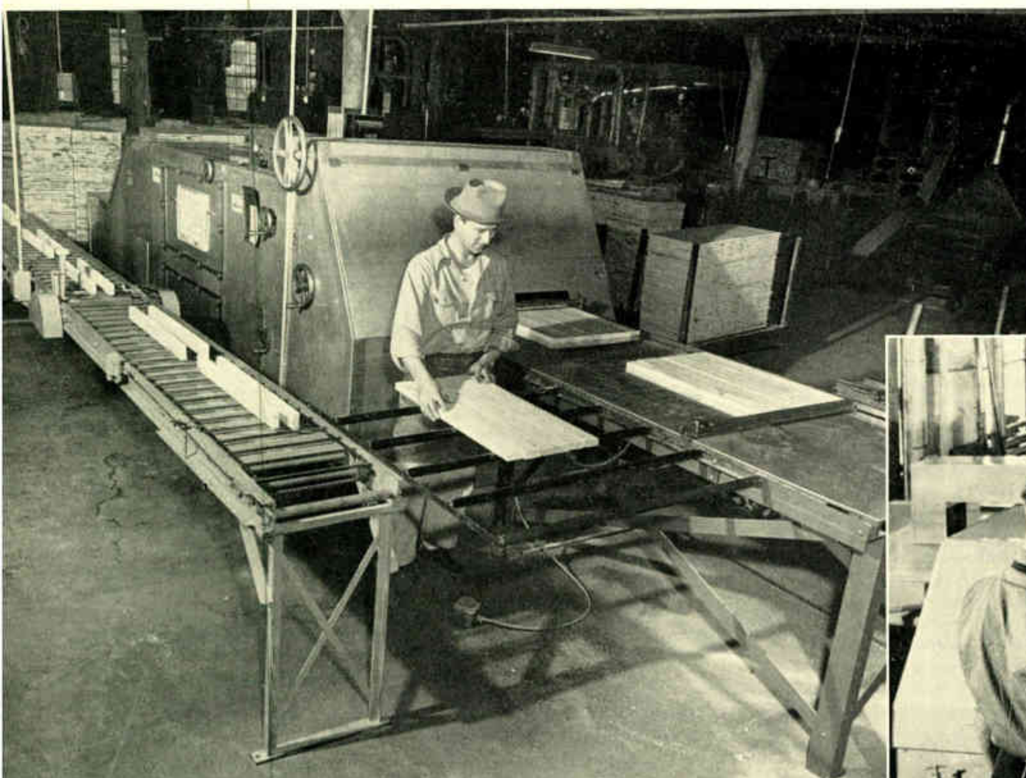
ing operation. These presses can be easily adjusted to handle panels up to 37 inches wide, and from ⅝ to 2½ inches thick. The lineal speed can be varied from 4 to 30 feet per minute. This type of press is more complex and hence more expensive than the batch type. However, because of the continuous flow of panels and the 100-percent duty cycle for the generator, production is higher.

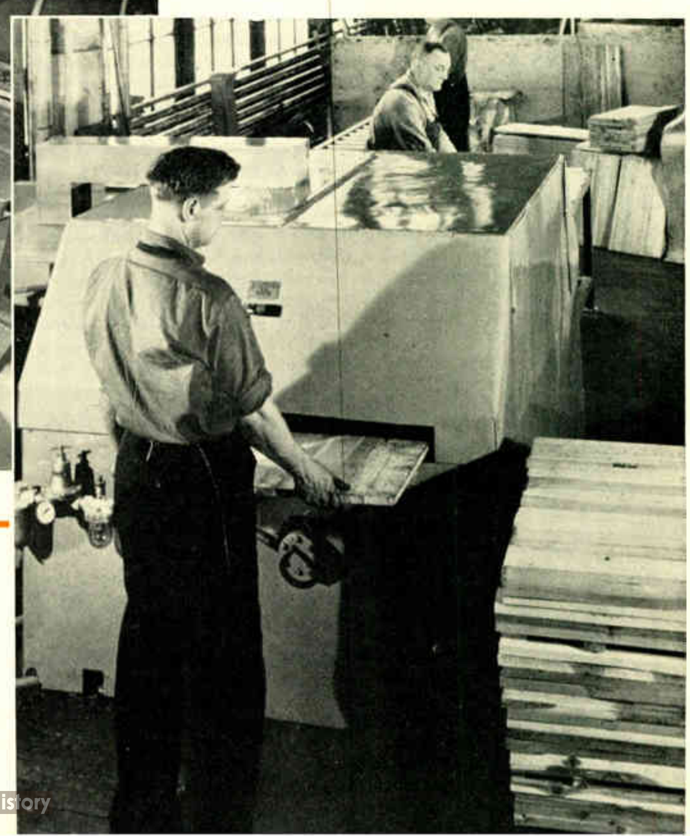
Edge-gluing techniques can be used where the width of the glue line, or the maximum path between electrodes, is less than six inches. Examples are tennis rackets, skis, golf-club heads, and wooden beams. For example, formerly individual hand-tightened clamps and forming blocks were used for each tennis racket. Glue was cured by placing these clamped assemblies in hot ovens for three hours at 200 degrees F. By adapting the press for heating by a five-kw r-f generator four rackets can be cured in about 45 seconds. Comparison of rackets produced by the old and new method showed several interesting things. The natural stress in the r-f cured racket opposes the stress imposed by the stringing of the frame, while the old method leaves the racket with stresses additive to those of the subsequent stringing operation. Bounce tests, used to test resiliency, show that r-f cured rackets are two to three times better. Furthermore, because the results are so uniform, r-f cured rackets can be processed in subsequent operations by automatic equipment not possible with oven-cured rackets. Hence, r-f heating has not only increased the quantity but has also improved the quality.

Bonding of plywood offers an example of through-heating by the use of radio frequencies. The usual method is to build up a sandwich of plywood panels on both sides of a central high-voltage electrode. The top and bottom platens of the press act as the ground electrodes. Since heat is not being forced from the outside into the center, many panels can be stacked for one press load. The finished product is uniform in moisture content, because the heat is even. This is in contrast to the excessive temperatures on the outer layers of plywood produced in heated-platen presses. Handling is somewhat reduced over the multiple-platen press, but for thin plywood, where the heat does not penetrate far, the economics favor the heated-platen press. Twenty-eight plywood panels 23 by 36 by ¾ inches, weighing 9.5 pounds per panel, can be cured in 16 minutes using a 10-kw r-f generator. This is a rate of 1.66 pounds per kw per minute.

The construction of plywood paneled doors illustrates the use of stray-field heating. A three-inch-thick skeleton framework of slats is glued on both sides and placed between two quarter-inch plywood panels in the press. Both platens of the press have a series of alternately spaced, high-voltage and grounded electrodes, each one-half inch wide and 1½ inches apart. The dielectric field passes from one electrode down through the plywood, along the glue line, and up through the same plywood panel to the next electrode. This system permits the gluing of both sides of the door without having to heat all the way through the door which in one case was 3½ inches thick. Using a 10-kw generator, a 3- by 7-foot door can be paneled with a heating time of two minutes.

Because dielectric heating can develop heat throughout the cross section of a material, the seasoning of wood appears as a logical application. As a general rule, however, such is not the case. Fast heating causes checking, hollow horning (collapse of inner cell structures) and fracture of the wood by the rapid release of steam pressure from its center. If the heating rate is reduced enough to eliminate these faults, the economics favor the standard drying ovens. The use of radio-frequency heating to evaporate water is fairly expensive. To offset this high cost, other factors must be important, such as extremely long kiln-drying times for specialty woods where a breakdown would





These views illustrate r-f heating with continuous (left) and batch (right) presses to make wide boards from narrow slats.

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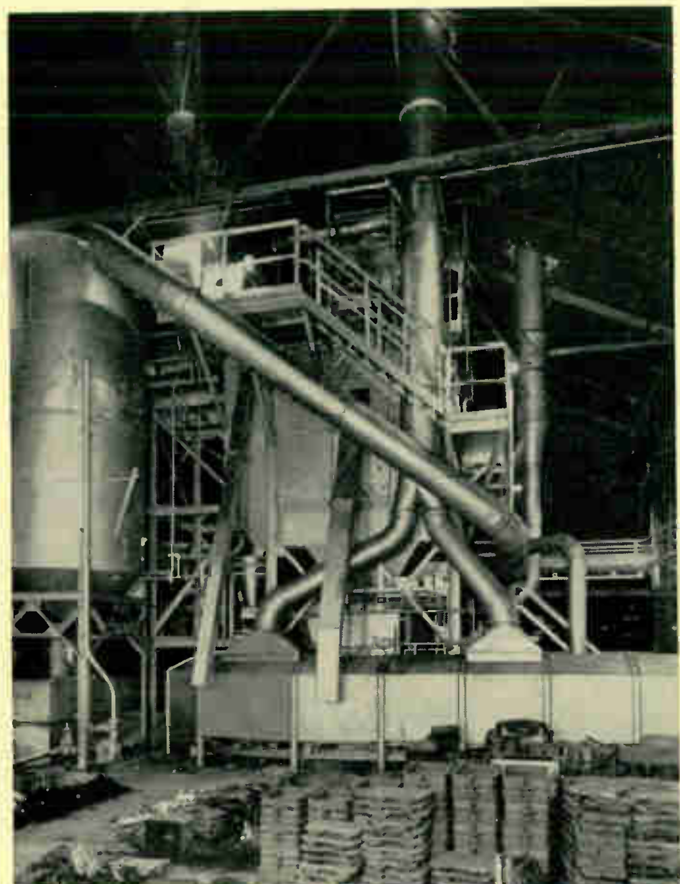
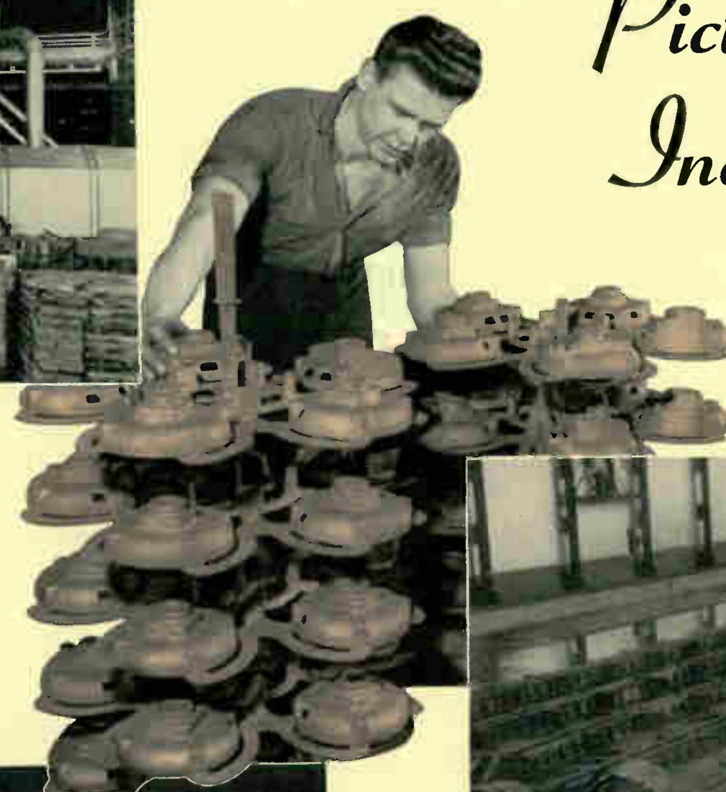
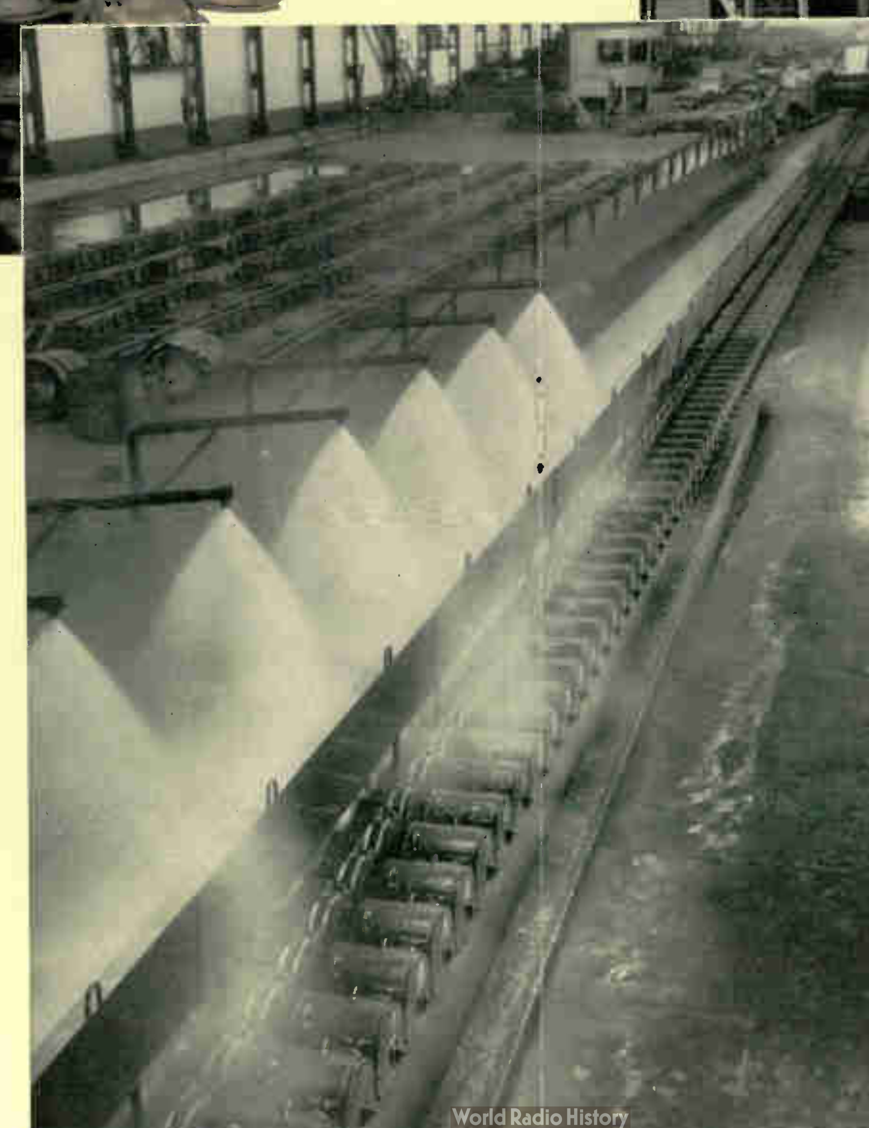
Pictures of Industry



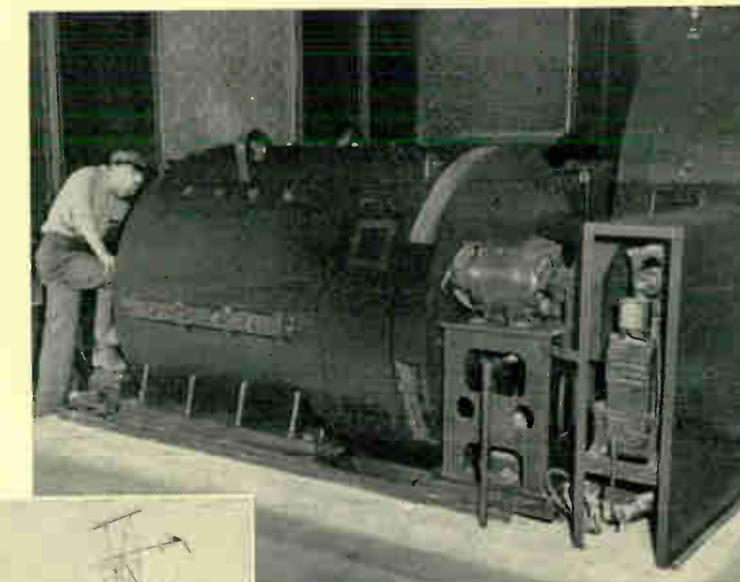
A SELF-CONTAINED automatic molding machine (left) in operation at Westinghouse Cleveland Works produces multiple sand molds, each containing five sets of four molds, ready for casting. A single pouring, which is accomplished manually, yields a casting (below) of twenty endbells for small motors. The molding equipment is arranged for automatic synchronized operation actuated by air and hydraulic power. Completed molds travel on a conveyor by the pouring platform, where the casting is poured, and cool as they continue around to rear of the machine. Here the flasks are shaken out and repeat the cycle. The machine was developed through the joint efforts of International Molding Machine Company, other organizations, and Westinghouse.

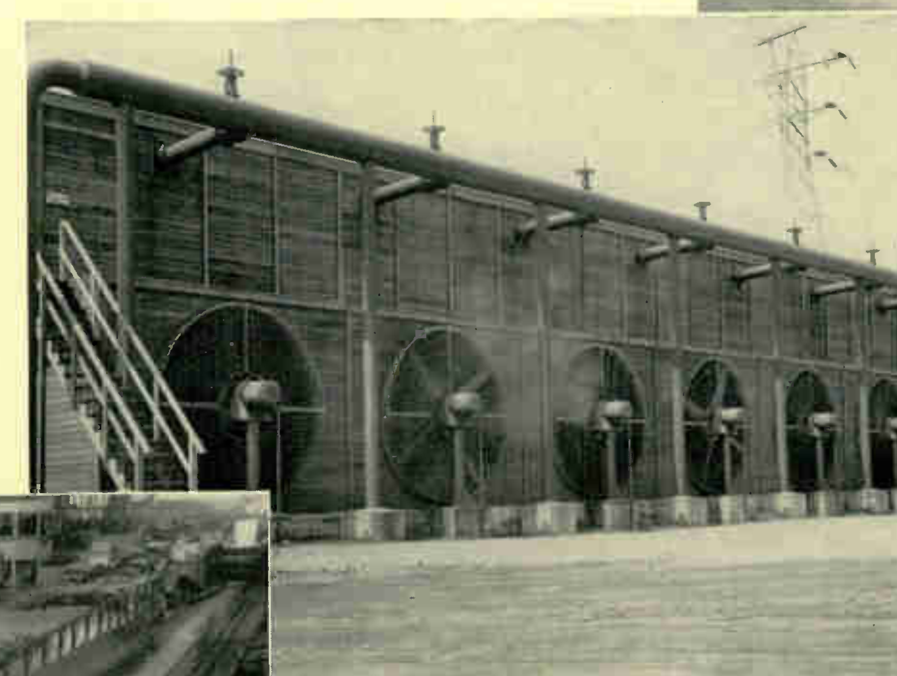


AS SPOTLESS and as pleasing in appearance as the most modern kitchen is this circuit-breaker control center for a dairy. The unit is painted both inside and out to give a special white finish. The control center contains the main breakers, feeder breakers, and combination Linestarters for motors.



THIS 900-hp, d-c motor (right) is directly connected to a flying shear that cuts steel into sheets as it emerges from a new hot strip mill. The magnetic brake holds the shear in position when stationary. The generator between the motor and brake supplies power for control and speed indication. The cooling tower for process water of the mill (below) is a unique application of gearmotors. Fans are overhung directly on the output shaft without the aid of a coupling or bearing. After emerging from the hot mill the steel is sprayed with water (below left) to cool it below the scale-formation temperature. The adjustable-speed runout-table motors are directly exposed to splashing water and hence are totally enclosed and watertight to prevent breakdown.





DURING the winter, track switches on railroads and street railways tend to freeze and stick if not properly cleared of snow and ice. Such switches create a hazard and interrupt schedules. They are kept in operation during periods of heavy snowfall either by crews of men (below left) or by electric heaters (below right). Power for the heaters, which are turned on only when needed, is supplied by a standard transformer.

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Dry-Type Transformers for Underground Use

The availability of glass, silicone, and other temperature-resisting insulations plus improvements in construction have enabled designers to produce a practical dry-type, submersible transformer. The unit has conspicuous advantages for applications outdoors or under the street in vaults without excessive handicaps of larger size or cost.

W. W. Satterlee, *Division Engineer, Westinghouse Electric Corporation*

Several completely sealed, dry-type transformers are in service. Experience with them has been eminently satisfactory and warrants their increasing use, which appears likely. The complete absence of liquids makes them essentially fireproof and explosionproof, which renders them attractive for service underground. Because they are hermetically sealed they are also applicable outdoors.

A dry-type transformer is devoid of all liquids. Its core, coils, and associated parts are cooled by natural or forced circulation of air. This principle is by no means of recent origin. In fact, the original Westinghouse transformer, built in 1885, contained no liquids. Since then, hundreds of thousands of small, dry-type units have been put into service. For many years, relatively large air-blast transformers served railway and other substation requirements. But, all were constructed with cellulose or class-A insulating materials, and the temperature rise of their windings was limited to 55 degrees C.

About 12 years ago, realizing the need for a transformer that would be essentially fireproof and free from explosion, Westinghouse introduced a new kind of air-cooled transformer,* insulated almost entirely with inorganic materials such as glass, porcelain, and mica. Today thousands of these air-cooled transformers, aggregating nearly two million kva, are in operation under almost all kinds of applications. They have been built in self-cooled ratings as large as 3750 kva and in forced-air-cooled ratings of 10 000 kva.

These transformers are of core-form construction (identified as type ASL). Glass tape is used to cover winding conductors. Spacers, which form air ducts in and support the windings, are made of glass or porcelain. All low- and high-voltage leads are supported on porcelain. Barriers of an organic material separate the windings from the core and from each other, but these barriers operate at temperatures appreciably lower than those of the windings since they do not

*"Tomorrow's Transformer Today," by H. V. Putman, *Westinghouse* Engineer, May, 1941, p. 19.
"Air-Cooled Transformers for Indoor Distribution Substations," by J. K. Hodnette, *Westinghouse* Engineer, November, 1944, p. 182.
"The Design and Operating Characteristics of Modern Dry-Type Air-Cooled Transformers," by W. W. Satterlee, AIEE Technical Paper 44-171, May, 1944.

The complete assembly and the core and coils for a 5000-kva ventilated dry-type transformer.

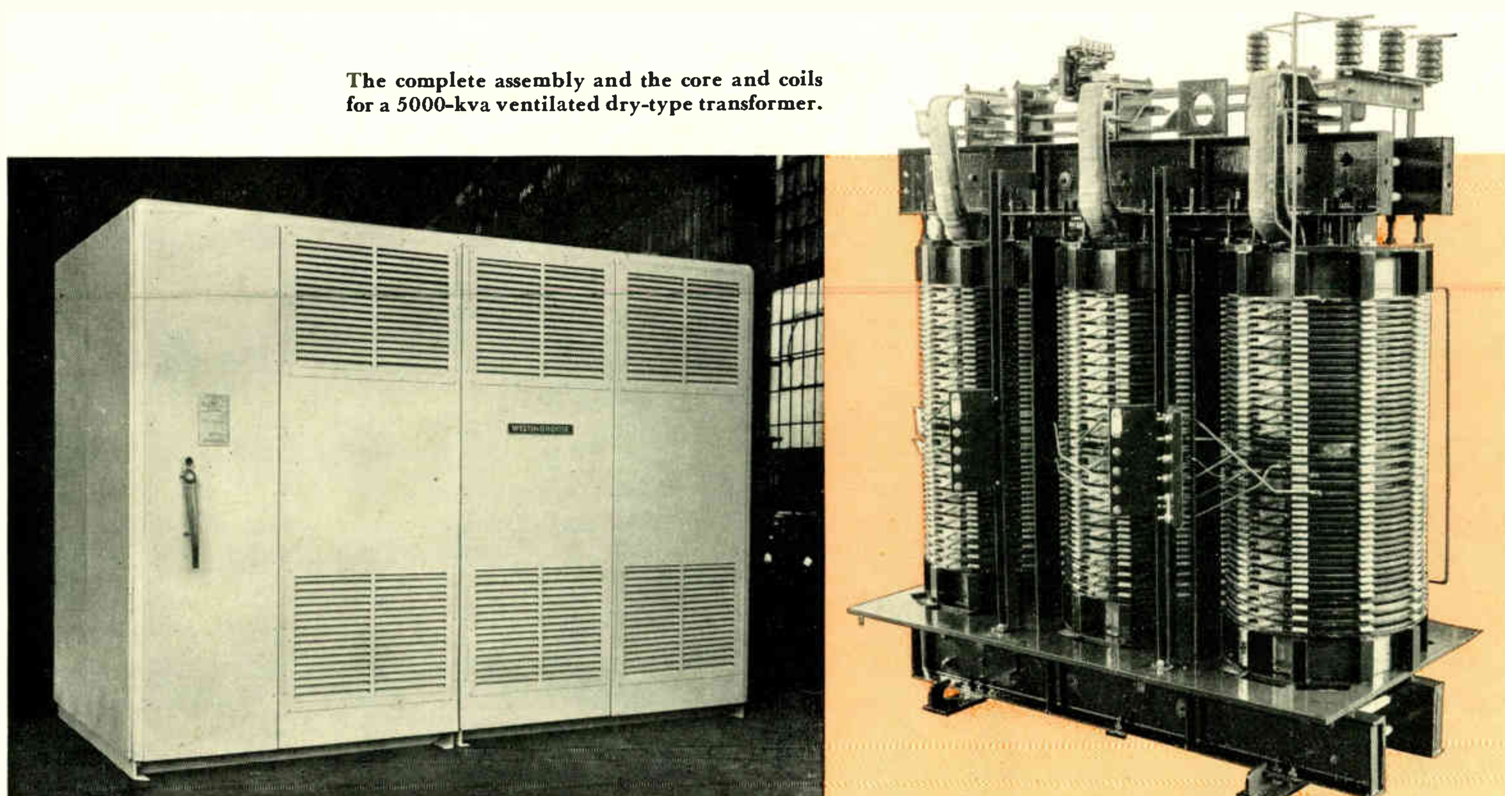

TABLE I—FIRST COSTS AND OPERATING COSTS OF DIELECTRIC-HEATING INSTALLATIONS

NEMA Generator Rating Kw	Initial Investment*	Operating Cost—Dollars per Hour**			
		Duty Cycle			
		100%	75%	50%	25%
2	$2500– 4000	$0.124	$0.107	$0.094	$0.079
5	4500– 7000	0.19	0.17	0.14	0.12
10	8000–18 000	0.40	0.35	0.29	0.24
20	16 000–35 000	0.69	0.59	0.49	0.39
50	40 000–70 000	1.36	1.13	0.90	0.67
100		2.98	2.51	2.05	1.59

*Total includes generator, transmission lines, presses or clamps, electrodes, and shielding.
**Assumes representative 1948 costs of power, tube replacement, and maintenance.

cause serious production loss, or where space for drying is limited. An example of the exceptions is the drying of stock from which bowls for smoking pipes or heads for golf clubs are made.

Shielding of Installations

Radio-frequency generators resemble a high-powered radio transmitter except that the energy from the generator is expended into some material between the electrodes instead of into an antenna and thence to space. However, transmission of the r-f voltages to the work permits some portions of the installation to act like small antennas. Since the frequencies used in r-f gluing are the same as those used for short-wave radio, a small amount of radiated energy could cause considerable interference with established communication channels.

The Federal Communications Commission requires that all radio-frequency heating installations be shielded so as to limit the radiated energy to a low value of ten microvolts per meter at one mile. Shielding is accomplished in either of two ways. The whole radio-frequency installation is enclosed in a shielded room made of a double-walled copper screen; or, since the generators are specifically designed to meet the regulations, the work-handling equipment and electrodes only are enclosed in a shield that eliminates radiation of radio-frequency energy. Presses are completely enclosed except for specially designed apertures. The shielding affords ideal protection to operating personnel, and, where parts of these shields are removable for easy access, they are interlocked with the generator so that no high voltages are present if an operator approaches the electrodes.

Economics of Radio-Frequency Gluing

A concept of the economics of r-f heating can be obtained from the information listed in table I.

The labor necessary to man these installations is small and depends on the type of installation. Usually one man can operate the 2-, 5-, and 10-kw units except on high-production installations such as core-stock presses where two or three men are needed to handle the material. The 20-, 50-, and 100-kw range usually requires two to four men because of the large masses involved. For example, a core-stock edge gluer of the batch type, using a 10-kw generator with a 75-percent duty cycle, produces 15 000 board-feet every eight hours. The cost of operating the r-f generator for this operation is approximately 8×0.35 = $2.80, or 18.6 cents per thousand board feet.

The use of lower cost raw materials, the savings in glue, the higher quality product, and the high production level with small space requirements must also be considered in analyzing the economics of an r-f installation.

The lower production cost, high production rates, and improved product quality of r-f applications have resulted in wide acceptance by the industry. The future offers even greater promise, since the rapid decline of virgin timber necessitates the introduction of new material-saving techniques. The use of waste material, such as sawdust, held together with plastic binder set by dielectric heating, will be used for molded assemblies, structural braces, and even core stock. Close cooperation between the woodworker and the radio-frequency engineer will continue to produce newer and perhaps even more significant developments.

Radio cabinets are glued with the aid of this r-f generator and a special jig.

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Cumulative Index

A cumulative index of all material appearing in the *Westinghouse* Engineer is available. This cumulative index includes reference to all subject matter that has appeared in the *Westinghouse* Engineer from its first issue, May, 1941 through November, 1947. Anyone wishing to have a copy will receive one without charge by addressing a request to the *Westinghouse* Engineer, 306 Fourth Avenue, Pittsburgh (30), Pa.

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touch them. Core-and-coil assemblies are treated with an organic Thermoset varnish. This treatment protects metal parts against rusting, locks hardware in place, adds to the mechanical rigidity of the structure and to its ability to withstand shipping stresses, and gives a measure of moisture resistance, especially during periods when the transformers are not in service. These transformers use ventilated cases and are normally designed for indoor installation.

Because of the excellent operating record of this family of transformers and the encouragement of certain operating engineers, a tightly sealed tank enclosing a new core-and-coil assembly has been developed. This provides a dry-type transformer entirely suitable for submersible or outdoor installation. The first one was designed and built with the cooperation of the Consolidated Edison Company of New York, on whose system it was placed in service in a street vault in New York on November 18, 1943. It is a 500-kva, three-phase, 13-kv network transformer and has operated continuously and satisfactorily for more than four years. Since then, two 500-kva, 11.8-kv submersible network transformers have been built for the Rochester Gas & Electric Corporation. These transformers were recently installed in sidewalk vaults in Rochester, New York. In addition, three 300-kva, 4-kv submersible transformers have been put into service in downtown Pittsburgh on the network system of the Duquesne Light Company. Views of all these are shown.

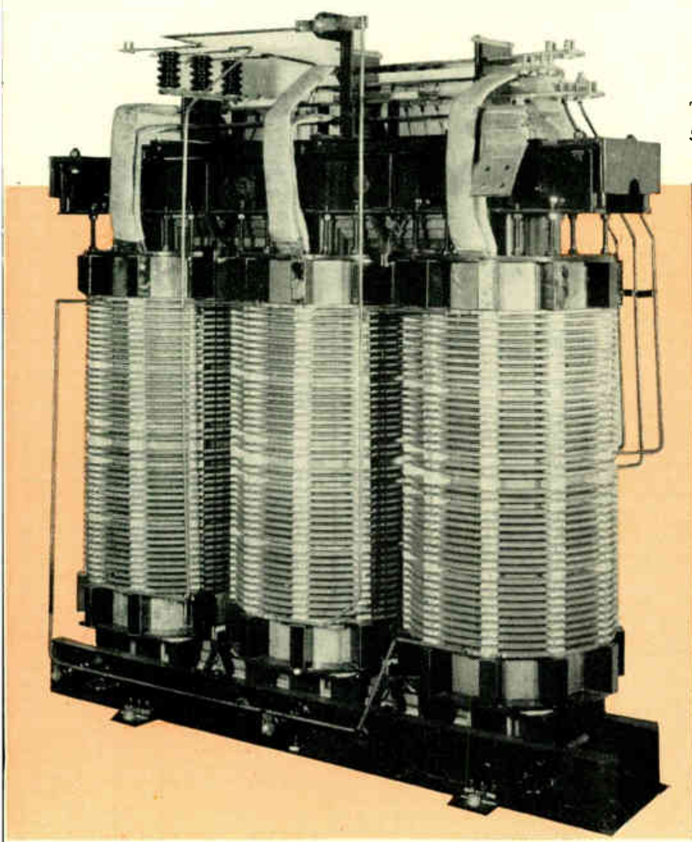
These submersible, dry-type transformers are of core-form construction; in appearance, they resemble closely the ventilated types. However, to meet operating conditions, the submersible design is constructed entirely of inorganic insulating materials (class H and class C) and with bonds of semi-inorganic materials such as silicones or melamines. Winding conductors are covered with glass and bonded with a silicone varnish. Porcelain or glass spacers form air ducts in the windings. Glass tubes center the low-voltage windings over the core. Clear cylindrical ducts of air separate the high-voltage and low-voltage windings. Core-and-coil assemblies are treated, although sparingly, with a silicone varnish, since the principal purpose of this treatment is to add mechanical rigidity to the assemblies during shipment. Plate glass provides insulation between phases. The hottest spot temperatures of their windings are less than the proposed standard for class-H materials. The highest temperature of the tank of these dry-type transformers, when carrying rated load, is unlikely to exceed the hottest tank temperature of the average liquid-immersed transformer.

Actually, the differences in the design and construction of these several submersible transformers are few. Mostly they relate to details and in their general arrangements, made necessary by the different conditions of design, installation, and operation. All of them are designed for operation with their tanks filled with nitrogen at atmospheric pressure.

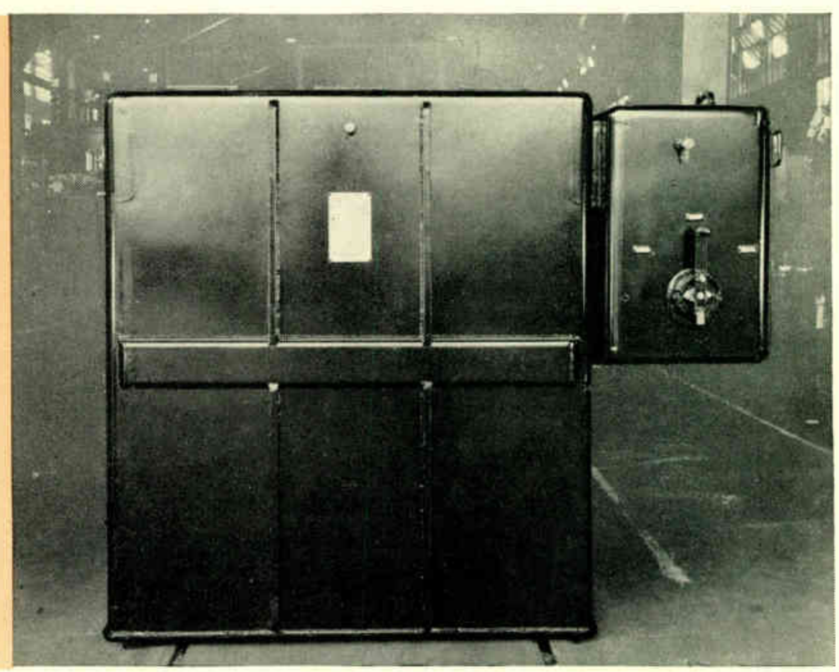
These submersible transformers have several advantages. They are devoid of all liquids; and, because their construction excludes organic materials, fire and explosion hazards are eliminated. They are built in tightly sealed tanks, and can be completely welded, so that no gaskets are necessary. The wells can be rebroken and remade should access to the interior become essential. These features, combined with operation in nitrogen, practically eliminate the possibility of vault explosion. Under no normal operating condition can a combustible gaseous mixture be formed. It is highly improbable that sufficient pressure could develop under any fault condition to rupture the tank.

Installation of these transformers is easily and quickly accomplished because fireproof vaults are unnecessary. Because all liquids are eliminated and as most valves, fittings, and gaskets are unnecessary, maintenance time and expense are reduced to a minimum.

Submersible, dry-type transformers are of comparatively simple design. They are free of most fittings, gaskets, and gadgets that always require attention. Operation in a tank



The complete submersible dry-type transformer, rated 500 kva, 3 phase, 11 800/216 volts, and its core and coils.



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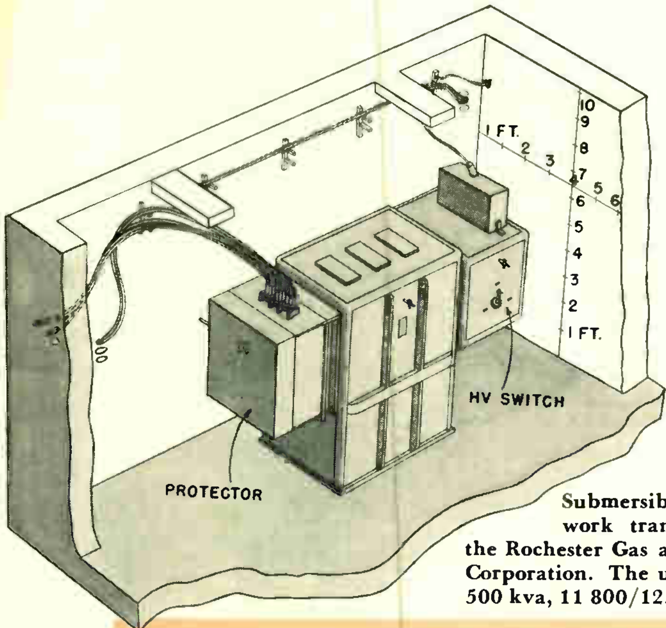


Submersible-type network transformer of the Rochester Gas and Electric Corporation. The unit is rated 500 kva, 11 800/125–216 volts.

TABLE I—LOSSES, TEMPERATURES, SOUND LEVELS OF SUBMERSIBLE DRY-TYPE NETWORK TRANSFORMERS

	500 Kva, 3 Phase 13 750/216 Volts in Service 1943	500 Kva, 3 Phase 11 800/216 Volts in Service 1947	300 Kva, 3 Phase 4160/208 Volts in Service 1948
Total Loss, Watts	6550	5350	4000
Low-Voltage Winding Average Rise by Resistance, Degrees C	102	82	110
High-Voltage Winding Average Rise by Resistance, Degrees C	112	93	111
Test Ambient, Degrees C	26	34	18
Temperature of Tank Wall Outside at Top, Degrees C	52	58	67
Temperature of Air at Top Inside Tank, Degrees C		70	114
Low-Voltage Winding Hottest Spot Temperature, Degrees C	147	131	151
Estimated Hottest Spot Temperature High-Voltage Winding	159	145	152
Sound Level, DB_{10}	76	62	58

filled with a noncombustible gas at atmospheric pressure should prove most satisfactory and economical. Better cooling might be obtained by the use of additional tank surface or by the use of fans to circulate the gas internally; but such expedients complicate the design, installation, and operation of the transformers. They also increase the size, cost, and maintenance of the transformers.

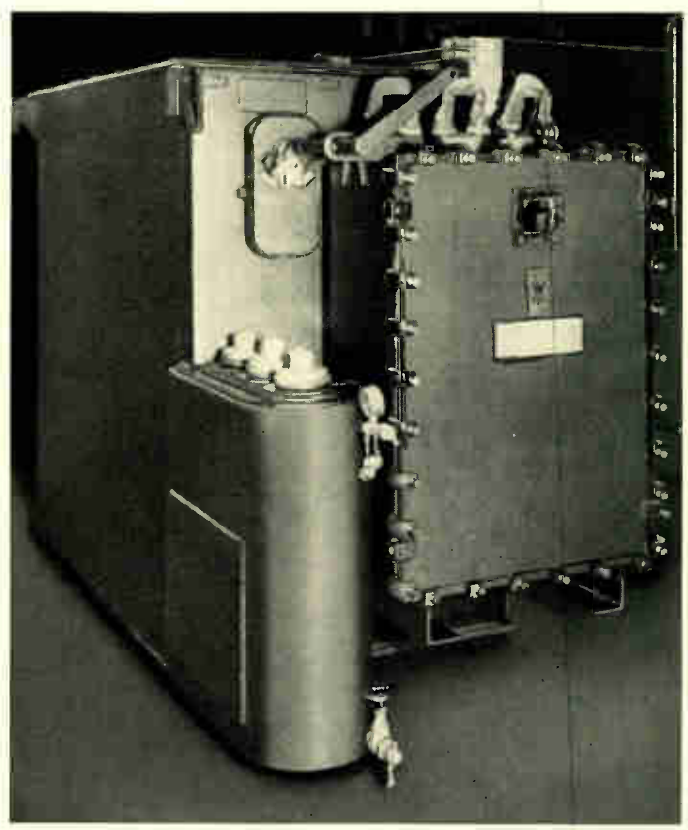
The design of sealed-tank dry-type transformers has not been confined to network application only. It has been extended to units suitable for portable service in coal mines. One of these transformers has been in service in a mine in West Virginia for about three years. Several more are being built. This transformer is equipped with disconnecting low- and high-voltage cables which add to its portability. The low-voltage cables connect to explosionproof air breakers mounted on the transformer case. The general design follows that of the submersible dry-type network transformers except for the very low height and other features necessary for mine service.

Insofar as possible these dry-type, submersible transformers are designed to be used instead of the equivalent liquid-immersed units. Table I gives a comparison of the total losses, temperatures, and sound levels of submersible dry-type transformers to date. As the tabulation shows, the original unit has higher loss, higher temperature, and a higher sound level than those built in 1947. This can be attributed to differences in ratings and detail requirements, to improvements in design and a desire to make this type of transformer competitive with other types of submersible transformers. In addition to the usual tests, these transformers were operated 125 percent of rated load until their windings reached constant temperatures. Samples of gas were then taken from within their tanks and analyzed for combustible gases. None were found. The pressures that developed within the tanks under this loading did not exceed four pounds per square inch.

A comparison of weights and dimensions of the dry-type network units with the same kva and voltage ratings of similar liquid-immersed transformers is provided in table II. This comparison is not necessarily exact, because the mechanical arrangements of the two types of transformers differ.

While the sealed-tank dry-type transformers have outstanding advantages, they also have certain disadvantages when compared with liquid-immersed transformers. For example, dry-type, sealed-tank transformers are usually larger. This

A portable sealed-tank dry-type transformer in service in a coal mine is shown above. Below is an external view of the first 500-kva, 13-kv submersible dry-type network transformer, installed in 1943. The high-voltage, single-conductor cables enter the transformer through a terminal chamber mounted on one end of the tank.



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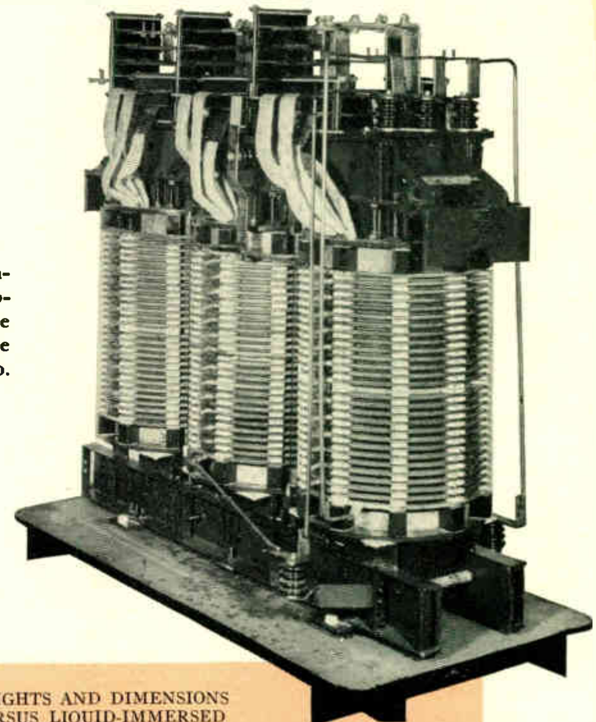
is most pronounced in length and height. Since no cooling tubes are necessary on the tanks of these dry-type transformers, their width is not greater.

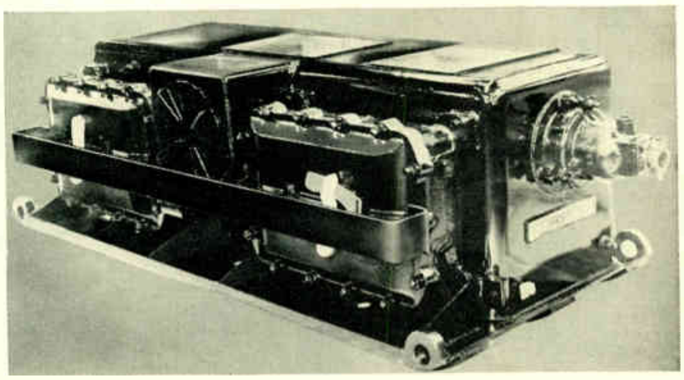
They are more expensive, principally because core-and-coil assemblies are larger since the major insulation is air and greater electrical clearances are necessary. The somewhat larger dimensions of these transformers may, in some applications, complicate or perhaps prohibit their use in place of liquid-immersed transformers.

Inorganic insulating materials present some difficult problems in the design and manufacture of these transformers. Also, silicone-bonded glass and similar products are relatively new and more costly. In addition, these new materials are difficult to fabricate.

These factors, coupled with the need of rather low sound levels for most network applications, make dry-type, sealed-tank transformers appreciably more expensive than liquid-immersed transformers.



Core-and-coil assembly of a 300-kva submersible dry-type transformer for the Duquesne Light Co.



A sealed-tank dry-type transformer for mine service, rated at 150 kva, 3 phase, 2400/208 volts, is shown above. A 300-kva, 4-kv submersible transformer, below, is arranged for low-and high-voltage cable connections. It does not have a high-voltage switch and provision is not made for a low-voltage network protector.

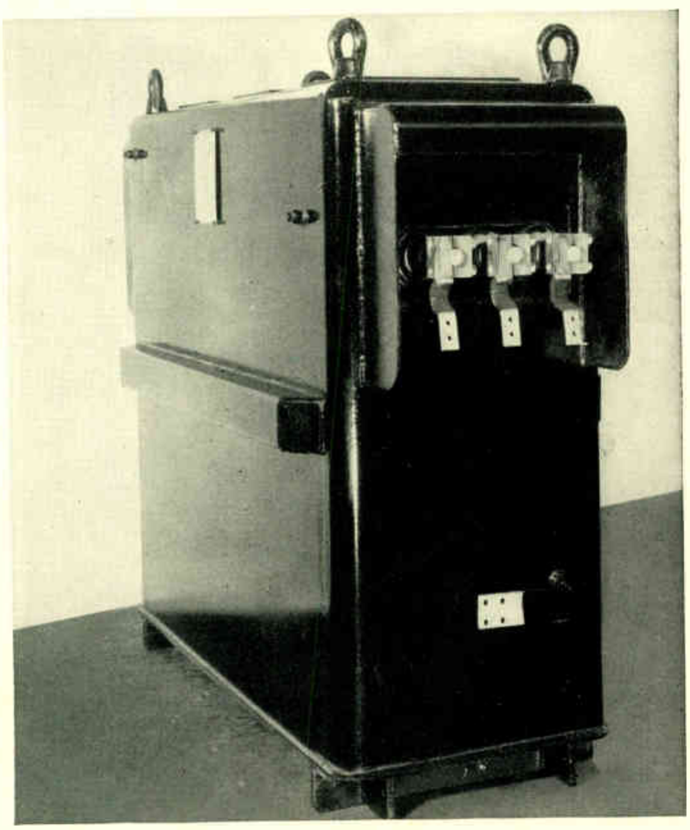


TABLE II—WEIGHTS AND DIMENSIONS DRY-TYPE VERSUS LIQUID-IMMERSED NETWORK TRANSFORMERS

	500 Kva—3 Phase				300 Kva–3 Phase	
	13 750/216 Volts		11 800/208 Volts		4160/208 Volts	
	Dry Type	Inerteen	Dry Type	Inerteen	Dry Type	Inerteen
Floor Space—Inches						
Transformer	45x81	39x70	39x80	41x63	30x83	34x71
Complete Network Unit	45x103	39x92	46x124	41x95		
Height—Inches						
Transformer	71	68	83	66	67	71
Weights—Pounds						
Core and Coils	6600	4350	7100	3950	4400	3400
Case and Fittings	3200	3300	3000	3600	2400	2500
Inerteen		2750		2750		2600
Total	9800	10 400	10 100	10 300	6800	8500

Considerable work has been done by a number of investigators to determine the possibilities of using certain gases under pressure in sealed containers to obtain an increase in dielectric strength and better cooling.* This and similar data by other authors show the possible use of a number of gases. Experimental work to date indicates that sulfur hexafluoride has the most desirable characteristics. This gas is noninflammable and reasonably stable. Data has been published indicating that dielectric strengths comparable to mineral oil might be obtained with the use of sulfur hexafluoride at pressures of two to four atmospheres. If the practical use of such a gas proves satisfactory, it may become possible to design and build sealed-tank, dry-type transformers with weights and dimensions comparable to those of liquid-immersed units.

However, transformers operating under pressures of two or more atmospheres will require tanks of special design and with considerable mechanical strength. The successful operation of such transformers will be entirely dependent upon maintaining the gas under the required pressure continuously. This cannot be accomplished easily and it may prove more satisfactory and economical over-all to make the transformers somewhat larger and to seal them at atmospheric pressure. Although the ultimate form of the sealed-tank dry-type transformer is yet indefinite, it has demonstrated that it is capable of fulfilling a long-felt need.

*"Gaseous Insulation for High-Voltage Apparatus," G. Camilli and J. J. Chapman AIEE Technical Paper 47-240, September, 1947.

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Statistics—
The Insulation Engineer's Crystal Ball

By
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Manufacturers and operators of electrical machinery have long desired to analyze the quality of insulation in terms that provide a basis for prediction of performance. A simple statistical analysis, in the hands of the insulation engineer, becomes a crystal ball that enables him to foretell the probable future of the coils in his machine.

TESTING each individual coil by breakdown test is the only method of determining with finality the dielectric strength of windings for high-voltage electrical machines—but unfortunately the winding itself is rendered useless in the process. Consequently it is impossible to apply this test to coils that are actually wound in the machine. The only practical method of evaluating their dielectric strength is to test representative samples and to predict performance of the remaining coils from an analysis of the results.

The breakdown test consists of placing one test electrode over a section of the coil insulation and connecting the other lead to the copper. The voltage is then raised by increments and maintained for one minute at each step until the insulation breaks down. The last voltage at which the insulation "holds" for the full minute is called the "hold" voltage. To reduce the possibility that a coil will fail after being wound in the machine, all coils are required to withstand a higher test voltage than is expected of the complete winding.

The insulation strength of a set of windings for a machine is expressed in terms of an average value of hold voltage with some degree of plus or minus variation. A higher average and a smaller degree of variation (which is equally significant) are indicative of better quality. These values are determined from several extra coils that are taped and treated, selected at random from the entire batch, and tested to breakdown. The data is analyzed and predictions are made as to the probable quality level and number of failures of the remaining coils used in winding the machine. These predictions are the insulation engineer's ultimate goal. They are obtained from a statistical analysis of the laws of probability.

Statistics Applied to Insulation

Insulation breakdown tests conducted on a large number of windings over a period of years indicate that where manufacturing processes are closely controlled the data collected follows closely the normal probability pattern. Consequently,

Theory of Probability

THE theory of probability was first investigated in connection with games of chance. The theory can be used to determine, for example, what the chances are of throwing a seven with a pair of dice or of throwing seven sevens in a sequence. The chance of the latter, incidentally, is 1 in 279 936.

One of the fundamental concepts of the theory of probability is the normal distribution curve. It can be plotted by putting a number of coins, such as twenty, in a box, shaking them, and throwing them out on a table. The heads are counted and recorded and the process repeated 999 times. The results of an actual test are plotted on curve *A* of Fig. 1, which is approximately a normal distribution curve. The number of heads per throw is the abscissa and the number of times each head count appears (frequency) is the ordinate. For example, 15 heads were counted 14 times. This curve indicates that the combination of 10 heads tends to appear most frequently, 9 and 11 heads a shade less frequently, 8 and 12 still less, and so forth. The arithmetic average of the number of heads appearing is 10.13.

Had the test followed the laws of probability precisely, the curve would have been as shown by *B* of Fig. 1, which is exactly the normal distribution curve, and the average number of heads would have been exactly 10. The larger the number of throws the closer the curve is to normal and the closer the average is to 10. For example, had 10 000 throws been made, the curves would probably have coincided and the average would have been but a few thousandths from 10.

Two principal conclusions are drawn from the normal curve: one, that the number of throws (or the data recorded) has a tendency to cluster about a center, which is the average of all observations; and two, most of the individual readings differ from the average (only 18 percent of the head counts are 10), but they are distributed about the average in a regular, predictable pattern. The amount by which the data differs from the average is measured by a constant called the "standard deviation."

The standard deviation (σ) is the root mean square of the individual deviations from the average. It provides an indication of the randomness (dispersion) of the data. If σ is large in proportion to the average, it indicates that the data varies widely; if small, it indicates that the variation is small and that a larger proportion of the data is near the average. To calculate the standard-deviation unit, the individual deviations from the average (either plus or minus) are squared, the squares are added, and the sum divided by the number of observations to obtain the average of the squares. The square root of this average equals one standard deviation. Standard deviation is in the same units or dimensions as the average. In the case of the coins, it represents a number of heads per throw.

The standard deviation is very useful in further analyzing the normal distribution curve. It can be proved mathematically that, in the case of a normal curve, 68.3 percent of the total frequency (683 in the case of 1000 coin head counts) falls within $\pm 1\ \sigma$ of the average (as indicated by Fig. 2.) Furthermore, an additional 27.2 percent (13.6+13.6) of the data falls between ± 1 to $2\ \sigma$ and 4.2 percent (2.1+2.1) more falls between ± 2 to $3\ \sigma$. Only 0.26 percent of all the observations lie outside the $3\ \sigma$ range, 0.13 percent on each side. Consequently, 99.87 percent (100−0.13) of the readings are above the $-3\ \sigma$ limit.

The tendency of data to follow a normal distribution curve is valuable as it permits extrapolation beyond the readings recorded with a fair degree of accuracy. For example, if the coins were thrown 100 times instead of 1000, the data would probably cluster between $\pm 1\ \sigma$ with a few readings beyond. The curve would likely not be normal. Yet because the average and the standard deviation can be calculated from the recorded data for 100 throws and the probable subsequent shape of the distribution curve is known, the data that would probably result if 1000 throws were made can be predicted. This method is employed to determine

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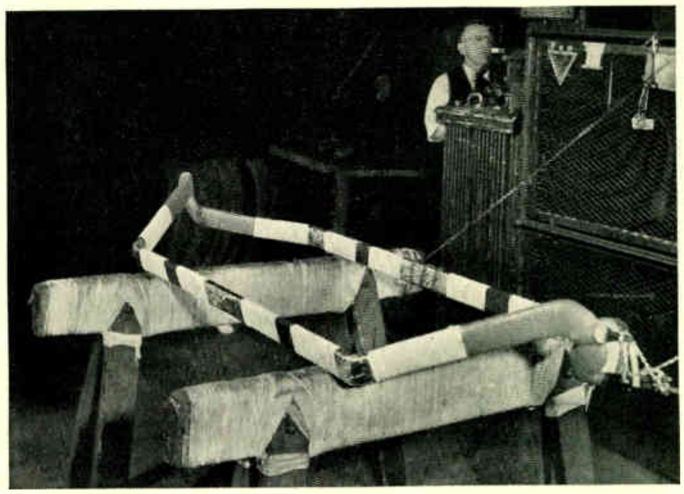
statistical analysis of the normal curve is applicable to evaluation of dielectric strength.

Consider, for example, a test in which two extra coils for a particular machine were made, selected at random, and tested to breakdown. Each coil was tested at six different sections to give a complete picture of variations within a coil and to obtain a total of 12 readings without incurring the cost of 12 coils. The results are given in the first two columns of table I. To generalize the results, each hold voltage was calculated as a percent of the average hold voltage (column 1).

Had the breakdown test been conducted with smaller increments, such as one percent kv, some sections would have withstood for a full minute voltages above the observed hold values in table I. For example, coil sections that withstood 93 percent kv (but failed at 103 percent kv) probably would have withstood some voltage between the two. Some would have failed at 94 percent kv, while others would have withstood up to 102 percent kv. Consequently, the observed hold voltages indicate the minimum dielectric strength for each class. A truer picture is obtained by assigning the coils to an average voltage class assumed to be halfway between the two recorded hold values, 98 percent kv (column 3). This classification is, in effect, an assumption that half the sections having an observed hold voltage of 93 percent kv would fail between 94 and 98 percent kv and the other half between 98 and 102 percent kv. Such is likely to be the case if a large number of coils were tested with a one-percent increment.

From the data, the standard deviation (σ) is calculated. As all voltages were calculated as a percent of the average, the average is obviously 100. The individual deviations of the midpoint voltages from the average are $100-78=22$, $100-88=12$, $100-98=2$, $107-100=7$, and $117-100=17$.

$$\sigma = \sqrt{\frac{1(22)^2+2(12)^2+4(2)^2+3(7)^2+2(17)^2}{12}} = 11.35 \text{ percent kv}$$



The breakdown insulation test of a large high-voltage coil.

This calculation of σ does not consider the number of observations, which obviously affects the accuracy of the predictions. As in the case of counting coins (see "Theory of Probability"), the greater the number of observations, the closer the calculated average—and the standard deviation—will be to the true values, which are obtained exactly only if an infinite number of samples are tested. To correct for the deficiency of testing only a small number of samples, an empirical correction factor is used. This factor is $\sqrt{N/N\text{-}2}$, where N is the total number of observations. It decreases as N increases.

The corrected value of σ is then $11.35\sqrt{12/12\text{-}2}$ or 12.5 percent kv. The average is corrected in similar fashion by another factor.

The results of the tests are plotted (Fig. 3) as frequency versus both relative midpoint hold voltage and deviation

the probable quality of a large number of electrical coils from the results of tests on a few.

The fact that the theory of probability predicts only a probability of occurrence—and not a certainty—must be borne in mind. The possibility exists—although it is infinitesimally small—that the coins may be thrown 1000 times and 10 heads be counted at each throw; or even more unlikely, that a group of 20 heads will appear at each throw. Nevertheless, in spite of these possibilities, engineers have found the predictions made by laws of probability to be sufficiently accurate that the method is an important industrial tool for quality control and other purposes.

Fig. 1—Normal distribution curve plotted from experimental data.

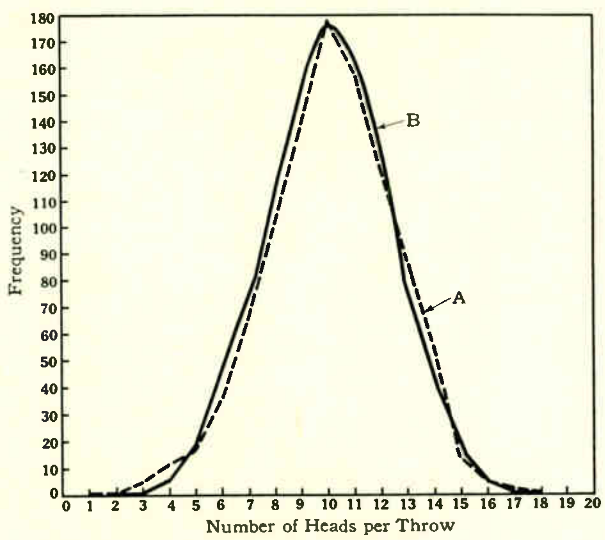
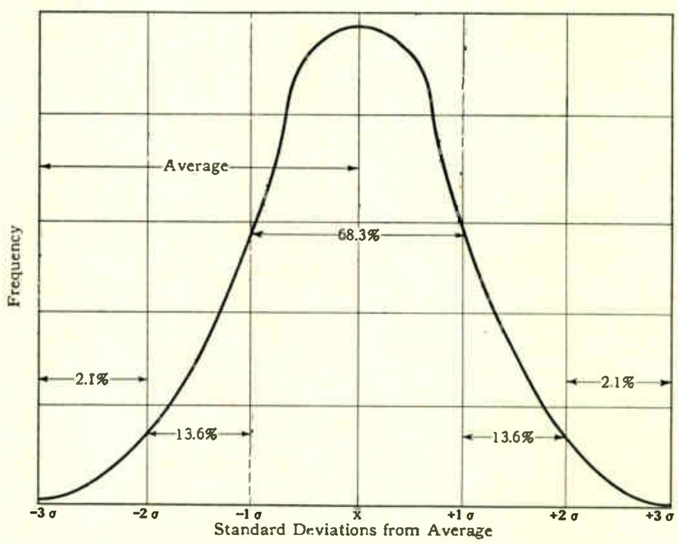


Fig. 2—Normal distribution curve plotted with standard deviation.



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from average in the form of a histogram (similar to a bar graph but not shaded). For example, the midpoint value of 78 is -22 percent kv from the average (100) or $-22/12.5 = -1.8\ \sigma$. The frequency of 1 (the number of coils that failed at the 78-percent-kv class) is then plotted at $-1.8\ \sigma$ or -22 percent kv. Other values are plotted in similar fashion.

The first criterion in evaluating the suitability of the coils is obtained by calculating the $-3\ \sigma$ limit, since 99.87 percent of the observations would be above this limit if the entire batch of coils were tested. Consequently, if the $-3\ \sigma$ limit is above the required coil test voltage, 99.87 percent of the coils would probably be satisfactory. In this case the $-3\ \sigma$ limit is $100-3(12.5)$ or 62.5. As the coil test voltage is 60, the units are thus far satisfactory. If the $-3\ \sigma$ limit were below the required voltage the entire batch of coils would be stripped and reprocessed.

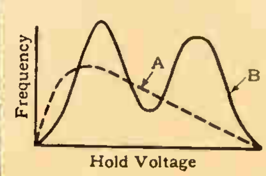
With the histogram and the actual distribution curve plotted and σ calculated, the normal distribution curve expected if a large number of coils were tested can be drawn over the range from $-3\ \sigma$ to $+3\ \sigma$ (see Fig. 3). Values selected from this curve outside the region of the data recorded (below 78 volts and above 117) are fairly accurate. However, if the data is extrapolated along a straight line rather than along a curve, more precise predictions of the probable results can be made. To put the data in the form of a straight line and thus obtain more accurate results, two additional curves are drawn.

These curves employ cumulative frequency (columns 4 and 5 of table I) at each voltage; that is, the frequency at each point is added to the sum of the frequencies at preceding points. In assigning the midpoint classification, it was assumed that half the sections in each class would have failed at a voltage above the midpoint and the other half below. Consequently, the cumulative frequency at each midpoint class is half the frequency of that interval plus the total of the preceding frequencies. For example, the cumulative frequency at 117 percent kv is $\frac{1}{2}(2)+3+4+2+1$, or 11 coil sections. The percent cumulative frequency (on the basis of a total of 12 observations) is 92 percent. Percent cumulative frequency is plotted arithmetically against percent midpoint voltage in Fig. 4. However, when percent cumulative frequency is plotted on a special scale designed for probability work, the curve is a straight line (Fig. 5), which can be extrapolated with greater accuracy, particularly in the critical area near the test voltage. Furthermore, cumulative percentage is valuable in another way. It indicates directly the probable number of failures in the total batch of coils. For example, if the coil test voltage is 60 percent kv, Fig. 5 indicates that about 0.07 percent of the coils (or 7 in 1000) would probably fail. Likewise, if one coil were tested at 60 percent kv, the probability of its failure is 0.07 percent. Also, if a complete winding (or a number of windings) is tested at 50 percent kv (individual coils are always tested at a higher voltage) the probability that an individual coil will fail is less than 0.01 percent (or 1 in 1000).

While the data of Fig. 5 is valuable in ascertaining the probability of failure of a number of coils acting individually, it gives little information as to the probability of failure of a machine using a number of these coils. In machines, where failure of a single coil is equivalent to failure of the complete winding, still another element of probability must be considered: What is the probability that any one machine will be wound with one or more defective coils that will cause failure, or without any at all? Apparently, this probability is dependent on the number of coils in the machine. The two factors, probability of failure of a single coil and probability of failure of a machine containing a number of coils in parallel, are linked by the formula $P_c = 1\ (1-p)^{n}$*, where p is the probability of failure of a single coil, n the number of coils in paral-

*AIEE Technical Paper no. 48-69, "Insulation Breakdown as a Function of Area," by L. R. Hill and P. L. Schmidt.

Coils for this 108 000-kva generator are analyzed by statistics.



← Fig. 7—Lack of control leads to skewed (A) or bimodal (B) curves.

Fig. 3—Recorded data from a breakdown test on samples.

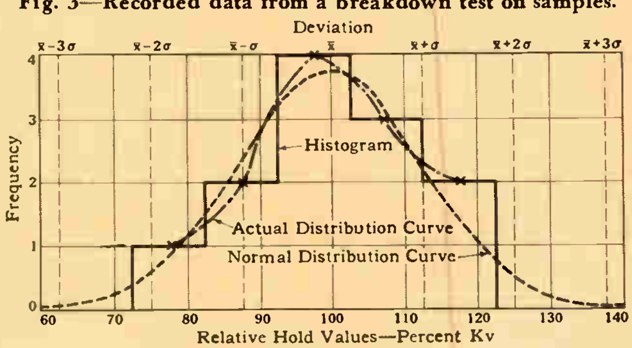
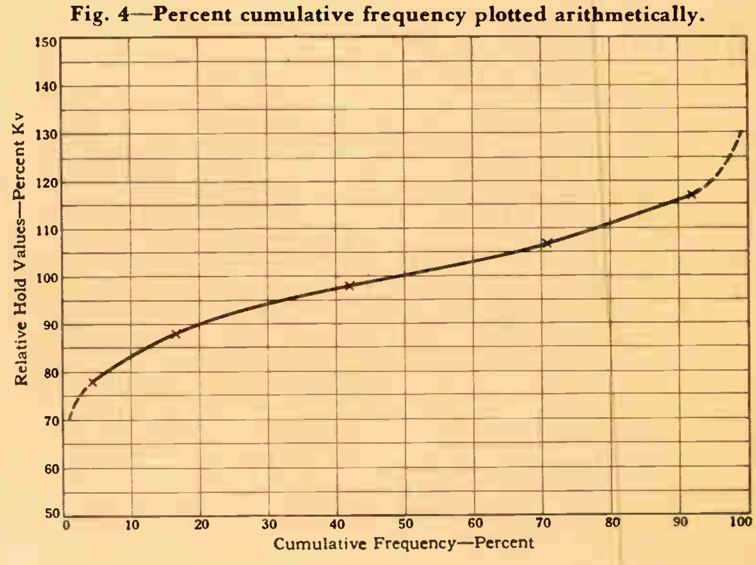


Fig. 4—Percent cumulative frequency plotted arithmetically.



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lel in the machine, and P_c is the probability of failure of the machine. This formula is plotted in Fig. 6 for different values of n. The insulation engineer uses Figs. 5 and 6 together. The data for Fig. 5 is obtained from the test data; Fig. 6 is purely mathematical expression of probability. For example, if the complete winding is tested at 50 percent kv, the probability of failure (from Fig. 5) of a single coil is less than 0.01 percent. The probability of failure of a complete winding containing 100 such units (from Fig. 6) is less than 1 percent. However, if the complete winding is tested at 60 percent kv, the probability of failure of each coil is 0.07 percent and the probability of failure of the machine is 6.6 percent. In using Fig. 6, it should be remembered that a "unit" may consist of a full coil or a half coil, depending on the design of the winding.

In general industrial practice, 2 or 3 coils, tested in sections to obtain 12 or 18 readings, are usually sufficient to obtain an accurate prediction of the probable behavior of a batch of coils for a number of machines. The cumulative-frequency curve (Fig. 5) is usually plotted directly from the data.

The Importance of Control

The dielectric strength of sections of even a single winding may vary over a wide or narrow range depending on the degree of control exercised in its manufacture. However, if materials are reasonably uniform and every phase of the process is closely regulated, dielectric strength will deviate only slightly from the average. If the variation is too great (which is indicated by a large standard deviation) or if test coils do not meet the requirements with respect to average dielectric strength, the entire set of coils is stripped of its insulation and reprocessed after analyzing the causes for reduced quality.

The accuracy of statistical analysis of dielectric strength depends entirely on the uniformity of the processes, the materials (which are inherently inconsistent electrically and mechanically), and the application of tape by human hands. These variables complicate the problem of establishing controls and of making the statistical analyses of performance. Changes in manufacture and hence in results lead to skewed or bimodal distribution curves (Fig. 7) which are very difficult to analyze, but indicate that a correction in the processing is definitely required.

Obviously, these variables require close supervision. This is accomplished by an elaborate system of controls that regulates every important phase of production. The impregnation process is checked by a continuous record of vacuum, pressure, and temperature. Chemical, electrical, and physical characteristics of the impregnant itself are measured at intervals. All coils are measured to insure sufficient application and consolidation of material. The data is plotted, studied, and analyzed for any significant change that may affect the quality of the finished product. When the results are coordinated with those obtained from statistical analysis of breakdown tests on coils and materials both, the accumulated information enables early detection and correction of changes that cause a reduction in dielectric strength. Statistical analysis thus provides a check on the process as well as the results. It has helped to maintain the desired dielectric strength of insulation.

The theory of probability is employed not only to determine probable dielectric strength of coils but for many other purposes as well. It is used for inspection of steels, representative samples of which are subjected to destructive tests to determine probable yield points, elongation, etc. Some tests need not be destructive; probable core loss, for example, is determined by non-destructive tests. The textile industry uses the probability theory to determine elongation and tensile strength and the metals industry to determine the probable dimensions of a large number of small precision castings. One of the most interesting applications is in crop harvest forecasting by the Department of Agriculture.

TABLE I

Observed Hold Voltage (Percent of Average) Percent Kv	Frequency (Number of Observations)	Relative Midpoint Hold Voltage (Percent of Average) Percent Kv	Cumulative Frequency	
			Number of Observations	Percent of Total
73	1	78	½	4.2
83	2	88	1	16.7
93	4	98	5	42
103	3	107	8½	71
111	2	117	11	92
	(Total) 12			

Fig. 5—Probability of failure of a single coil is determined from this curve, which is obtained from test data.

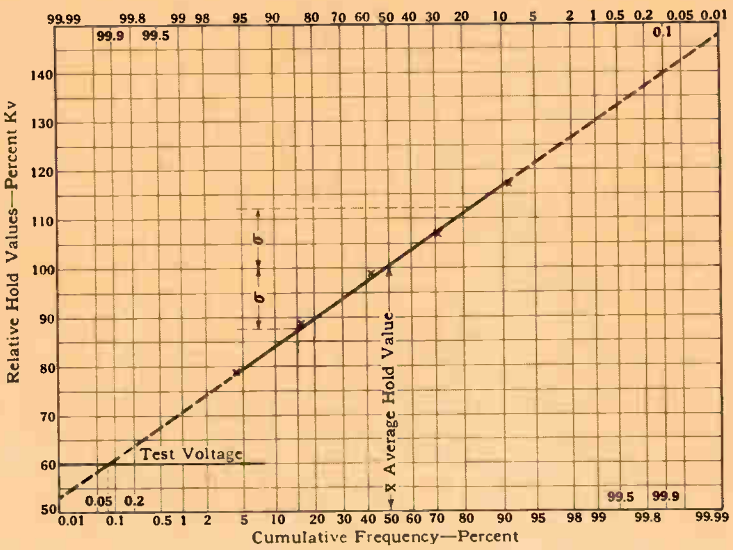
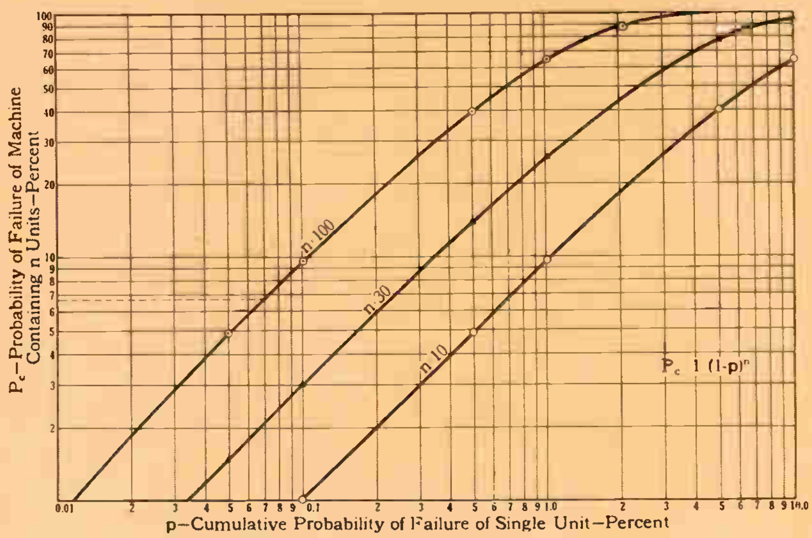


Fig. 6—The probability of failure of a high-voltage winding with a number of units in parallel is determined from these curves.



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Stories of Research

Keep Your Powder Dry

The common plaint, "it's not the heat but the humidity," really applies to a neat and thorough piece of research done by I. N. Elbling and R. H. Runk of the Westinghouse Research Laboratories. The problem involved the relationship between "sticky" weather and electrical heat losses in insulating materials made of phenolic molding powders. These losses are proportional to the power factor of the dielectric. Elbling and Runk first showed how a high relative humidity (around 90 percent) leads to absorption of water by these powders and to a consequent increase in power factor. Then they investigated techniques for preventing this occurrence.

Absorption of moisture takes place when partially processed plastic molding materials in powder form are exposed to conditions of high humidity. If fillers in the powders are of a highly porous type, absorption takes place in much greater degree. This moisture introduces an unwanted polar material into the plastic, thereby substantially raising the electrical losses in the material. In polar material the molecules tend to orient themselves in accordance to the direction of an electrical field. If exposed to an alternating field, as in the case of a dielectric in an a-c application, these molecules reverse themselves every cycle causing electrical losses in the form of heat.

Elbling and Runk knew that if power factor is allowed to get out of hand, a series of cumulative electric troubles follow. The resultant heat deteriorates organic materials in the dielectric, liberating acids or other polar materials. These "by-products" lead to still higher power factor and consequently higher operating temperatures. Under the cumulative impact of these factors, the dielectric degrades mechanically or electrical breakdown occurs, or both.

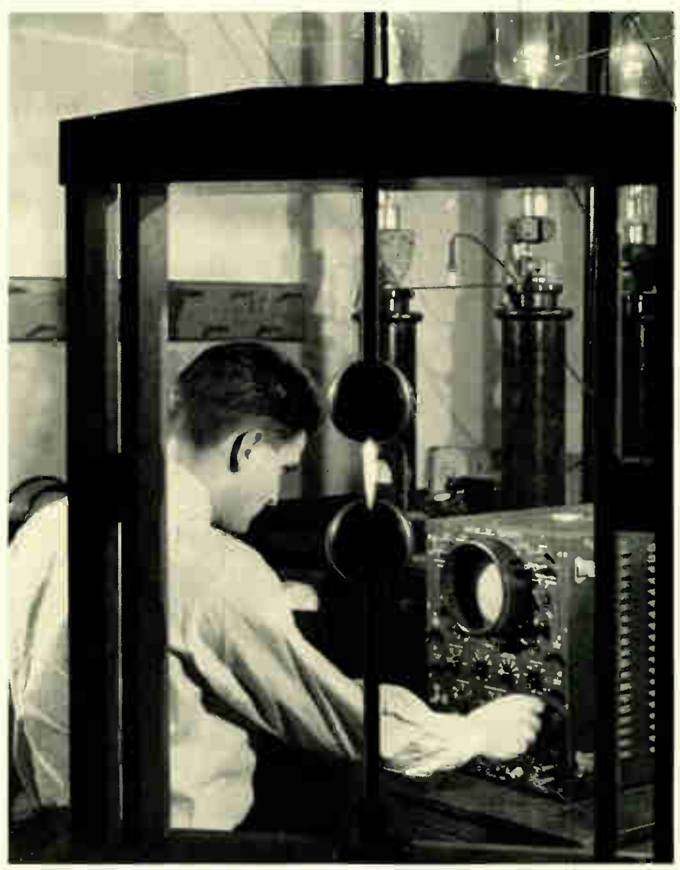
Exhaustive tests disclosed both cause and cure of the difficulty. Even short exposure of molding powders to high humidity results in excessive absorption of moisture, and this absorption is accelerated if the fillers used are of the coarse, porous type (wood-flour filler, for example). In one test, a 40-minute exposure of the powders to 90-percent relative humidity resulted in a seven-fold jump in power factor.

The cure, Elbling and Runk determined, lay in pre-drying the powders before molding, thus reducing the power factor considerably. The trick here is to heat the powders just enough to dry out excessive moisture without prematurely starting to "cure" the plastic. Tests showed the ideal heating time to be 30 minutes in a convection oven at 176 degrees F. Best results are also obtained if the powders are dried in layers no more than a quarter inch in thickness. Walnut-shell flour proved to be a much better filler for certain insulations than wood-flour because it absorbed less moisture.

Research chemist Irving N. Elbling prepares to make a power-factor measurement on a small disc of molded plastic material.

Counting Volts

The electrical voltage at which an air gap breaks down depends on its length. Consequently, by calibrating an adjustable gap to obtain data of voltage versus distance, the maximum or crest values of high voltages can be determined. Here Glenn C. Thomas is using an already calibrated sphere gap to calibrate the output of an adjustable-voltage power supply for insulation breakdown studies. This particular gap is equivalent to a 90 000-volt crest.



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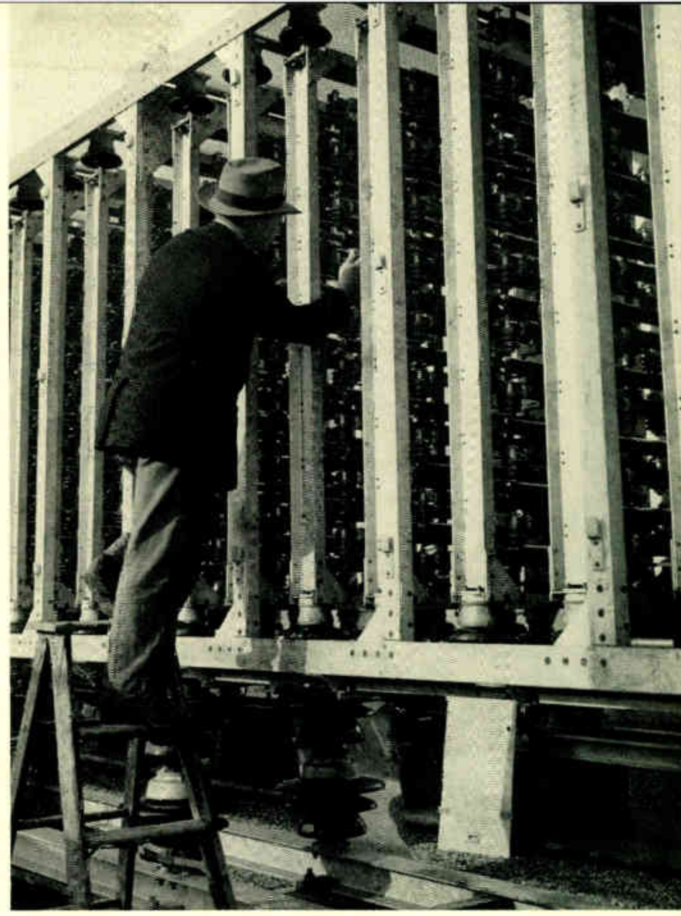
Application Problems of Series Capacitors

The operation of a series capacitor in a power system is subject to pitfalls that stem from inductive-capacitive resonance and other conditions. To avoid them, engineers considering the installation of a series bank must analyze the circuit carefully.

A. A. Johnson
Central Station Engineer
Westinghouse Electric Corporation



This resistance bank prevents resonant conditions on the 66-kv line employing a 10 000-kva series capacitor.

Series capacitors are coming into their own as a powerful tool for utility operators. These capacitors can be applied to power circuits* with considerable improvement in voltage conditions provided engineers are alert to avoid certain undesirable phenomena, the possibility of which has deterred the use of a series bank even where it could best solve a difficult problem. But in many cases the difficulties can be avoided and the improvements can become a reality.

Three major phenomena may be encountered in a circuit employing a series capacitor: subsynchronous resonance of a motor during starting, ferro-resonance of a transformer, and hunting of a motor during steady-state operation. One, two, or all of these may occur.

Subsynchronous Resonance during Motor Starting

When an induction or a synchronous motor is started (the latter as an induction motor) through a series capacitor, the rotor may lock in and continue to rotate at a speed below normal or synchronous. This condition is known as subsynchronous resonance. It is caused by the capacitor, whose capacitive reactance in conjunction with the inductive reactance of the motor establishes a circuit resonant at a frequency below that of the power supply. The rotor, in effect, acts as a stable asynchronous generator. It receives power at rated frequency from the stator windings and transposes it to the subsynchronous frequency, which it returns to the circuit containing the capacitor. This circuit, being resonant, imposes a minimum of impedance to the subsynchronous voltage and consequently conducts a large current. A motor operating under these conditions may be damaged by excessive vibration or heating.

The subsynchronous frequency is dependent on the relative sizes of the motor and the capacitor. The capacitor rating is determined by the circuit rating (other conditions remaining the same, the ratings are proportional). Consequently, the resonant frequency is related, indirectly, to the rating of the motor in proportion to that of the feeder. This frequency is usually 20 to 30 cycles for a 60-cycle motor whose input equals half the circuit rating.

As the motor size decreases with respect to the capacitor and circuit ratings, its reactance increases. During resonance, capacitive and inductive reactance are equal. Because capacitive reactance increases with decreasing frequency, the subsynchronous resonant frequency is lower when the motor requires a smaller proportion of the circuit rating. A motor requiring less than five percent of the circuit rating may resonate at a subsynchronous frequency of five cycles or less if it starts under load.

The most common method of preventing subsynchronous resonance is to damp out this frequency by placing a resistor in parallel with the capacitor. While the amount of resistance to use can be calculated, the results thus obtained are usually one half to one tenth the values that experience proves necessary. Calculations are inaccurate because of the difficulty of giving precise consideration to such variables as inertia of the motor and load, starting load, speed of acceleration, the type of starter, and other load in the circuit. For example, load elsewhere on the circuit, when a motor is started, reduces the possibility of subsynchronous resonance by providing a damping effect similar to that of parallel resistance.

The resistance should be as high as possible in order to hold to a minimum its continuous losses, which are equal to the square of the voltage across the capacitor bank divided by the resistance. It is common practice, then, to apply resistors that are adjustable over a predetermined range, particularly in the larger installations.

When low ohmic resistance is used, the resistor can be disconnected after the motor reaches full speed and the risk of resonance has passed. Switching can be accomplished manually or by remote control over a pilot wire or power-line carrier channel with electrically operated switching equipment.

Subsynchronous resonance can also be avoided by use of parallel resistors across only two phases of a three-phase series capacitor. Such a solution is permissible where the omission of resistors from one phase does not unbalance the voltage appreciably. The amount of unbalance is determined by the resistance. The higher the resistance, the less the unbalance. But the resistance necessary, not the degree of un-

*"Series Capacitors Approach Maturity" by A. A. Johnson, *Westinghouse* ENGINEER, July, 1948, p. 106.

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balance, determines the ohmic value. At least one such installation is in service and is operating satisfactorily.

Subsynchronous resonance can exist only during motor starting. Hence, resonance can be prevented by inserting resistance in series in the supply leads to the motor instead of in parallel with the capacitor. A contactor is required to short circuit the series resistance after the motor reaches full speed. If the circuit contains only a few motors such a scheme may be more economical than a single large resistance in parallel across the capacitors. To be effective, the series resistance must be in the stator circuit of the motor. Resistance in the rotor circuit of a slip-ring motor does not give the desired damping but affects primarily the amount of slip between the subsynchronous frequency and the frequency of the current through the rotor circuit.

If motors are started infrequently, subsynchronous resonance can be avoided without using resistance by short circuiting the capacitor during starting. If a temporary unbalance is tolerable, the same result can be achieved in some cases by short circuiting only one phase of the bank, which simplifies the switching equipment.

The reactance of a capacitor is inversely proportional to frequency, while that of an inductor is directly proportional. Hence, in a series circuit consisting of capacitance and inductance the voltage drop across the former increases as frequency is reduced. Therefore, a condition of subsynchronous resonance in a power circuit causes an increase in the voltage drop across the capacitor. This voltage may be large enough to cause the protective gap in parallel with the capacitor bank to flash over, thus short circuiting the capacitor. This halts the resonant condition and permits the motor to accelerate normally to full speed. After a time delay the capacitor is automatically restored to the circuit. This sequence of operations may make it possible in some installations (particularly where motors are started rarely) to use the gap alone to prevent subsynchronous resonance and perhaps eliminate the need for parallel resistors. However, heavy-duty gaps in series with resistors to dissipate the energy stored in the capacitors may be required.

The gap is set to break down at twice rated current (twice rated voltage) at rated frequency. Consequently, during subsynchronous resonance at half rated frequency the gap flashes over at rated current since the capacitive reactance is doubled. The lower the frequency the smaller the current required to break down the gap.

In general, the possibility of subsynchronous resonance should be checked for all circuits in which the largest motor requires more than five percent of the circuit rating. Experience indicates that standard motors rated less than ten percent of circuit rating encounter no difficulty if started at no load. In fact, motors rated up to twenty percent usually accelerate satisfactorily if started at no load and across the line. However, when high-inertia loads are involved the circuit must be checked for subsynchronous resonance even if the power requirement of the largest motor is as low as five percent of the circuit rating.

Ferro-resonance in Transformers

A transformer bank when energized draws a high transient exciting current. If a series capacitor is in the circuit it may create a resonant condition that causes the high current to continue. This is known as ferro-resonance.

Ferro-resonance is cured automatically in most cases by the parallel gap. The magnetizing inrush current is probably of sufficient magnitude and low enough in frequency to cause a voltage drop to appear across the capacitor (and across the gap) high enough to break down the gap. As the transient period approaches its end, the current in the gap decreases. The steady-state current through the gap for a short period is usually too small to maintain the arc and therefore the gap clears, restoring the capacitor to the circuit. The possibility that the gap alone can prevent ferro-resonance is checked by oscillographic tests after the capacitor is installed.

If tests indicate that the gap is inadequate, ferro-resonance can be eliminated by shunting the capacitor with a resistor or by having a certain minimum load on the transformer side of the capacitor when the bank is energized. Of course, a parallel resistor applied to prevent subsynchronous resonance of motors also prevents ferro-resonance of transformers.

In some cases, such as 2400- or 4160-volt circuits, the voltage rating of a series bank would be very low (and its cost high) if installed directly in the line. To permit application of a capacitor having a higher voltage rating, a transformer in series with the line is sometimes employed to step the voltage up from the required drop in the line to the capacitor rating. Such transformers must be designed carefully to prevent ferro-resonance.

A series capacitor, when installed in a long circuit supplying a transformer of abnormally high steady-state exciting current, may resonate during normal operation at a frequency corresponding to a harmonic component of the exciting current. Fluctuating loads may cause such resonance even though it did not appear when the transformer was energized. Resonance in this case is eliminated by a parallel resistor, by changing the transformer winding, or by replacing the transformer with another having a normal exciting current.

Hunting of Motors during Normal Operation

Hunting of a lightly loaded synchronous motor can be caused by disturbances such as switching of power circuits and changes in load or excitation of the motor itself. Such hunting cannot be directly attributed to resonance. The principal factor in predicting hunting is the ratio of feeder resistance to total feeder reactance (including the series capacitor) between the power source and the motor terminals. If the ratio is less than one and is not negative, hunting is unlikely. Violent hunting of a synchronous motor was encountered upon application of a series capacitor in one instance because the ratio of feeder resistance to reactance was approximately four.

A synchronous motor, when fed through a long line excessively compensated by a series capacitor, may hunt if started during periods of light load. Such hunting is avoided if the power-factor angle of the load (after the motor is started) is equal to or greater than the impedance angle of the circuit (including the capacitor). The tangent of this impedance angle is the ratio of total circuit reactance (feeder reactance minus capacitor reactance) to feeder resistance.

Hunting is not limited to synchronous motors. Series capacitors should not be applied to circuits supplying either synchronous or induction motors driving reciprocating loads such as pumps or compressors. In addition to problems of subsynchronous resonance, the motors once started may hunt, causing objectionable light flicker. The frequency of hunting is sometimes equal to, or a direct multiple of, the frequency of power pulsation, which further aggravates the situation. A cure for hunting may be the installation of a heavy flywheel to increase the rotating mass. However, this solution may enhance the possibility of subsynchronous resonance, which is equally undesirable.

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What's New!

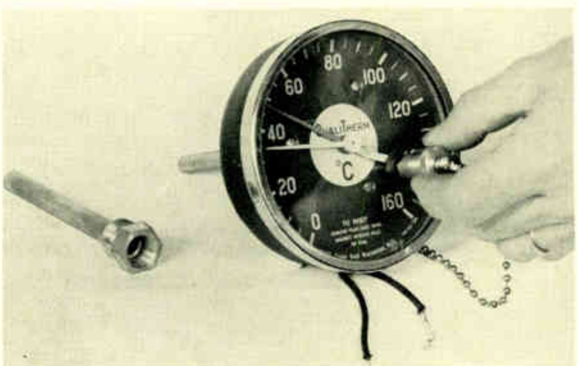
. . . . for Transformers

Automatic Oil Conditioner—Conditioning oil in transformers has long been considered a nuisance job by utility operators. But this operation, so essential to maintain proper functioning, is destined to step out of the "nuisance" class. In fact, at the same time, it will step out of the "job" class, for conditioning will be accomplished automatically and continuously and will require little supervision from maintenance personnel.

Transformer oil is at present reconditioned periodically to remove accumulated moisture, acid, and sludge by a crew of men that travel from substation to substation and transformer to transformer. At each, a filter press is attached to connections at the top and bottom of the tank. Oil is circulated by a pump through the filter and then returned to the transformer. The oil is recirculated several times until tests indicate that it is satisfactorily conditioned.

A new transformer-oil conditioner containing no moving parts accomplishes the same task and does it constantly. The flow of oil from the tank to the conditioner and back again is effected by natural thermosiphon action caused by heat losses in the core and windings. Consequently, an oil pump is not required.

As long as the absorbent material remains effective, the properties of the oil (or Askarel) are maintained essentially the same as the new liquid. The oil should test satisfactorily when the conditioner is installed. If after several years of operation, annual inspection tests indicate deterioration of the oil, the conditioner is simply replaced. Trial installations over a four-year period have demonstrated that the conditioner holds dielectric strength,



power factor, neutralization number, and interfacial tension to values required by good operating practice.

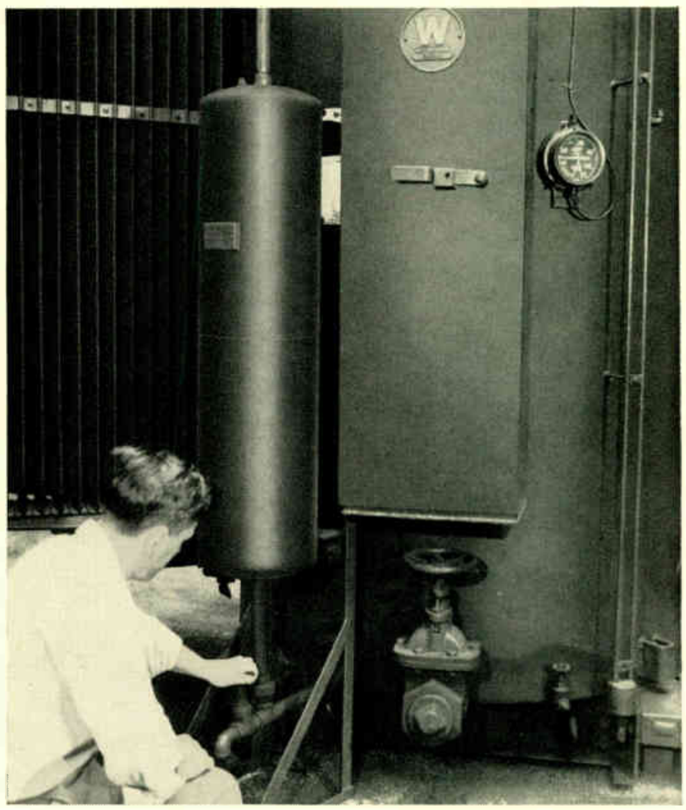
The conditioner consists of an all-welded steel tank, about four feet long and twelve inches in diameter, filled with conditioning agent in granules roughly ¼ to ½ inch in size. The granules provide abundant surface of contact and assure ready passage of the insulating liquid.

From one to four thermosiphon oil conditioners are required, depending on the amount of oil in the transformer and its design. On existing transformers, the conditioners are mounted with a pipe support to the ground. Oil connections are made to the top filter-press connection and to either the bottom filter-press connection or to the main drain.

High-Visibility Temperature Indicator—A new highly accurate temperature indicator can be read even under the worst conditions of visibility. This high degree of visibility is assured by contrasting colors between the background and the hands and numerals, a uniform scale, and shockproof and weatherproof construction, which eliminates fogging of the glass. In such construction, resetting of the maximum-temperature indicating hand cannot be accomplished by the usual knob protruding through the glass. Consequently the hand is reset by "wiping" a small magnet over the face of the cover glass. The magnet, which is screwed into a hub on the side of the instrument for safekeeping when not in use, is attached to a light chain to prevent loss. The temperature indicator can be furnished with an alarm contact that indicates when a preset temperature is reached. An oil-tight mounting will permit removal and reinstallation of the unit without changing the oil level or disconnecting the transformer.

High-Visibility, Liquid-Level Indicator—Companion to the temperature indicator is an instrument to indicate the level of liquid in the transformer tank. It consists of two separate, independently replaceable assemblies, each oil tight and weatherproof so that it is impossible for fluid to reach or affect the scale. The bezel or outer assembly includes the calibrated dial and the indicating needle, which is directly mounted on a shaft carrying a powerful magnet. The bezel covers and protects the mounting screws with which the body is attached to the tank wall. The body encloses another powerful magnet directly coupled through a shaft to the float arm. Any motion of the float arm rotates the body magnet, whose magnetic force acts through the separating walls and displaces the bezel magnet and the indicating needle. The instrument can be furnished with an alarm contact for low-level indication whenever the fluid falls below a predetermined level.

The magnetic temperature indicator (extreme left) is reset by an external magnet. At left is the liquid-level indicator. The oil conditioner (below) maintains the qualities of transformer liquids.



. . . . in Lighting

Shock- and Fire-Resisting Fixtures—Two new-type lighting fixtures have been developed for the Navy, which is seeking to improve lighting conditions aboard ship. The fixtures, one for fluorescent and the other for incandescent lamps, are built to resist both shock and fire conditions to which Navy equipment may be subjected. Manufactured from aluminum and a translucent plastic, the units will withstand a shock impact of 2000 foot-pounds. When enveloped by fire, the plastic produces chiefly nitrogen, which because it is inert helps smother the flames. The plastic, which is used both to reflect and transmit light, is a glass-melamine Micarta developed during the war and first used for building shipboard electrical control panels.

The fluorescent fixture is about two feet long and contains two 20-watt lamps. The sides are curved and made of the plastic while the remainder of the unit is aluminum covered by white enamel. This construction provides a combination of both indirect and direct lighting. The incandescent fixture is built in two sizes, 8 and 13 inches in diameter, for 50- and 150-watt bulbs respectively. Each is made solely of the plastic. The 150-watt unit transmits about two thirds of the light directly and one third indirectly. Metal louvers below the lamps on both fluorescent and incandescent fixtures provide diffusion of light and avoid direct glare. The units are now under test by the Navy.

A Smaller Spotlight and Floodlight—Although hundreds of types of lamps exist in most every size, shape, and color, lighting applications demand that additional light sources be developed. Two new 75-watt lamps, a spotlight and a floodlight, provide flexibility where small, inconspicuous illuminants are needed.

These mushroom-shaped, hermetically sealed, internal-reflector lamps are the smallest available for 115-, 120-, and 125-volt service. Each is only 5³⁄₁₆ inches in overall length and 3¾ inches in diameter. Designated as R-30, the lamps supplement the larger 150- and 300-watt units. The spotlight, which produces a sharp, narrow beam, is recommended for lighting small areas with intense illumination, whereas the broad, diffuse beam of the floodlight is best for larger areas and lower intensities.

One-Watt Fluorescent Light—Having overcome production obstacles, the 115-volt, one-watt fluorescent lamp is now available in quantity. The walnut-size lamp, which costs less than one-tenth of a cent to operate for a 24-hour day, has an average life of one year. It has a two-prong base for wall outlets.

Invisible ultraviolet light, which is generated inside the lamp by an electrical discharge through a rare gas, is converted to visible by the phosphor coating. A tiny resistance in the base serves as a ballasting unit.

Streamlined Automotive Accessory Lamps—A new 25-watt, 6- to 8-volt utility lamp, with a 4½-inch sealed-beam bulb provides a portable emergency light when plugged into the cigarette lighter of an automobile. This lamp can also be mounted permanently on the rear of a car to light the motorist's path when he travels in reverse, as when backing out of a garage.

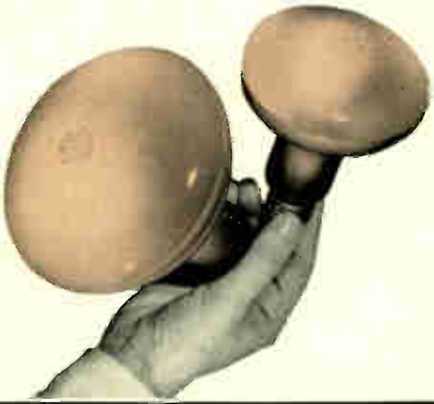
Matching the new utility lamp are four other automotive lamps of the same dimensions and construction. These are 35-watt fog lamps with either an amber or a clear lens and 30-watt spotlights with or without a filament shield that produces a narrower beam spread.

In addition, a new, larger 12-volt, 40-watt spotlight has been developed for trucks, buses, and marine craft. Its range is approximately one-half mile.

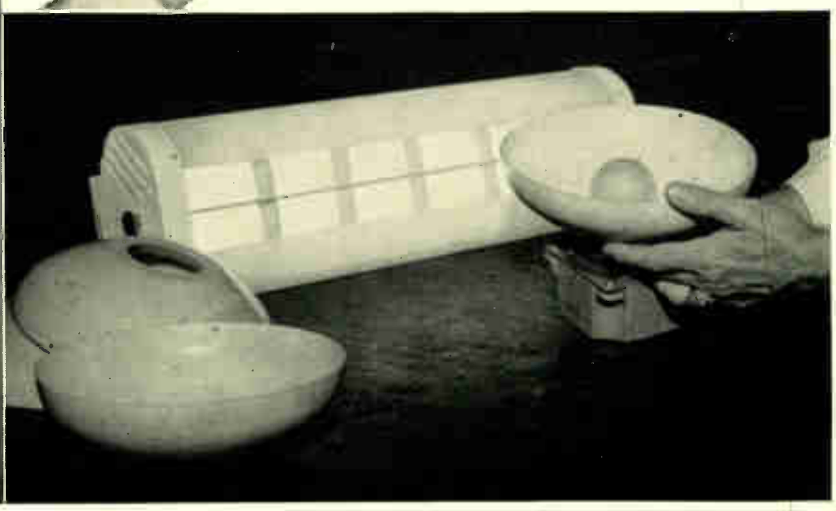
. . . . in Literature

Network Protectors—Low-voltage secondary networks, in which the primaries and secondaries of the transformers are interconnected, provide better voltage regulation and may reduce the transformer capacity required to supply a certain load. The network protector, which connects the transformer to secondary mains, assures proper operation of the system in event of primary or secondary faults or reverse current. The CM-88 protector, which is built in ratings of 75 and 150 kva for outlying business sections and heavily loaded residential areas, is described in booklet B-3977 (24 pages). Operation, features, and control relays of the protector are discussed.

Dry-Type Transformers—Dry-type transformers are taking over in many an application formerly the bailiwick of the liquid-filled type. Dry-type units are now built in capacities ranging from a fraction of a kva (for toys, controls, etc.) to several thousand (for power centers.) Features, advantages, and applications of standard and special units in all sizes are discussed in booklet B-4009 (12 pages).



The new 75-watt floodlight (right) is compared to the companion 150-watt. The one-watt fluorescent lamp (below left). The shock- and fire-resistant lighting fixtures for vessels of the U.S. Navy (below right).



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Electronic Tube Data—Data concerning functions, prices, characteristics, and interchangeability of electronic tubes is given in Catalog 86-020 (16 pages). Sheet numbers containing detailed information on individual tubes are listed.

Mercury-Vapor Streetlighting—Mercury-vapor lamps, with their advantages of greater efficiency, less maintenance, and lower cost per lumen, are cutting an important niche in streetlighting. Information on types of lamps, photometric curves, and operation is given in booklet B-3876. A typical situation is analyzed from the application and cost viewpoints.

Electric Heating Guide—A 42-page illustrated manual, "Electric Heating for Homes" (B-3768-A), provides to contractors, architects, and engineers a practical guide for the design and installation of home-heating equipment. It reduces the usually complicated procedure of selecting the required heating capacity for a room to the simple process of selecting data from the proper charts. The charts take into consideration such factors as floor area, window area, single- or double-pane glass, degree of insulation, and number of exposed walls. Information is included on the selection, location, and installation of unit heaters, determination of wire sizes for electrical circuits, and climatic conditions of various sections of the country. The price is two dollars.

Electric Heating Units—For high accuracy of control and low heat waste, electric heaters are hard to beat. Increasing quantities of such units are being built into equipment for domestic, commercial, and industrial applications. The story of the many sizes and forms that they and their controls take is told in the 24 pages of Catalog 28-020. The catalog contains a complete description, prices, dimensions of strip, oven, immersion, and cartridge heaters, glue and solder melting pots, thermostats, switches, and contactors. A quick-finder index and technical application data make the information easy to find and the equipment easy to apply.

Motor Book—"Fractional-Horsepower Electric Motors," by Cyril G. Veinott, Manager of the Westinghouse Industrial Motor Section, Small Motor Division, has been completely revised by the author. The book, which contains practical information for repairmen, engineers, and salesmen, covers principles of operation, repair, windings, and construction features of common and special types of small motors. The scope of the book varies from a discussion of stripping, impregnating, and baking of windings to application, selection, and testing of motors. The appendix includes a trouble-diagnosis chart, a glossary of terms, and a list of visual training aids (motion pictures and film strips—available from manufacturers and other organizations). The 554-page book is published by McGraw-Hill Book Company, Inc., New York, and sells for four dollars.

Cathodic Protection against Corrosion—Corrosion of underground pipe lines, gas lines, and cables, is usually caused by stray or electrolytic d-c currents departing from the structure. It is prevented by cathodic protection, which consists of passing direct current between ground and the pipe in such a direction as to prevent corrosion. Oil-immersed copper-oxide rectifiers are employed to supply direct current. The theory of cathodic protection is further explained and features and ratings of rectifiers are given in booklet B-3996 (8 pages.)

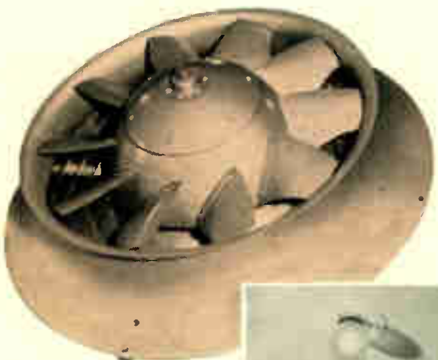
These booklets can be obtained by writing to *Westinghouse* ENGINEER, P.O. Box 1017, Pittsburgh (30), Pa.

. . . . in Welding

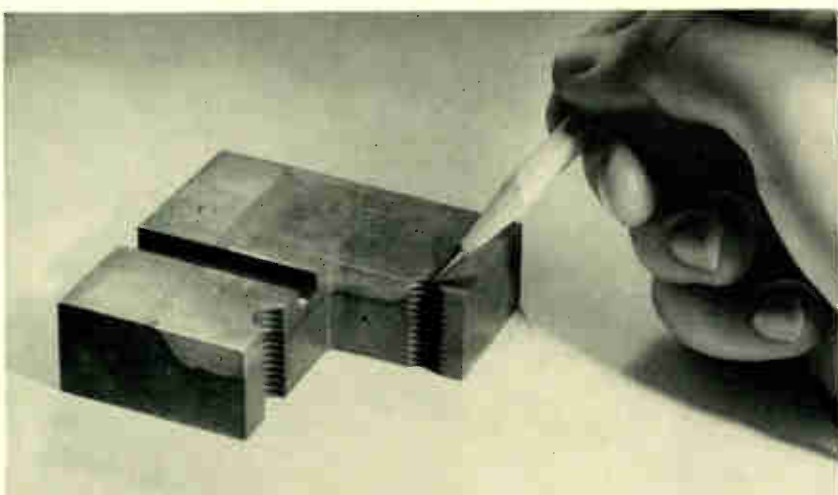
Electrodes—During recent months, new electrodes have been coming from the development laboratory on almost a production basis. Two of these, Freemachineweld and Castingweld are for welding cast iron. Freemachineweld deposits metallic nickel to produce soft, readily machined welds in cast iron. It is used to salvage defective castings and incorrectly machined castings, as well as those broken in service. Castingweld deposits high-strength carbon steel. While the deposit is not machineable, due to carbon pickup from the cast iron, its much lower cost recommends it for repairs that do not require machining.

LoH (contraction of low hydrogen) is the outgrowth of wartime research that disclosed hydrogen, dissolved in molten metal and subsequently trapped in the solidified steel, as the cause of underbead cracking in alloy-steel welding. In addition to welding alloy steels satisfactorily, it is also used on high-sulphur and high-carbon steels.

Five hard-surfacing electrodes (Hardentough 250, 350, 450, 550 and W.H.) are effective in rebuilding worn parts and supply-



The ventilating fan (left); installed (below right). Freemachineweld deposited without preheating on cast iron (below left) was subjected to five operations—drilling, tapping, milling, shaping, and sawing.



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ing harder surfaces to resist impact and abrasive wear. They derive abrasion resistance from the presence of carbon and chromium as extremely hard chromium carbides. Hardentough 250 (average Brinell hardness of 250) deposits machineable metal for repair of shafts and similar worn parts. Hardentough 350 and 450 are of intermediate hardness. Their deposits are not machineable but they have good resistance to impact and moderate resistance to abrasion. Hardentough 550 is high in alloying ingredients which imparts higher hardness and superior abrasion resistance. Hardentough W.H. is moderately hard as welded, but when subjected to severe impact it hardens to over 500 Brinell on the surface. It thus provides a very tough under deposit that will stand severe impact and a hard outer surface for high abrasion resistance.

Sixteen grades of stainless steel, comprising both the chromium-nickel and straight chromium types were developed. Most of these are available with two different coatings—a titania lime coating for both a-c and d-c welding machines, and a lime coating for d-c reverse polarity only.

. . . . in Ventilation

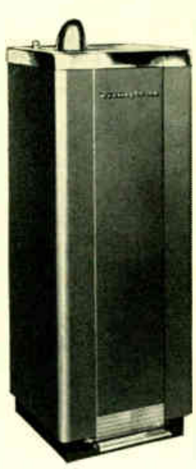
Of Public Conveyances—Good news is in the wind for travelers who during the passing summer have gasped for a breath of fresh air on crowded, stuffy streetcars, subways, and buses. It comes in the form of a redesigned model of a powerful fan developed during the war to ventilate hulls of Navy ships. A ventilation system having four such fans keeps a streetcar about eight degrees cooler and provides about ten times as much fresh air as is supplied by present systems.

The fan itself occupies only sixty percent as much space as a standard fan of the same air capacity, 3500 cubic feet per minute. It has a high efficiency, attributed largely to its axial-flow design. (Standard, ventilating fans are usually of the propeller type.) The fan consists of a 23-inch aluminum wheel mounted on a motor shaft. Both wheel and motor are encased to assure that stray air currents do not pass off the sides of the fan and that the air is kept moving forward.

A ventilation system employing these fans operates with the windows closed, even during the hottest summer weather. The speed of the fans is controlled by thermostats so that the amount of air circulated through the car varies with fluctuations in temperature. The fans are mounted in the ceiling and receive their air supply through inlet grills. Air is discharged into the car uniformly through five concentric metal rings that diffuse the flow. A gentle breeze is created, without the usual direct blast or draft. The system is called pressure ventilation because fresh air is forced into the car at a pressure that is low but sufficient to minimize the amount of air entering from other points. Air leaves from openings in the car body.

During the summer, air is not recirculated. During the winter, however, the fans operate and part of the air is recirculated.

. . . . for Office and Factory



Water Cooler—The remaining days of summer are being made more comfortable by a new line of water coolers guaranteed against electrical or mechanical defects for a period of five years. The coolers feature hermetically sealed refrigeration and lubrication systems that assure a long, trouble-free, and dust- and dirt-free life and eliminate belts, shaft seals, and flared connections. Other outstanding features include a new pedal control, automatic stream-height control, and built-in carafe (a glass water bottle) filler. The coolers are finished in blue-grey baked enamel.

. . . . for Industry

Wound-Rotor Lifeline Motor—The Lifeline family of motors continues to be prolific. First started in the polyphase, squirrel-cage induction type, the single-phase motor and the gearmotor have been added. The most recent offspring is the wound-rotor motor—and still others have been conceived.

The wound-rotor unit, like the squirrel-cage, is built in sizes of 1 to 15 horsepower (frames 203 to 326), for a variety of speeds, voltages, and frequencies. It is of open, drip-proof construction and is available with several types of flanges or brackets for horizontal or vertical mounting.

Lifeline features were incorporated into the design wherever possible. The frame, feet, and pulley end bracket are steel. The slip-ring end bracket is close-grained grey cast iron. Sealed prelubricated ball bearings normally require no further lubrication for at least five years. The motors have sliding box-type brushholders that provide adjustable spring tension, uniform pressure, and consistent wear along the surface.

. . . . for Airports

Portable Marker Lights—To deter the possibility of an airplane pilot guiding his craft into an unseen obstruction is the function of two portable highway markers. The markers are used to indicate temporary obstructions such as soft spots on the runways or landing strips, new construction work, and damaged aircraft. They are also employed on highways to identify road blocks and to isolate streets during fire or accident.

One of the markers is suitable for either day or night use and the other is for night use only. Both contain as a light source a coiled neon-tube lamp, which is flashed 120 times a minute. The lamp is powered by a dry-type battery whose average life is 150 hours. For obstruction marking, a red lamp approximately equivalent to a 2-watt incandescent is employed. White, gold, green, or blue lamps are available for other applications. The lamp housing is of clear glassware in all cases. For day as well as night use, one unit contains the flashing lamp mounted on a large, clearly visible orange cone. The battery housing is cast aluminum and the cone is lead-coated steel. All internal parts are of non-ferrous, non-corrosive materials. The weight and height of the nighttime marker are 22 pounds and 14⅝ inches; of the combination marker, 34 pounds and 30½ inches.

Large Wind Cone—Airplanes take off and land against the wind so that the necessary air speed is acquired with a lower ground speed and less runway distance. A new wind cone, three feet in diameter by twelve feet long, indicates wind direction with a high degree of visibility and a high degree of response. Sealed-in ball bearings give a positive indication with the slightest breeze. The unit, which is intended for larger airports, is available for beacon-tower or pipe mounting and with or without complete external and obstruction lighting.

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Personality Profiles

The route by which *R. E. Kirby* became an electronics expert has been devious. After graduating in 1939 from Penn State College with a degree in Chemical Engineering, he joined the West Virginia Pulp and Paper Company at Tyrone and became assistant superintendent of the pulp mill. Kirby's career in electronics began in 1943, when he was commissioned in the Navy and undertook an advanced electronics program that sent him to Princeton, MIT, and Bell Laboratories. While overseas as an Electronics Officer his interest in radio-frequency heating was aroused by an article, by co-author Kinn, in the IRE Proceedings. Upon his return to civilian life in 1946, he joined Westinghouse under Kinn in the Industrial Electronics Division and has concentrated on the application of r-f heating to industry.

Kirby finds r-f heating particularly fascinating because of its use in manufacturing the tools of his favorite sports, tennis and golf. His visits to plants in the interests of r-f application have enabled him to observe at first hand the construction of laminated tennis rackets and golf-club heads, assembled with the aid of r-f heat.

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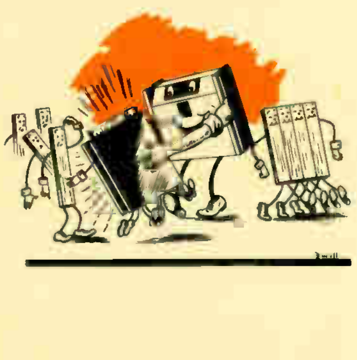
The life of *T. P. Kinn* has been influenced by a number of Westinghouse "greats." In 1928, during an AIEE convention at the University of Colorado, Kinn had the opportunity to act as guide for Dr. Joseph Slepian, noted for his fundamental work in arc interruption. Dr. Slepian persuaded him to join Westinghouse, which he did in June after graduating with a B.S. in Electrical Engineering. Hearing that Westinghouse needed engineers for radio-development work, Kinn was interviewed by Dr. L. W. Chubb, then in charge of radio research and now Director Emeritus of the Research Laboratories. Dr. Chubb assigned him to the Radio Division, under Dr. J. A. Hutcheson, the present Director of Research.

Kinn has been active in many phases of radio. He has been a "ham" ever since his youth. His activities with the Company include development of mobile and stationary equipment for aircraft, marine, and civilian operations, the first portable radio system for the Marines, the first all-wave submarine transmitter, the 500-watt transmitter for Station WLW, Baltimore (then the world's largest), and the installation of a railroad radio in 1937 at the East Pittsburgh Works. Kinn, who "punched" cattle in Colorado, avers that these "critters" are much more difficult to handle than billions of orderly, well-behaved electrons.



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Since his last appearance on these pages in September 1944, *G. L. Moses* has been honored with two awards. One as co-author of an article on the application of silicone insulation that received the AIEE best-paper award and the other from the Navy for war work on insulation development. All of which points to his wide experience in the insulation field, in which he has been active for the last eleven years.

Moses' direct contact with insulation problems began when he joined Westinghouse shortly after graduating from Bliss Electrical School in 1923. He was first engaged in Railway Sales, where he became familiar with the difficult conditions under which traction motors and their insulations must operate. In fact, he was so much impressed that he investigated the problem thoroughly and authored several papers on the subject. Leaving Railway Sales, Moses spent eight years in Renewal Parts Engineering and five in Railway Control Engineering. He then joined the Development Insulation Section, which he now heads.

An engineer of long experience, Moses believes in doing things the easy, efficient way. A fisherman, he is building a cabin on the shores of a mountain stream, so that he can do his casting from the front porch.

• • •

William Schneider, in addition to being an engineer, is also somewhat of a linguist. He studied six languages, five of which—German, French, Spanish, Latin, and Greek—he acquired before coming to America from Germany in 1930. The sixth, English, he learned in high school in America.

Schneider entered Carnegie Institute of Technology, graduating in 1936 with a Bachelor of Mechanical Engineering degree. Forthwith, he joined Westinghouse and was assigned to the design of large a-c machinery. In 1939, he was assigned to similar work on ignitrons.

In 1945, the war just ending, reconversion problems called for larger numbers of engineers. As such men were not available in the Pittsburgh area in the quantity required, a branch engineering office, using local technicians, was opened in New York. To help establish this operation, Schneider was sent to New York City "for a couple of weeks." But there he remained for almost two years, taking complete charge. Under his guidance, the design of all types of a-c equipment was accomplished. When the office closed in 1946, Schneider returned to East Pittsburgh, and was made Manager of the Commercial Insulation Section shortly thereafter.

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W. W. Satterlee has become a successful transformer design engineer, but not by the usual route. After graduating from high school where he telescoped the usual four years into three he served his apprenticeship as a machinist and became an expert machine operator and tool maker. For ten years he worked at his trade, until 1918 when his job at a firearms company in Meriden, Connecticut, suddenly became nonexistent at the end of World War I. Satterlee decided that this was the moment to make a radical break and explore the possibilities of becoming an engineer, which had always attracted him. Courses taken in mechanical engineering from International Correspondence Schools qualified him for a job as a draftsman in the Transformer Divison.

Drafting was all right but Bill Satterlee still wanted to be an engineer. Westinghouse Technical Night School was now open to him. His interest in the subject so impressed the Westinghouse engineers who taught some of the courses that in June, 1922 he was called into the front office and told that he was now a transformer design engineer.

From then on, his progress was continuous. In 1945 he received the silver W, highest award that Westinghouse can tender to its employes, for his work on core-form and dry-type power transformers. He is now division engineer.

Back in 1936 when color photography was new, he became interested in it. His movie camera not only became part of his vacation equipment but also served in his work as well. One of his color movies is a complete record of the design and manufacture of a network transformer.

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Pictures from the Sky

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