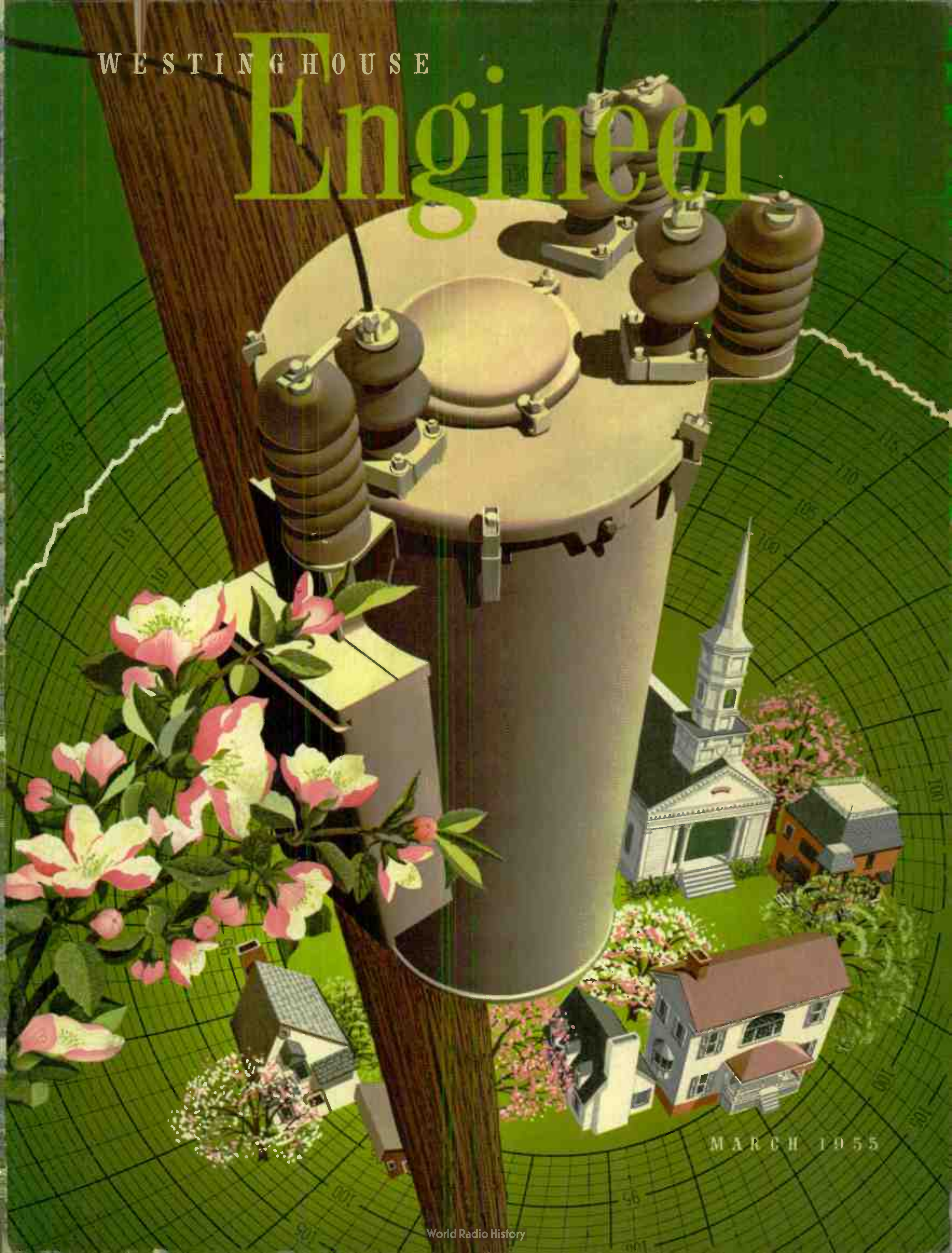
WESTINGHOUSE Engineer



MARCH 1955

Engineering Problems— An Endless Procession

Engineers thrive on problems. And it's a good thing they do, because in their day-by-day tasks they certainly run into just about every size, shape, and description. Many tax the imagination, and others merely tax the patience. And some do both. There are problems that require a whole new concept or approach, while others require but relatively minor changes in an older concept.

Engineering problems run the gamut from the simple to the staggering, but few are monotonous or dull to the engineer with imagination and zeal for his work. Consider a few random examples of recent engineering tasks.

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Coil winding is not ordinarily thought of as a noteworthy event. However, it's a different matter when the spools for the magnets are 15 feet in diameter and 15 feet long and the "wire" consists of hollow copper bar slightly more than an inch square and weighing 22 tons. A completed magnet is 22 feet in diameter and weighs 38 tons. Two such magnets were wound last year as boosters for the huge cyclotron at the University of California.

To provide a turntable for this super-sized winding job, a rotating-type crane was borrowed from a local shipyard. It was inverted and a winch motor installed underneath to rotate it slowly.

The copper bar—a little over an inch in each dimension with an extruded hole for water cooling—came in 65-foot lengths. These were joined by sleeves heated with special torches and soldered. Each joint was tested for tightness up to 600 pounds pressure of Freon with an electronic mass spectrometer searching for leaks. After soldering, the "wire" had to be straightened, wound with two layers of glass tape and fed to the slowly turning spool. Each of the 12 layers contains 18 turns. Each layer is held in place by a stainless-steel band under tension of one ton.

Embedding (i.e., potting) magnetic amplifiers, transformers, selenium rectifiers, small vacuum tubes, and other circuit elements in plastic provides components that are impervious to moisture, highly resistant to shock, and otherwise indifferent to outside influences. But the elements may be subjected to considerable internal influence. In reacting into solid form, the potting resins shrink and set up pressures on the elements. The added stresses created by environmental factors, such as thermal and mechanical shock, may cause the resin to crack or cause malfunction of some of the "protected" components.

A study to determine these internal stresses is under way. The potting material is cast around a sensing element containing strain gauges. Measurements can be made not only as the resins set but also as the finished component is exposed to temperatures from −65 to 85 degrees C.

The effects of many variables—various resins, type, particle size, and concentration of filler material, different plasticizers and catalysts, and various curing cycles—are being explored.

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Each of the three rows of rotating blades of the axial-flow compressor for the 216 000-hp transonic wind tunnel at Tullahoma is a disc 18 feet in diameter, rimmed by six-foot-long blades. A complete bladed disc is 30 feet in diameter and weighs 82 500 pounds. The discs with spacers between are bolted together to form the rotor of the compressor.

How to balance such an immense structure presented a formidable problem. Its physical size made dynamic balancing at the factory impossible. To provide a highly accurate static balance, an ingenious special machine was devised to balance separately the components of the rotor. Also, to eliminate unbalance due to tolerances in the 1200-pound blades, each blade was weighed and its center of gravity determined, so that the row of blades could be arranged on the disc in a balanced condition.

The balancing machine for the rotor disc consists of a flat-surfaced horizontal table about nine feet in diameter, with a spherical seat about three feet in diameter. If the table and its load are not in perfect static balance, the table tilts. Oil is supplied to the bearing under pressure to float the table and disc on a film of oil, giving a nearly frictionless support.

The tilt is noted by a pair of indicators mounted under the discs 180 degrees apart. The disc is rotated through four quarter revolutions and readings taken at each quadrant. From the data thus obtained, the location and amount of unbalance is computed.

The machine is so sensitive that, even though the total weight of the table and disc is nearly 50 tons, a silver dollar placed on the hub of the blades causes a tilt.

• • •

There are times when a big synchronous motor should just creep. Fundamentally there is just one way to cause a synchronous motor of several thousand horsepower, normally running, say, at 900 rpm, to run at 8 or 10 rpm. That is to reduce the power-supply frequency accordingly.

Various ways of doing this have been tried. They work, but all leave something to be desired, usually by way of cost or complexity.

A new scheme gives better results. The circuitry is too involved to describe briefly but the equipment consists simply of two sets of rotating machines. One is a pair of motor-driven Rototrols on the same shaft and connected to oppose each other. By control of the time delay in their common circuit, the power between them is made to oscillate at a low rate—from one half to two cycles per second. This signal is fed to three motor-driven exciters, which are connected in Scott-T connection to give balanced three-phase power at whatever rate the Rototrols are oscillating. While these are rotating machines, they are physically small. For a 4000-hp synchronous motor built for a steel mill, the exciters have to develop only 28 kw each.

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Gyroscopes have always held a special fascination for young and old. The drive motor for a recent new one becomes particularly interesting because of the small numbers attached to it. This tiny unit develops only 10 000 cgs units of angular momentum (generally this number is in the millions). It operates at 8000 rpm. There is no power output except when the gyro precesses, but the internal power developed to spin the flywheel is approximately 0.0003 hp. Power consumption is between two and three watts. The spin-motor rotor weighs less than one ounce and has an outside diameter of slightly over one inch. It runs on a preloaded pair of ball bearings whose diameter is only 0.3125 inch and which use 1/16-inch steel balls. The stator core, containing the winding, has an outside diameter of 0.8 inch. The shaft, which is stationary and serves to mount the motor, is less than a tenth of an inch in diameter. All parts are machined to tolerances of about 0.2 mil and then parts are selectively matched for even greater accuracy of fit. RWD

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The Cover

The inconspicuous voltage regulator is a silent "watchdog" over voltage levels in distribution systems. It does its job so quietly and so well that it is seldom noticed. On this month's cover, artist Dick Marsh portrays pictorially the function of these regulators.

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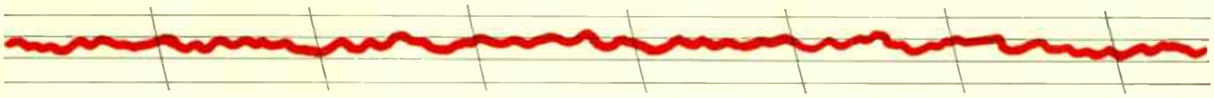
Controlling Voltage in Distribution Systems



H. E. Lokay, *Electric Utility Section, Industry Engineering Dept., Westinghouse Electric Corp., East Pittsburgh, Pa.*

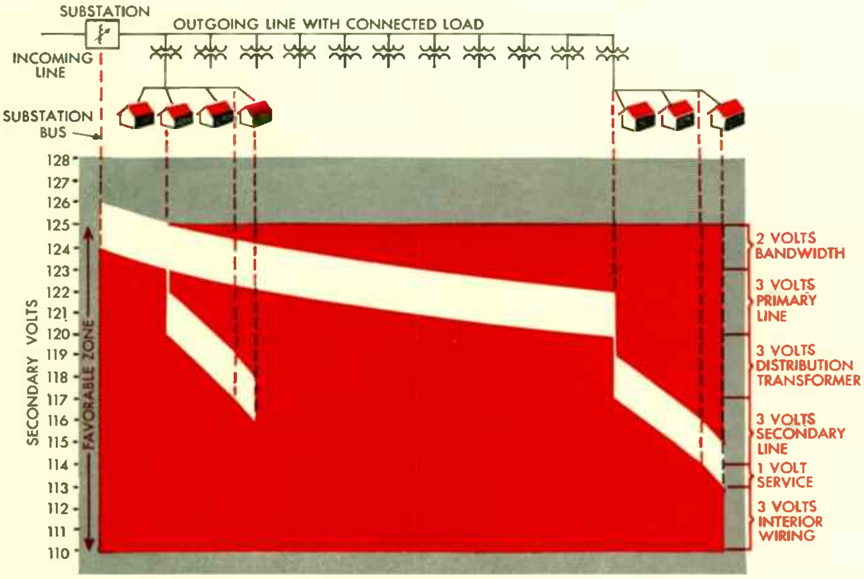


Fig. 1—A voltage profile of a residential feeder. Full-load voltage drops allocated to each of the different feeder components are indicated at right, totaling 15 volts.

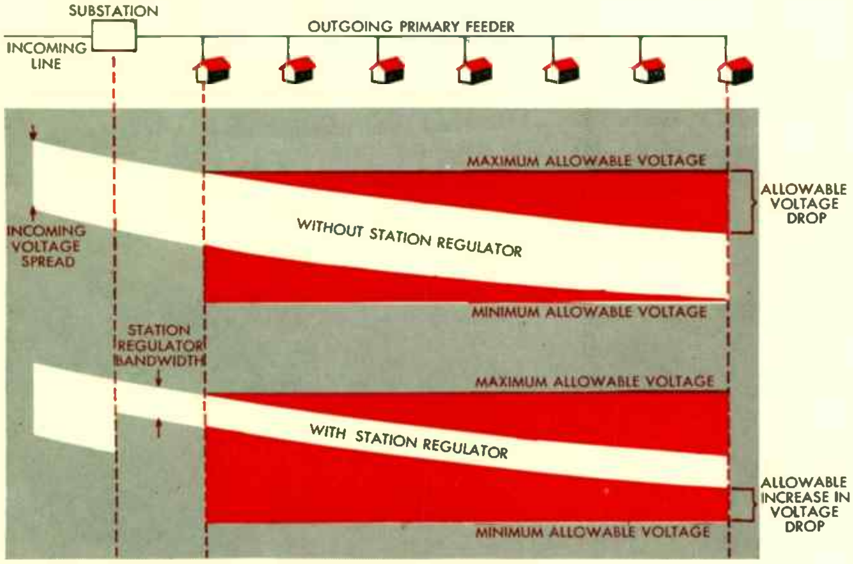


Fig. 2—A full-load voltage profile of the same feeder with and without a substation regulator. Note that substation regulator increases allowable feeder-voltage drop.

Most electrical equipment is designed for best operation within certain voltage limits. The task of keeping voltage on the relatively "straight and narrow path," thus insuring that it arrives at the equipment within these limits, falls to the voltage regulator.

Because of rapid growth of new loads, proper voltage control in distribution systems is becoming an increasingly important and necessary requisite of economic[1] and efficient operation. This necessitates judicious application of voltage control in the system to obtain maximum flexibility with a minimum of investment.

The voltage spread (i.e., the range between maximum and minimum levels) at the service entrance, which results in proper utilization voltage at the consumer's equipment, forms the basis of voltage control throughout any system. This, in turn, requires a correlation of operating-voltage spreads within the entire distribution system.

System-Voltage Spreads and Voltage Drops

Voltage spreads at various points in the system and voltage drops of system components must be known to determine the right method and regulator for voltage control. A typical combination of voltage spreads and drops is listed in Tables I and II[2]. A 120-volt base is assumed throughout. For instance, with a ten-volt feeder drop, a two-volt bandwidth for any voltage-regulating equipment on the system, and an average drop of three volts in the consumer's interior

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This is the first section of a two-part article; the second section, which will appear in the next issue, will discuss capacitors for voltage control.

wiring, the minimum utilization voltage is 110 volts—the lowest value of the favorable zone.

Feeders serving only industrial loads are similar to rural feeders, because the distribution transformer is located at the industrial plant with no secondary line. Also, if the industrial load is relatively small and other residential loads are served from the same feeder, it can be handled as a residential feeder. The exception is when the industrial load is at the end of the feeder, in which case the rural voltage-drop combination is applicable.

The voltage spreads of Table I conform to the allowable voltage drops of the system components. Voltage drops for each system component are shown in Table II. A profile of residential feeder with the voltage drops allotted to each feeder component is shown in Fig. 1.

Methods of Controlling Voltage

The voltage in a distribution system can be controlled at the source or generator location, at substations throughout the distribution system, and along the primary feeders. Where the generator feeds directly into the distribution system, the generator bus voltage can be regulated economically to keep a constant voltage at the load center for any load condition. In large systems, generator-voltage regulators usually are used only to maintain the desired bus voltage for prevailing load conditions, and reactive power-flow requirements.

In Table III, various methods of improving voltage regulation on existing distribution systems, and their advantages and disadvantages, are cited (proper generator-voltage control is assumed).

Economic system design usually dictates use of voltage regulators in substations to control the output voltage spread. Without regulators, the voltage spread on the incoming side of the substation would be passed along the feeder (Fig. 2). Since the allowable feeder-voltage drop is the difference between the service-entrance spread and the substation-output spread, substation regulators make possible an increased allowable feeder-voltage drop and greater load-carrying ability. Maximum output voltage, of course, is limited by the nearest customer. Regulators can be applied in substations for bus regulation or individual feeder regulation (Figs. 3 and 4).

Bus Regulation—Bus regulation, i.e., holding the voltage of a substation bus within fixed predetermined limits, is accomplished by tap-changing-under load (LTC) mechanisms within the substa-

TABLE I—VOLTAGE SPREADS AND LEVELS*

Location	Residential Feeder			Rural Feeder		
	Voltage Level		Voltage Spread	Voltage Level		Voltage Spread
	Maximum	Minimum		Maximum	Minimum	
Point of utilization	125	110	15	125	110	15
Service entrance	125	113	12	125	113	12
Distribution transformer (Primary side)	125	120	5	125	118	7
Substation bus†						
Full load	125	123	2	125	123	2
Light load	123	121	2	123	121	2
Substation transformer output	132	115	17	132	115	17

*Table assumes 120-volt secondary base and utilization voltage to keep within EEI-NEMA favorable zone.

†Assumes no express feeder drop to first distribution transformer. Voltage level values would be raised by the amount of this drop if there were an express portion.

TABLE II—VOLTAGE DROPS FOR SYSTEM DESIGN AT FULL-LOAD CONDITIONS*

Portion of Feeder	Residential Feeder	Rural Feeder
From first distribution transformer to last distribution transformer	3 volts	5 volts
Distribution transformer	3 volts	3 volts
Secondary line	3 volts	—
Service line	1 volt	2 volts
Total	10 volts	10 volts

*Table assumes 120-volt secondary base and utilization voltage to keep within EEI-NEMA favorable zone. Values are not rigid, in that other combinations may be possible.

TABLE III—METHODS OF IMPROVING VOLTAGE REGULATION

Method	Conditions That Dictate Its Use	Advantages	Disadvantages
Increasing conductor sizes.	When the load on feeders increases to where low-voltage conditions cannot be economically corrected with regulators and/or capacitors. Long-range planning.	Reduces line losses. Some lamp flicker improvement.	Expensive. Not flexible. Reclaim value probably low.
Increasing primary voltage.	Necessity for long feeders due to lack of substation sites and increased load area.	Lower losses when serving same load. Voltage drop decreases by square of voltage increase. Longer lines possible. Reduces lamp flicker. May not be too expensive if going from a delta to a wye system.	Expensive. Reclaim value may be low. May require lineman educational program.
Changing lines from single to multi-phase.	Necessity of feeding three-phase loads. Increasing load on single-phase line. Long-range planning.	Can serve three-phase loads. Increased load-carrying ability. When going from 1ϕ to 3ϕ with same load, voltage drop is reduced to ⅙. When going from 1ϕ to 2ϕ drop is reduced to ½.	Expensive.
Transferring loads to new feeders.	Heavily overloaded feeders. Extra large load on feeder.	Reduces voltage drop on feeder. New feeders can be at a higher voltage. Possible increase in load-carrying ability.	Expensive. Requires feeder right of ways. Must be able to get away from substation.
Installing new substations and primary feeders.	Increased load. Long-range planning.	Relieves heavy loaded feeders by transfer of loads. More than one power source is available in area.	Expensive. Substation sites may be hard to find. New right of ways needed for both subtransmission lines and new primary feeders. May be substation getaway problems if new feeders added to existing substations.
Installing regulators at substation.	Wide voltage variation of incoming subtransmission line.	Bus voltage can be held constant or made to rise with increasing load. Not as expensive as reinforcing each feeder. High reclaim value. Easily installed.	Requires some maintenance. Will not relieve excessive voltage drop on feeder.
Installing regulators out along feeders.	Excessive voltage drop on primary feeder. High voltage on feeder during light-load conditions.	Will maintain correct voltage regardless of load conditions. Easily installed. High reclaim value. Can be used for obtaining correct voltage during emergency and reconstruction periods. Low cost. May allow increased feeder loading.	Requires some maintenance. Does not reduce line losses.
Installing switched capacitors.	Increasing use of low power-factor loads.	Provides reactive kva. Improves power factor. Can be located at substation or out on feeder. Low cost. Easily installed. High reclaim value. Releases system capacity.	Must be switched to improve voltage regulation. Must be coordinated with other voltage-regulating equipment. Does not correct for IR line drop.

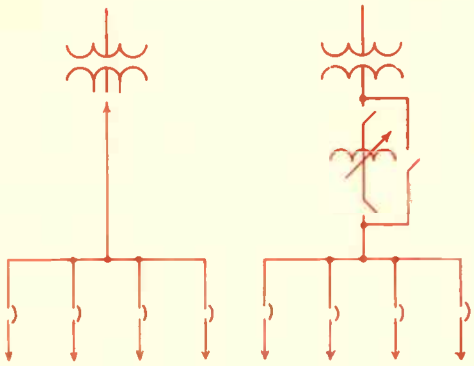


Fig. 3—A simplified schematic diagram showing bus regulation.

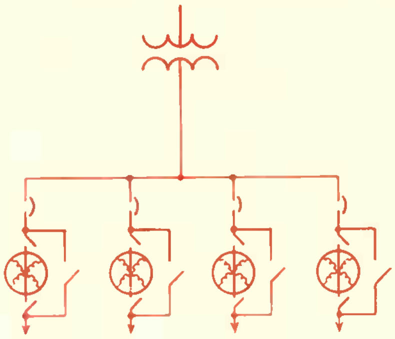


Fig. 4—A similar diagram shows individual-feeder regulation.

Fig. 5—Regulators applied to distribution feeders remote from the substation correct excessive voltage drop on the line.

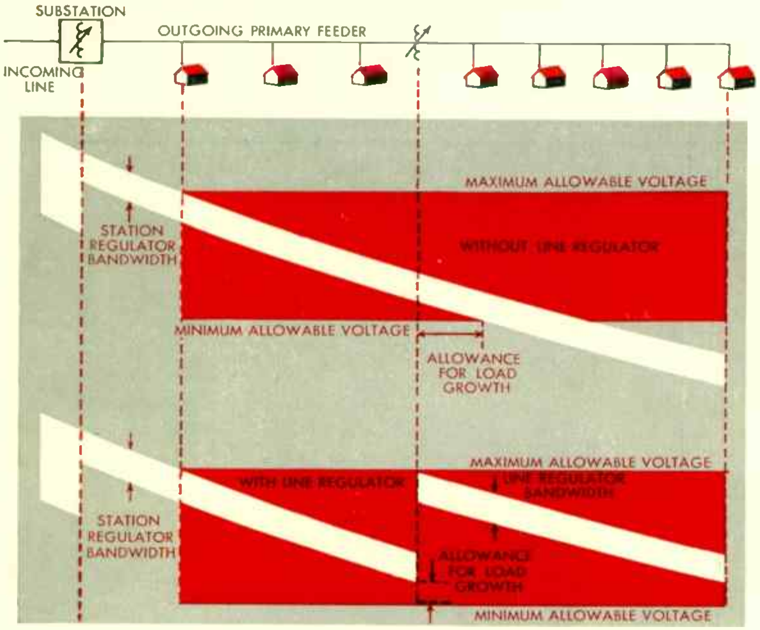
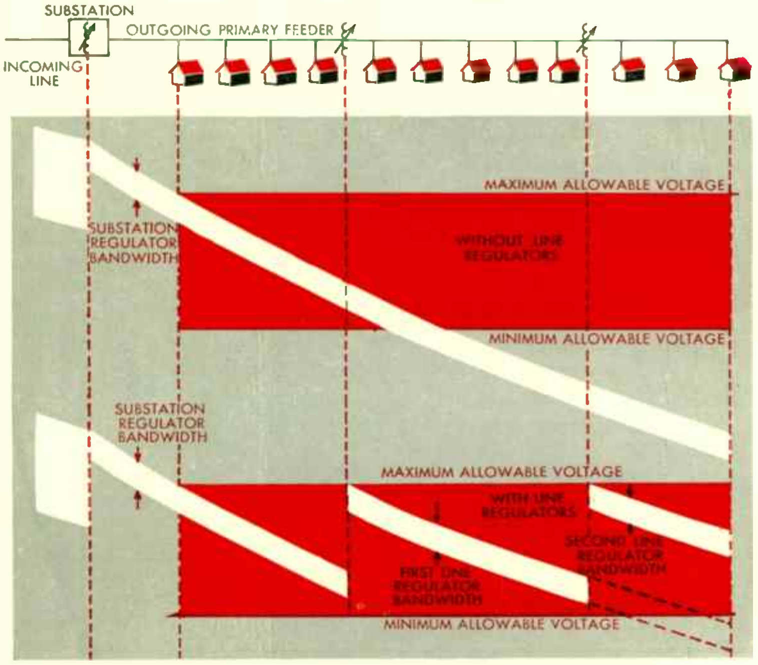


Fig. 6—The effect of line regulators applied in series along a distribution feeder. Some considerations limit their numbers.



tion transformer, or with step-type voltage regulators applied between the low-voltage bus and the substation transformer. Both the LTC and step regulator are predominantly three-phase regulators. The control intelligence of the tap-changing mechanisms is usually taken from one of the phases at the bus; therefore, the voltage held at the bus coincides with the loading or voltage changes occurring on the controlling phase, regardless of the requirement of the other two phases. For good bus regulation with three-phase regulators, loads on each phase as well as along each feeder should be balanced, should have coinciding full- and no-load peak periods, and have feeders of similar length and size with equal express portions if necessary.

If substation loads are predominantly single phase, phase unbalance could occur for relatively long durations even though peak-load currents may be equal. Therefore, single-phase regulation—where voltage control of each phase is independent—should be used so that each regulator receives its intelligence from the phase in which it is located.

When voltage on individual feeders is not held within prescribed limits throughout full- and light-load conditions, individual feeder regulation should be used. This is generally necessary for feeders serving both industrial and residential loads when supplied by the same substation bus.

Three-phase bus regulation is increasing in use. This trend is due to the increasing amount of three-phase loads, smaller capacity substations located at load centers, and the increased application of shunt capacitors and supplementary regulators.

Individual-Feeder Regulation—Individual-feeder regulators hold the voltage of one feeder within predetermined limits and operate independent of the regulation of other feeders served from the same substation bus (Fig. 4). Thus various types of feeders—industrial or residential—with different load cycles can be fed from the same substation. Use of different size feeders is possible with this arrangement and the express portion of primary line out to the first load can be different for each feeder.

Where more than one feeder is served from a single bus, individual-feeder regulation can be accomplished with induction or step regulators. Three-phase regulators or banks of single-phase regulators, depending on whether the phase voltages on the unregulated feeder are balanced, can be used.

Supplementary Regulation—Supplementary regulation is any regulation applied to the distribution feeders remote from the substation. Typical examples are the regulation necessary on long rural feeders and feeders served from suburban substations located in fringe areas. It supplements substation regulation and corrects any excessive voltage drop on the line (Fig. 5). Voltage regulators for this purpose are predominantly of the single-phase, pole-mounted step type, or three-phase banks of switched capacitors. The voltage drop allowed beyond the line regulator is equal to the service-entrance spread minus the bandwidth of the line regulator. The

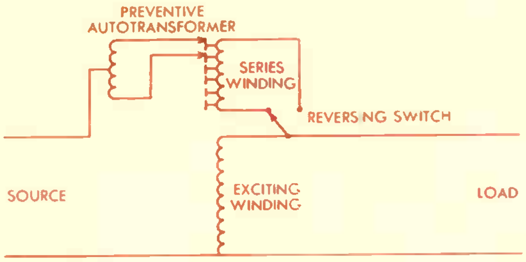
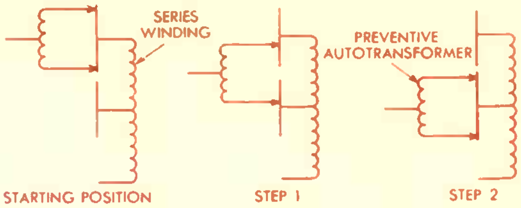


Fig. 7—The step regulator is composed of an autotransformer and a tap changer integrated into one compact unit.

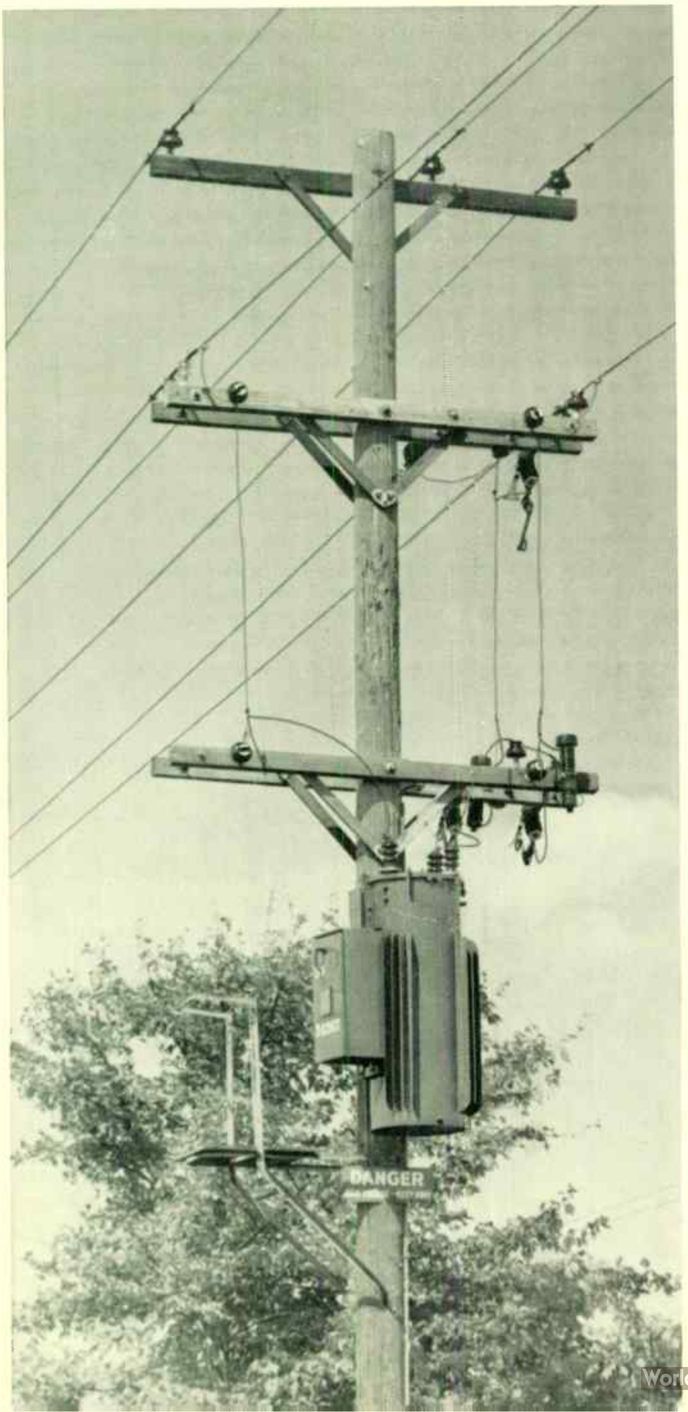
Fig. 8—The sequence of connections used for a tap-changing operation.



line regulator is located at the point where feeder voltage falls below the minimum allowable value, with consideration for load growth.

Line regulators can be applied in series along a feeder (Fig. 6), but thermal capacity of the feeder and line losses limit their number. In certain instances, line regulators are in the initial feeder design. However, this may exclude the possibility of adding line regulators as a corrective measure when load growth causes excessive feeder-voltage drop.

Fig. 9—A pole-mounted step regulator, type URL-16.



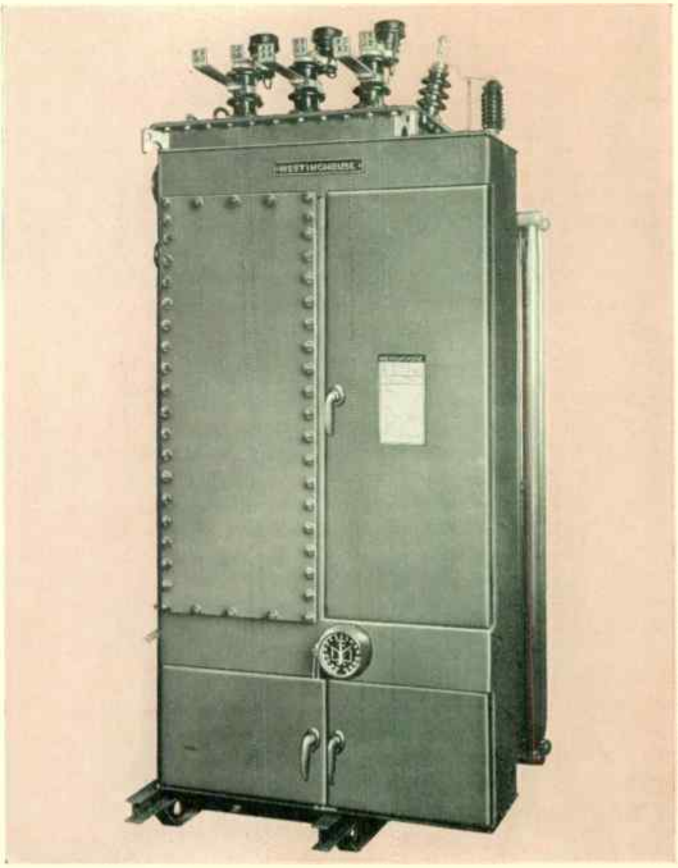


Fig. 10—The type URS regulator for substation application.

Types of Regulators

Step Regulators—The step regulator consists of an autotransformer and a tap changer built into an integral unit. The primary or exciting winding is connected in parallel with the circuit and the secondary or series winding is connected in series with the circuit (Fig. 7). Taps are on the series winding, and automatic tap-changing-under load is obtained without opening the load circuit by using a mid-tapped preventive autotransformer. Sequence of connections for a tap-changing operation is shown in Fig. 8. To obtain both an increase and decrease in circuit voltage by the voltage rating of the series winding, a reversing switch is used, as shown in Fig. 7.

Voltage-regulator steps must be small enough to avoid objectionable lamp flicker during a tap change, and the largest magnitude seems to be a 1¼-percent step for normal regulator operation. The bandwidth for the voltage-regulating relay must be larger than one voltage step to have stable operation. Step regulators are of two types—for pole-mounted installations (Fig. 9) or substation applications (Fig. 10). The voltage-regulating range is generally ± 10 percent in either 16 or 32 steps.

Tap-changing mechanisms can be incorporated with the substation transformer in the form of a tap-changing-under-load transformer. In this case, regulator action is the same as large step regulators for substation application. Such a tap-changing transformer is more economical than separate transformer and regulator units in a substation. Also, in many instances it is economical to use line-type step regulators in substations for individual-feeder regulation.

Induction Regulators—Induction feeder-voltage regulators operate on the transformer principle although their internal construction resembles that of an induction motor (Fig. 11). Induction regulators have a stator and a rotor, with a primary or shunt winding on the rotor and a secondary or series winding on the stator. The secondary winding is connected in series with the line to be regulated, while the shunt or rotor winding is connected across the line and supplies excitation for the regulator.

The voltage induced in the secondary winding increases or decreases the line voltage, depending on the position of the rotor. Since the circuit is not open at any point, the change of voltage is smooth and gradual in either direction. Operation is initiated by the voltage-regulating relay, whereupon a driving motor automatically moves the rotor in the proper direction to restore the output voltage to the desired value.

Two main types of modern induction regulators are used—single phase (Fig. 11) or three phase. The latter unit consists of three single-phase units mechanically connected by a flexible-shaft assembly and mounted in one tank. The three-phase unit is operated from one control. All units generally have a ± 10-percent regulation range.

When first costs, maintenance, and quality of regulation are considered, step regulators are used for supplementary regulation, individual-feeder regulation of low- and high-capacity feeders, and bus regulation. Induction regulators are normally used for individual-feeder regulation of medium- and large-capacity feeders.

Control of Voltage Regulators

Regulator controls are required to maintain a predetermined voltage at a point in the distribution system. The degree to which the regulator performs its function depends upon the capability and accuracy of its controls.

The method of control depends upon the type of equipment, the benefits desired, and the intelligence available for use as a control signal. Theoretically, any intelligence that can be measured, and that changes only when a regulator operation is required, can be used with voltage-regulating equipment. Step and induction regulators use voltage as a control signal, while switched capacitors—when used for voltage control—use voltage, current, time, or combinations of each as a signal.

Voltage-Regulating Relay—The voltage-regulating relay (frequently called the primary relay) receives intelligence from the circuit in which the regulator is located. It controls the operation of voltage-regulating equipment so that voltage at some point in the distribution system can be held at a desired value. When a circuit-voltage change exceeds the limit for which the relay is set, the contacts close and initiate a regulator operation, which continues until circuit voltage has returned to the preset value. The difference between the upper and lower value of relay settings is the bandwidth.

When voltage is used as the signal, the relay is a contact-making voltmeter, generally of the solenoid-operated bal-

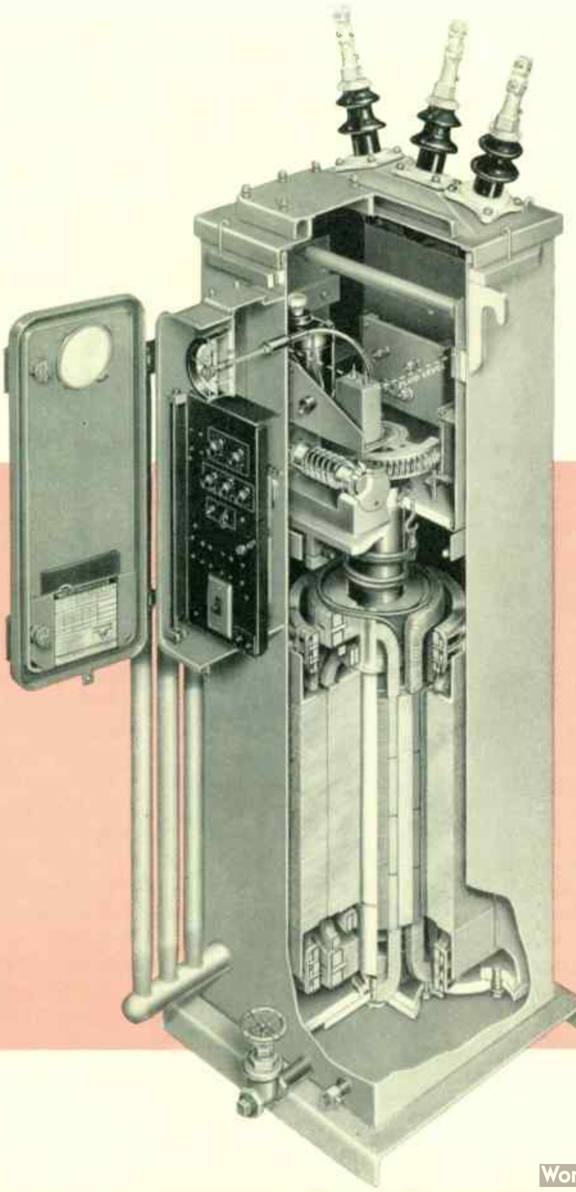


Fig. 11—A cutaway view of a single-phase induction regulator.

Fig. 12—SJS voltage-regulating relay is a balanced-beam type.

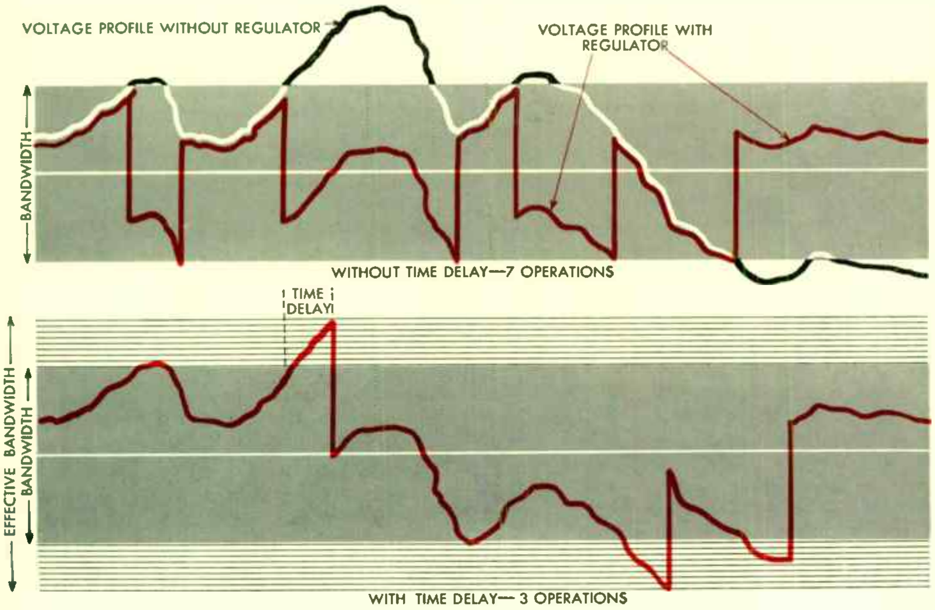


Fig. 13—Top diagram shows the unregulated voltage profile (black) and the regulated profile (color) without time delay; bottom diagram shows the effect of time delay.

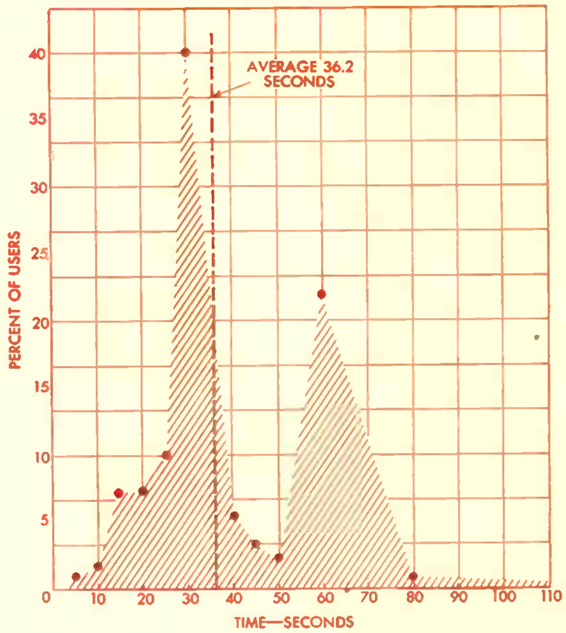


Fig. 14—A survey of time-delay settings for station-type step regulators shows that 30 seconds is most common.

anced-beam or induction-disc type. A balanced-beam relay, as used with station-type step regulators, is shown in Fig. 12. A similar relay is used with induction regulators, and the induction-disc type is used with line-type step regulators.

Bandwidth—The bandwidth setting of the voltage-regulating relay is an important factor in the effectiveness of the regulator. It is the output voltage spread of the regulator, because as long as circuit voltage remains within the bandwidth, no regulator operation takes place. In turn, as shown in Fig. 2, the regulator output spread is an important factor in the load-carrying ability of a feeder and, hence, in system revenue. The bandwidth is manually set and should be as small as possible without resulting in excessive operation and maintenance. For substation regulators, the bandwidth setting should not be greater than two volts. The bandwidth for line regulators should not be greater than three volts—two is desirable. Line regulators having relatively large steps (2½ percent and above) require a larger setting because the bandwidth must be larger than the percent voltage change of one step for stable operation.

Time Delay—The time-delay setting affects the number of regulator operations necessary to maintain a certain output-voltage spread. The time-delay relay limits excessive operations due to momentary disturbances that cause the voltage to go out of the bandwidth (Fig. 13). Excessive operations can be prevented by increasing the bandwidth, but this results in an increased output-voltage spread and an even larger effective bandwidth. A time-delay relay is undoubtedly more economical.

Induction regulators used in substations do not generally have time-delay relays in their control circuits, because the voltage change is smooth and gradual. However, in applications such as feeders serving rapidly fluctuating loads, time-delay relays may be needed.

With station step regulators, a relay is necessary and a 30-second setting is commonly used. The results of a survey on time-delay settings for station-type step regulators are shown in Fig. 14. Single-phase, line-type regulators may not require a separate time-delay relay. When the voltage-regulating relay works on the induction-disc principle, an inverse-time characteristic is used; i.e., the greater the change in voltage out of the bandwidth, the less time required for relay action. If the induction-disc principle is not used and a time-delay relay is required, the settings for line regulators are slightly greater than for the station regulator. This allows the substation to operate first for any variations that may occur in source voltage.

Line-Drop Compensator—If voltage regulaitors must maintain a predetermined voltage automatically at some point remote from the regulator location, line-drop compensators must be used. The line-drop compensator introdiuces a voltage drop in the voltage-regulating relay control circuit proportional to load current. This voltage drop is equivalent to the line voltage drop to the regulation point, usually selected as the load center. Therefore, the output voltage of the regulator is automatically increased during heavy-load periods and decreased at light load. The line-drop compensator is manually set, with dials calibrated in volts, and is located on the control panel of the regulator (Fig. 12). Settings are based on peak-load conditions when maximum compensation is desired. Load growth on a feeder affects the compensation, and periodic checks are necessary.

With bus regulation, there may be no particular load center where voltage should be held constant, so the line-drop compensator is then used to vary the bus voltage with load only. A high voltage (126 volts) is generally held for peak-load conditions, while a lower voltage (122 volts) is maintained for light-load conditions.

Conclusion

Obviously, many factors must be considered in choosing the most suitable means of controlling voltage in distribution systems. In addition to those methods mentioned here, capacitors are still another means of control. Their application will be discussed in a subsequent article.

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An Engineering Personality

Norman L. Mochel

In Westinghouse, mention of Norman Mochel brings to mind "metals." Or, mention "metals" and you think of Mochel. And, only to a slightly lesser extent is this true in a half-dozen national societies in the metals and testing field, and a dozen or so government and military committees dealing with different aspects of metals. Two things, out of literally dozens we might mention, bespeak the general recognition that has come to him for his achievements in the general field of metallurgy and testing. For one, he was chosen by the American Society for Testing Materials to give the first H. W. Gillett Memorial Lecture on the occasion of the 50th anniversary of the society in 1952. Also, he is currently serving as president of ASTM.

Without continuing, for a moment, the recital of a pretentious list of accomplishments, one might well ask how it is that a man becomes so outstanding in his field. Particularly, as in Mochel's case, from a standing start, because he did not have the benefit of college training.

Always, of course, there must be a good measure of innate ability. But there must be supporting characteristics. In considering Mochel's career, at least two are in conspicuous evidence.

What Mochel lacked in formal training, he more than made up by an ability to learn from people. People figure to an uncommon degree in his career, not alone because he likes people but because of a particular ability to profit by the experience of others. One cannot engage Mochel in conversation about his favorite subject of metals but that he does not mention somebody, perhaps a name that figured in his career three decades ago, and cite something learned from him that bears on the point at hand.

It was Professor Eccles, he says, a high-school teacher in his native Pittsburgh, who laid the groundwork for his interest in heavy industries based on iron and steel. Mochel speaks affectionately of John B. Thomas for whom he worked soon after joining Westinghouse in 1912. Thomas imbued him with early and lasting interest in materials, specifications, welding, foundry practices, and heat treating of metals. He speaks of "JB" with genuine tones of reverence, for teaching him how to "read" drawings, to use tools, and for encouraging him to go to night school. Mochel speaks humbly but proudly of a brief but profitable association with George Westinghouse, particularly on one of his pet and now historically famous projects, the geared turbine for the *Neptune*—the first turbine-driven vessel built in this country.

William Bole, Vice President and General Manager of the Westinghouse Machine Company, "one of the great iron foundrymen of his time," Mochel says, "for some reason took a special interest and tutored me in heat treatment of steel. Later he bequeathed me his library and his membership in ASTM."

There are many more men, now famous names in Westinghouse history, whom Mochel credits for his rise to his present position as an authority in the field of metallurgy and metallurgical testing: E. S. McClelland, Chief Engineer; Francis Hodgkinson, long Chief Engineer of Turbine Engineering; H. T. Herr, Vice President, and others.

Another sort of characteristic, we suspect, underlies Mochel's career. This is perhaps a combination of several things: an insistence on precision, order, and neatness. Nothing about him is ever in disarray, be it personal dress or his laboratories. One, figuratively, could "eat off the floor" of any of his metallurgical laboratories at the Steam Division. "You can't gauge results that come from dirty test facilities," is a Mochel maxim.

When the Office of Naval Research formed its Research Advisory Group in 1945, Mochel was on the panel. Also, he was active on the Project Committee of the War Metallurgical Committee, dealing with the behavior of ferritic steels at low temperatures. The National Advisory Committee for Aeronautics had him serve as a member of the sub-committee on Heat Resisting Materials from 1944 to 1950, and chairman for three years.

The end of the war brought no termination to the call for Mochel's services by government agencies. He is a member of the ASTM Ordnance Advisory Committee, has been a representative on the Industry Advisory Committee to the Munitions Board, and on the panel on Power for Propulsion.

Although Mochel's primary responsibility for Westinghouse lies with metals for steam and gas turbines and related steam-power equipment, he is frequently called in to advise on metallurgical problems attending to generators, transformers, x-ray equipment, aviation gas turbines, steel-mill motors, atomic-power equipment, and a wide variety of other heavy equipment. He also played an important role in assisting a group of technical experts in a survey of the company's metallurgical facilities, which resulted in a long-range metallurgical program.

Thus Mochel, who has learned from people, has become an outstanding figure in metallurgy by being a great teacher.

These are the things that lay behind a steady progress in position. In 1920, when Westinghouse established its Steam Division at South Philadelphia, he became its Metallurgical Engineer and built up the metallurgical laboratories and practices there. His position later became that of Division Engineer, Metallurgical Division; and still later, Manager of Metallurgical Engineering, Steam Division. Mochel has long served as a consultant for other branches of the Westinghouse family, and in 1944, his title was changed to Manager of Metallurgical Engineering and Consulting Engineer, which position he now holds.

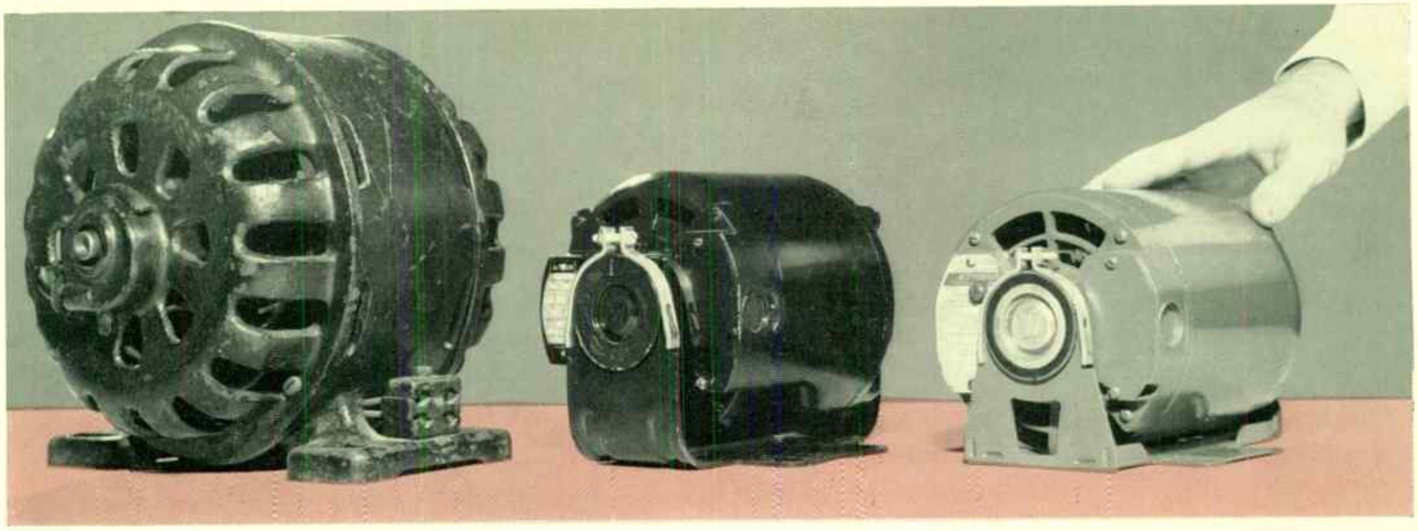


Fig. 1—A comparison in size between motors of 1903, 1946, and 1955; all are of ¼-hp, 1725-rpm, 60-cycle rating.

A New Design for Small Motors

The weight reductions made in fractional-horsepower motors in the last 50 years average to about a pound a year. All this, while at the same time improving electrical and mechanical performance! A brand new fractional-horsepower motor is the latest step in these directions.

CHARLES F. IRVIN, *Industrial Engineering Department, Small Motor Division, Westinghouse Electric Corporation, Lima, Ohio*

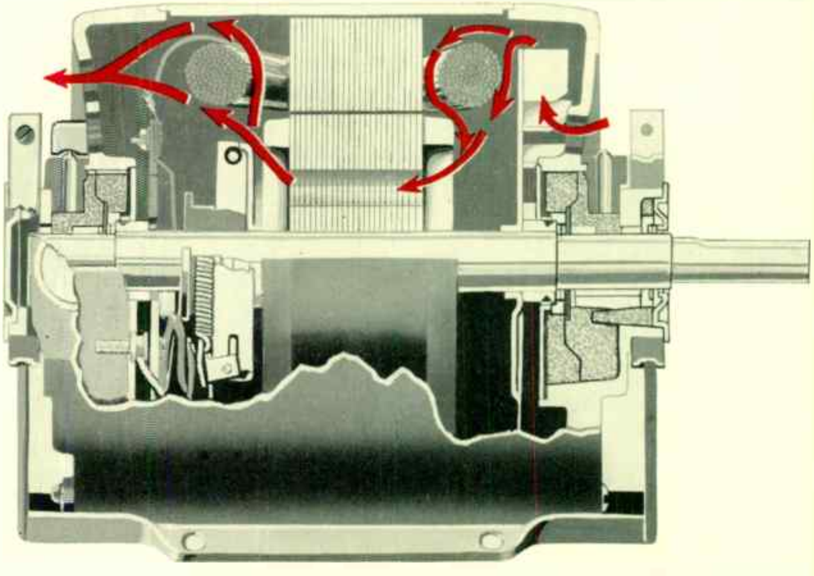
FRACTIONAL-HORSEPOWER motors, like their integral-horsepower counterparts, are undergoing a general re-rating program designed to produce a motor both smaller and lighter for a given power output. The new standard proposed by NEMA is the 48-frame size, which differs from the previous 56 frame primarily in shaft height (reduced from 3½ to 3 inches) and in mounting dimensions. However, in addition to reduced size and weight, the new Westinghouse fractional-horsepower motor has better insulation, a new ventilation system designed for efficient cooling at a low noise level, a unique new connection board, and numerous other design improvements.

The initial redesign to a 48-frame size encompasses Westinghouse motors in the four-pole, open, drip-proof, fully guarded ratings from one-third through one-eighth horsepower, continuous duty, 40 degree C temperature rise. Later designs will include the two-pole ratings up through one-half horsepower and the six-pole ratings up through the one-quarter-horsepower size.

Actually, the present re-rating program is but part of the continuing trend toward smaller motors that are at the same time better electrically and mechanically. Contrast, for example, the one-quarter horsepower motor of 1903 with the new fractional-horsepower motor of the same rating (Fig. 1). The weight has been reduced from 69 pounds to but 16 for the new motor. The new motor is six pounds lighter than the motor of nine years ago—about a 27-percent reduction. Obviously, such a drastic cut in size and weight necessitated the solution of a number of engineering design problems.

Ventilation—A reduction in motor size without a decrease in power output makes an improvement in ventilation efficiency imperative. Since sound level is an important factor to the user, this increase in ventilation efficiency cannot be accompanied by greater windage noise—preferably there should be less. But in designing the new motor, engineers also gave themselves certain other restrictions; namely, that the ventilation system should produce the same amount of cooling regardless of the direction of motor rotation, and that all ventilation openings should be in the motor end shields so that universality of motor mounting would not be restricted by the ventilation system.

Fig. 2—Cutaway of the new motor, showing path of ventilating air.



The final ventilation system developed is actually simple, but effective; it is based on obtaining maximum operating efficiency from the internal ventilating fan. A shrouded fan is mounted on the motor shaft; this fan draws cool air in at its center, through the rear end shield, and produces a positive-pressure, straight-through cooling. Intake air enters the fan perpendicular to the fan blades and at a maximum relative velocity for most efficient operation. Because it moves cold air, which is more dense than hot air, the fan moves a greater weight of air; the result is a 10-percent increase in ventilation ability over a system that displaces hot air.

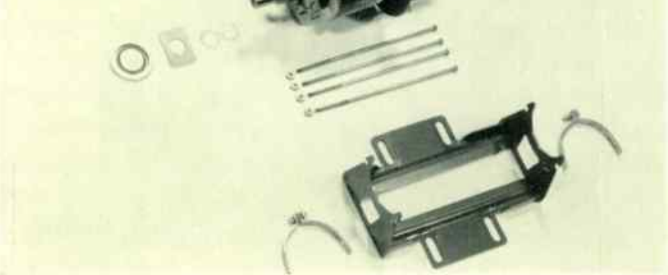
The fan exhaust is an enclosed area inside the rear end shield of the motor. Air is diffused around the motor coil extensions, passes over the rotor end ring into the rotor-core ventilation holes, and then over the coil extensions and out the front end shield (Fig. 2).

This system virtually eliminates the normally encountered windage noise at the fan-exhaust area, since the air is completely diffused and traveling at a relatively low velocity through the end-shield openings. Also, there are no revolving fan blades passing close to ventilation holes to cause a high-frequency whistle, as is characteristic with many designs. Also, the area of maximum air turbulence inside the rear end shield is entirely enclosed; the inside surface of the shield itself is purposely made extra smooth to prevent high-frequency windage noise. The result is a low-noise, high-volume ventilation system.

The cooling improvement over the previous (56-frame) motor is sizable. The hot-spot winding temperature of the one-quarter horsepower, open split-phase motor, for example, is 25 percent less than for the older motor. For the one-sixth horsepower motor the corresponding decrease is 40 percent, and for the one-third horsepower motor 10 percent.

Equally important is the fact that this new ventilation system affords cooler running bearings. The heavy load bearing at the shaft-extension end of the motor has a temperature rise of but 18 degrees C, compared to 35 degrees for the 56-frame motor. Lower operating temperature retards oxidation and evaporation rates of lubricants; since these are primary factors in the life of the lubricant, the useful life of the bearing is significantly increased.

Fig. 3—Simplicity of the motor is shown by disassembled parts.



Motor Protection—The straight-through ventilation system is tailored for the optimum protection afforded by the Thermoguard protective system. With straight-through ventilation, the thermostat is more responsive to abnormal temperature regardless of which end of the motor it occurs in.

Connection Board—The connection board for the motor incorporates in a single unit all the necessary connections. The new board is mounted in the wound primary of the motor on four support studs; this provides a rigid and accurately controlled means of maintaining the relative location of the connection board in the wound primary, so that solid wires from the winding coils can be attached directly to the connection board without special provision for flexing.

This concept of a unitized connection board has several advantages. There are absolutely no electrical connections inside the winding. This eliminates trouble caused by short circuits, grounds, and open circuits in the winding connections. Further, the assembly and disassembly of the motor is simplified by eliminating the flexible leads normally used for connections from the wound primary to the motor end shield.

A novel method for making rotation and voltage connection changes has been incorporated in the motor. Quick-disconnect plugs are used. Interchange of plugs in making winding connections requires no tools and line connections in the motor need not be disturbed. Change in direction of rotation of the motor is accomplished by the simple interchange of two quick-disconnect plugs. Additional connectors are provided on dual-voltage motors to allow switching from parallel to series connection, for changing from 115-volt to 230-volt operation. This takes a matter of perhaps ten seconds after the conduit-box cover is removed, compared to the three or four minutes that are required to change connections by other methods.

Additional Improvements—By a centerless grinding process, the complete shaft of the motor is machined at one time, which assures a precision finish on all diameters and a very concentric relationship between these diameters. All components utilized in the rotor core are carefully correlated to obtain a finished unit with the least possible electrical unbalance. Extreme emphasis on the control of concentricity of all parts going into the assembly of the motor assures excellent balance and low slip-frequency noise.

A new lubrication system affords a more than adequate supply of oil (some 22 percent more than the present 56-frame motor) and assurance that the oil will not leak out of the motor in any position, regardless of whether the motor is running or standing still. The system is designed to give long years of service under loaded operating conditions.

The resilient base for the new motor is fabricated, which results in a 15-percent reduction in weight, with increased rigidity and strength.

Stator slots are insulated with a laminated combination of Mylar film and 100-percent rag paper bonded together. The combination has a high dielectric strength as well as high mechanical strength. The present rag-paper insulation has a total dielectric strength of 4500 volts, compared to 8500 volts for the new insulation—in spite of reduced thickness.

After the steel frame is applied to the wound core, the complete assembly is dipped in a thermosetting phenolic-resin insulating varnish, which gives a highly moisture-resistant coating over the whole wound primary and frame.

The end result is a motor that is not only physically smaller, but electrically and mechanically much superior to its larger predecessor. It represents one more step in the continuing effort to improve fractional-horsepower motors.

ENGINEERING HIGHLIGHTS IN Appliances

Electric appliances, by the nature of their application, must present an attractive appearance; but back of the sleek exteriors lies much solid engineering. Here are a few examples, gleaned from the most recent appliance developments.

Making It Hot for Dishes—A new dishwasher is pretty particular about the temperature of the water it uses. Moreover, if the temperature isn't right, it does something about it. It works something like this: You put in the dishes and set the timer to start the cycle of washing, two rinses, and drying. When the wash water comes into the machine, the water temperature is measured by a thermostat in the bottom of the tub. If it isn't hot enough (over 140 degrees F) the timer stops and a built-in heater raises the water temperature to where it should be. Then the timer starts again and the washing proceeds. This control works automatically during the washing cycle and second rinse.

The timer dial of the dishwasher now rotates with the timer to show what cycle the machine is in. Thus the user can skip any part of the cycle if desired. This can save both water and power; for example, if the dishes are only slightly soiled, they can be merely rinsed and dried, or put through part of the washing cycle, rinsed, and dried. This also enables the dishwasher to be used as a plate warmer by merely using the drying cycle.

New Ranges—Both the new built-in range (above right) and the 40-inch range feature larger ovens. The built-in unit has a 24-inch wide opening: the surface-cooking unit has four detachable plug-in heating elements. The 40-inch range unit has a 30-inch oven; this oven has a double thickness of insulation on all sides and a Fiberglas seal around the door, thus providing uniform, efficient heating.

No Defrosting for Refrigerators—The time-consuming task of defrosting a refrigerator is eliminated in all seven new Westinghouse refrigerators. Four of the models include Frost-Free automatic defrosting, the other three defrost at the touch of a button. In the model at right the button is at the top right. Another feature of this new refrigerator is the dispenser for fruit juices: this device automatically mixes two different juice concentrates under pressure with the proper amount of precooled water to deliver ready-mixed juice. Each of the two compartments holds a pint of juice concentrate, and a two-quart precooling water tank draws a constant supply of fresh water from the household water system.

Automatic Percolator—A Cup a Minute—A cup of coffee a minute was the goal of engineers in designing this new automatic coffee maker. The unit has two heating elements—a 650 watt and a 350 watt—and two thermostats. When the coffee maker is plugged in, both heaters are energized to raise the temperature of the water quickly. When the temperature of the water gets to about 165 degrees F one thermostat operates, cutting out the 650-watt heater. The smaller heater continues to pump coffee in the percolator until the temperature reaches about 190 degrees, at which point the second thermostat operates, cuts out the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second heater, and turns on a light indicating that the coffee is done. When the temperature drops again to 175 degrees, the first thermostat recloses, energizing the 650-watt element for the warming cycle. The brew is thereafter kept hot indefinitely.

Most percolator-type coffee makers have a perforated metal spreader on the coffee container, the purpose of which is to distribute water evenly over the grounds. This is necessary only because water bubbling against the top of the percolator is not distributed evenly over the coffee grounds; the result is packing of the coffee sufficiently that water does not pass through it but instead goes out the sides. The top of the new Westinghouse coffee maker is designed to spray the water evenly over the grounds, thus eliminating the need for a spreader. A further measure to prevent packing is the use of an extremely fine aluminum screen—952 holes to the inch—for the coffee container. This allows water to flow more readily out of the container, but prevents coffee grounds from seeping through.

TV Gets Classy Chassis—The television chassis is developing character of its own with a new "L-chassis" design that departs from the more conventional inverted pan, a carryover from the radio chassis. The new L shape permits a saving in volumetric space and allows designers to take full advantage of the new, shorter 90-degree-deflection television picture tube (see photograph). On the base of the L chassis is a flat-pan subchassis where most of the small component parts—resistors, condensers, tube sockets, etc.—are pre-assembled. "Sew-wiring" and dip-soldering techniques, developed originally for 5-tube radios in 1952, are being employed. The wireman starts with a spool of wire at one point and, with a continuous strand, "sews" together all terminals that are to be connected. The terminals are all purposely made at a common height. Then after the wiring is finished, the joints are dipped in solder — in just a few seconds about 60 percent of the small components are soldered in place. Any unwanted bits of wire can be snipped away. Besides being a time-saver, this reduces the possibility of error, omission, or a poorly soldered joint.

Comparison of the new L-shape TV chassis (right) and former type.

A further circuitry simplification results from connecting filaments in series, thus reducing wiring and eliminating a bulky filament transformer. This change has been made practical by a new industry-wide line of receiving tubes with 600-ma filaments. All tubes, including the picture tube, can be series connected. Since all tubes are designed to heat at the same rate, none are subjected to high filament voltage during the warm up period.

New Tools for House Cleaning—Two new vacuum cleaners add to the versatility of cleaning devices. One is the new canister-type machine (above, number 1), the other a tiny portable cleaner, called the Porta-Vac (above, number 3). The canister cleaner uses the "Toss-A-Way" disposable bag, which can be removed from the cleaner in an upright position to avoid spillage of dirt, and a new lightweight hose, composed of a vinyl covering over a steel-wire coil. Fans are of the two-stage turbine type, driven at a normal half-load speed of about 17 000 rpm by a ½-hp motor. The Porta-Vac is about the size of a portable radio, and weighs but seven pounds. It is designed primarily for limited living spaces, or for tasks like cleaning draperies or upholstery, where portability is useful. For its size, the Porta-Vac is a powerful machine. For example, it can produce a static pressure of 40 inches of water and deliver 30 cubic feet of air per minute under open conditions, compared to 55 inches, and 58 cubic feet for a large tank-type cleaner. Other machines in the photo above are the electric floor polisher (number 4) and the standard upright cleaner (number 2).

Rotary Broiler—In designing a new rotary broiler, engineers managed to wrap up a lot of desirable objectives in one design. The unit (number 5, above) is simple, functional, lightweight, and yet versatile.

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External metal parts are all of aluminum; the ends of the broiler are cast, the rest of the casing is sheet aluminum. The result is strong, but lightweight for portability. The heating element, mounted at the back, is removable for easier cleaning of the rest of the case. The front cover, which acts as a heat reflector, also is removable for easier cleaning.

The rotisserie has no temperature control, for the simple reason that when engineers and home economists investigated, they found that virtually all foods cook equally well at one wattage. The heating element is therefore rated at 1500 watts.

Keeping a rotisserie motor cool (it operates within a few inches of the heating element) is no small problem. Underwriters' standards require a 65-degree-C maximum temperature rise. Fans didn't work satisfactorily. But something simpler did. The bottom and top of the motor housing are vented; and a vent hole inside the broiler allows heat to escape by this path and out through the opening in the top of the rotisserie. The result is a sort of "chimney" effect, with sufficient draft to carry away heat rapidly. To further increase heat dissipation, the aluminum nameplate on the outside of the motor housing is anodized for better radiation characteristics. Simple, but effective.

The bottom of the rotisserie is a grey enamel pan. To increase the versatility of the device a pan identical to the inset pan for the electric roaster oven is used; this means that the rotisserie and pan can be used separately, or on top of the roaster. When used separately a support stand is provided for rotisserie and pan. The rotisserie is large enough for all family uses; it easily handles a ten-pound turkey or large hams, beef, or other roasts, with room to spare.

New, Tougher Food-Waste Disposer—Food-waste disposers live a rough life. Their "diet" includes every conceivable type of food waste, including bones, all of which must be ground fine enough that it does not clog the drain. And the disposer must live with the diet day in and day out for many years. A new food-waste disposer (number 6, above) is specifically designed for long life and heavy duty. It utilizes hardened chrome-molybdenum-vanadium steel for the vital shredder ring, which must be hard and tough enough to macerate tons of bones and other food waste in its lifetime. The shredder teeth have a unique configuration that retains the food waste in the unit until it will float freely down the drain. The high torque, reversible one-third-hp motor is Thermoguard protected. An automotive water-pump type of seal is used to prevent leakage, and tapered roller bearings absorb the severe impact loads imposed when large bones are shredded.

Toaster Simplified—On the new toaster (above, number 7), the degree of brownness desired is set on a small dial. For each setting of the dial there is a specific time required for toasting; a new thermal control sees to it that variations in voltage or toaster temperature do not affect the toasting time. Note also the new casing construction; the whole unit has been simplified to make it even more foolproof and long lasting.

It "Tweets" and It "Woofs"—A new high-fidelity radio-phonograph has been designed for the true "hi-fi" enthusiast who wants everything from 30 to 15 000 cycles—every sound most human ears can hear. If you're a hi-fi fan, you may be interested in these further particulars:

The tuner has full f-m and a-m tuning range; the amplifier develops 10 watts of undistorted output, from 20 to 60 000 cycles, well beyond the audible-frequency range; the amplifier has push-pull output, uses a heavy-duty output transformer, and dual speakers (a "tweeter" and a "woofer") matched through a dynamic crossover network; the three-speed record player has a variable-reluctance pickup.

Of special interest to the distaff side is the new functional design, which matches television, record storage, and table modular units, permitting a variety of furniture combinations.

The *Symphony Hall*—a modular high-fidelity radio-phonograph.

Designed to bridge the gap between research and practical application is a new . . . . .

Steam

DEVELOPMENT LABORATORY

THE CRITICAL pressure of steam—pressure at which water and steam have the same density—is now of more than academic interest to turbine designers. Steam power-plant developments are sufficiently advanced to convince engineers that steam plants operating at pressures above the critical pressure are entirely practical. Conversion of this engineering concept to practical reality—a 5000-psi, 1200-degree F turbine now being designed—will be one of the first major developments tackled at the new Development Laboratory of the Westinghouse Steam Division at South Philadelphia.

The laboratory is in reality a $6 000 000 tool designed to carry out just such development. The laboratory is the stepping stone between a fundamental concept developed by research and its practical application to a steam-division product—steam turbines for electric-utility and industrial power plants; gas turbines for electric utility, industrial, and other special use; axial-flow compressors for gas turbines and high-powered wind tunnels; and heat exchangers, including condensers, feedwater heaters, evaporators, air and hydrogen coolers, and special heat-exchange equipment for gas turbines and atomic power-plant requirements.

In addition to facilities for component development on these products, the laboratory is equipped for testing prototypes, complete units, and special components in a high-bay machinery test aisle, which will handle steam turbines up to 12 500 kw, and gas turbines up to 15 000 kw.

Aerodynamic Development

Much effort will be directed toward the solution of fluid dynamic problems. The emphasis on this phase of research is readily explained. Consider the losses of an efficient electric-utility steam plant: about one third are caused by fluid dynamic inefficiencies in the turbine-flow path, while the rest are a combination of such things as boiler, pump, heat-transfer, mixing, mechanical, and electrical losses. Consider a very efficient 200 000-kw electric-utility steam plant—taking all generating costs into account, an improvement of one percent in the station heat rate may justify an additional capital investment of some $175 000!

All types of turbine and compressor blading can be developed and tested in the laboratory equipment provided: the long, tapered and twisted exhaust-end blades, designed for three-dimensional flow, can be evaluated in a low-pressure turbine test facility; partial-admission control stages and intermediate-height reaction blading can be tested in a multistage turbine test facility; gas-turbine blading can be investigated in an air-turbine blade-test facility; compressor blading can be tested in a variable-density tunnel, a compressor wind

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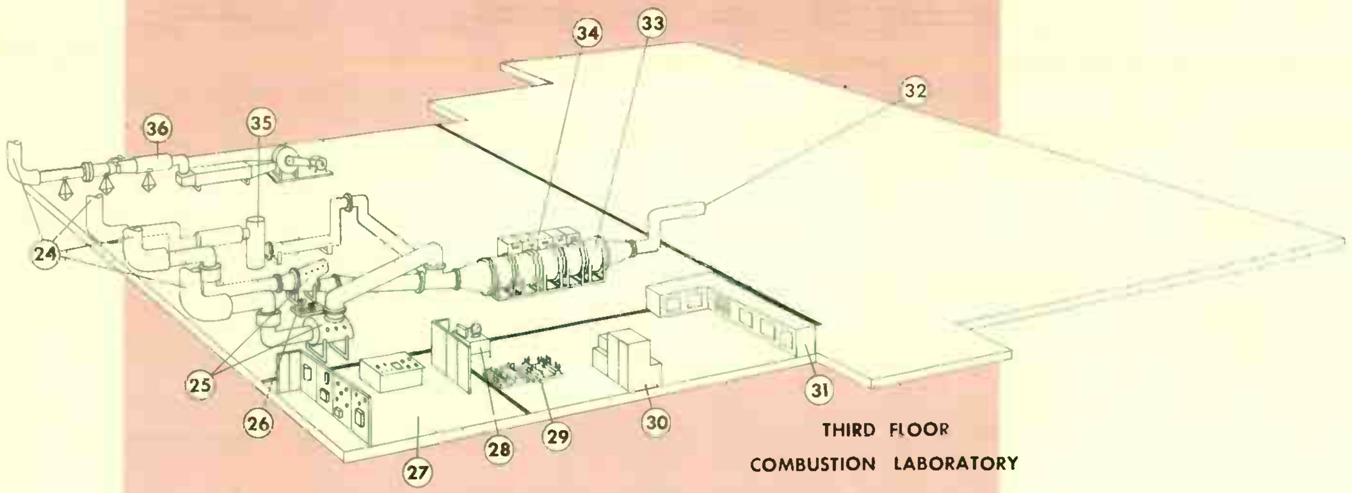
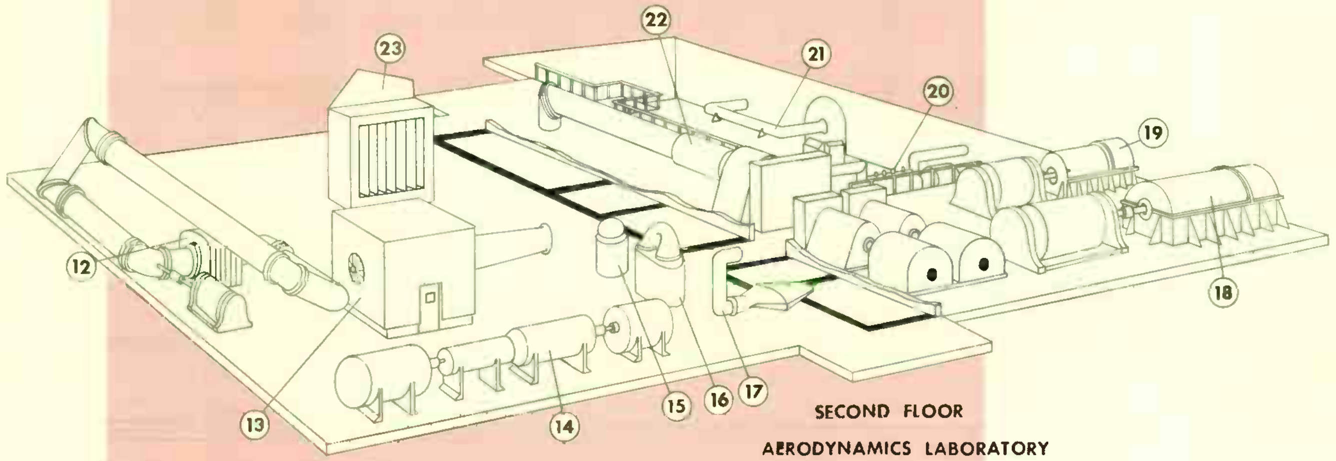
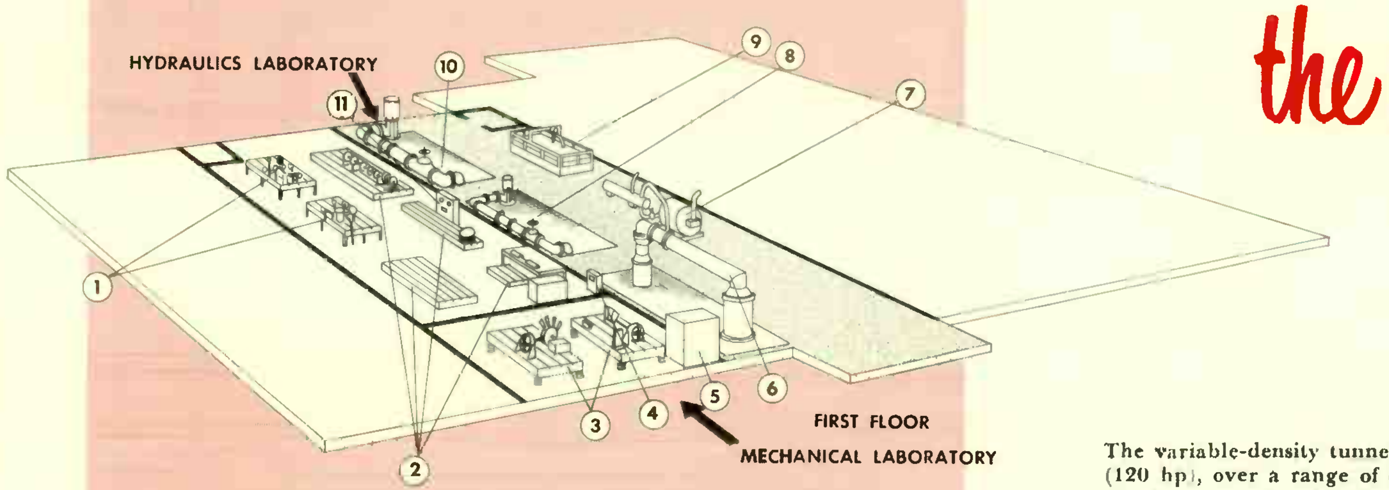
This article was written by Matt Matthews, Assistant Editor, based on information furnished by the Westinghouse Steam Division.



THIRD FLOOR
COMBUSTION LABORATORY



SECOND FLOOR
AERODYNAMICS LABORATORY



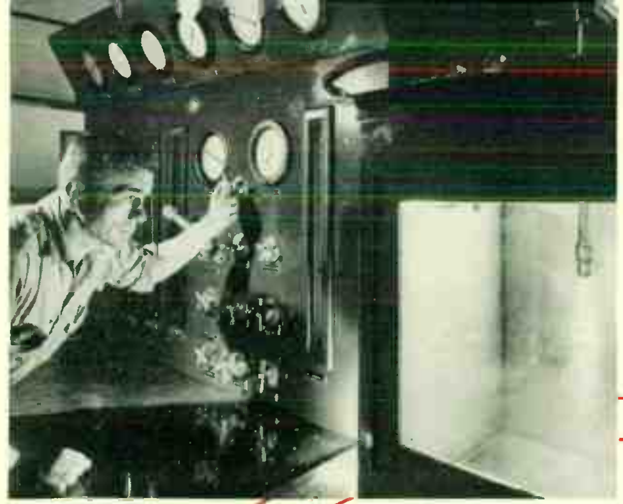
FIRST FLOOR
MECHANICAL LABORATORY

1—Control test stands
2—Mechanical test stands
3—Vibration tests
4—Heat-exchange circuit control panel
5—Five-kw amplifier
6—Heat-exchange tunnel
7—Flash evaporator
8—Six-inch pump test
9—Two-inch pump test
10—Twelve-inch pump test
11—Pump-test control panel
12—Variable-density compressor and turbine wind tunnel
13—Blower box
14—Scale model of transonic leg of AEDC wind tunnel
15—Probe calibration rig
16—Exhaust-hood tester
17—Diffuser test
18—Low-pressure turbine tester
19—Multistage tester
20—Turbine-blade tester
21—Scale model of supersonic leg of AEDC wind tunnel
22—Compressor wind tunnel
23—Large cascade
24—Exhaust gases
25—Combustor-development tests
26—Fuel-distribution stand
27—Control room
28—Fuels weighing scale
29—Fuel-oil pumps
30—Fuel-nozzle tester
31—Physical testing of oils and oil ashes
32—Compressed air
33—Electric air preheater
34—Electric-heater control
35—Direct-contact heat-exchanger test
36—Blade-corrosion tester

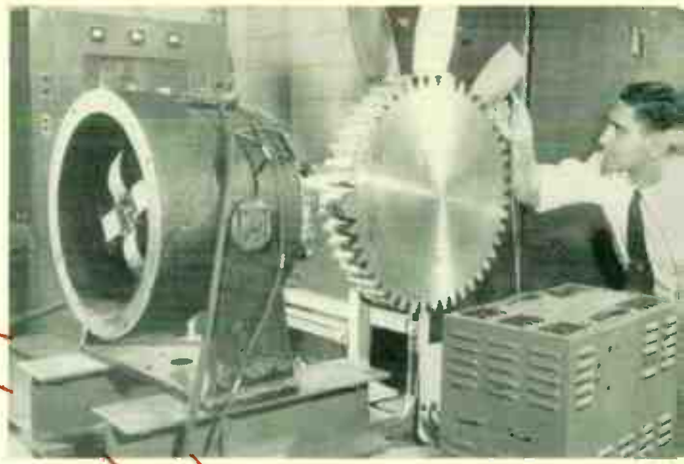
the new Laboratories

FOR DEVELOPMENT OF TURBINE EQUIPMENT

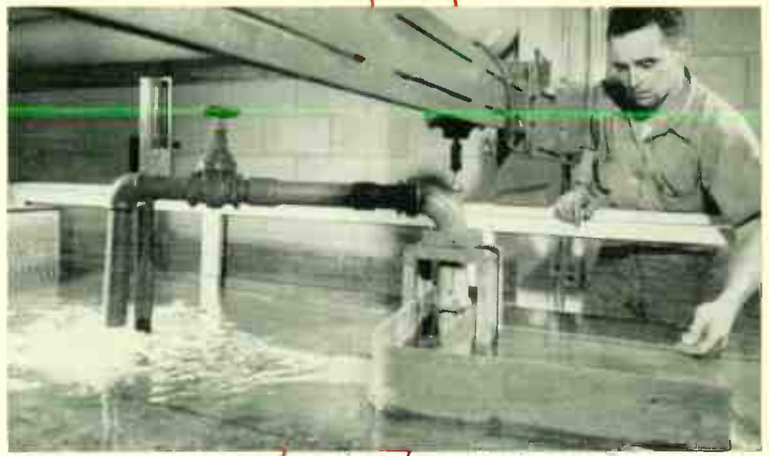
Fuel-nozzle development is an important phase of the gas-turbine combustion development program. This fuel-nozzle test stand permits study of spray patterns with various nozzle configurations at various flows and pressures.



Combustion equipment will be used to measure the relative rate of corrosion of various turbine-blade metals. Hot exhaust gases from a residual oil combustor pass over test specimens at approximately the same velocity as gases entering turbine nozzles. Corrosion is measured by weight loss of the blade.

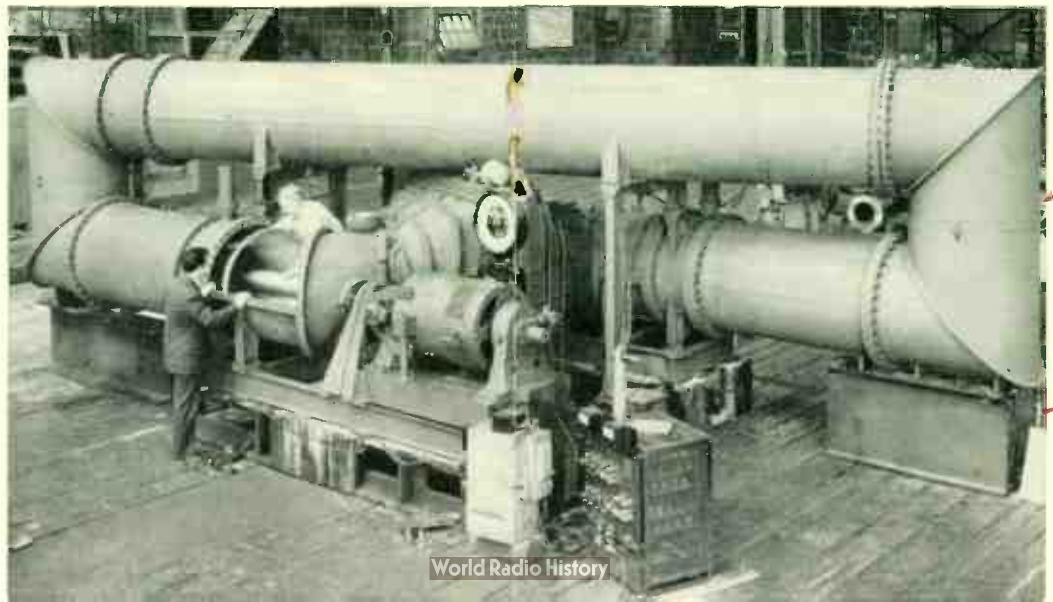


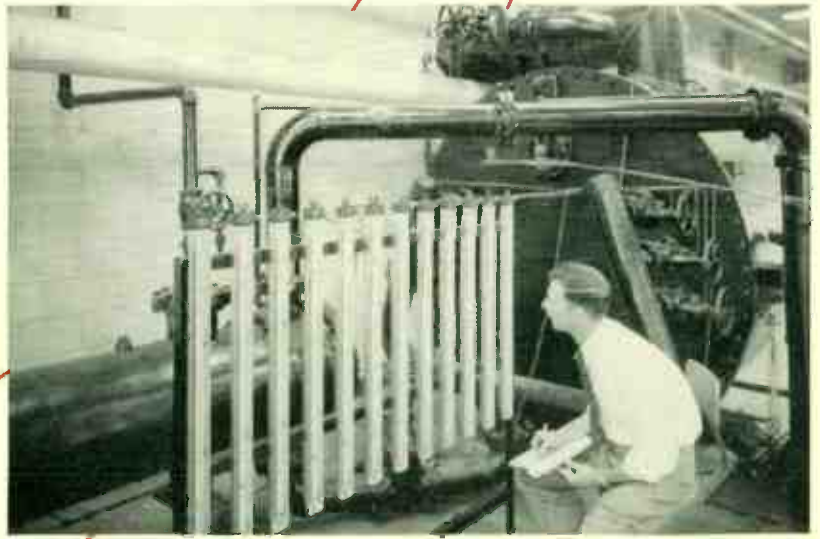
Typical of stationary-type vibration tests performed on turbine blading is this check for resonant blade frequency. Test setup is mounted on a seismic mass, a heavy platform supported by springs, to eliminate external vibration, and the vibration exciter induces vibration in the blade disc.



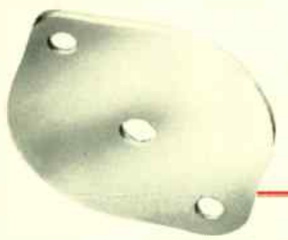
The flow of water in pumps and channels is three-dimensional and often very complex. It has been found that for a test to be of value, the water must flow under conditions that are similar to those found in the actual application. This test facility is used to check the effect of various intake tunnel designs on the turbulence at the pump inlet.

The variable-density tunnel is designed to test either compressor or turbine models at low power (120 hp), over a range of densities in order to determine Reynolds-number effects. High Mach numbers can be tested also, using low-pressure Freon. Highly loaded compressor or turbine stages can be investigated. The variable-density tunnel is especially useful for selecting the more promising model designs, which can next be tested full scale in the more expensive high-power test rigs.

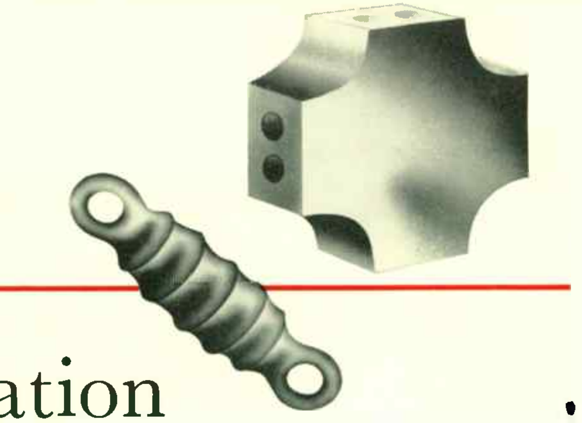




The past decade has shown a great increase in the effort devoted toward conversion of sea water into potable water. This prototype flash evaporator being tested uses low-temperature waste-heat sources to convert sea water to commercially pure water. While there are many successful schemes for purifying sea water, their cost is still excessive. If waste-heat sources can be successfully utilized, costs will be appreciably reduced.



While many insulating materials are somewhat ill at ease at high frequencies—thousands of megacycles—others are being trained for a useful life in this rather difficult environment.



High-Frequency Insulation

Reuben Lee, *Advisory Engineer, Components Engineering, Electronics Div., Westinghouse Elec. Corp., Baltimore, Maryland*

A "perfect" insulation material for universal application at all frequencies apparently doesn't exist—at least, it hasn't been found. High frequencies impose especially severe restrictions on the electrical properties of the insulator. While there are some materials that possess the necessary electrical properties, they have other physical shortcomings that limit their application. On the other hand, most of the mechanically adaptable materials have inherent electrical shortcomings that become pronounced at high frequencies.

"High-frequency" means different things to different people. For the purpose of this article, it refers to radio frequencies—10 kilocycles to 100 000 megacycles, as shown in Fig. 1.

Characteristics of High-Frequency Circuits

At high frequencies, normal lumped properties of component parts such as coils and condensers become distributed. In frequency regions of low overall coil impedance, dielectric losses become excessive. Consequently, coils must have low insulation capacitance to minimize heating. Typical variations of choke-coil impedance and losses are shown in Fig. 2. Capacitors also undergo impedance changes with frequency, but the variations are less pronounced. When coils are operated outside of their designed range, they become capacitive; conversely, if capacitors are operated at too high a frequency, they become inductive. Usually, any component has a range of frequencies over which it operates properly. Insulation of the component plays a large part in determining this range.

Except for transient effects, capacitance is usually negligible in 60-cycle apparatus; but at radio frequencies, capacitive reactance from conductors to ground may be low enough to cause large capacitive currents. To prevent bypassing r-f power, careful design is required. Conductors must be kept short; the insulation must have low capacitance; and insulation power factor (or dissipation factor) must be small. For example, consider asphalt-bonded mica, which has a power factor of 10 to 15 percent at 100 degrees C.[*] At 60 cycles, this high power factor is undesirable from the standpoint of insulation life; but at radio frequencies it is intolerable, because the high r-f loss current would destroy the insulation in a few minutes. To illustrate this further, consider a conductor at ten kilovolts insulated from ground with solid insulation, which has a ten-percent power factor and 3000 micro-microfarad capacitance. At 60 cycles, capacitive current would be 0.0113 ampere[†]; loss current would be 0.00113 ampere, and power loss 11.3 watts. If this same conductor were used at the same voltage at one megacycle, capacitive current would become 188 amperes, loss current 18.8 amperes, and power loss 188 000 watts—if that much power were available!

Similarly, lead inductance that is negligible at 60 cycles may interpose such high impedance to certain high frequencies as to effectively block transmission of power. When frequency is high enough so that either lead inductance or capacitance is prohibitive, r-f transmission lines are used in place of simple conductors. These lines must be insulated with low-loss ma-

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[*] "Developments in Insulation for Rotating Machinery," by G. P. Gibson and G. L. Moses, *Westinghouse* Engineer, July, 1954, p. 137–41.

[†] $I_c = E\,(2\pi f)\,C = (10\,000)\,(2)\,(\pi)\,(60)\,(3000 \times 10^{-12}) = 0.0113$ ampere.

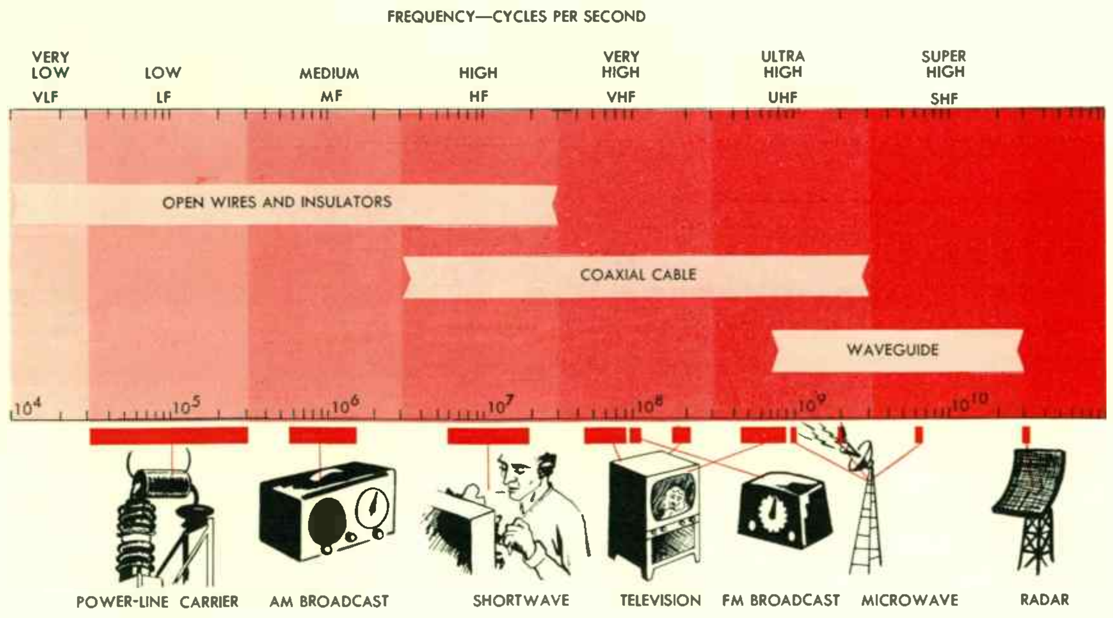

Fig. 1

The Federal Communications Commission has assigned these frequency band designations. While not all high-frequency applications are communications, all frequencies used fit into the pattern that is set by the FCC.

Fig. 2

Choke-coil impedance losses vary with frequency due to the effects of distributed capacitance.

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tunnel, or a blower box. Turbine and compressor airfoil shapes can be examined in a large cascade tester for determination of the optimum blade configuration, and for studying secondary flows.

Heat-Transfer and Hydraulic Development

The design of heat exchangers and hydraulic equipment is based to a large extent upon empirical data, usually obtained from tests of models or prototypes. Each new design must be tested over a wide range of operating conditions to verify its performance. Several permanent heat-transfer test facilities have been installed for this purpose, facilitating complete development and performance testing of the whole gamut of power-station auxiliary equipments: steam condensers; hydrogen, air, and oil coolers; feedwater heaters; evaporators for power plants, and for purifying sea water; and gas-turbine regenerators and gas coolers. Hydraulic test facilities are provided for the development and evaluation of characteristics of all types of pumps for condenser service application. These facilities also permit testing power-plant circulating- and condensate-water circuits. While auxiliaries are less spectacular than main turbines, their reliability and efficiency are just as important.

Consider, for example, the surface condenser: it lowers exhaust pressure on turbines so that more energy can be extracted by the turbine. (Approximately one third of the work output from the turbine results from the expansion of steam from atmospheric pressure down to the condenser vacuum.) One means for reducing turbine exhaust pressure or condenser size, involving the phenomenon of "drop-wise" condensation, is presently being studied. Ordinarily, condensing steam on a cooled-metal surface almost completely covers the metal with a film of water, thereby setting up a barrier to heat transfer. By application of suitable "promoters" such as fatty acids or water-repellent silicones, it is possible to induce dropwise condensation, where the condensate does not wet the surface but instead forms in spherical droplets. If dropwise condensation can be satisfactorily and economically achieved, an appreciable gain in cooling efficiency will result.

Dynamic Mechanical Development

The principal dynamic mechanical problems encountered in the design of turbines involve vibration; most common are vibration of shafts, blades, stationary parts, and supporting structures. Of these, blade vibration, particularly in the low-pressure end of the turbine, is the most complex. The problem becomes more difficult with increasing turbine size, which requires exhaust blades that are larger and more highly stressed.

Vibration of exhaust blading is nearly always caused by vibratory forces set up by flow variations in the steam itself. Engineers know that structural features of turbines cause these flow variations. Such things as the exhaust hood that turns the flow of steam just after the last blades, structural members in the exhaust hood, stationary vanes preceding the rotating blades, and manufacturing variations in nozzles and blades all contribute. While much is known on the subject, there is yet more to learn. Although the nature of the vibration-causing forces is understood in a general way, more data is needed to find their exact magnitude and effect on turbine blades.

Two series of exhaust-blade vibration tests are planned: Stationary-type tests will be run on special test specimens to determine vibration deflection patterns, stress patterns, and natural frequencies; and "rotating" tests will be conducted on blades in a special low-pressure turbine that permits variation of speed, steam flow, pressure, and temperature while the blade is being analyzed.

Gas-Turbine Combustion Development

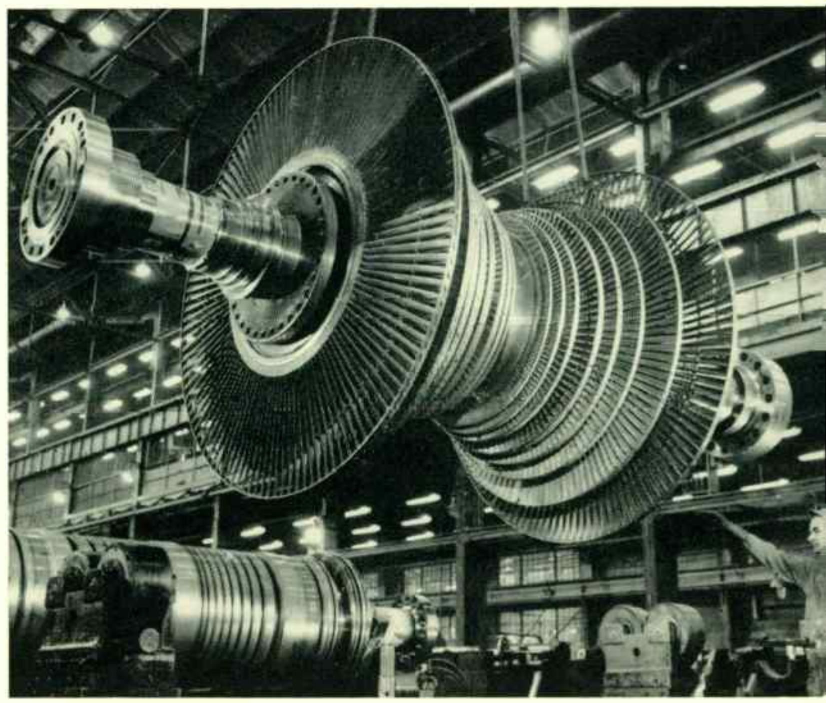
Gas-turbine combustion problems are twofold: (1) the effective release of chemical energy by combustion of fuel within highly confined spaces, and (2) the high-temperature corrosion of residual-oil ash on turbine and turbine-blade materials. Fundamental gas-turbine combustion studies are being conducted at the Research Laboratories in Pittsburgh. The information obtained is of valuable assistance in combustor development, and is supplying answers to such fundamental phenomena as flame stability, flame speed, combustion processes, and wall cooling.

The combustor—the heart of the gas-turbine power plant—is the stainless-steel tube containing the flame. A satisfactory combustor comprises a fuel-spray nozzle and a sheet-metal basket matched to give the optimum fuel-air distribution in the combustion zone. Facilities for gas-turbine combustion development are installed in the laboratory. Two combustion-chamber passages are available for testing various burner configurations. In conjunction with the combustion test program, a fuel-nozzle development program is under way. Design and testing of various liquid, gaseous, and dual-fuel nozzles is an important phase of the program.

In the combustion of residual oil, corrosion of blade materials from oil ash formed during the combustion process is the second basic combustion problem being attacked in the laboratory. While oil additives seem to offer an immediate answer, they are only the first step in the solution of a difficult problem. New turbine and blade alloys, blade plating, and blade coatings are also being investigated.

The research scientists are constantly developing new and better materials and processes, and contributing new basic knowledge of the nature and characteristics of the various materials needed for steam apparatus. The new steam laboratory will enable engineers to take full advantage of these developments.

A steam-turbine double-flow, low-pressure rotor.

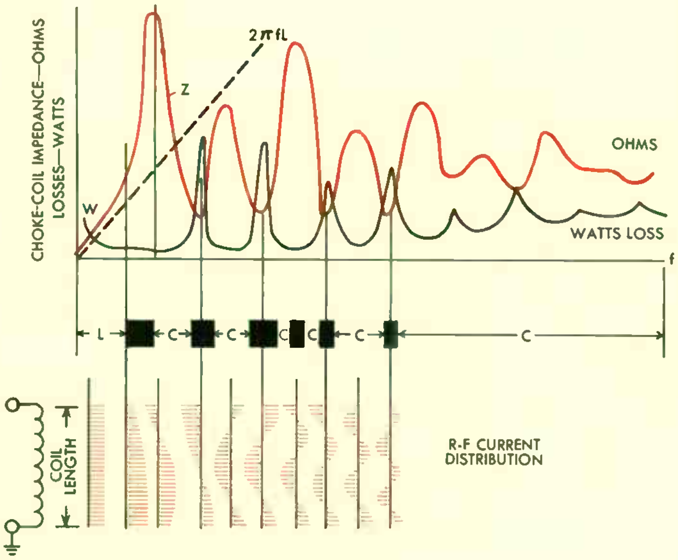


terial, or precious r-f power is wasted. Low-impedance transmission lines are made in the form of coaxial cable, with flexible solid-polymeric dielectric between center and outer conductors. And finally, at ultra-high frequencies, even these transmission lines become virtually useless and then wave guides must be used.

R-f transmission lines have distributed inductance and capacitance, and voltage may vary with distance from the power source. Transmission-line impedance varies with frequency unless the termination is perfect—that is, equal in both amplitude and phase to the line-surge impedance. Consequently, lines may be comparatively short and still have standing waves on them because of imperfect termination. If an air-dielectric, r-f transmission line is supported at intervals by insulators, minimum loss results when these insulators are placed at intervals corresponding to the minimum-voltage points of the standing wave.

High-Frequency Equipment

High-frequency equipment is characterized by the use of electronic tubes. Consequently, the study of high-frequency insulation is associated closely with electronic circuits, where relatively high impedances are common, even when large amounts of power are involved. Typical physical arrangements of tubes, coils, condensers, etc., are illustrated in Figs. 3 and 4, which are views of a high-frequency transmitter of 3-kilowatt rating. A side view showing how the 60-cycle power equipment (at the base of the transmitter), is shielded and spaced away from the high-frequency components is illustrated in Fig. 3. This is done for three reasons: (a) to prevent damage to low-frequency components by heating effects of stray r-f currents; (b) to prevent loss of r-f power;



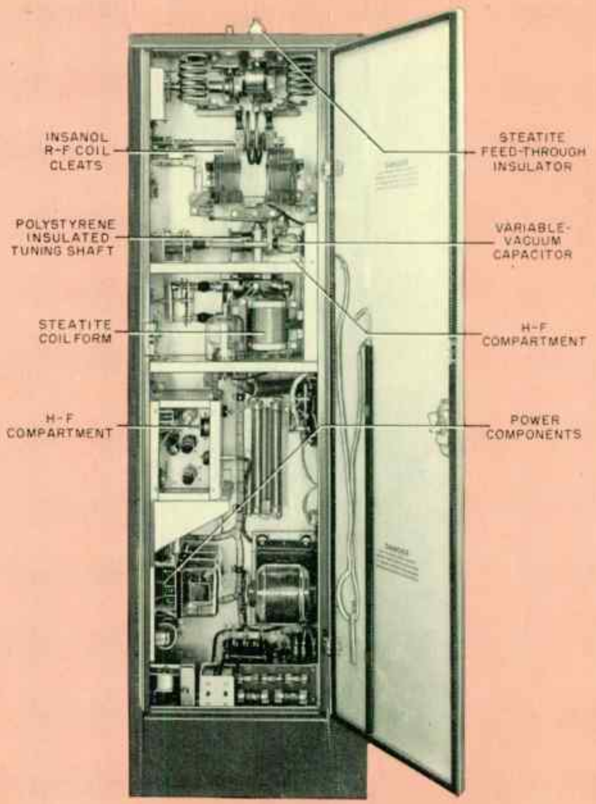
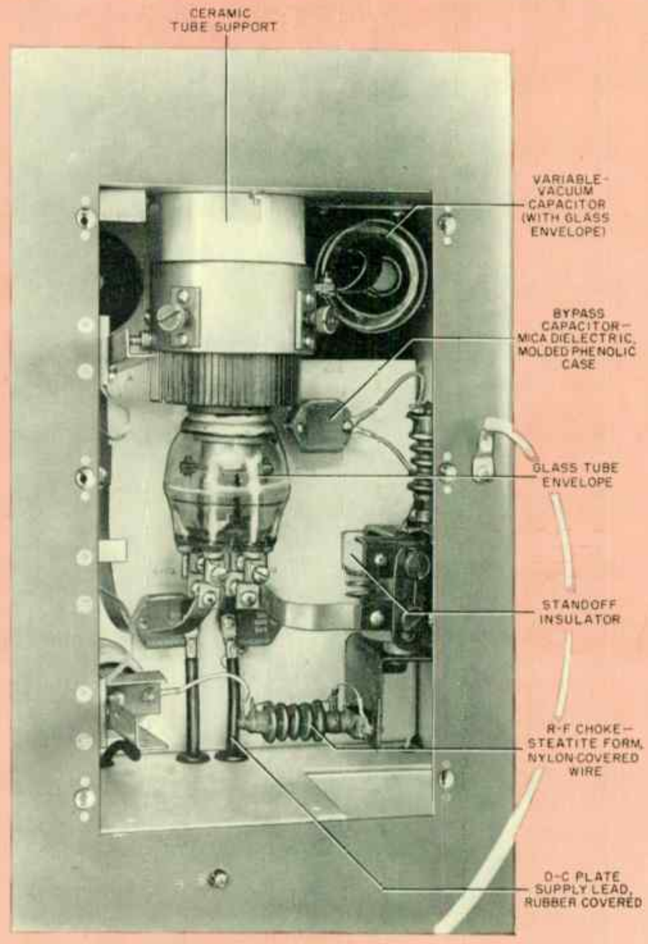


Fig. 3—A 3-kw transmitter with side door open.

Fig. 4—The power-tube compartment of the 3-kw transmitter.



and (c) to prevent pickup of unwanted signals by nearby receivers via power-supply lines. In general, low-frequency insulation between windings or from windings to ground does not function as insulation for r-f voltages, and must be supplemented by shielding, r-f chokes, and bypass capacitors.

An enlarged view of the top of this unit appears in Fig. 4; this shows typical disposition of parts in a high-frequency transmitter. The r-f compartment is operated at moderately high voltage with an overall efficiency of about 70 percent. Consequently, wasted power in the form of heat must be carried away from the compartment to prevent overheating of components. Even with cooling means, the components located adjacent to electronic tubes must be capable of withstanding high ambient temperatures.

Because of the close spacing of component parts, corona problems often arise. Corona can be reduced by the use of rounded corners or by specially shaped insulators to provide long creepage paths. As insulation voltage is increased at a given frequency, insulator temperature increases, at first approximately following a square law. Eventually, a voltage is reached at which the loss rises suddenly, corona forms on screw threads and other sharp edges, and insulation overheats. This is a very unstable operating condition, and may cause the insulation to break down completely. Even though complete breakdown is not reached, with intermittently high operating voltages, such as occur in modulation or keying operations, a nonlinear load represented by operation above the critical voltage may result in loss of high-frequency power and possible malfunctioning of the equipment. Increase of temperature with voltage on a steatite stand-off insulator is shown in Fig. 5.

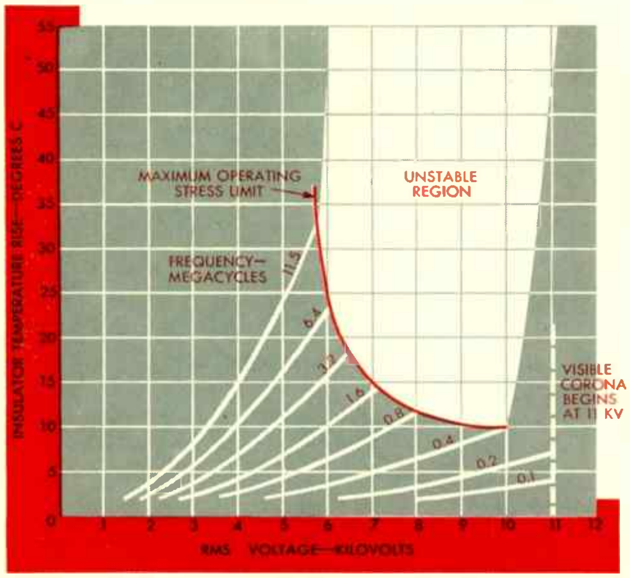


Fig. 5—Temperature rise in a two-inch standoff insulator is a function of frequency and voltage.

Equipment using high-frequency insulation is usually attended by operating personnel, and access is provided to the apparatus for frequent cleaning. Therefore dirt accumulations can be wiped off, and so long as dirt does not penetrate the insulation itself, the long creepage paths provided in outdoor apparatus are unnecessary. Exceptions are antenna lead-in and strain insulators. Ceramic or glass insulators are good for such applications because dirt does not penetrate and is easy to clean off. Another factor militating against large creepage distances is the small dimensions that are necessary because of limited space.

High-Frequency Insulation

Thus high-frequency insulation has peculiar demands upon it, some of which are significant in low-frequency insulation but to different degrees. Ideal high-frequency insulation should have the following characteristics: (1) high dielectric strength, (2) low loss, (3) low dielectric constant, and be (4) corona resistant, (5) non-tracking, (6) heat resistant, (7) mechanically strong, (8) easy to machine, (9) impervious to moisture, (10) impervious to dirt, and (11) easy to clean.

The relationship between power factor and dissipation factor is shown in Fig. 6. For small loss angles, these two properties are nearly equal. Dissipation factor is the property usually given for high-frequency insulation and is therefore discussed here. Many properties, both electrical and mechanical, of various kinds of insulation materials are given in Table I. Note that no single insulation in this list possesses all of the properties described as ideal. As silicones are used more and known better, perhaps they will fit into the high-frequency picture. The use of silicone materials, although expensive, may become quite practical, because the amount of insulation used in a given piece of high-frequency equipment is small.

The kind of insulation used at higher frequencies depends to a large extent on the power level involved and on the necessity for keeping loss to a minimum. For example, solid-dielectric coaxial cable is commonly used up to 3000 megacycles, and wave guide above this figure for high-power work. Yet a type of transmission line known as Micro-strip, in which Teflon is sandwiched between two thin, flat conductors, is used for space and cost reasons in low-power receiver applications up to 9000 megacycles. In the latter case, losses may be rather high, but the power available is sufficient to make it possible to lose considerable power and at the same time have plenty left for useful signals.

Low dielectric constant (i.e., low insulation capacitance) is just as important as low dissipation factor in high-frequency insulating materials. For constant values of both properties, total insulator current increases with frequency and eventually becomes so great as to rob the circuit of too much power. While variations may occur with frequency in both dielectric constant and dissipation factor, they are more likely to occur in dissipation factor. Consequently, if a material has a fixed dielectric constant, but dissipation factor, δ, decreases with increasing frequency, the increase in current with frequency is offset by decrease in δ, so that a tolerable loss is maintained over a considerable band.

The information in Table I is subject to much qualification. In an otherwise desirable material, a single property not necessarily listed in the table may completely determine its suitability for any particular application. For instance, Teflon undergoes cold-flow at room temperature. Unless the material is held in compression in all directions, it does not provide reliable mechanical support. This fact prevents the use of Teflon for stand-off insulators in transmitters, where its low dissipation factor and dielectric constant would be highly desirable. On the other hand, Teflon can be used in Micro-strip because it has virtually no weight to support, and therefore will not cold-flow at any ambient temperature.

Polystyrene is used wherever its low maximum-operating temperature is not a disadvantage, and where loss must be kept to a minimum. A typical application is its use in mounting panels for high-quality receiver work. Polyethylene is used

TABLE I
PROPERTIES
OF
INSULATING
MATERIALS

Material	Low-Frequency Dielectric Strength —Volts per Mil (Sample 0.060" thick)	Dissipation Factor (at 10^6 cps)	Dielectric Constant (at 10^6 cps)	Corona Resistance	Arc Resistance	Maximum Operating Temperature —Degrees C	Tensile Strength—Psi	Machining Qualities	Moisture Absorption —Percent
Polyethylene	300	0.0002	2.25	Poor	—	75	1 800	Good	0.03
Teflon	400	0.0003	2.0	Poor	Good	200	2 000	Good	0.00
Polystyrene	450	0.0003	2.5	—	Good	85	7 000	Good	0.05
Glass-bonded mica (Insanol)	360	0.0021	7.0	Good	Good	325	5 000	Fair	0.003
Steatite (Al Si Mag 196)	360	0.0030	5.7	Good	Good	1000	10 000	Poor	0.02
Pyrex glass (Low loss)	1000	0.0008	4.0	Good	Good	400	10 000	Poor	0.00
Fused quartz	1500	0.0002	3.8	Good	Good	1000	7 000	Poor	0.00
Titanium dioxide	150	0.0002	96.0	Good	Good	1000	4 000	Poor	0.1
Polyester film (Mylar)	*	0.0160	3.0	Poor	—	105	17 000	Good	0.5
Mica splittings with alkyd bond	450	0.0280	5.0	Good	Good	125	—	Good	0.1
Melamine glass laminate	450	0.0420	4.5	Fair	Fair	140	6 000	Fair	0.1
Phenolic paper laminate	640	0.0450	4.5	Fair	Poor	115	10 500	Good	1.2
Silicone glass laminate	400	0.0034	3.8	Fair	Good	200	32 000	Good	0.13

*Maximum availabe thickness 0.0075 inch.

as insulation between conductor and casing in a flexible coaxial cable. In both of these applications, voltage and mechanical stress are comparatively small and low loss is important.

Glass-bonded mica, such as Insanol, is excellent for use as stand-off insulators up through the h-f (30-megacycle) band. Here its difficulties are largely mechanical. This material does not thread readily. Round holes can be drilled and square edges sawed, but frequent sharpening of the tools is necessary. The insulator is attached to supports or conductors held by inserts molded into the material, or by metal caps held on with babbitt metal. Steatite (a high-frequency porcelain) is also molded but the threads are stronger and the extra expense of inserts or caps is eliminated. The resistance of this material to moisture absorption is improved greatly by glazing the surface. This also makes cleaning easier. Steatite insulators are available in a variety of forms and are widely used at all frequencies up to and into the vhf (300-megacycle) band. Pyrex glass with special constituents for low loss is sometimes preferred to Insanol or steatite. It is very easy to keep clean, and for certain special uses, such as antenna lead-in insulators, the extra cost is justified.

The use of fused quartz is limited to laboratory and other special applications. It has very low loss and is strong mechanically, but it must be made into special pieces because it is extremely hard and thus difficult to machine.

Titanium dioxide has a low dissipation factor but its high dielectric constant makes it generally unsuited for insulators at high frequencies. Its principal use to date is in r-f capacitors. One valuable feature of this material is that with proper mixture of constituents it is possible to obtain temperature compensation of capacitance, and thereby keep circuits in resonance with changing ambient temperatures. Variable capacitors up to 100 micromicrofarads have been made using this material as the dielectric.

Mylar is used as layer insulation in coils and capacitors. It is available in very thin sheets, is flexible, and conforms well to irregular coil surfaces. The dielectric strength of these thin sheets is quite high, but the corona-starting voltage is far below the dielectric strength. Since corona eventually causes insulation to break down, the practical working voltage of Mylar is limited by corona to that of impregnated paper of comparable thickness. Mylar is useful as a supplementary material in combination with other insulation. Unlike paper, it does not adhere well to most impregnating bonds.

The use of mica splittings with high-grade bonds is an old and well-established practice in 60-cycle power applications, especially in high-voltage generators. The moderately high dielectric constant of mica limits its use to frequencies of 100 megacycles or less. Even at these frequencies, the bond must

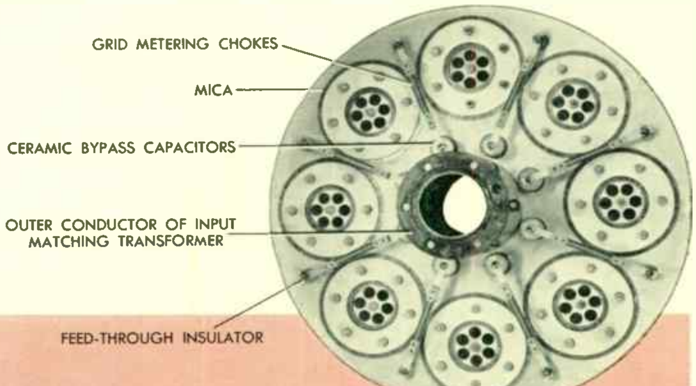


Fig. 6—Fundamental electrical properties of a dielectric.

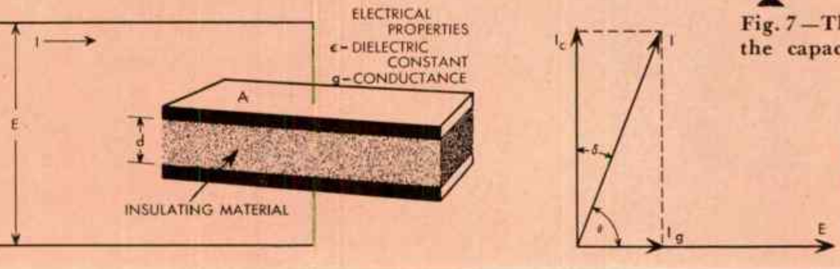


Fig. 7—The Symmetron, a multitube vhf amplifier, utilizes the capacitance of insulation in the electrical circuit.

Capacitance $C \backsim \frac{\epsilon A}{d}$

Loss current $I_g = Eg$

Capacitance current $I_c = E\omega C$

Power factor $\cos\theta = \sin\delta = \frac{g}{\sqrt{g^2+\omega^2C^2}}$

Dissipation factor $\tan\delta = \frac{g}{\omega C}$

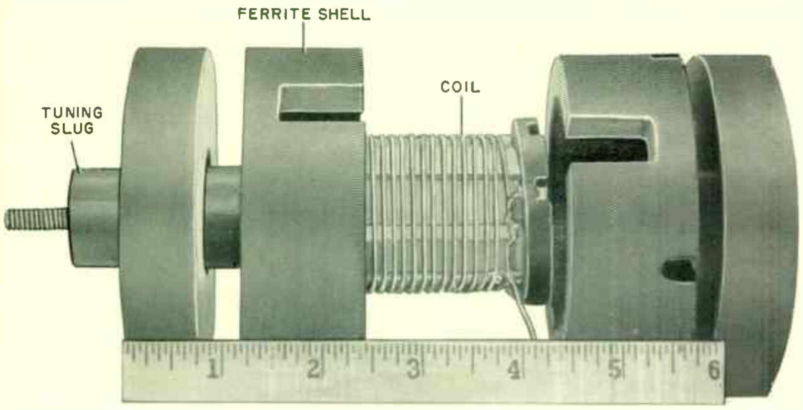


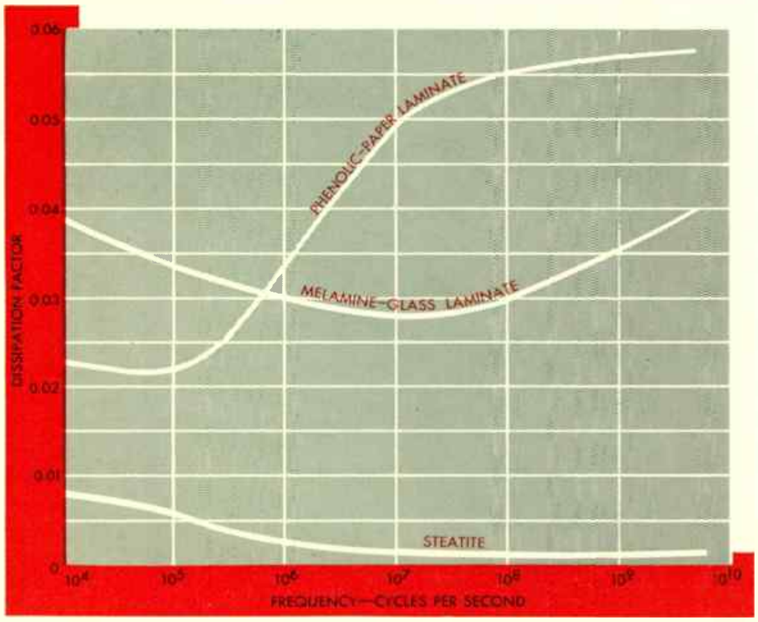
Fig. 8—This transmitter variable tank coil of approximately 5000 volt-ampere rating is for use at 1.5 mc and 2300 volts. The coil is wound on a coil form made of glass-filled Teflon and is spaced from the coil form by means of cleats positioned under the winding.

have low power factor to avoid overheating in transmitter applications. Ingenious schemes have been devised whereby the high capacitance of this material is not a handicap. The underside of the Symmetron, (Fig. 7) a multitube vhf amplifier, embodies a bonded-mica plate in the dual role of insulation and cathode-bypass capacitor. The grid-bypass capacitors in this amplifier are ceramics of titanium-dioxide composition.

Of the laminates, melamine glass and phenolic paper have the same general undesirable property of high loss. Moreover, this loss changes with frequency so that at some frequencies melamine is the preferred material and at other frequencies phenolic is preferred. The variation of dissipation factor for these materials is shown in Fig. 9, which also gives the comparison with a typical steatite. The superiority of steatite is at once evident.

Silicone-glass laminates have appreciably lower dissipation factor than melamine or phenolic laminates. For this reason, there is considerable promise that this material will come into use as a high-frequency insulation, particularly in those applications where mechanical qualities are important. The low moisture absorption of this material is another factor that is in its favor.

Fig. 9—Dissipation factor of insulation varies with frequency.



Combinations of some of these materials have been made with varying degrees of success. One instance is the molding of glass fibers in Teflon to reduce its tendency to cold-flow. Mechanical strength is increased, but so are moisture absorption and dissipation factor. A successful application of this material is shown in Fig. 8.

Many electronic developments have come as a result of the extended use of some property of no use at power frequencies. Silicones are a case in point. They were developed primarily for high-temperature work at 60 cycles but their moderately low loss and dielectric constant assures them a place in high-frequency insulation of the future. Therefore as progress is made in materials at low frequencies, a few of these will be found to be suitable at high frequencies.

• • •

New Materials and Processes

Fire Retardant Insulation in Mass Production—A year ago a new fire-retarding insulation for circuit breakers and switchgear was just emerging from the Research Laboratory. Already it has replaced about 85 percent of previously standard Micarta barrier materials. The new material, known as Redarta, can be made in virtually any desired shape. Exposed to an arc, Redarta requires twice as long to ignite as the older materials, and after removal of the arc the flame goes out about three times faster. This is of great benefit in reducing the likelihood that trouble in one compartment will spread to the next. Paper impregnated with the same fire-resisting resins is also being used in condenser bushings.

Redarta insulation as a replacement for Micarta in the various functions of barriers, bushings, bus supports and spacers, is superior in electrical, mechanical and moisture-absorption properties to the grades of material previously used. Thus the flame-retardant characteristics have been obtained, together with improvement in other important properties.

New Process Saves Selenium, Makes Better Rectifiers—A new process has been developed for the manufacture of selenium-rectifier cells, known as type K. The new process employs the evaporation method of coating the base plates with selenium and achieves three important results. First, cell electrical characteristics are improved, forward resistance being about 30 percent less and reverse resistance about 100 percent greater than for cells previously made. Second, because the processing is more precise, better control of selenium usage results, with thinner, more uniform layers, thus reducing the total consumption of this very critical material. Third, contamination of the process is largely eliminated, greatly reducing the rate of rejects, improving the cell uniformity, and again conserving selenium.

A Liquid That Stays Liquid—Organic damping oils, such as the commonly used polyisobutulene, freeze at 20 to 30 degrees below zero C. The better-known silicone fluids can be taken to about minus 50 before congealing. A new synthetic damping medium—containing a critical amount of phenylmethyl polysiloxane—remains liquid down to something below −80 degrees C.

The low freezing point is especially valuable for magnetic-amplifier use. These require damping fluid to absorb mechanically and magnetically induced vibration. If the fluid solidifies at the low temperatures encountered in high-altitude flight, the shrinkage imposes stresses on the Magamp that drastically modify its characteristics.

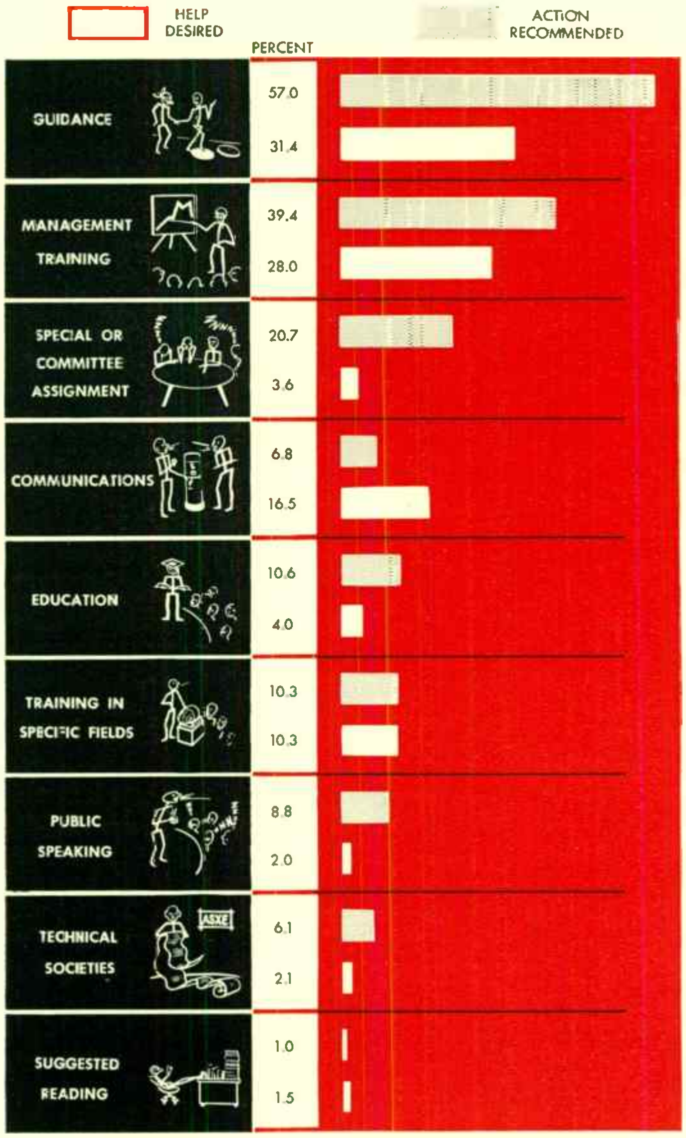
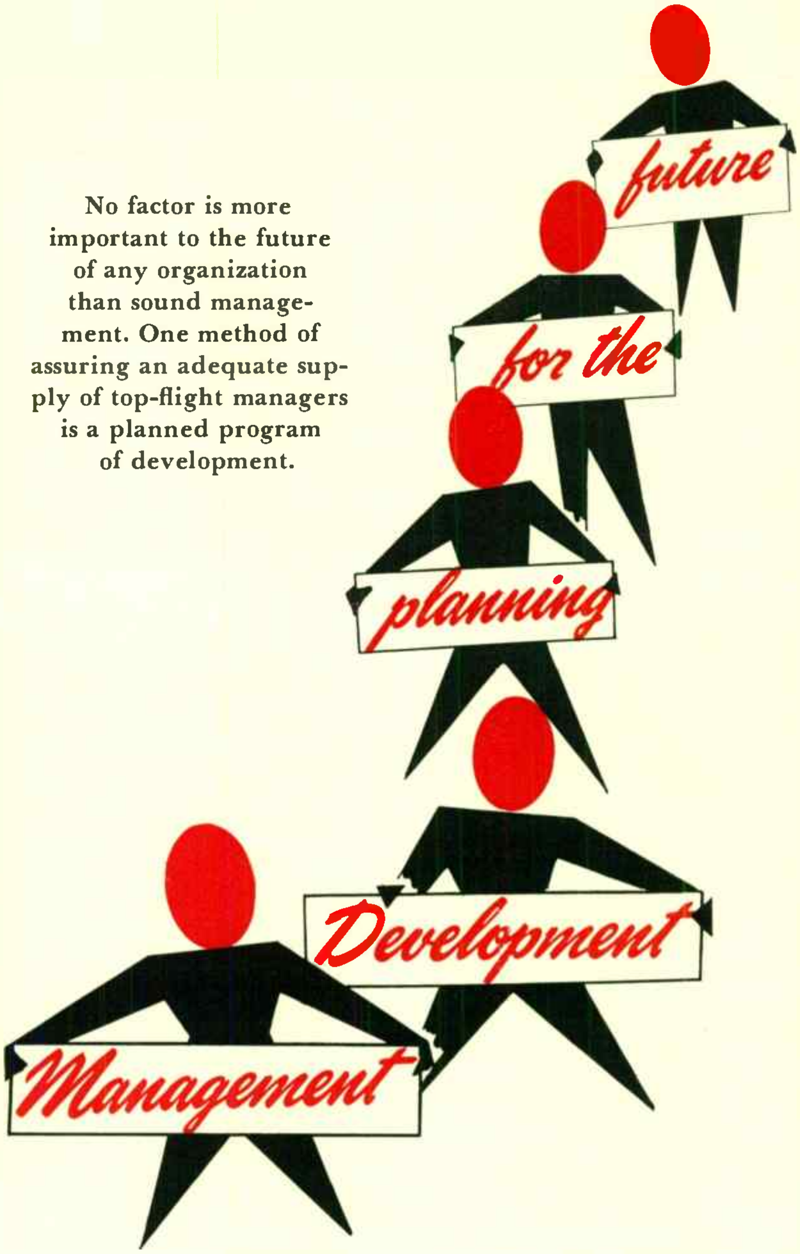


Fig. 1—These responses were helpful in indicating specific needs.



No factor is more important to the future of any organization than sound management. One method of assuring an adequate supply of top-flight managers is a planned program of development.

THE PERFORMANCE of a new machine can often be predicted with almost pinpoint accuracy before the device is built. Many business decisions that were once made on the basis of intuition or educated guesses can now be made with almost scientific accuracy. But unfortunately, in the realm of evaluating human performance, no such means exist for accurate prediction. Perhaps the biggest single calculated risk in industry today is the selection of a man for an important managerial position.

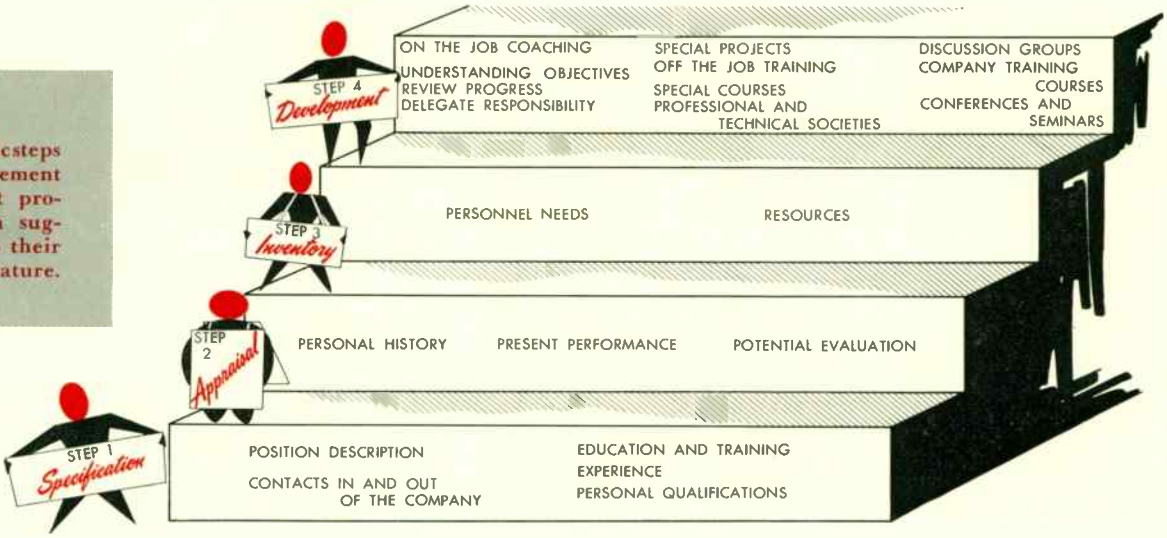
To further compound an already complex situation, a serious shortage of suitable managerial talent exists throughout industry. This was brought about by many factors—the depression of the 30's with its resultant low influx of new men, two wars, and the tremendous expansion of industry in the past decade, to name a few. The net result has been what is sometimes called "the great American manhunt" for managerial talent.

The problem posed is really two-fold—to locate potential management personnel within the organization, and to make available to each man the opportunity and the training to advance as far as his capabilities and ambition permit. This is no small order! It calls for some sort of well-organized and carefully executed plan to assure that both aspects are carried out. At Westinghouse, this has taken the form of a Management Development Program, initiated in 1950.

Programs designed to produce top-flight managerial talent are nothing new in industry; but perhaps because the problem being dealt with is somewhat nebulous, they vary from rigid supervision and control of a few carefully screened individuals to a process of osmosis, in which the most talented individual is assumed to always rise to the top. The Westinghouse program is neither of these, but rather a compromise. It involves a system whereby the performance and potentialities of about 10 000 men are periodically appraised; and, based on these appraisals, individuals are offered opportunity to further develop their knowledge through formal training programs, their personal characteristics through informal counseling, and to develop their experience through varied job assignments. There is neither pushing nor pulling; the program is firmly based on the principle that in the end result, nothing will advance a man except his own efforts. But care is taken to assure that road blocks do not develop to discourage incentive. In one sense this program might be called a "planned osmosis."

Written by Richard W. Dodge, based on information supplied by the Management Development staff of Westinghouse.

Fig. 2 The four basic steps of the management development program and a suggestion as to their scope and nature.



Deciding who is to be included in any management-development program involves setting some kind of arbitrary limits. Westinghouse includes two groups. The first consists of all present management personnel; the second group consists of non-supervisory personnel who are considered to have management potential.

Several things the program does not do. It does *not* select a handful of young college graduates and say to them, "One of you is going to be president of this corporation in 1980," and carefully convoy them toward that goal. Neither does it merely point to that far off peak and tell all employes "There it is—go get it!" The aims of the Westinghouse program are broader in nature.

As conceived and put into practice, the program actually has four objectives: (1) it establishes a uniform means of appraising and counseling individuals throughout the company; (2) it creates and maintains a company-wide inventory of talented personnel from which vacancies can be filled; (3) it helps assure that promising men have ample experience opportunities; and (4) it sets up an educational program designed to expose potential managers to general business and management policies and practices.

Even if nothing else were involved this would be a most worthwhile group of objectives; but as the program has progressed many other beneficial results—some of them unforeseen—became apparent.

The Program and How It Works

Obviously a preliminary step in organizing any such program is to determine exactly what your requirements are, i.e., get a clear-cut definition of each managerial position in the company. This monumental task was accomplished by the rather simple expedient of having each supervisor write a complete description of his own position on a carefully prepared form—and then compare notes with his immediate supervisor and iron out any differences of opinion.

Curiously, this rather routine step brought about a remarkable response. Supervisors at all levels were enthusiastic. Responsibilities were more clearly defined, not just to the supervisor, but also to his immediate superior. Moreover, it provided detailed specifications for every supervisory position in the company, and thus furnished a basis for making the best company-wide use of available talent. For example, it pointed out similar jobs in different locations, thus simplifying the overall problem of planning replacements.

Appraisal—With this preliminary step out of the way, the program moved into its initial stages. Next came the two-fold task of (1) appraising each man's performance in his present position, and (2) estimating his potential for the future. All of the management-development group are appraised by their immediate and next higher supervisors. This helps assure an accurate evaluation of the individual, and, of course, lessens the chance of personal prejudices affecting the results.

The factors on which individuals are appraised are spelled out in some detail on a special form to assure uniform appraisals. The appraiser first rates the individual in four general areas: (1) what he is, which includes personal characteristics such as leadership, mental alertness, character, etc.; (2) what he knows, which consists of factors such as knowledge of assigned work, current developments in his field; (3) how he works, which covers planning, organizing, working with others, etc.; and (4) what he accomplishes, with respect to quantity and quality, costs, and so on. The appraiser then rates the individual's performance on an overall basis, in one of eight categories.

In addition to merely rating the individual, the appraiser is also asked to give reasons and examples of factors that influenced his rating. This provides a basis for later discussion of the appraisal with the individual, as well as adding to the general fund of information.

All of the above relates strictly to present performance, and gives only a general indication as to whether the individual has the capacity for future advancement. Evaluation of potential, also accomplished on a carefully prepared form, is intended to aid this process. The two supervisors are asked to indicate what they feel the individual's degree of potential to be. They suggest what the next step might be for the individual, and when he may be ready for it. Finally the two supervisors are asked what development is needed to prepare the individual for advancement.

Counseling—Thus far, the appraisal has been of no direct value to the individual being appraised. The next step makes it so. This involves counseling of the individual, an informal discussion of the performance review (but not the evaluation of potential) between the appraiser and the individual appraised. By far and large, this has been one of the most productive and well-received parts of the program to date. The findings are reviewed with the individual and constructive suggestions offered as to what the man can do to improve his performance. The individual is told what his strong points are, and counseled as to weak points.

In the counseling, the reviewer is asked to draw from the individual certain general information. This includes what goals the individual has, what he believes his outstanding abilities to be, what he is doing to improve himself, and what help he wants or expects from the company. Obviously, these are the types of questions that can be handled well only in informal, friendly discussion—and every attempt is made to keep the counseling at this level. Several measures have been instituted to assist supervisors in this sometimes difficult human-relations project.

Inventory—With the positions defined and the individuals appraised, a complete management inventory was made for the entire organization. This charts management positions in the corporation, and the present managers. Where possible two replacements are listed for each job. These are preliminary indications, intended to suggest possible replacements in case of immediate need. This procedure not only points out the high-potential men, but, equally important, reveals weak spots in the organization where replacements are either not available or are not suitable. Also, with information available on all management-development personnel, the task of finding suitable replacements on a company-wide basis becomes entirely practical for the first time.

Training—The preceding steps are largely for the purpose of gathering information from which a program can be implemented. Next follows specific action to assist the individual in overcoming any deficiencies, whether in personal characteristics, training, or experience. Individual counseling and guidance are, of course, of prime importance. But, also, specific educational programs at several different colleges are utilized.

The most extensive is a 16-month course conducted by Harvard Business School, which leads to a master's degree in business administration. To this is sent a carefully selected group of outstanding young people; participants are between the ages of 28 and 35, and have five to seven years' experience. The first 15 men will complete the course in June of this year. Another program is the Sloan Fellowship for one year's study at Massachusetts Institute of Technology. Still another program—for selected key supervisors with outstanding potential—utilizes advanced-management programs at several colleges and universities. These range from 4 to 13 weeks in duration.

These three courses afford the individual the opportunity of close association and exchange of ideas with men of comparable level from all phases of industry—as well as an excellent grounding in management principles.

A condensed two-week course on business-management principles has also been instituted for Westinghouse men, and is conducted at the Educational Center.

These programs are all designed to cover general business principles. More specialized is the Westinghouse Policy Conference, intended to paint a clear picture of company policies, procedures, and practices for top-level managers. This is conducted by staff officers of the company who are responsible for particular functions, and by key members of their staffs.

Results to Date

The long-range objective of the Management Development Program, of course, is to assure an adequate supply of management personnel throughout the company. Only the first steps have thus far been taken toward this objective. A shorter term goal, however, is improvement of the effectiveness of managers at all levels; in this respect, as well as several others, results are already apparent.

For one, the "procedural phase" has provided a wealth of background information, all available in one place for study. Purely from the standpoint of statistics, it furnishes data previously unavailable. For example, the responses shown in Fig. 1 were invaluable in indicating specific needs. A high percentage of both appraisers and individuals being appraised expressed a desire for more guidance and counseling. Likewise many indicated a need for more training in management principles. These and the other figures give clues to specific deficiencies that otherwise would have been difficult to find.

Particularly, this first phase of the program has focused attention on the overall problem, and created an awareness of the need for development of qualified personnel on a planned basis. Also spotlighted are specific positions where adequate replacements are not available, necessitating some immediate action to correct the situation.

Having a complete and usable central file of all management and potential management personnel has many advantages. Occasionally a position about to become vacant in one company division has no suitable replacement available. This situation can now be recognized well in advance and measures taken to find a qualified replacement elsewhere in the company. This, in effect, makes the whole organization more closely knit, and extends considerably the opportunities of everyone concerned.

Implementation of the program is well under way. As of the end of 1954, 15 men are attending the Harvard MBA course, four have completed or are attending college under the Sloan Fellowship, 75 have completed or are attending the advanced management courses, 155 have completed the business management course, and 100 have attended the Westinghouse Policy Conferences.

In the Future . . . . .

The Westinghouse Management Development Program is not intended to serve as a gigantic machine that tests and psychoanalyzes each individual—and then with a whirring of gears and flashing of lights digests the information and flashes a neon-lighted number indicating the position where the individual should eventually wind up. Rather it is an organized effort to assure that the best management procedures are followed and that no individual of talent is stultified.

To keep the program from becoming a mechanical procedure, which in an organization as large as Westinghouse could easily happen, "headquarters-itis" is carefully avoided. Policies and procedures are set up by a headquarters team—which assures a uniform base—but the implementation is at local, or plant level; and a lion's share of the benefits are derived by local management and individuals.

Obviously this is not a program intended to form all promising individuals into a precise mold, designed according to someone's specifications as to what the "ideal" manager should be. And for good reason. No one yet has been able to lay down precise specifications for a top-flight manager, except in the broadest of terms.

Instead the program is designed to broaden the individual, both from the standpoint of experience and formal education. No ticket to success is offered to anyone; but the way is made smoother for those of ability, by offering them the chances to develop their talent, and by assuring them ample opportunity and incentive to progress. From the company standpoint, the program will help assure an adequate and well-trained supply of managerial talent for the future.

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Drilling for oil within the boundaries af a city presents problems. Noise and appearance must be considered. A new drilling-rig to operate in Los Angeles is all contained in a frame building sound-proofed by layers of nylon batting on the outer walls. Power is applied exclusively by a-c motors.

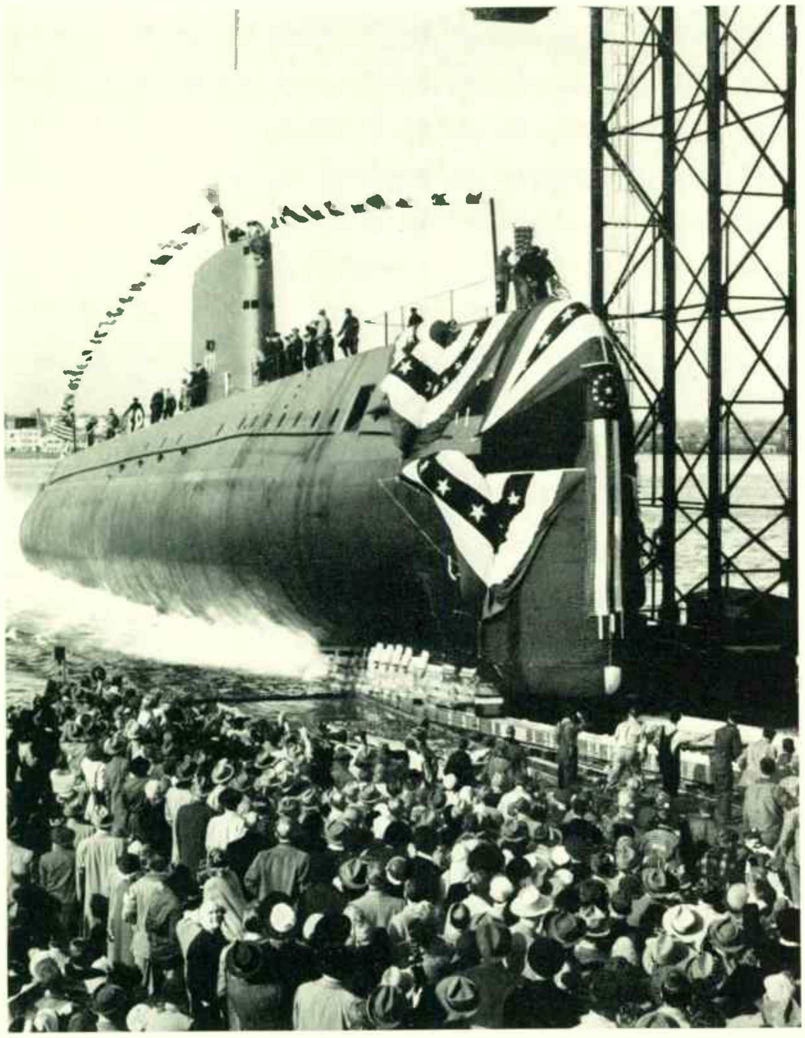
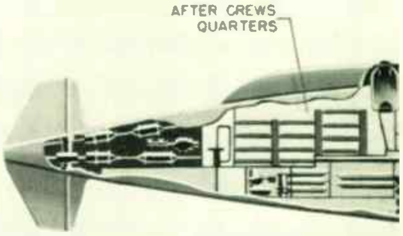


Fig. 1—Launching of the USS *Nautilus*. Photo by General Dynamics Corporation.



The Nuclear

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Foreword—The authors wish that it were possible to give individual credits, but it is not possible to do so in a paper of this nature. They are acting as spokesmen for a much larger group. The engineering development presented in the following paper is the work of scores of companies and government agencies, and thousands of individuals. All of the work done has been under the sponsorship of the United States Government with the Atomic Energy Commission and the Department of the Navy supporting the work through a unique joint organizational arrangement established to make maximum use of the facilities and abilities of both organizations.

This paper has been reviewed and cleared by the appropriate authorities to insure that no matters of security interest are disclosed herein. Of necessity, certain aspects have been handled in a general rather than a specific fashion and certain others have been omitted altogether.

The historical interest of the U. S. Navy in nuclear propulsion dates back to 1939 when, shortly after the discovery of fission, it was quickly appreciated that this process offered a potential method of propulsion for naval vessels. First, because of the state of early research, and later because of the pressure of war work, little was done toward nuclear propulsion until the end of World War II. However, a report of an advisory committee to the Manhattan District, known as the Tolman Committee Report, made policy recommendations to the Manhattan District in 1944. This report recognized the urgency of providing power for the propulsion of naval vessels, but nothing significant was accomplished until 1946.

In the spring of 1946, the Manhattan District initiated a project, known as the "Daniels Power Pile," which was aimed at the development and construction of a small experimental land nuclear-power plant. The Bureau of Ships and the Westinghouse Electric Corporation were included among those industries and government activities asked to send technical representatives to the Clinton Laboratories (now Oak Ridge National Laboratory) at Oak Ridge, Tennessee, to work on this project. Throughout the fall of 1946 and most of 1947, the group thus assembled worked on the "Daniels Pile." In September of 1947, a preliminary study was completed. However, the Atomic Energy Commission, which had taken over atomic-energy activities from the Manhattan District on January 1, 1947, decided that further work on this type of reactor should be halted pending an extensive survey of alternate pile types. Shortly thereafter, acting on informal requests from the Navy representatives, a first study of the application of a high-pressure, water-cooled reactor for a submarine was undertaken by the remaining personnel of the Daniels Pile Division at Oak Ridge. This work elaborated upon an idea first proposed by Dr. A. M. Weinberg of Oak Ridge in April, 1946, for use of this type of reactor for power production.

The Department of the Navy in December, 1947, formally stated the importance attached to the development of a nuclear-powered submarine, and requested that action be initiated by the Atomic Energy Commission for the early development, design, and construction of a suitable reactor for this purpose. On April 2, 1948, the Chief of the Bureau of Ships, Vice Admiral E. W. Mills, USN, addressed the Undersea Warfare Conference in Washington and summarized the Navy's efforts up to that date to obtain action on the development of the nuclear-power plant for a submarine.

This speech really marked the formal beginning of the *Nautilus* power plant. Shortly there-

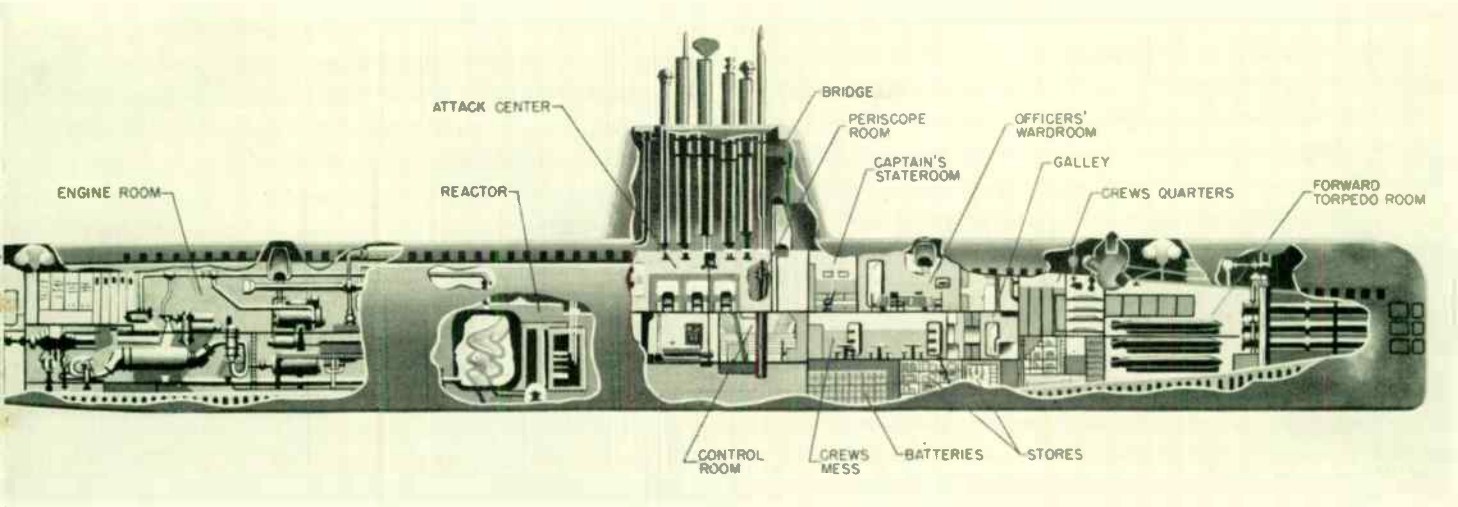

Fig. 2—Cutaway sketch of USS *Nautilus* showing reactor and engine room. Official U.S. Navy photograph.

Propulsion Plant of the USS NAUTILUS

To a first approximation, the amount of energy that may be released within a reactor, and hence the amount of power that may be produced thereby, does not depend upon the size of the reactor as determined by nuclear consideration. Any amount of power, from a few watts up to hundreds of thousands of kilowatts of heat may be produced from any size reactor provided this energy can be removed from it. In the smaller reactors, it is interesting to note that the limitation on the power production is not a nuclear one, but, rather, one that is dictated by the ability of the engineer to remove the desired amount of heat from the small volume of the reactor required by the nuclear consideration.

The application of the heat released in the reactor to the production of useful power, in general, is achieved through a conventional thermodynamic cycle. This does not, however, mean that this part of the system is necessarily identical with a similar cycle used for conventional chemical fuels. Indeed, the reverse is almost always true because, when using conventional fuels, the engineer is given a temperature level of approximately 3000 degrees F in the combustion gases with which to start. By proper design the materials used to make the boiler tubes or gas-turbine blades can be considerably cooler than the combustion gases.

In a nuclear reactor, almost the opposite is true. The materials in the core of the reactor proper must be the hottest in the entire system, and these are the very materials that have the most severe requirements already imposed on them as regards neutron absorption, radiation damage, strength, and corrosion. Furthermore, at least in the case of the mobile power plants, where efficiency normally means increased cruising range and decreased fuel consumption, one of the really big incentives to go to a higher temperature, and therefore a more efficient power plant, is lacking. The weight of the nuclear fuel itself is an almost inconsequential part of the total weight of a nuclear power plant. Thus improvements in efficiency do not mean that the ship will have significantly increased cruising range as is true in the case of conventional fuels. These factors add up to the fact that the "conventional" power-plant end

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This article is part of a paper presented at the 62nd Annual Meeting of the Society of Naval Architects and Marine Engineers, held November 12, 1954. Another portion of the paper will be published in a subsequent issue.

after, the AEC established the Submarine Thermal Reactor (STR) as a formal project. The Argonne National Laboratory of the Commission was assigned the research and conceptual design aspects, making use of some of the former "Daniels Power Pile" group who were transferred from Oak Ridge. To the Westinghouse Electric Corporation the Atomic Energy Commission assigned the development, engineering design, construction, and operation of the STR Mark I prototype plant; and the design and construction of the subsequent shipboard plant, Mark II. Mark I was to be land-based. Mark II will power the USS *Nautilus*. Westinghouse's first contract on this work with the Bureau of Ships was executed in June, 1948; and with the Atomic Energy Commission in December, 1948.

Active development work by Westinghouse began in early 1949, with the official establishment of the pressurized-water type of reactor as the one selected for this project. At the same time Westinghouse purchased a former airport site near Pittsburgh, and the Commission built the Bettis Laboratory there. Construction of the Mark I at the National Reactor Testing Station in Idaho began on almost the same day, in August, 1950, that Public Law 674 was signed by the President of the United States. This law authorized the construction of the first nuclear-powered submarine, later named USS *Nautilus*, SSN-571, to be powered by STR Mark II.

Throughout 1951 and 1952, development, design, and construction of the Mark I proceeded simultaneously with design of the Mark II. At the same time it was necessary to build up a technical program, to train engineers and scientists in the new skills and techniques involved, to establish production facilities for new materials and new equipment, to procure scarce materials during the height of the Korean War build-up, and on several occasions to remove materials from strike-bound plants. The technical problems that evolved, and the solutions, are outlined in this article.

On March 30, 1953, at 11:17 p.m., Mountain Standard Time, the Mark I reactor was first made radioactively critical. On May 31, 1953, the Mark I was first operated at power. In June, 1953, a sustained full-power run, simulating an Atlantic crossing submerged, was concluded successfully. The keel of the *Nautilus* had been laid in Groton on June 14, 1952, and the fabrication and installation of her power plant was progressing in 1952 and 1953. When she was launched on January 21, 1954, most of the major components were already installed. Although the Mark II plant installed in the *Nautilus* is a nominal duplicate of the Mark I, many design changes have been incorporated.

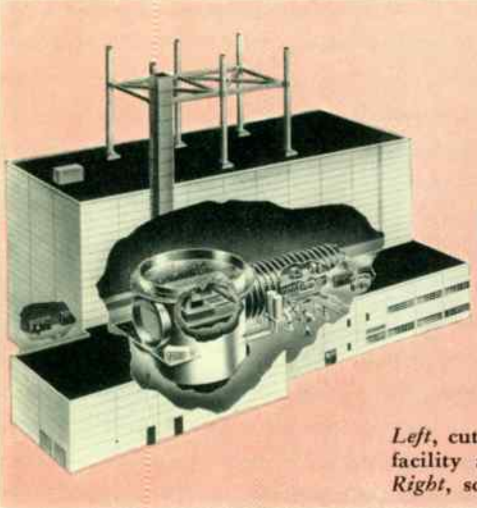


Fig. 3

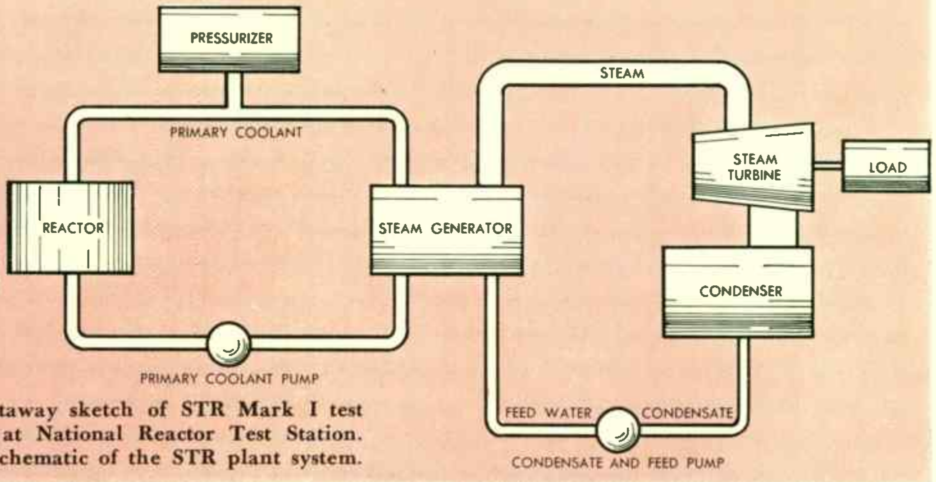


Fig. 4

Left, cutaway sketch of STR Mark I test facility at National Reactor Test Station. *Right*, schematic of the STR plant system.

of a nuclear power plant usually operates at the lowest possible temperature.

The thermodynamic cycle chosen for the Submarine Thermal Reactor was in fact one that permitted operation at just about the minimum temperatures that would allow the generation of useful power. The cycle selected for the Submarine Thermal Reactor uses ordinary water maintained under high pressure so that it does not boil, to transfer heat from the reactor into a steam generator. This generator is basically a shell-and-tube-type feedwater heater. Ordinary boiler water at relatively low pressures on the other side of the tubes (from the primary coolant) boils and forms steam, which is used to drive steam turbines for propulsive power and to generate electricity to meet auxiliary electrical requirements.

Some of the problems that have been met can be understood by looking at the general breakdown of funds spent in nuclear engineering over a number of years and covering several projects including the STR. Roughly, 28.1 percent has gone into mechanical engineering, including heat transfer; 36.8 percent has gone into metallurgy and metallurgical engineering work; 11.2 percent has gone into theoretical and experimental physics work; 11.3 percent has gone into electric and electronic engineering development; 6.9 percent has gone into chemistry and chemical engineering, and 5.7 percent has gone into operational engineering and testing. The predominant effort clearly has been in fields of specialization other than physics.

STR Power Plant

The equipment to be mounted in the hull of a nuclear-powered submarine is so functionally interrelated that it must be considered as a single power plant. However, it requires hull space of such size that it was necessary to divide it into two physically separated compartments to provide adequate water-tight integrity in the event of battle damage to the submarine hull, Fig. 2.

The reactor compartment contains the nuclear reactor, all steam-generating equipment, and the auxiliary systems. The engine room contains the propulsion equipment, all steam-driven items, associated control panels and switchgear, as well as the main control point for the equipment in both submarine compartments.

The primary-coolant system, located in the reactor compartment, consists of a reactor pressure vessel, which contains a nuclear reactor and coolant loop, Fig. 4. The water coolant (called primary water), which is also the moderator, is circulated by canned-motor-type pumps through the reactor vessel to be heated, and then through the steam generators for transfer of heat to the water on the secondary side. The wet steam rises to the steam separator where the water is removed, providing dry and saturated steam.

The coolant loop is provided with stop valves to permit isolation of parts for maintenance purposes.

From the separator the steam is carried through pipes that penetrate the bulkhead and diverge in the engine room to supply steam to the main propulsion turbine and to the ship's service turbine-generator sets. Condensate is pumped back to the steam generators.

General Plant Layout

Reactor Compartment—The reactor vessel is located vertically in the compartment. In the lower part of the compartment are the primary-coolant pumps. Outboard of the pumps is the steam-generating equipment. In the upper part of the compartment, above the steam-generating equipment, is the steam separator, from which emerge the main steam headers that lead aft to the engine room. Aft of the main pumps is located the pressurizer unit.

These components outline the main areas in the reactor compartment. The areas between them are filled with secondary equipment and related piping and cables, electrical and pneumatic control panels, valves, motor-generator sets, and instruments.

Engine Room—The engine room is located adjacent to and aft of the reactor compartment. This space is divided into upper and lower levels. Each level is provided with a walkway running fore and aft along the horizontal centerline. Components also have to be located on intermediate levels because of their varying size. These intermediate levels are accessible from either the lower or upper level.

Primary-Coolant System Components

Reactor Vessel—The reactor vessel houses the nuclear core. The shell is fabricated from carbon steel.

Thermal Insulation—The thermal insulation in the reactor compartment is conventional in type.

Steam Generators—The steam generator transfers the heat energy of the radioactive primary water to nonradioactive steam. In operation, the primary water enters the forward end of the steam generator, and passes through the tubes, which are rolled and welded. As the secondary water flows across the bundle, boiling takes place.

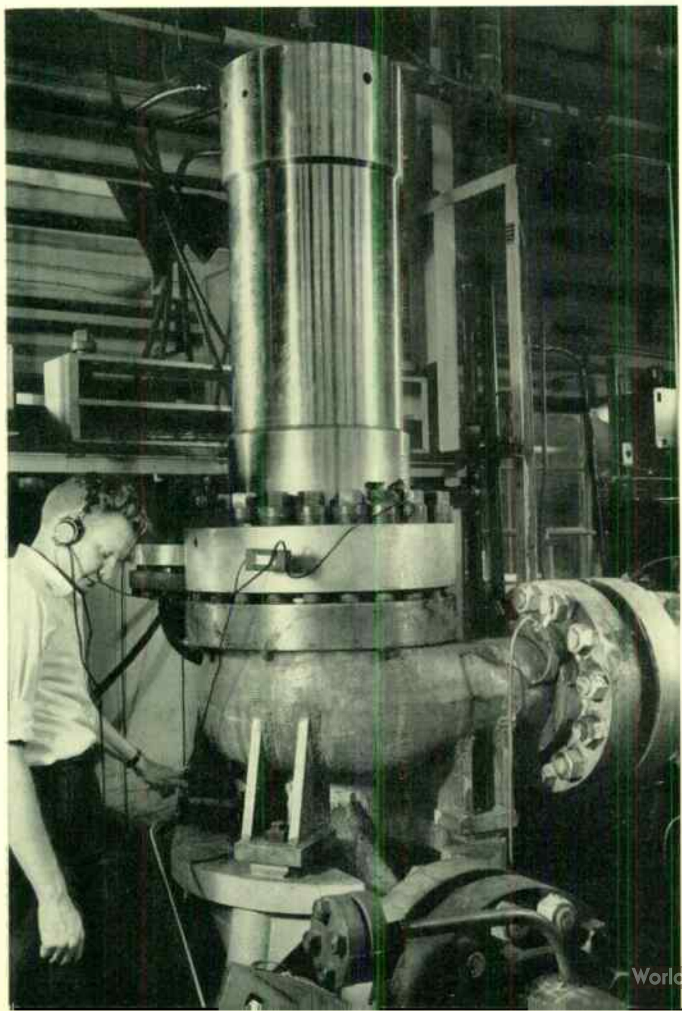
Water is fed into the bottom of the shell side through a header beneath the generator shell. Feed lines branch from this header and distribute the water into the bottom part of the shell.

Main Coolant Pumps—The main coolant pump, as shown in Fig. 5, is of the centrifugal type driven by a three-phase induction canned-motor type unit, absorbing full system pressure across the Inconel stator can. The complete pump unit, as shown in Fig. 6, consists of an electrical stator assembly, canned-rotor assembly, pressure housing with integral cooler, bearings, pump impeller, and lower bolting ring. The drive unit is assembled into the volute that forms part of the primary loop.

Within the motor, cooled primary water is circulated by means of an auxiliary radial-vane impeller. From the impeller, water flows downward through the "air-gap" to the lower-radial and upper and lower thrust bearings, and into the cooling tubes that form part of the heat exchanger. The water is then brought to the top of the pump where it enters the motor frame and the auxiliary impeller suction. Some water from the auxiliary impeller is bypassed from this circuit to circulate water to the upper radial bearing. The bypassed water flows through the bearing, then directly back to the auxiliary impeller suction.

Motor heat is dissipated to the primary water being recirculated within the pump. A close-fitting labyrinth-type seal on the shaft just below the thrust bearing and a double Belleville spring arrangement prevent the motor cooling water from circulating freely with the high-temperature primary coolant water. Heat from the end turns is transferred by conduction to the pressure shell.

Fig. 5—Main coolant pump in test loop.



The upper and lower journal bearings are made of graphitar, backed by stainless-steel shells with spherical seats for self-alignment. These seats rest on cylindrical rings of Stellite. Shaft-journal surfaces are Malcomized stainless steel.

The upper thrust bearing, a tapered-land type, is made of graphitar with runners of stainless steel. The lower thrust bearing is a fully equalized, pivoted shoe-type bearing.

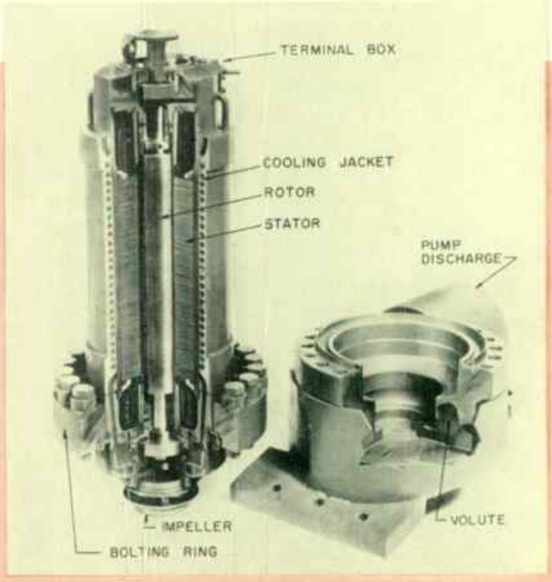


Fig. 6—Cutaway view of main coolant pump.

The conductor slots are kept as narrow as possible to reduce the stress in the can where it bridges the slots. Beyond the end of the stator punchings, support is provided by the back-up cylinders to which the can ends are welded.

Main Coolant Loop Piping and Valves—Hydraulically operated stop valves, as shown in Fig. 7, are provided for isolating the primary-coolant system. The primary coolant, which acts as the operating fluid, is directed into the valve cylinder by suitable pilot valves.

The piping is designed to take up its own expansion as well as that of the components to which it is connected.

Shielding—Shielding the radioactive power-plant components without adding a prohibitive amount of weight was one of the major arrangement problems. As finally resolved, the shielding is such that essential controls and equipment can be manned while the reactor is operating.

Necessarily, piping and electric cables penetrate the shield. The penetrations must be water-tight and air-tight to prevent leak-through of radioactive airborne particles and they also must be arranged to attenuate properly any radiation leakage through them.

Primary-Coolant Auxiliary Systems

A considerable number of auxiliary service systems are required to insure proper operation of the primary-coolant system. Pumps similar to but smaller than the main coolant pumps are used in these systems.

Charging System—The system must be filled with pure water initially, and addition of water must be possible at any time. There are numerous charging lines to the main loops so that a section that has been isolated for servicing can, by operating the isolating valves, be recharged without a shutdown or risk of sudden loss in pressure.

Pressurizing System—The pressurizing system is designed to maintain a controlled pressure in the primary-coolant system and its auxiliary systems under all operating conditions, and also serves the function of providing surge capacity.

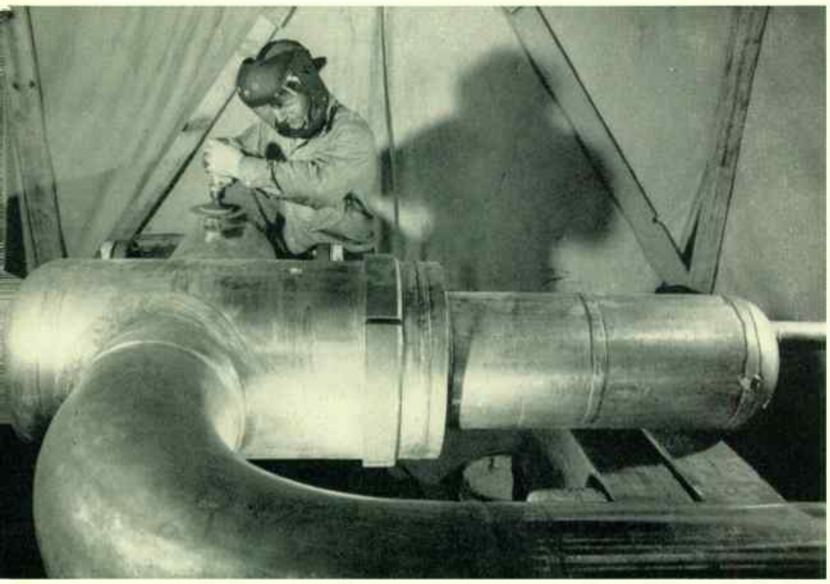
Pressurizing is obtained by providing sufficient heat to build up a head of steam in a pressurizing tank. The pressurizing tank is connected to the primary-coolant system, thereby transmitting the developed pressure to the system.

Steam Plant

The primary purpose of the steam plant is to convert the heat energy developed by the reactor into useful shaft horsepower for ship propulsion. In addition, the steam plant also supplies power to all auxiliaries for power-plant operation, and all electrical equipment and lighting systems, including sufficient power for charging the battery.

The steam plant is patterned after a conventional shipboard installation insofar as the handling of the steam and condensate is concerned. The design is such that the steam system is subdivided into identical port and starboard steam plants, which can be operated simultaneously, either cross-connected or isolated from each other.

Fig. 7—Primary-coolant main valve.



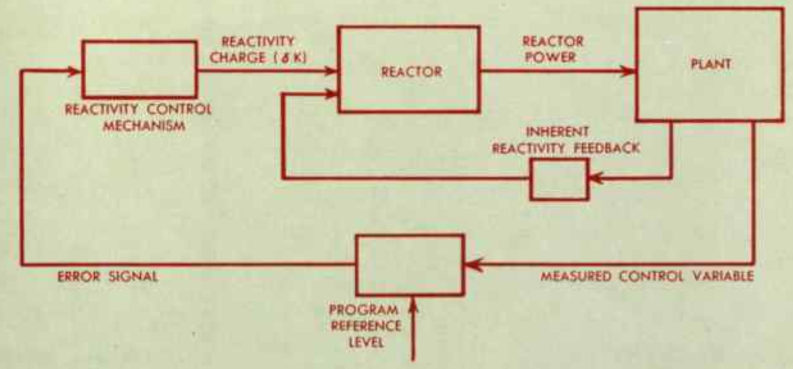


Fig. 8—Control system schematic drawing.

The main engines are geared, marine-type steam turbines. There are auxiliary-power turbine generators with auxiliaries such as condensers, air ejectors, condensate pumps, and lubricating-oil systems.

The design of the condensers, the circulating-water piping, and pumps for all units became special problems. The circulating-water system of a conventional plant, land-based or shipboard, is designed for low ambient pressure. In the submarine, the equipment in the circulating-water system had to be designed for high pressure to contain the sea water for static conditions corresponding to maximum submergence, in addition to providing the large heat-transfer surface and high flows necessary for disposing of the waste heat.

Power from Turbine to Propeller

To convert the shaft horsepower from the low- and high-pressure turbines into useful thrust, it passes through the reduction gears, the clutch, and finally through the propulsion-motor shaft. The power is then applied directly to the propeller.

The propulsion-system clutch enables the propulsion motor and propeller section to be disengaged from the turbine and main reduction-gear section. If a clutch were not used, the propulsion motor, when in operation, would have to overcome the inertia and friction losses of the turbine rotors and reduction gear in addition to overcoming the normal propeller load. The clutch also permits some angular and parallel misalignment of the drive shaft. It incorporates a thrust link that serves to locate the reduction gears axially and transmit any axial forces due to these gears to the main thrust bearing.

Control System

A schematic representation of the plant-control system is shown in Fig. 8.

Control panels are provided in the maneuvering room for control of operation of the plant. Complete instrumentation required for operating the power plant is provided on the power panel. The power panel is to provide normal control of the power plant.

The propulsion panel has all of the controls necessary for operating the main shaft. These include the speed controls for the turbine and propulsion motor.

Maneuverability

A submarine must be maneuverable. In terms of a nuclear-powered submarine, this means that the power plant must be capable of varying output rapidly and of changing quickly from quiet operating condition to one of full power ahead. The power plant for the *Nautilus* is designed to function in several ways: normal operation, i.e., propulsion by the main geared turbines, with steam furnished by the reactor system; or emergency operation with electric-motor drives by use of power supplied by a battery or a diesel generator.

Requirements for Application to a Submarine

One of the basic design problems for submarine equipment is compactness. In general, the space for equipment is much less than that which would be required for a commercial design. For example, heat-exchanger designs had to be chosen not by reason of being the optimum from heat-transfer considerations but for space reasons; certain design features were employed that would not be commercially feasible for use in a conventional steam plant.

Equipment weight is of paramount importance since it cannot exceed the amount set by the displacement of the submarine. For stability reasons the center of gravity is required to be low in the hull. In locating the heavier plant components, this factor had to be taken into consideration. Normally, however, lead ballast is used to achieve the required center-of-gravity location. A ballast estimate is made at the time the overall weight estimate is prepared for the vessel. If the components weigh more than estimated, then ballast is removed from the ship to maintain buoyancy. In doing this, so much ballast may be removed that a center-of-gravity problem is created. Such a situation would require that the ship size be increased to accommodate the needed ballast and maintain necessary stability.

Personnel Safety

Although personnel safety is a factor to consider in operating a steam power plant within a submarine, of more urgent concern is positive protection from nuclear radiation.

The shield reduces the radiation to a level such that, during a cruise lasting the life of the reactor, the average crew member will receive less radiation than he would during a lifetime from cosmic rays; natural radioactivity in the sea, air, drinking water, and ground; routine chest and dental x-rays; television screens, and luminescent instrument dials.

The radiation-monitoring system for the submarine, which is to insure proper radiation levels for personnel protection, has air-particle detectors, gamma detectors, boiler-leak detectors, and a discharge system-activity indicator. The air detectors sample the activity of the air in the shielded area and in adjacent compartments. Gamma detectors are installed in various sections of the ship. The boiler-leak detectors warn of a ruptured boiler tube in the steam generator, which would allow radioactive coolant to enter the unshielded steam system. The discharge system-activity indicators insure that radioactive water is not discharged at a dock or elsewhere where it would produce a hazard.

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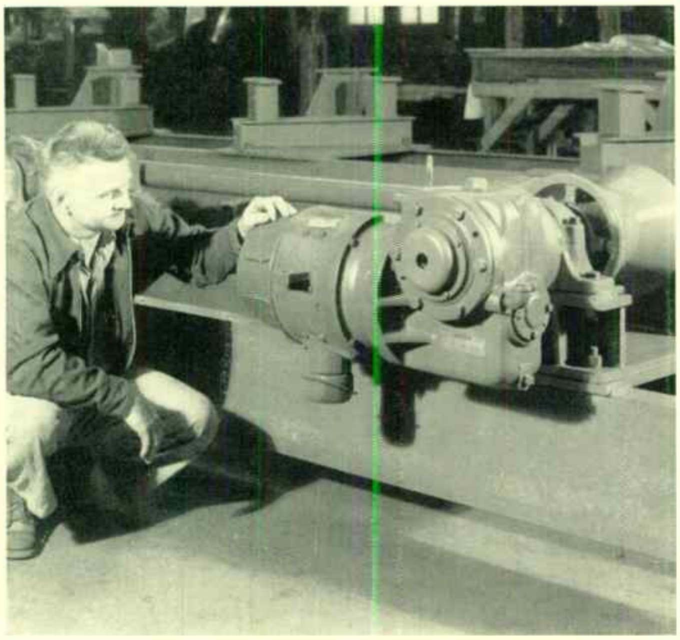
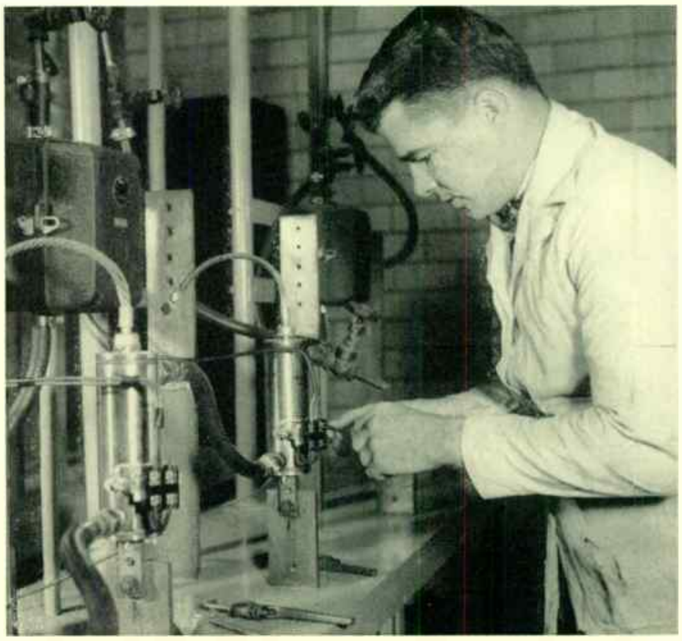


This shaft-mounted gearmotor will drive a pipe roll in a new mill.



The thermostatically controlled ignitron installed for testing.

What's NEW!

Gearmotors "Ride the Rolls"

SOMETIMES a topnotch idea lies dormant for many years before a successful application is found. The fundamental concept of supporting a driving unit on the shaft being driven is not new—several patents are on record, dating back at least three decades, discussing versions of this basic principle. However, gearmotor design engineers were able to put the idea to good use recently when faced with a problem of saving aisle space.

Roll tables in aluminum and steel mills have been driven with conventional flexibly coupled, rigidly mounted gearmotors. Valuable aisle space is required for the shaft extension, the coupling, and the gearmotor. Any space that can be saved is like money in the bank to the mills. Therefore, a drive has been conceived that mounts directly on the roll shaft extension. The gearing "surrounds" the shaft, and the motor is mounted at right angles, as pictured above. A torque rod anchors the gearmotor housing to prevent its turning, and the complete drive "rides" with the roll. Besides saving many valuable inches of aisle space, the new unit also eliminates foundation and coupling problems. And the "floating" gearmotor can be replaced in a jiffy if ever necessary.

A similar story can be told for the cotton-card gearmotor. At one time, all textile machines in a mill were driven from either a waterwheel or a steam engine, with power transmitted to individual machines by lineshafts and belts. More recently, electric motors have been used in similar arrangements. Since the card, the machine that combs cotton fiber prior to spinning, has not changed in basic design for many years, it has not been necessary to make any major rearrangements in card rooms. Consequently, card machines, lined up under lineshafts, have scarcely more than belt space between units.

By applying the same "floating" gearmotor principle, a unit has been developed that will fit in approximately the same aisle space normally required for a belt pulley. Conversion is simply a matter of removing the belt pulley and mounting the gearmotor on the card shaft. A torque arm anchors the unit to the card frame and prevents the gearmotor from turning with the card shaft.

A double-reduction set of helical gears reduces motor speed to proper card-operating speed. The 1½-horsepower, high-torque motor is totally enclosed and non-ventilated, and is especially designed for card service.

The space-saving feature of the "floating" mount, plus the simplicity of installing, maintaining, and replacing units, has left gearing engineers eagerly looking for further applications. So if you've got a space problem, just let them know.

Thermostatic Water Control for Ignitrons

A NEW welding ignitron has thermostatic control; this accomplishes two things—it reduces the amount of cooling water used, and provides protection to the tube and associated equipment in case of water failure. For thermostatic control to be effective, a way had to be found to measure the internal temperature of the ignitron. This was done by enlarging a small area of the inner cylinder of the ignitron so that it contacted the outer cylinder, thereby providing a heat-conducting path through the water jacket. The thermostat, mounted on the outside of the tube, responds to the temperature of this "spot," and can be used with a solenoid water valve to turn cooling water on and off as needed, or stop tube operation in case of insufficient water flow.

New Jet-Engine Lubricant Tested

A NEW silicone lubricant with outstanding thermal and load-bearing properties is being vigorously tested by materials and aviation gas-turbine engineers.

The silicone fluid has satisfactorily passed thermal stability and viscometric tests ranging from −65 degrees F to 500 degrees F. Steel-to-steel bearing-load tests have shown the fluid to have excellent lubricating qualities up to 107 000 pounds per square inch bearing area.

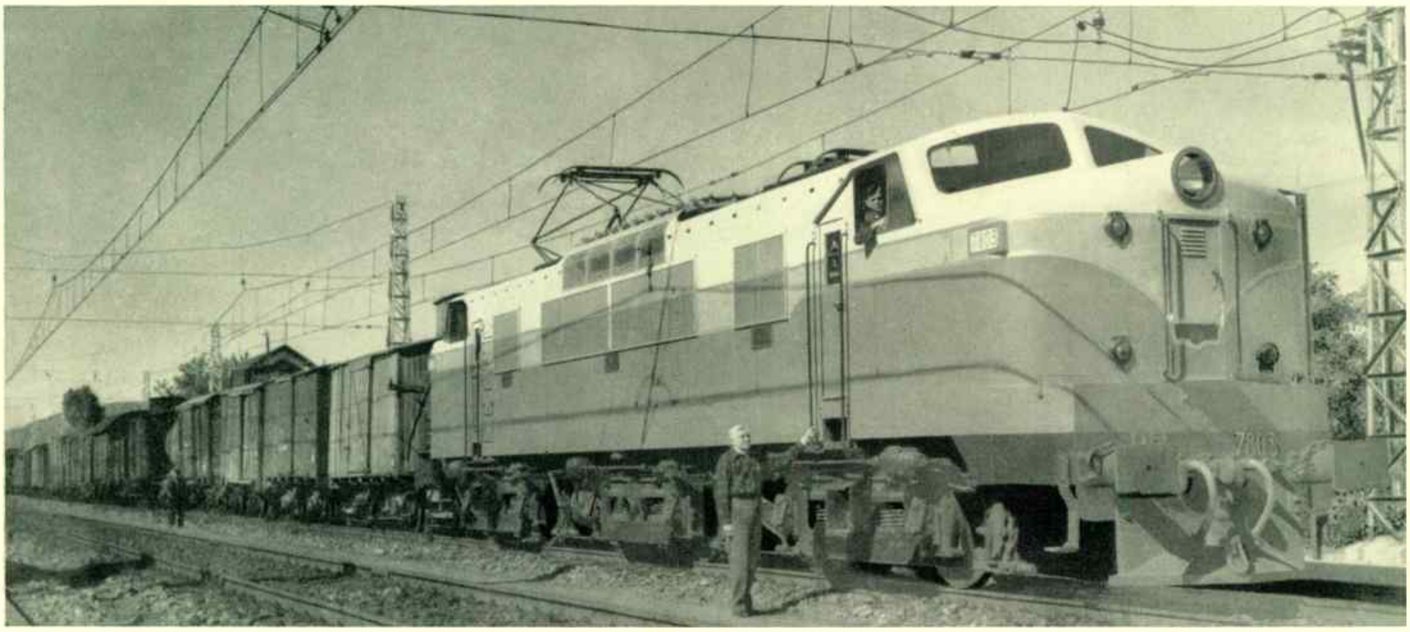
Present commercial silicone oils are well known for their high degree of thermal stability combined with a favorable viscosity-temperature relationship. These oils also possess desirable properties such as high flash temperature and low pour and freezing temperatures. In spite of this array of good qualities, however, they have always been poor lubricants for ferrous-metal surfaces under boundary lubricating conditions where the film of lubricant between surfaces approaches the thickness of two or three layers of molecules.

The problem of developing good lubricating properties for steel versus steel was approached through modification of the silicone oil molecule. It was assumed that the conventional silicone molecule is not absorbed strongly enough on the steel surfaces to form a close-packed film or protecting layer. As a result, metal-to-metal contact is not prevented on parts that continually rub together. Research studies were thus concentrated on the alteration of the silicone-oil molecule to produce a material capable of forcing a surface chemical reaction at the metal-oil boundary.

The new lubricant has been tested under the most severe laboratory-induced conditions. One such device is the Shell four-ball testing machine. Here a steel ball is rotated while held against three steel balls. The entire four-ball assembly is immersed in a container filled with the fluid to be tested. While one ball is turned at a constant speed, the other three stationary balls can be accurately pressed against it, the system acting as a finely controlled "nutcracker." Metal-to-metal pressures can be built up until the parts actually "seize" or weld. In this testing equipment, bearing pressures of 107 000 pounds per square inch have been attained on the new lubricant without seizure. Presently available jet-engine lubricants will cause seizure of the metal parts between 14 000 to 27 000 pounds per square inch bearing area.

The new lubricant has also been tested in a Westinghouse turbo-jet engine. At the completion of this test, the engine was completely torn down and examined. No evidence of wear was found, and the system was entirely free of any sludge derived from the new lubricating silicone oil. This type of lubricant is being manufactured by Dow Corning Corporation.

Dynamic Braking at 3000 Volts **—For Renfe, a Spanish railway electrification, 3000-volt, d-c locomotives with dynamic braking have been developed. Dynamic braking at such a high voltage is unusual if not unique. Instead of attempting to pump the energy back into the system—which at a given instant may have no load to accept it—it is dissipated in resistors carried on the locomotive. This simplifies the control. Also by a new control scheme these resistors serve the function of both accelerating and braking resistors.**



Personality Profiles

To paraphrase an old saying, ". . . electronic equipment is only as good as its weakest insulation." One of *Reuben Lee's* primary aims is to see that there are no weak links in his designs—in other words, application of the best high-frequency insulating materials available. These materials have not blossomed full-bloom overnight. They have come to their present state slowly, with much selection and rejection. Lee has been instrumental in the metamorphosis, always on the lookout for new materials that will improve the performance of his equipment.

His interest and ability in the design of inductive components for electronic apparatus are evidenced by 25 patents. He is a member of three major company committees—insulation coordination, specialty transformers, and magnetic amplifiers. He is also a member of the Radio Electronic Television Manufacturers' Association committee on special-quality electronic components.

Lee's ability as an author also deserves some mention. He last appeared in the ENGINEER in November, 1950 with a discussion of Fosterite insulating materials. He has written many technical papers and articles, and his book, "Electronic Transformers and Circuits," so far has sold several thousand copies.

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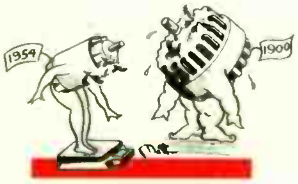
C. F. Irvin, who authored the article in this issue on the new fractional-horsepower motor, is a member of the development section of the Small Motor Division's Industrial Engineering Department. Here he has helped in the endless search for new materials and has participated in developing improved designs, such as the new 48-frame motor. Irvin came to the division in 1945, just after graduating from Ohio Northern University with a B.S. in Mechanical Engineering. Before joining his present section, Irvin had gained considerable background by working on several other aspects of small-motor design and production.



Sometimes, on this page, we try to indicate someone's personality or character with an illustrative anecdote. The one we have about Irvin doesn't particularly fall into that category, but it at least does prove that hard work pays off. And we do mean hard work. Seems that last summer he decided to try his hand at golf and entered the plant's Divot Diggers Tournament. After a more than considerable amount of exercise, he wound up with a first game score of 190—for 18 holes. But wait—there's more. His efforts were well rewarded because, due to what he describes as "a tricky handicap system," he wound up with second prize in overall net score, and a first prize in the last round of play. Anyone for golf?

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There's been little doubt in *H. E. Lokay's* mind about his career since he first started to experiment with things electrical in high school. It was to be electrical engineering, and Lokay has not strayed from that course. After high school he worked as an electrician in an industrial plant, then entered the Navy, where he was an electrician's mate. After discharge, he entered Illinois Institute of Technology, and earned his B.S. in Electrical Engineering in 1951. Since that time his work in the Electric Utility Section at East Pittsburgh has largely been in the distribution field, where he has become familiar with the different methods of voltage regulation, of which he writes in this issue.

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Commander *Louis H. Roddis, Jr.* is the son of a Naval officer and is a Naval Academy graduate (1939). After service at sea, he earned his Masters Degree in Naval Architecture and Marine Engineering from Massachusetts Institute of Technology in 1944. Following duty at the Philadelphia Naval Shipyard, he was on the staff of the Commander, Joint Task Force I during the Bikini test in 1946, and then went to the Clinton Laboratories of the Manhattan District (now Oak Ridge National Laboratory) with the first group of people working on the Daniels Power Pile. Since then, he has served in various capacities in the Bureau of Ships and the Atomic Energy Commission in connection with the nuclear ship-propulsion program.

Commander Roddis' coauthor in this issue is *John W. Simpson* of the Westinghouse Atomic Power Division. Simpson is also a Naval Academy graduate (1937), and although he joined Westinghouse shortly after graduation, he has maintained contact with naval engineering problems throughout his career. After the usual period in the Graduate Student Course, Simpson joined the Switchgear Division, and except for one year at the Research Laboratories, spent his time in the marine section of Switchboard Engineering until 1946; he was made manager of the section in 1944. Then his career took a different turn, and he went to Oak Ridge, where he spent two years on the Daniels Power Pile project. He returned to the Switchgear Division in 1948, but when the Atomic Power Division was formed, he joined this group, and became assistant manager of engineering in late 1949. In 1952 he became assistant division manager, in which position he was responsible for the development and engineering departments. Late in 1954 Simpson was made manager of the PWR Project, which has the task of designing and constructing the central-station reactor.

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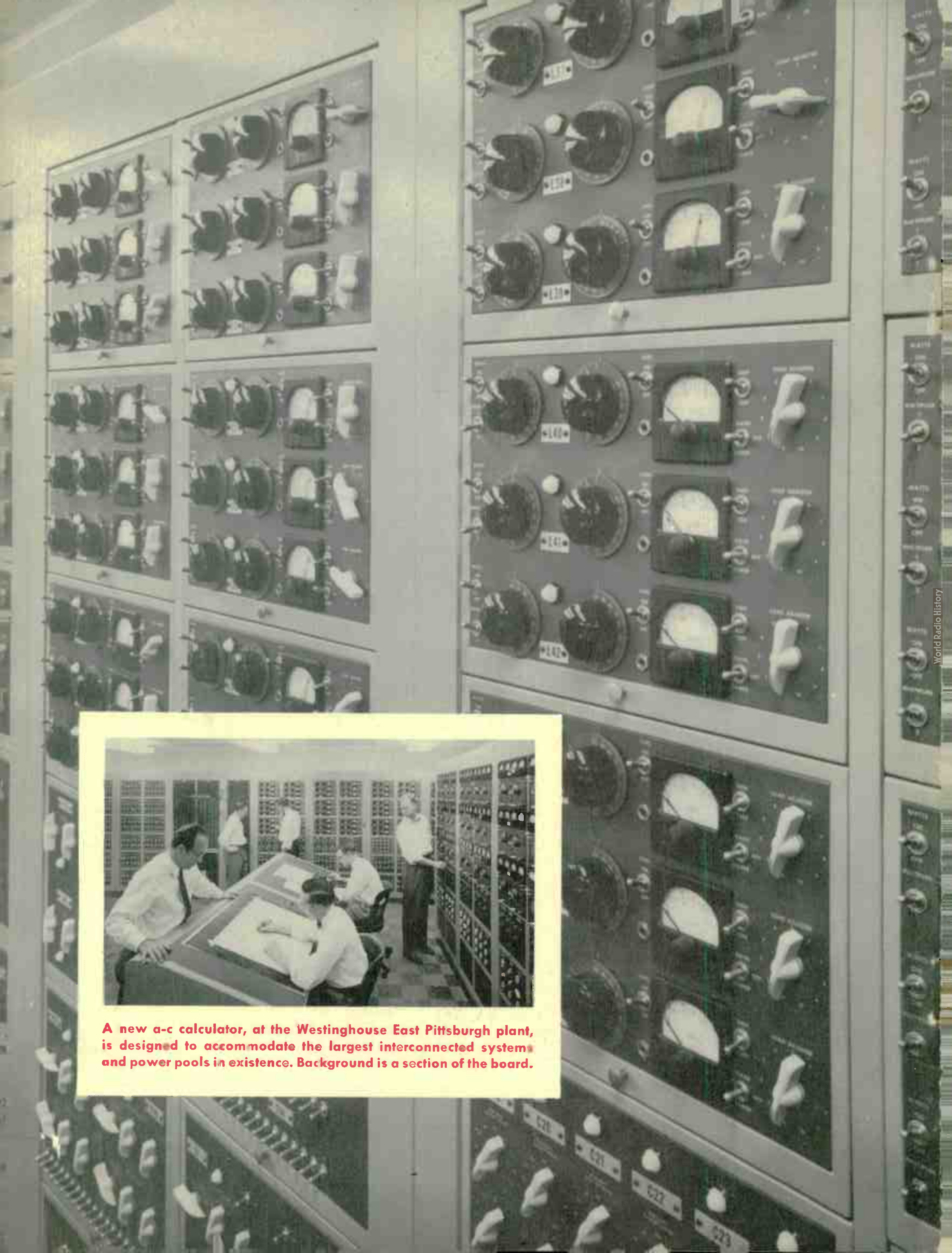
An Engineering Highlight—

High-Definition Fluoroscopes for Industrial Use—A rocket-motor charge containing a void or fissure, or a rocket motor incorrectly assembled is not only worthless as a weapon but also may, by misfiring, become a hazard to the firing crew. To prevent this during the war, rocket charges and motors were x-rayed. This required literally miles of film. This was not only costly in film and facilities but placed an enormous strain on the nation's film-manufacturing plants.

X-raying on film is now unnecessary. Inspection is by high-definition fluoroscopes. After the war the Naval Ordnance Laboratory at White Oaks, Md., by discarding traditional features and by meticulously choosing each variable affecting image definition, succeeded in improving fluoroscopy until it would approximate the former minimum standards for radiography. Westinghouse engineers have incorporated these and other ideas into commercial models of fluoroscopes for rocket fuel and rocket-motor inspection on a mass-production basis.

By comparison with conventional fluoroscopes whose approximate limit of resolution is a 45-mesh screen, the new high-definition fluoroscopes readily show the detail of one of 70 mesh. Image definition has been increased by use of the finest detail phosphors commercially obtainable, by oil cooling the rotating-anode tube to permit an increase in the x-ray output, by employing the smallest size focal spot, and by establishing a tube and screen to obtain magnification of any defects.



A new a-c calculator, at the Westinghouse East Pittsburgh plant, is designed to accommodate the largest interconnected systems and power pools in existence. Background is a section of the board.