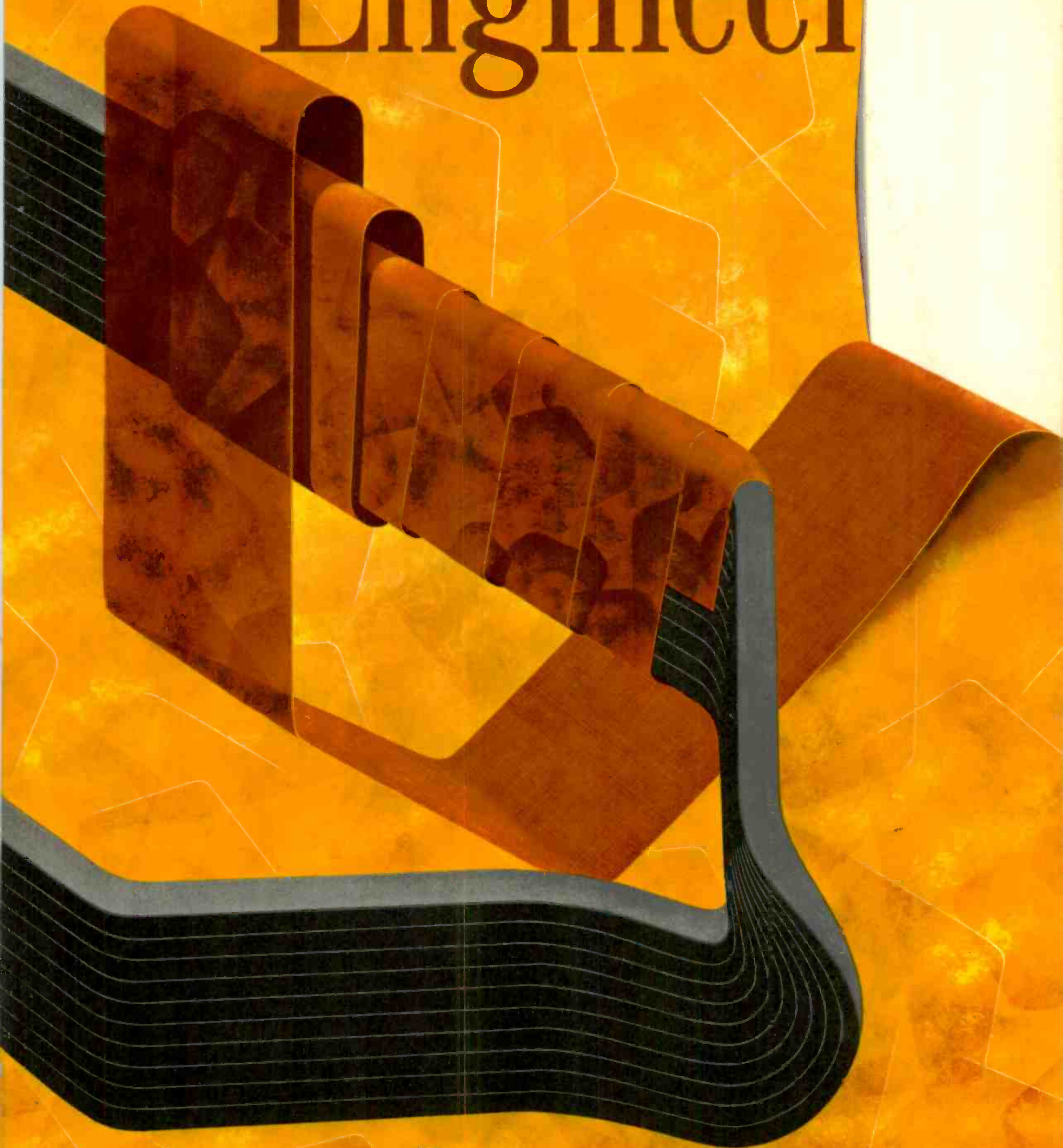
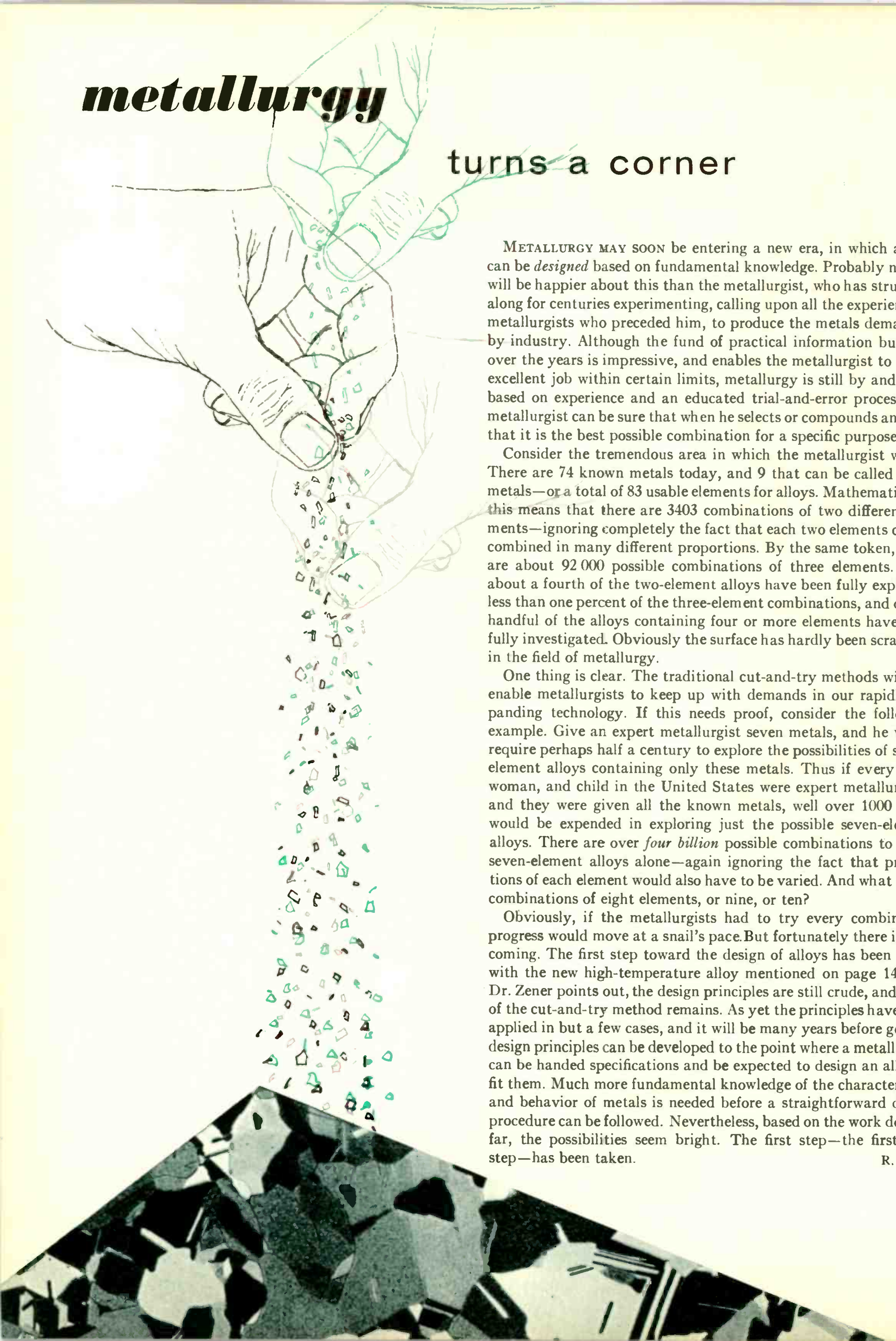
WESTINGHOUSE Engineer



SEPTEMBER 1956

metallurgy turns a corner



METALLURGY MAY SOON be entering a new era, in which alloys can be *designed* based on fundamental knowledge. Probably no one will be happier about this than the metallurgist, who has struggled along for centuries experimenting, calling upon all the experience of metallurgists who preceded him, to produce the metals demanded by industry. Although the fund of practical information built up over the years is impressive, and enables the metallurgist to do an excellent job within certain limits, metallurgy is still by and large based on experience and an educated trial-and-error process. No metallurgist can be sure that when he selects or compounds an alloy that it is the best possible combination for a specific purpose.

Consider the tremendous area in which the metallurgist works. There are 74 known metals today, and 9 that can be called semimetals—or a total of 83 usable elements for alloys. Mathematically, this means that there are 3403 combinations of two different elements—ignoring completely the fact that each two elements can be combined in many different proportions. By the same token, there are about 92 000 possible combinations of three elements. Only about a fourth of the two-element alloys have been fully explored; less than one percent of the three-element combinations, and only a handful of the alloys containing four or more elements have been fully investigated. Obviously the surface has hardly been scratched in the field of metallurgy.

One thing is clear. The traditional cut-and-try methods will not enable metallurgists to keep up with demands in our rapidly expanding technology. If this needs proof, consider the following example. Give an expert metallurgist seven metals, and he would require perhaps half a century to explore the possibilities of seven-element alloys containing only these metals. Thus if every man, woman, and child in the United States were expert metallurgists, and they were given all the known metals, well over 1000 years would be expended in exploring just the possible seven-element alloys. There are over *four billion* possible combinations to make seven-element alloys alone—again ignoring the fact that proportions of each element would also have to be varied. And what about combinations of eight elements, or nine, or ten?

Obviously, if the metallurgists had to try every combination progress would move at a snail's pace. But fortunately there is help coming. The first step toward the design of alloys has been taken with the new high-temperature alloy mentioned on page 146. As Dr. Zener points out, the design principles are still crude, and some of the cut-and-try method remains. As yet the principles have been applied in but a few cases, and it will be many years before general design principles can be developed to the point where a metallurgist can be handed specifications and be expected to design an alloy to fit them. Much more fundamental knowledge of the characteristics and behavior of metals is needed before a straightforward design procedure can be followed. Nevertheless, based on the work done so far, the possibilities seem bright. The first step—the first long step—has been taken.

R. W. D.

WESTINGHOUSE
Engineer

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In This Issue

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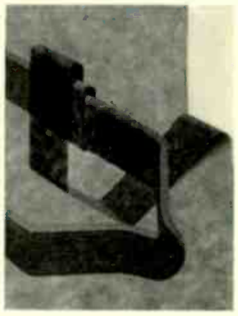
THE COVER



Layers of overlapping mica splittings are bound between suitable backing material, and the "sandwich" slit into suitable tape widths for insulating high-voltage generator windings. This recipe is shown symbolically by cover artist Dick Marsh.

Editor . . . RICHARD W. DODGE
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Fig. 1a

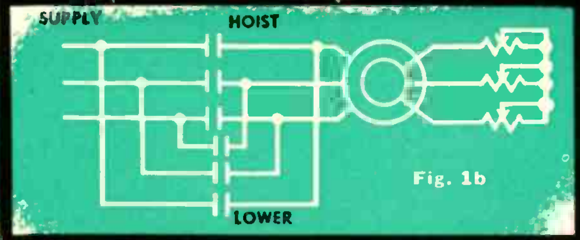


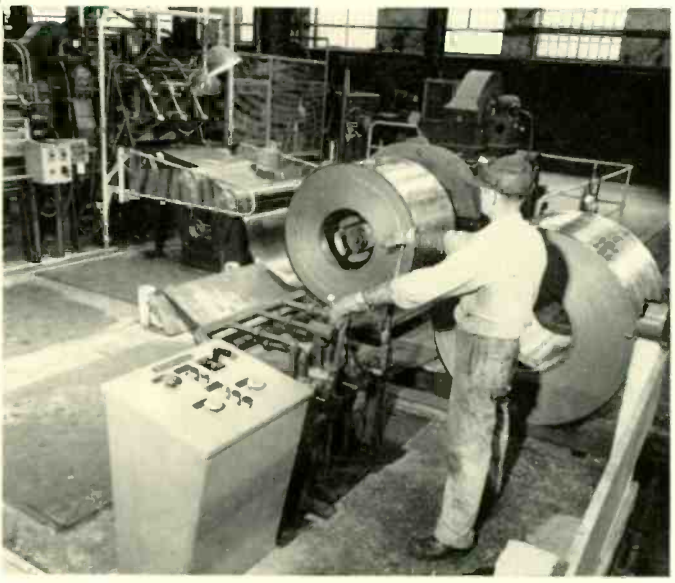
Fig. 1b

Motor braking of various forms control the "muscles" of modern industry. A type of control must be selected that will give the motor the necessary reflexes and coordination for the task it must perform.

Fig. 1a—Automatic counter-torque braking permits the crane operator to safely lower a load of molten iron.

Fig. 1b—Adjustable counter-torque for braking this overhauling load is obtained with secondary control.

Fig. 2—This side-trimming line is a typical example of a continuous metal-processing line on which regenerative braking is applied for torque or tension control.



A Key To Industrial Progress...

MOTOR BRAKING

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INDUSTRY TODAY DEPENDS on the ability to control drives accurately. The operation of machine tools, processes, and material-handling systems all depend on accurate control. An important phase of drive control is braking. As industry demands more accurate and faster operating speeds, the braking action or control becomes more important. At one time, the electrically-driven lathe could coast to a stop. Today, that same machine may have to stop in a fraction of a revolution, and to an accurately predetermined position, if it is to fit with other automatic operations designed for high production rates. Picking the best braking scheme for a particular application involves recognition of the requirements of the job, and a fundamental knowledge of the basic characteristics of each available type.

Braking can be defined as the application or generation of a force that produces a restraint or deceleration, or retarding or stopping action to a rotating member such as the rotor of an electric motor. Hence the category of motor braking includes speed control, torque control, deceleration, and holding as well as stopping.

A braking method may be needed to produce a retarding or controlled action to maintain a given speed (speed control) or condition (torque control). An external force, such as an overhauling load on a crane (Fig. 1) may tend to rotate the motor independently of the normal motor rotation caused by the electrical power applied. A braking method is needed to keep the speed under control. In the steel-processing industry, (Fig. 2) braking action (torque or tension control)

TABLE I CHARACTERISTICS OF ELECTRIC-MOTOR BRAKING

EXTERNAL BRAKING METHODS

METHOD	BASIC OPERATION	APPLICABLE MOTOR TYPES	SPECIAL REQUIREMENTS TO PRODUCE BRAKING	USE
Friction Braking	Friction elements (shoe or disk) electrically, mechanically, pneumatically or hydraulically actuated produce braking load	All types	None	Stopping Holding
Magnetic Particle Braking	Magnetic-particle (dry or fluid) coupling mechanically connected to motor produces braking load	All types	Excitation power	Stopping Holding Deceleration Torque-tension control Speed control
Eddy-Current Braking	Magnetic coupling unit mechanically connected to motor develops eddy-currents which produce braking load	All types	Excitation power and motor rotation	Stopping Deceleration Torque tension control Speed control
Hydraulic Braking	Hydraulic pump type device mechanically connected to motor produces braking load	All types	Motor rotation	Stopping Deceleration Torque-tension control Speed control

INTERNAL BRAKING METHODS

METHOD	BASIC OPERATION	APPLICABLE MOTOR TYPES	SPECIAL REQUIREMENTS TO PRODUCE BRAKING	USE
Dynamic Braking by A-C Excitation	Application of a-c single-phase power makes motor operate like a generator	Three-phase squirrel-cage and wound rotor	A-c single-phase power and motor rotation	Stopping Deceleration Torque-tension control Speed control
Dynamic Braking by A-C Excitation of Special Winding	Application of a-c voltage to special winding makes motor operate like a generator	Three-phase squirrel-cage with special windings	A-c single-phase power and motor rotation	Stopping
Dynamic Braking by Capacitors	Capacitor provides excitation so motor operates like a generator	Three-phase and single-phase squirrel cage	Motor rotation	Deceleration Stopping
Dynamic Braking by a Capacitor Resistor-Rectifier Circuit	Discharge of d-c power from capacitor into motor makes motor operate like a generator	Most single-phase types; three-phase squirrel cage and wound rotor	Motor rotation	Deceleration Stopping
Dynamic Braking by D-C Excitation	Application of d-c power makes motor operate like a generator	Most single-phase types; three-phase squirrel cage and wound rotor	D-c excitation power and motor rotation	Stopping Deceleration Torque-tension control Speed control
Dynamic Braking with Resistors	Motor operates like a generator and pumps power into a resistor load	All d-c types if field excitation is maintained; a-c d-c universal; a-c synchronous d-c excited fields	D-c excitation power and motor rotation	Stopping Deceleration Torque-tension control Speed control
Regenerative Braking	Motor operates like a generator when it runs above normal or synchronous speeds and pumps power back into the line	Most a-c and d-c types except synchronous	Electric power and rotation above normal or synchronous speed	Deceleration Torque-tension control Speed control
Plugging or Counter-torque	Power lines are disconnected and reconnected to produce a reverse motor torque	Most three-phase types; single-phase repulsion (special) a-c d-c universal; d-c shunt, permanent-magnet and series	Electric power	Deceleration Stopping Speed control Stalled-tension control

must maintain proper tension in the steel strip as it is unwound from the reel.

A second broad category for braking occurs when it is desirable to slow down or stop a motor or machine faster than the normal stopping permitted by the connected motor load. This action may also include holding at standstill. Here a braking system actually adds to the existing natural retarding torques, which are made up of the load and its frictional forces.

Two fundamental differences exist between dynamic and regenerative braking methods:

First, dynamic braking occurs at motor speeds below the normal operating speed of the motor (synchronous speed in the case of an a-c motor); regenerative braking occurs only at motor speeds above normal operating speed of the motor. The overspeed is caused by either imposing a torque (overhauling load) on the motor to speed it up, or by changing the normal operating speed, such as could occur with a two-speed a-c motor.

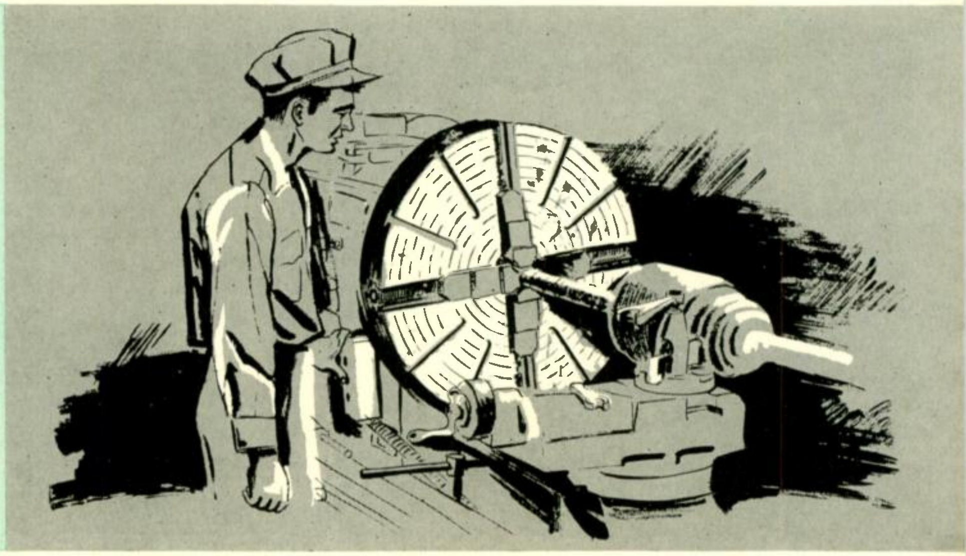


Fig. 4a—Operator employs plugging to bring work piece to a quick stop. The motor is momentarily energized in the reverse direction.

Motor-Braking Methods

Braking action is developed essentially by one of three methods; physical (frictional or resistive), generating (dynamic and regenerative), or counter-torque (plugging). Each has characteristics which make it best suited for a particular application (see Table I).

The *physical* (frictional or resistive) method is usually developed in a device coupled to the drive motor, or engine, and is considered an *external* braking system. The shoe brake is an example. The most significant characteristic of this type is that heating is not developed in the motor while braking. This is particularly applicable on machine tools with severe braking duty cycles, where additional motor heating due to braking would be a limiting factor. Since both stopping and holding torque is available with shoe brakes, this method is particularly suitable for crane and elevator applications. Furthermore, most shoe brakes afford braking action even on power failure, making them fail safe.

It should be kept in mind when applying external braking systems that space in addition to that of the motor will be required, as well as motor-shaft and coupling facilities. Also, the external brake mechanism adds to the rotating inertia of the motor.

In the *generating* braking method (dynamic and regenerative), torques are developed within the braking device by virtue of the fact that it is rotating. External braking systems falling in this category are eddy current (in effect, an electric motor) and hydraulic (in effect a hydraulic pump).

When electric drive motors are employed, generating methods can be more conveniently applied within the motor itself, thus eliminating a coupled device. This becomes an *internal* braking system.

Secondly, the energy produced by dynamic braking is dissipated either in a connected load such as a resistor or within the motor windings. The motor acts as a heavily-loaded generator. Excitation of some sort must be provided, either from a power source or generated within the motor itself. Braking torques disappear at low and zero motor speeds. In regenerative braking, the motor is always connected to the power system, and the power produced in braking is returned to the line.

The generating method is best suited for applications where speed or torque regulation is required in certain speed ranges, and where a holding action is not needed. When used in an internal system, no extra space is required at the motor or motor shaft for braking equipment. Although additional inertia to the motor has been eliminated, braking heat is produced in the motor, so that a larger frame motor for a given horsepower rating may be required. Electric power, either supplied or self-generated, is needed during braking.

Counter-torque methods (plugging), like generating, are most commonly employed in internal braking systems. Here, the power input leads are reversed or reconnected (Fig. 4b) so that torques are developed that attempt to rotate the motor in the opposite direction. At zero speed, the braking torque will accelerate the motor in the opposite direction unless removed, since this torque exists whether the motor is rotating or not.

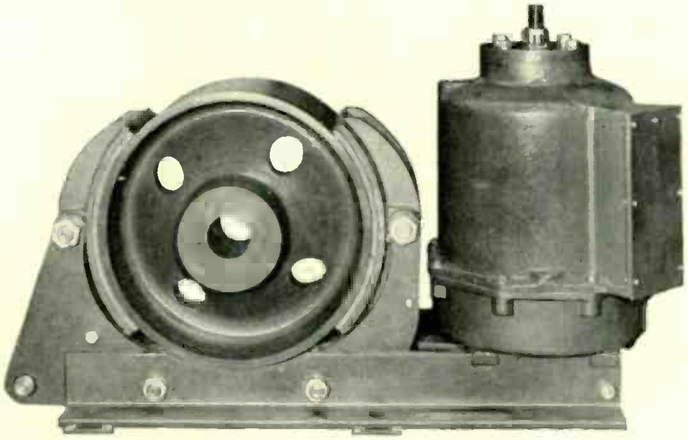
This characteristic is useful in applications where a stalled tension is required, such as on unwind reels in the textile, metal process, or paper industries. By proper control, the correct amount of braking torque can be produced.

With counter-torque methods, speed and torque regulation can be provided at any speed range, as shown in Fig. 7. A speed indicator (plugging or zero-speed switch) may be required to prevent false motor reversal after stopping, or for speed sensing. As with generating methods, braking action produces heat in the motor, so that a larger frame motor for a given horsepower rating may be required; likewise, electric power must be available during braking operation.

Application of Braking Methods

In applying a braking method, the driven load must be considered. An overhauling load or flywheel opposes the braking system, while friction or other positive load aids the braking system. Some positive loads, such as fans, change with speed. This can be an important factor in determining accurate braking requirements.

The braking cycle affects the design of the system and equipment. For example, where braking forces are high, but of short duration, the problem is one of mechanical design. A rubber calender is a typical application of this type of braking, where it may be necessary to stop the rolls instantly to prevent serious injury to an operator. Although several methods may provide the same stopping time, a severe braking method on a gear drive with considerable back lash can cause gear-tooth breakage. For example, dynamic braking by d-c excitation supplies braking torques more gently than plugging.



Self-adjusting d-c magnetic brakes (Type SA) are designed for steel-mill and crane service, and can be used on all applications requiring rapid stopping and holding of a motor, such as on hoists, conveyors, turn tables, and lift bridges.

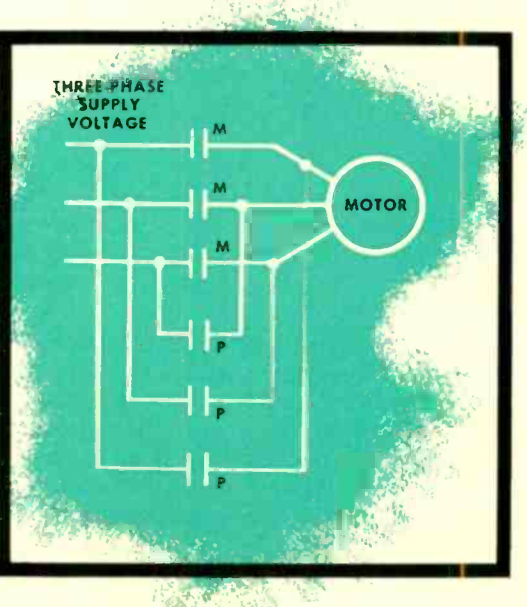


Fig. 4b—In plugging, or counter-torque braking, main contactor (M) is opened, and plugging contactor (P) closed to produce a reversed torque in motor.

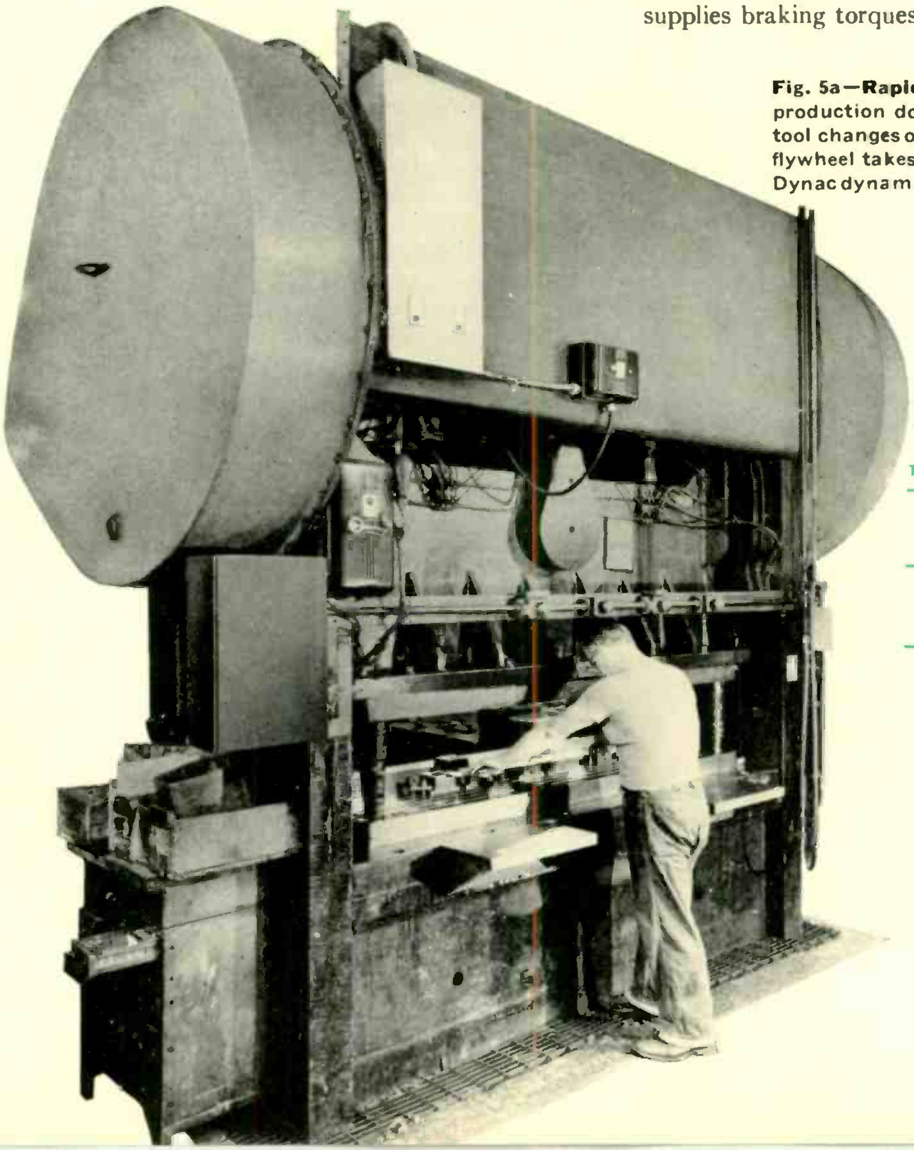
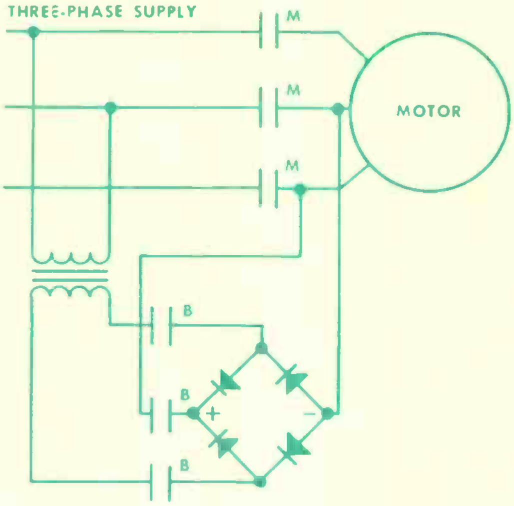


Fig. 5a—Rapid braking on this vertical press reduces production down-time whenever stops are made for tool changes or for emergencies. Without braking, the flywheel takes eight minutes to coast to a stop; with Dynac dynamic braking, only 24 seconds are required.

Fig. 5b—Simplified schematic of the Dynac dynamic braking system. Direct-current is applied to one phase of the motor, which makes it operate like a generator.



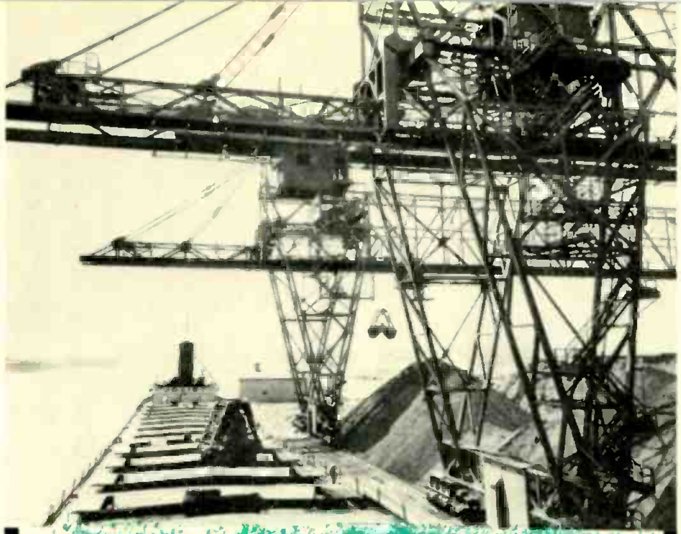


Fig. 6a—A combination of both shoe braking and dynamic capacitor braking solves a rail-clamp application on this ore bridge.

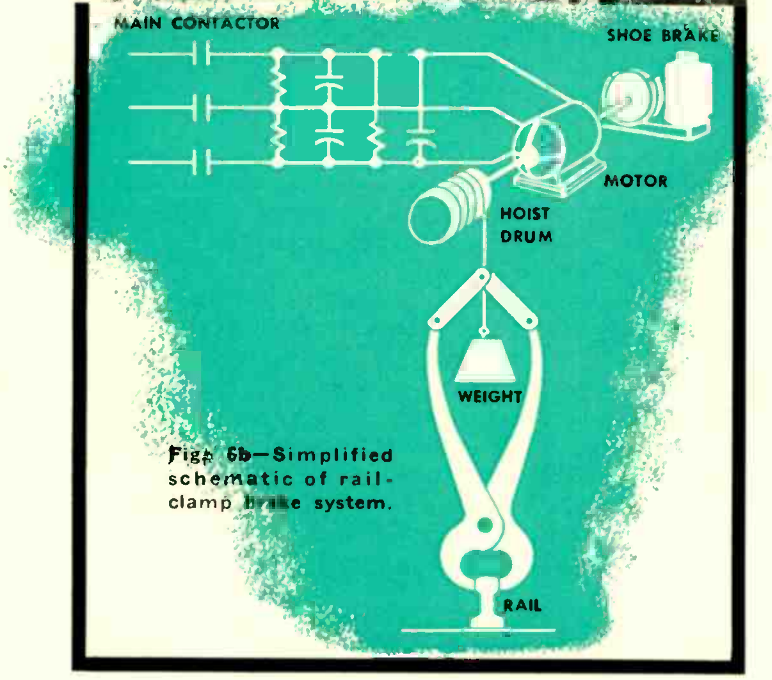


Fig. 6b—Simplified schematic of rail-clamp brake system.

Braking-currents developed in the motor must be considered when applying internal electric braking. Except for a-c plugging, most current magnitudes are of the same order as those encountered in accelerating the motor. When applying dynamic braking to d-c motors, the current peaks during braking must not be higher than the commutator can handle. Two-hundred percent of full-load current is a typical limit. Some motors can handle more. If a high rate of braking action is desired, then more than one step of dynamic braking must be used. Heat dissipation within the braking device becomes a major problem where the braking action must maintain a controlled tension, such as on the unwind stand of a metal-processing machine. If a counter-torque or dynamic-braking method is applied for some duration at reduced motor speeds—the condition must be checked to make sure the motor will not overheat. Forced ventilation may be required.

On a highly repetitive stopping cycle, using a shoe brake, a larger than normal brake may be required to decrease the brake wear.

On an existing application where the braking method is added, the method chosen may affect the existing control. For example, the size of an a-c linestarter must be derated when applying plugging. If a lathe is driven by a 5-hp, 220-volt motor, using a 25-ampere reversing starter, the controls are inadequate for plugging service. A 50-ampere unit must be used.

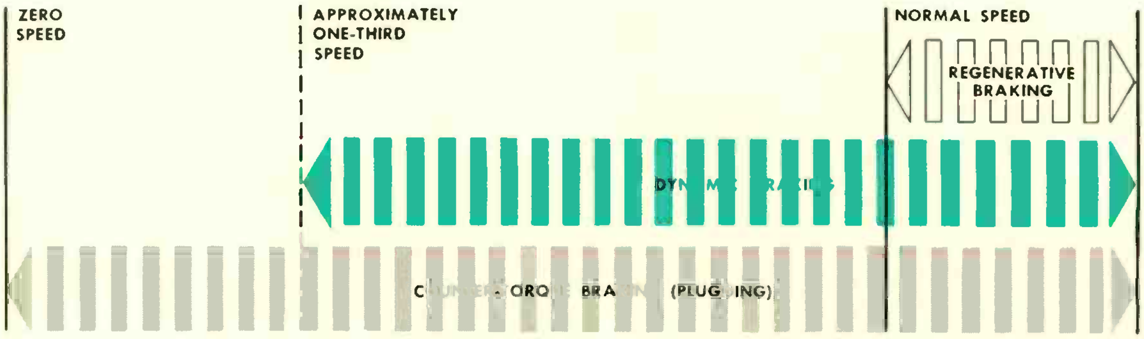
In comparing the first costs of braking methods, comparable braking results should be examined. In some horsepower sizes, shoe-brake applications are approximately the same price as plugging where shoe-brake torques are applied at 100 percent of the motor full-load torque, and plugging is applied at full voltage. Full-voltage plugging will actually stop a motor in about half the time of a 100-percent torque friction shoe brake. Hence, to obtain the same stopping time as plugging, the shoe brake must be twice the size, making plugging the lower first cost. If, on the other hand, reduced-voltage plugging were applied to make the plugging time comparable to the 100-percent torque shoe brake, the additional control makes the plugging system more expensive than the shoe brake. When proper comparisons are made, the most expensive braking system may prove most economical in the long run.

When no single system provides all the necessary qualifications, then two or more methods can be combined to satisfy a given application. For example, the new Westinghouse rail-clamp control combines two systems to provide safe, economical control on bridges. As the control scheme shows (Fig. 6b), after hoisting the rail-clamp weight, the squirrel-cage motor is held up by means of the shoe brake. When lowering, the shoe brake is released and dynamic braking by capacitors takes over to provide a safe, slow lowering speed, even with the rail-clamp weight tending to overspeed the motor in that direction.

On a steel process line with an adjustable-voltage drive, regenerative braking can be used on the uncoiler for tension control while the line is in operation. At standstill, counter-torque is needed to maintain the tension in the strip.

Many ramifications exist in the detail design of a particular braking application. Characteristics of each braking method can be desirable or undesirable for a particular case. They should be carefully considered to assure use of the best suited braking method or methods. ■

Fig. 7—Typical speed and torque regulating range for application of regenerative, dynamic, and counter-torque braking.



An engineering personality

AARON WEXLER

▪ Dr. Aaron Wexler has run the gamut in research from the university laboratory to the industrial laboratory, from actual experimentation to several levels of administration, and finally to his present post as associate director of the Westinghouse Research Laboratories. And he has accomplished all this in a remarkably short time.

Things have moved at a fast pace for Wexler since he arrived in this country from Russia at the tender age of 10 months. His family settled in New York, and he attended the public schools in that area. The stepped up pace begins here, however, as Wexler graduated from high school at the age of 16, and then enrolled at the Polytechnic Institute of Brooklyn. In 1942, just before his 20th birthday, he graduated from college with a B.S. in chemistry. Immediately after graduation he went on to graduate work in physical chemistry at Johns Hopkins University under a National Fellowship award. Here he earned both his M.S. and his Ph.D. in 1944, at the age of 21.

At Johns Hopkins, Wexler got his first taste of low-temperature research. He did his graduate work under Professor D. H. Andrews, who first interested him in the possibilities of research at ultra-low temperatures. During his graduate work, and after, he participated in an Armed Forces research project that ultimately developed a superconducting bolometer, a sensitive infrared detector.

This work drew the attention of several people at Westinghouse, including one of his former professors, then a member of the Laboratories. Dr. J. W. Hickman suggested to Dr. J. A. Hutcheson that Wexler be invited to join Westinghouse and establish a new low-temperature laboratory. This was an exciting and challenging prospect to Wexler, and in 1947 he accepted the offer and embarked on his new project.

It involved setting up a laboratory that could produce temperatures close to absolute zero, or about minus 460 degrees F. The ultimate aim was to investigate the properties of matter at supercold temperatures, which often gives clues to behavior at other temperatures. However, Wexler soon found that the techniques of obtaining, maintaining, and experimenting with low temperatures offered much room for improvement. His approach to his new task displayed his penchant for thorough analysis of problems.

Low-temperature work up to this time had been characterized by some major difficulties. One serious hindrance was the fact that liquid helium took about a day to produce, and then experiments had to be performed within a few hours, which was as long as the helium could be held in a liquid state. Wexler remedied this situation. The result was a low-temperature "thermos bottle," capable of holding helium in the liquid state for nearly a year. This one development alone has proved of enormous value. This and other techniques Wexler and his laboratory developed are now used around the world. Since that time, the laboratory he founded has won world-wide recognition for studies of the electrical, magnetic and thermal properties of materials at low temperatures.

In 1952, Wexler was made an advisory physicist and in 1953 was named manager of the magnetics and solid-state physics department. Here Wexler departed from the role of the experimental scientist and became a research administrator. Last year he moved one step further away from actual experimentation when he was named an associate director of the Research Laboratories in overall charge of chemical activities. His objective is the development of new classes of materials, both to meet increasingly stringent materials requirements, and to make possible entirely new lines of electrical equipment.

Away from the Laboratories, Wexler likes to relax with his wife and three boys, ages 7, 4, and 1—although "relax" may not be the appropriate word with boys of that age. He professes to only casual hobbies, including hi-fi, occasional golf, and—under some pressure—gardening.

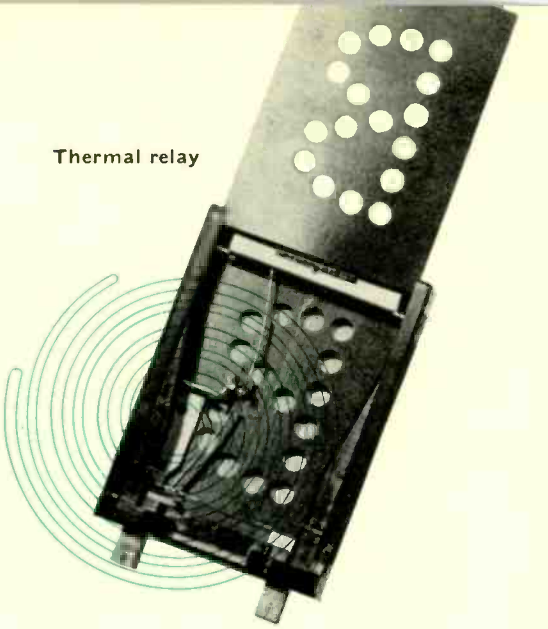
Wexler's work in low-temperature physics has gained considerable attention. He has twice represented Westinghouse at international conferences abroad, in 1951 and 1955. On the latter occasion he was invited to present a paper at the International Conference on Low-Temperature Physics at the University of Paris. Last spring he also was honored by Brooklyn Polytech, when he was one of 100 alumni presented Certificate of Distinction awards at a centennial celebration.

As to his chosen field of research, Wexler has some firm convictions. Wexler believes strongly in the concept of balance as applied to research, with respect to both personnel and program. He feels that one of the most important functions of a research administrator is to build a balanced group of people who complement one another. The idea man, the ingenious experimenter, the highly critical man, the one with a penchant for precise measurement—all are essential to overall research productivity. Each must be encouraged and provided with the opportunity to achieve satisfaction along the lines the individual feels is appropriate to him.

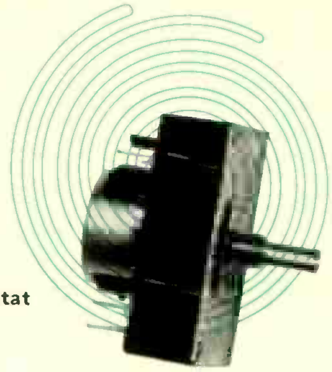
Partially because of these views, he has attracted to the Research Laboratories many people who have assumed positions of leadership along both scientific and administrative lines.

Wexler is also convinced that a progressive industrial research laboratory having a broad, balanced program ranging from advanced development to fundamental research gives exceptional opportunities for creative work by all its researchers. As he puts it, "The cross fertilization of ideas that occurs in such a mixed group can be a tremendous factor in your results. The exposure to the methods and ideas of those in other fields and with different viewpoints not only produces a broadened outlook, but also makes each person alert to possibilities he might otherwise not know existed."

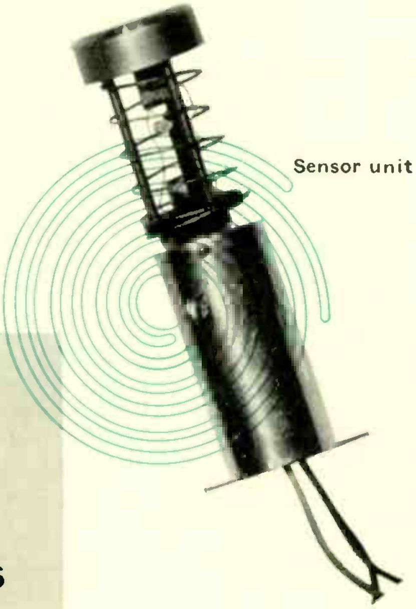
Like most people in a supervisory position, Wexler admits that occasionally he misses actual work in the laboratory. But, although he is thus far best known for his low-temperature work, there can be little doubt that he is fully as adept at applying his analytical ability to administrative problems as to those of a purely scientific nature. ▪



Thermal relay



Main switch and rheostat



Sensor unit

TEMPERATURE CONTROL for Range-Surface Units

VINCENT L. CARISSIMI
The Bryant Electric Company
Bridgeport, Connecticut

THE DESIGN OF an automatic cooking-control device for range-surface units presents a number of unique and interesting problems.

Usually in the design of electric temperature-control systems, thermal masses, conditions of thermal transfer, and thermal shock considerations are well defined and constant for the specific application. Unfortunately, the designer of a range-surface control has jurisdiction only of the actual sensing unit and its position relative to the range surface unit and cooking vessel. All other parameters can be changed at the will of the housewife in her daily preparation of foods. Thermal loads range from delicate sauces and "boiled dry" vegetables to three pounds of fat for deep frying; heat-transfer media (the cooking vessel) vary from light-walled aluminum pots to heavy glass vessels; heating coils come in a variety of sizes from 6-inch, 1250-watt units up to 8-inch, 2600 watt and vary substantially from low to high thermal mass elements; and finally, the range of temperature control desired is 145 to 425 degrees F.

An automatic cooking control has essentially two main functions. First, the control must provide an infinitely variable range of controlled temperature points under any conceivable operating condition. Secondly, during the constant-temperature process of boiling, wattage input control must be provided so that the degree of boiling can be varied from a gentle to a rolling boil—but with thermal protection to prevent foods from burning, should the pot boil dry.

In addition to these two primary considerations, the control should be unaffected by variations in line voltage and ambient temperature, and should be easily installed and serviced. The end use of the control in the highly competitive appliance industry firmly limits the cost of the device, and immediately excludes a number of design approaches used for industrial applications.

Shur-Temp Cooking Control

The Bryant Electric Company "Shur-Temp" control system (Fig. 1) consists of four principal elements: (1) the main switch, a combination double-pole switch and rheostat for "on" and "off" operation and selection of operating temperatures; (2) the sensor unit, which senses pan temperatures and provides a means for infinite temperature selection and control through the boil zone; (3) a thermal relay, triggered by the sensor unit, for breaking the main-load circuit; and (4) a ballast, which serves both as a dropping resistor and a voltage compensating means.

The sensor element is the nerve center of the system. The construction of the element and its location relative to the surface-unit coils and cooking vessels is shown in Fig. 1. It consists of three bimetal units—sensor, control, and com-

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The author wishes to acknowledge the efforts of Earl Bullis, Jr., Bryant Electric Company, and George Nagel and Robert Lackey, New Products Engineering, who were instrumental in developing the Shur-Temp control system.

pensating—insulated from each other, but connected mechanically in series, so that each contributes to the operation of the sensor contact.

The *sensor* bimetal member is integral with the sensor cap, and responds to the temperature of the cooking vessel. With a rise in vessel temperature, the sensor bimetal causes the contacts to break. The second *control* bimetal has its thermal sense reversed from the sensor element so that an increase in bimetal temperature causes the contacts to close. A heater of resistance wire is wound around this control section, and by providing a rheostat to vary current, the temperature of the control section can be infinitely varied.

The third section—the *compensating* bimetal—insures that variations in calibration will not occur because of ambient temperature changes caused by adjacent burners or ovens that are in operation.

The system as described thus far is capable of controlling an infinitely variable range of vessel temperatures with an inherent temperature sensitivity of 2 degrees F. However, a further study of the application of cooking control shows that additional refinements must be added to give the operating characteristics desired.

Testing throughout the development stage of the Shur-Temp system was done with special copper "hamburgers", in which thermocouples were imbedded. Another test utilized copper "potatoes" in 3 pounds of fat. Repetition of test conditions was more easily controlled with these ersatz loads and actual temperatures could be measured accurately.

Surface-heating elements in use today vary from 1250 to 2600 watts. Even the smallest is more than sufficient to maintain any cooking process required in the home—the trend to larger wattage elements is to gain more rapid initial heating. Since only about 150 watts are required to maintain a pot of peas at 200 degrees F, the thermal unbalance of the system can be appreciated.

Furthermore, a considerable lag exists between the time the surface coil is turned on and the time the sensor unit feels the heat rise. This time lag is caused principally by the poor thermal contact between coils and pan bottoms. Also present are the thermal impedances caused by the magnesium oxide filler and the sheathing of the coil, the boundary layer between coil and pan, the pan itself, and the boundary impedance between the pan and sensor-unit cap.

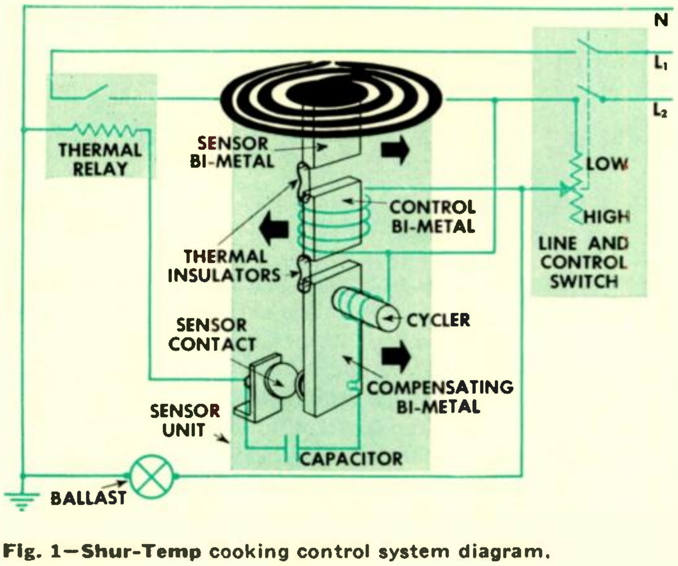


Fig. 1—Shur-Temp cooking control system diagram.

Obviously, an anticipating type of control is required. This is provided by mounting on the ambient compensating section a thermal storage mass, and winding an auxiliary cycler heating element about this mass. This heating coil is in series with the sensor contacts so that when the sensing device calls for heat and electrical energy is supplied to the surface unit, the cycler mass is also heated. Thus, the compensating bimetallic section, whose thermal sense is the same as the sensor section, is heated and causes the contacts to break, anticipating arrival of the heat wave from the surface coils to the vessel. The time constants of the cycler and compensating section are such that the contacts remain open until the sensor portion of the system feels the heat wave and regains control of the system. In actual operation, temperature swings on an empty frypan at 250 degrees F are limited to 15 degrees on a 2100-watt range surface unit. The anticipating feature also limits initial overshoots on heating from a cold start.

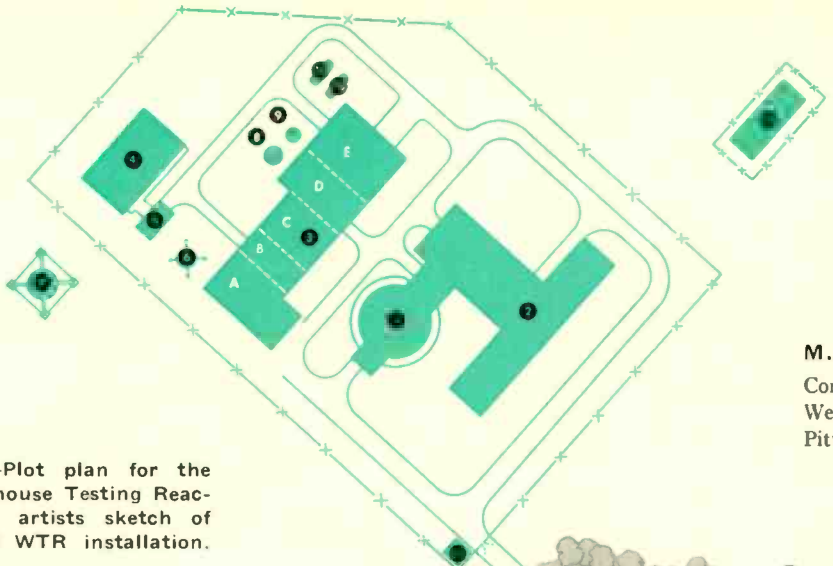
The anticipating structure also accomplishes boiling control. Without the anticipating device, a temperature setting of slightly higher than boiling temperature for the cooking load would cause the sensor element to continually call for heat, with a resulting vigorous boil, caused by full-wattage input to the surface unit. However, with the anticipating section in the circuit, only a short "on time" is necessary to heat the compensating bimetal to a temperature that causes the contacts to break. Since this temperature is relatively low, the cooking rate of the cycler mass and compensating bimetallic structure is low and a relatively long "off time" results. Thermal constants of the system are designed so that "on" and "off" periods are of a duration that will not cause surges or periods of "high boil" and "no boil" during the cycling period. Thus, a low percentage input is achieved that causes only a slight boil in the cooking load. By selecting higher temperatures, an infinite variation of percent inputs can be obtained to provide various degrees of boiling.

Other Components—Since the sensor unit is basically a sensitive creep-type thermostat whose contacts are subject to false makes and breaks caused by mechanical shocks, a relay with a time-delay action controls the actual surface unit. A further advantage of the relay is that wear on the main load-carrying contacts will not cause a calibration change.

The hot-wire relay has a time lag of approximately one-half second. Unaffected by ambient conditions and capable of being mounted in any position, this rugged relay has a life of several million cycles.

A dropping resistor and means for maintaining correct calibration settings, regardless of line-voltage fluctuation, is accomplished with a 120-volt, 25-watt light bulb. The dynamic resistance-versus-temperature characteristic of the tungsten filament provides compensation to the extent that a 10-percent change in line voltage results in only a 15-degree change in vessel temperature at a 425-degree setting, or a 3-degree change at the 200-degree setting.

The desired operating characteristics of an automatic cooking control were established with the cooperation of many range manufacturers and their home-economics departments. Tests have been conducted on all phases of cooking, and the absence of burning oatmeal, peas, or bacon and eggs left at cooking temperatures for two to three hours bears testimony to the degree of temperature control achieved. ■



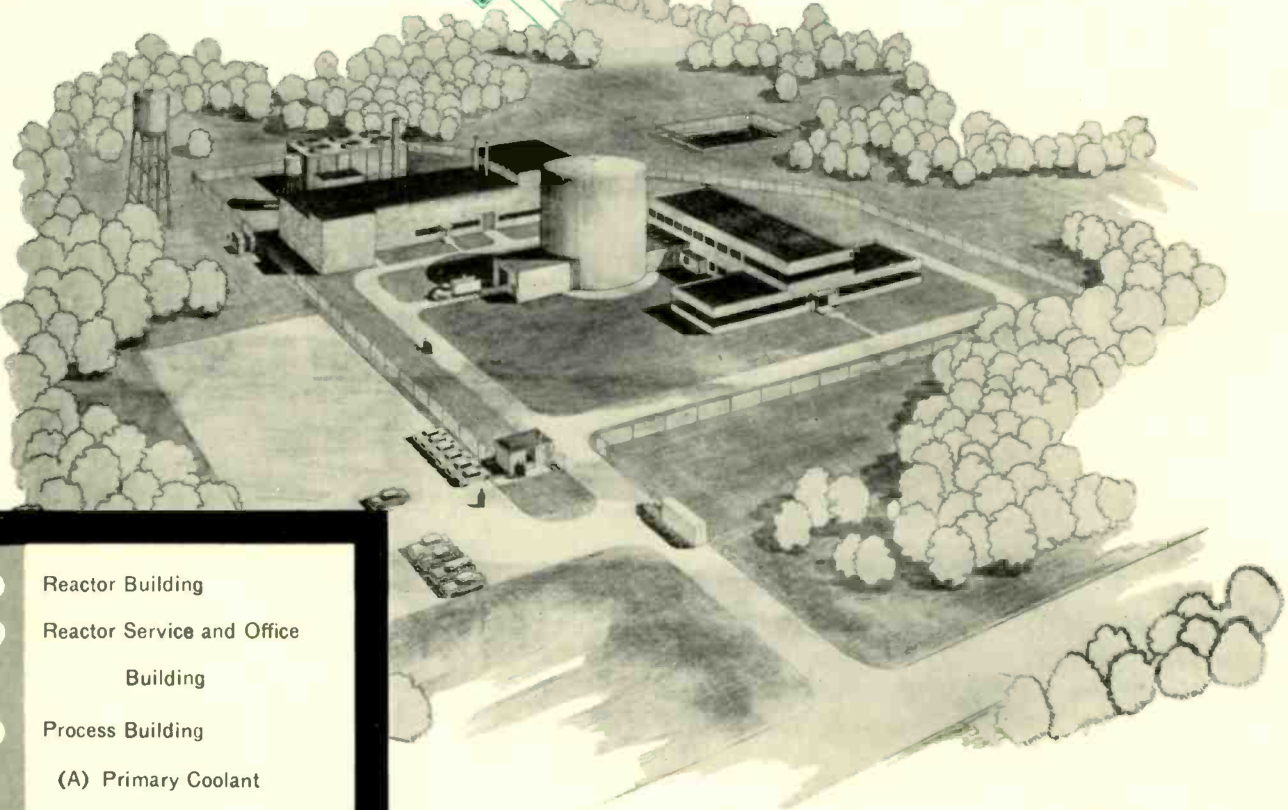


Fig. 1—Plot plan for the Westinghouse Testing Reactor and artists sketch of proposed WTR installation.

- ① Reactor Building
- ② Reactor Service and Office Building
- ③ Process Building
  - (A) Primary Coolant Equipment
  - (B) Waste Disposal
  - (C) Ventilating Equipment
  - (D) Plant Service Equipment
  - (E) Machine Shop
- ④ Cooling Tower
- ⑤ Pump House
- ⑥ Primary Coolant Tower
- ⑦ Fire Tower
- ⑧ Demineralized Water Storage
- ⑨ Fuel Oil Storage
- ⑩ Chemical Storage
- ⑪ Guard House
- ⑫ Retention Basin

M. A. SCHULTZ
Commercial Atomic Power Activity
Westinghouse Electric Corporation
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Westinghouse
TESTING REACTOR

▪ The Westinghouse Testing Reactor, when placed in operation late in 1957, will provide a versatile facility for irradiation experiments that can be conducted under conditions of high flux, high temperature, and high pressure. The power output of the reactor will be nominally 20 megawatts but the plant has designed-in capabilities of ultimately going to 60 mw.

The reactor plant will be built near the center of an 800-acre tract of land located at Waltz Mill, Pennsylvania, 30 miles southeast of Pittsburgh. The tract, consisting of a large level area protected on the west, north, and east by hills approximately 150 feet high, is conveniently adjacent to sources of potable water, natural gas, and electric power as well as a railroad and a large creek. The proposed plot plan for the reactor site is shown in Fig. 1. The buildings are arranged to provide for future expansion.

The reactor building will consist of a vapor shell 72 feet high by 70 feet in diameter placed above a concrete basement 32 feet deep (Fig. 2). A 7-foot wide canal bisects the circular basement area, which provides an annular subpile room extending 10 feet radially beyond the vapor shell for high-pressure test-loop installations. A pressure seal between this area and the shell maintains the integrity of the shell.

The canal provides direct connection to the hot-cell area located in the reactor-service building. Thus, radio-active specimens can be conveyed under water, via the canal, between the reactor and the hot cells.

The reactor-service building houses a hot laboratory and decontamination area, the reactor control room, an industrial hygiene laboratory, tracer and instrument laboratories, change rooms, a laundry, a library, a cafeteria, and all office areas including space for customer personnel. The facilities in this building are all conventional with the exception of the hot cells located directly over the canal. The main reactor control room is on the second floor of the service building.

The process building, located directly behind the reactor building, is divided into five operational areas. One area contains the two main circulating pumps for primary process water, a shutdown circulating pump, an ion exchanger, and the primary-loop heat exchanger. Another area houses all of the waste-disposal equipment. A third area contains air-handling equipment for the entire plant. Equipment for conventional power services to the plant—air compressors, steam generators and their appurtenances—is located in the fourth area. The fifth area will be used as an erection shop for test loops and will also contain machine tools and equipment for plant maintenance.

The Reactor

The initial power output of the reactor will be 20 megawatts. A secondary cooling system is designed to handle this output with 85-degree F cooling water. With lower-temperature cooling water or additional cooling-tower capacity, more power can be dissipated by the secondary plant. The practical limitation on reactor output is the high-pressure testing thimbles. These thimbles will be made of stainless steel of minimum wall thickness to maintain maximum flux levels, minimum gamma heating stresses, and still provide an operating life of one year at 20 megawatts or below. The thermal neutron fluxes available in the reactor for the various testing holes and thimbles will range from 10^{13} to 10^{14} neutrons per square centimeter per second.

Reactor Core Structure—The core unit is mounted between two 3½ inch thick stainless-steel tube sheets approximately 50 inches in diameter, which are bolted to each end of a large flanged aluminum tube section 44 inches long. Suspended between the tube sheets in counterbored holes geometrically arranged in the tube sheets are a number of closely-spaced vertical aluminum tubes in a hexagonal arrangement.

The aluminum tubes serve as guides for either a fuel-element assembly, a control rod, or an experimental thimble. The first arrangement of the core will be with one large central high-pressure thimble and six symmetrically arranged smaller high-pressure thimbles, as shown in Fig. 3.

Due to the downward flow of the cooling water, fuel assemblies are not locked in place but are held by friction, gravity, and water flow. A large number of aluminum tubes are provided in addition to those required for the fuel assemblies. These additional tubes, arranged around the periphery of the core proper, serve as test holes for material specimens, which can be inserted from the top of the reactor.

Fuel Assemblies—A section through a fuel assembly is shown in Fig. 4. The assembly consists of three concentric fuel-bearing cylinders held together by a central mandrel tube, a spoked aluminum bracket, and a threaded stainless-steel fitting at each end. The fittings are provided with spherical ends to permit lifting the assemblies by means of special handling tools. The assemblies are completely symmetrical and may be turned upside down in the core-mounting tubes to obtain maximum burnup. The fuel-bearing cylinders are made of a uranium-aluminum alloy clad with aluminum.

Reactor Design and Operation—The uranium fuel loading of the WTR will be greatly influenced by the test specimens in the holes and thimbles. It is desirable to arrange the fuel elements to surround the thimbles with neutron-producing material and also to have a reasonably long core so that flux variations along the axis of the experimental thimbles is not excessive. Because of these requirements, the critical mass is between 10 and 12 kilograms of U^{235}.

The metal-to-water ratio selected for the WTR core is one to one. This value yields somewhat higher critical masses than if the core contained a larger portion of water; however, a more negative temperature coefficient results. The higher metal-to-water ratio causes less serious flux depressions by experiments with high-neutron absorption properties and, in addition, allows low coolant flow to obtain the required surface heat-transfer coefficient.

A 25-percent burnup of the U^{235} in each fuel element is expected. The lifetime of a fuel element under the above power and flux conditions will be about four months. Reactor loading will be adjusted once a month, so that each fuel element will be irradiated for four loading cycles. An attempt will be made to keep the excess reactivity as small as possible and to burn out each fuel element evenly. Present calculations indicate that an excess reactivity of approximately 10 percent will be required in the loading. This excess reactivity breaks down to approximately 4 percent for depletion and the remainder for equilibrium-xenon and peak-xenon override. Peak-xenon override is possible for about one hour.

Control Rods—Each rod consists of an aluminum-clad cadmium cylinder to which a fuel-element assembly is attached. The control rods are guided in the aluminum spacer tubes in the core structure and in stainless-steel extension guides above and below the core support plates. These guides also serve as shrouds to prevent side thrusts on the control rods resulting from radial coolant flow. A simple piston-type shock absorber is provided for each rod. The shock absorber, attached to the control-rod extension shaft, contacts the top surface of the upper extension guide when the rod is fully inserted. The control-rod shaft is connected to the lower end of the drive shaft by a d-c scramming magnet. The sealed magnet-coil connections are brought out to the top of the reactor through a hollow drive shaft. Rod scramming is effected by de-energizing this magnet coil. The scram is by gravity drop plus the downward pressure of coolant-water flow.

The control-rod drives are of the rack-and-pinion type, mounted on the top of the reactor cover and connected to drive shafts penetrating the pressure vessel (see Fig. 5). A unique control-rod drive system is provided so that regardless of how many rods are moving at any time, the maximum insertion rate of reactivity by means of the rods is limited.

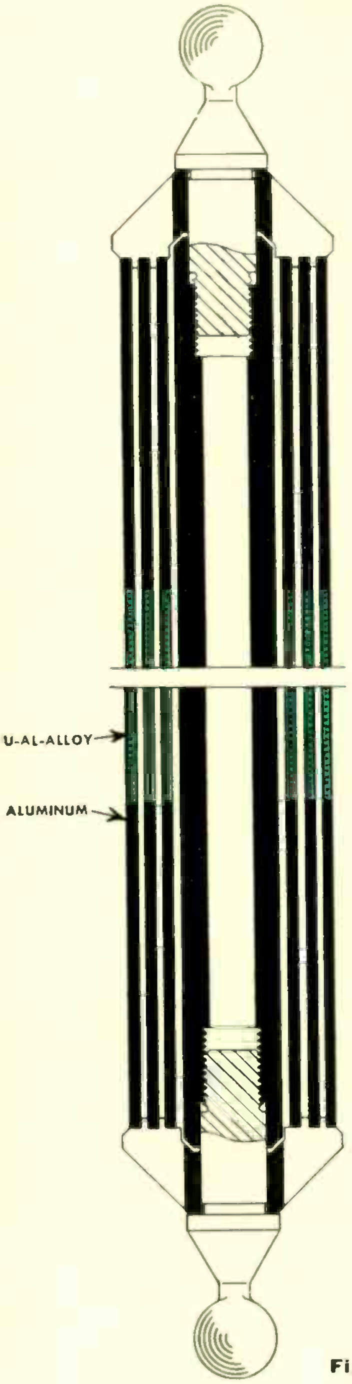


Fig. 4—Cross-section of WTR fuel assembly.

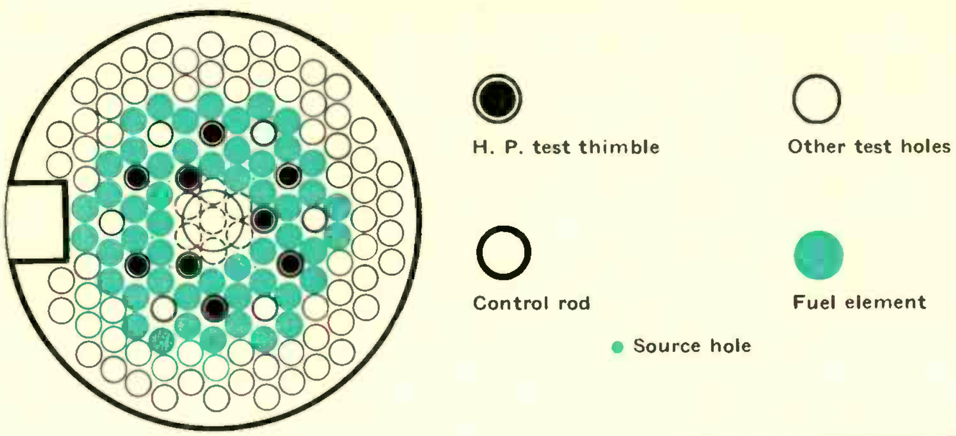
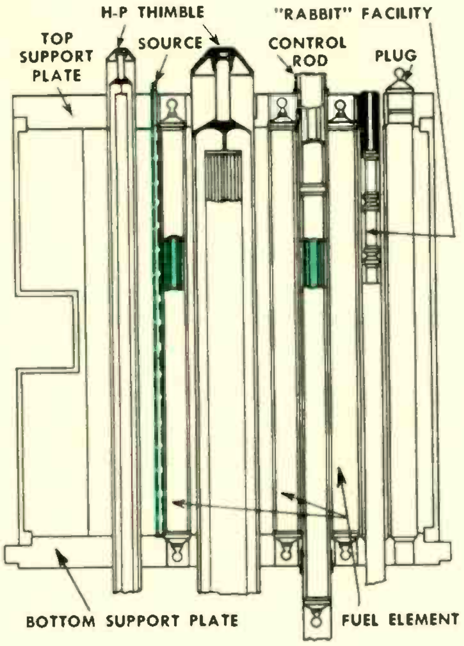


Fig. 3—Cross-section of WTR core structure.



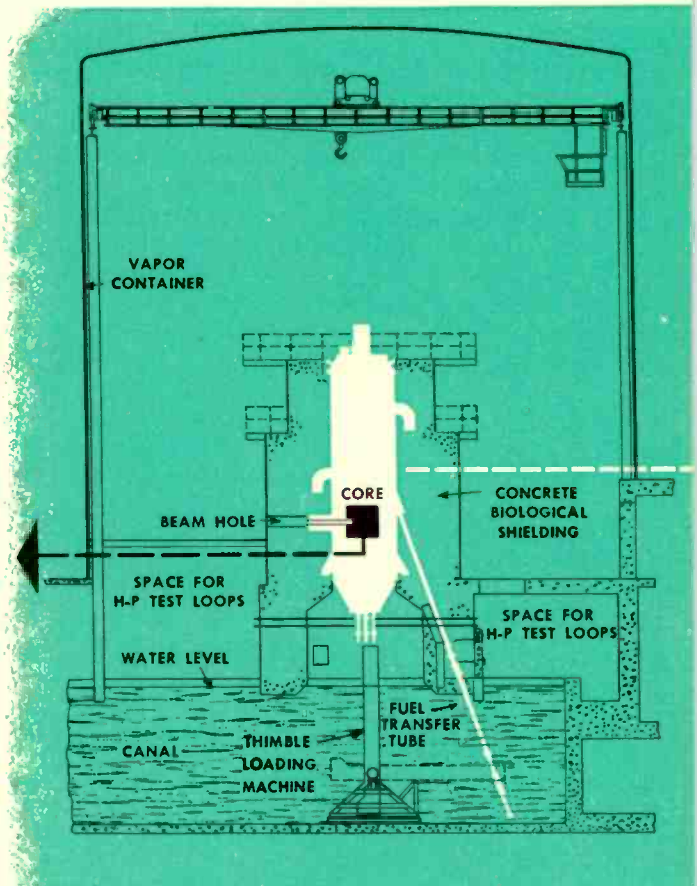


Fig. 2—WTR reactor building

This is accomplished by the equivalent of a poorly-regulated power supply whose characteristics are such that as more control drive motors are placed on the line, the speed of each motor decreases.

The nuclear instrumentation system will be a conventional, duplicate-channel arrangement. Seven detecting elements and channels cover the start-up range, the period range, and the power-operation range. Two sets of instrumentation will be used for the first two ranges and three for the power range. The neutron detectors and their associated instruments will be of the long-life, shock-proof type.

Pressure Vessel

An outline drawing of the pressure vessel and its internal structure is shown in Fig. 5. The maximum internal pressure caused by the primary-loop water will be 112 psi. A design pressure of 150 psi has been selected for the pressure vessel. The vessel has an outside diameter of 8 feet and an overall height, including the upper and lower enclosure covers, of approximately 33 feet. The vessel will be made of one-inch stainless steel in three flanged sections, bolted together. The two lower sections will be permanently grouted into concrete shielding and, in addition, will be internally seal welded after mounting to insure complete water tightness. The smaller top section, conical in shape, is penetrated by a number of flanged pipe sections, which serve as outlets for instrumentation wiring and tubing for test specimens inserted into the core structure from above. Piping is also provided for through-put experiments.

Thermal shielding to prevent excessive temperature rises in the external concrete biological shielding is provided. Two stainless-steel cylinders of approximately two- and three-inch wall thickness, respectively, surround the core structure and are fastened to a number of heavy radial brackets welded to the pressure-vessel wall. The brackets also support the core structure and shielding below the core.

The coolant water for the reactor and thermal shields enters the reactor through two 18-inch stainless-steel pipes in the upper part of the pressure vessel. The water passes through the core in a downward direction, then reverses flow, and passes through the annular spaces between the thermal shields, and exits through two 18-inch stainless-steel pipes directly above the thermal shields.

A large stainless-steel cylinder with a bottom plate, attached to the underside of the top cover, supports several flanged tubes that serve as guides for the scramming magnets. The magnets, drive shafts, guide tubes, support cylinder, and the control-rod drive mechanism are removable as a unit with the top cover, providing access to the reactor core. A special mounting platform is provided on the wall of the reactor building to support and test control-drive mechanisms when they are removed from the reactor.

Biological Shield—The main biological shield surrounding the pressure vessel is high-density concrete. The shield is designed to reduce radiation to a maximum of one milliroentgen per hour at the center line of the reactor shield face. The thickness of the concrete shield is approximately 7 feet. The shielding above the core consists of 18 feet of water and 6 inches of lead. This arrangement will keep radiation to tolerance level (7.5 mr/hr) during reactor operation.

Test Facilities

The core is completely penetrated by one 6-inch, and six 2¾-inch holes for high-pressure testing thimbles inserted through and bolted to the bottom closure plate of the pressure vessel. These thimbles are primarily intended for testing fuel elements and other materials in water or other coolants having a temperature maximum of 600 degrees F and a pressure maximum of 2000 psi.

A remotely-operated machine for loading and unloading test-thimble units is mounted in the canal below the reactor. After feed lines are cut, this machine can remove the test thimble remotely and automatically without the necessity of personnel occupying the subpile area. Loading or unloading these thimbles can be done only during reactor shutdown.

Provisions are made for five rabbit facilities near the rim of the core. Each rabbit facility consists of an aluminum tube inserted from the bottom of the reactor. A stainless-steel extension tube attached to the lower end of the aluminum tube connects with a loading and unloading valve system located in the work canal outside the reactor concrete shielding. A test specimen to be irradiated can be sealed in a small container and inserted in the tube system through the valves. Specimens are forced up to the end of the rabbit tube in the core structure by water under slightly higher pressure than reactor cooling water. A small opening at the top of the rabbit tube provides escape for the pressurized water and also provides a cooling medium for the test piece in its final position. The rabbit specimen is retracted by dropping tube water pressure so that reactor water forces the container back to the loading station. The rabbits can be used during reactor operation.

In all other core positions not occupied by a fuel element, control rod, high-pressure thimble, or rabbit tube, canned

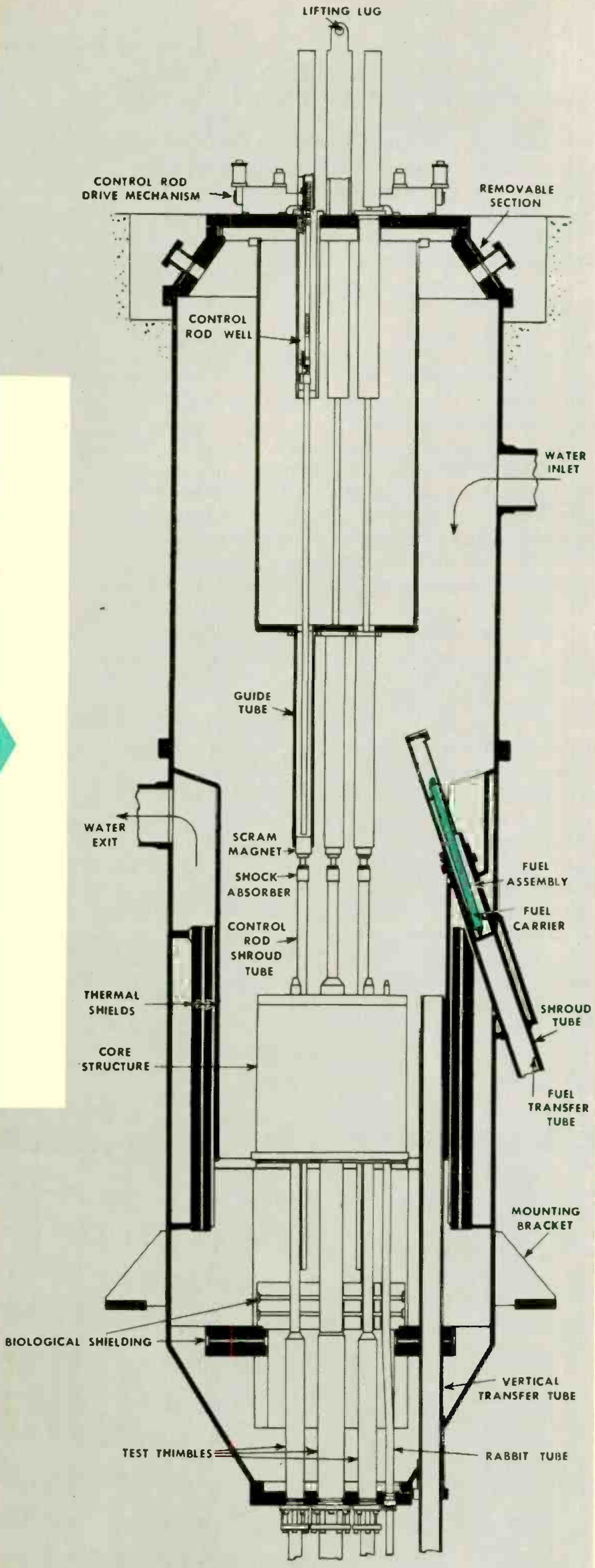


Fig. 5—General assembly drawing of reactor, control rods, and pressure vessel.

samples can be inserted for general radiation testing. These specimens are installed from the top of the reactor when the top plate is removed.

In addition, the central mandrel of each fuel element is hollow, so that small-diameter specimens can be irradiated right in the heart of a fuel element.

A horizontal beam hole having an eight-inch inside diameter extends from the surface of the reactor concrete shield directly to the outside of the active core. The beam hole plug will be made of material similar to the reactor shielding to preserve flux integrity. The beam hole will have a rotating lead shutter to facilitate changing experiments.

Plant System Operation

The primary coolant system with instrumentation and control indicated is shown in Fig. 6. Primary-loop coolant water is fed to the reactor from a 60 000-gallon storage tank. Water enters the reactor near the top of the reactor tank and splits into two streams. One stream cools the reactor while the other passes through the reflector region and cools the low-pressure experiments. The two streams join past the lower core plate and flow through the thermal shields and out of the reactor.

Orifices at the fuel-assembly exits distribute coolant flow through the assemblies. These orifices also provide some of the required static pressure on the fuel assemblies to prevent boiling at hotspots.

When the reactor tank is open, the water level is maintained by a seal tank with an adjustable weir by which the water level can be controlled. In the event of a break in the primary-coolant line, water level above the core is maintained at a minimum of 4½ feet by the location of the exit water line in the pressure vessel.

Exit water flows from the reactor through the seal tank into a 30 000-gallon surge tank. The surge tank permits 30 seconds of full flow from the head tank if power to the process water pumps is interrupted. The two-section, water-to-water heat exchanger can dissipate the 20 megawatts of heat from the reactor coolant. The water from the heat exchangers is returned to the head tank, with the exception of 50 gallons per minute, which is passed through a mixed-bed ion exchanger to maintain primary water purity.

Secondary-Loop Water System—Heat contained in the secondary coolant water is dissipated in a cooling tower capable of cooling 12 000 gpm of 100-degree F water to 85 degrees at a wet-bulb temperature of 75 degrees F. The secondary water will be treated to prevent algae growth.

Waste Disposal—The waste-disposal system consists of collection tanks, evaporators, and a retention basin. The wastes processed by this system can be classified in three categories: (1) wastes of low activity that do not require treatment before discharge to the retention basin; (2) wastes that require treatment before discharge to the retention basin; and (3) wastes that are sufficiently radioactive to require shielding.

The wastes of the first group will be collected in the tanks and held for sampling. After satisfactory analysis, they are discharged to the retention basin, and then run off when they have decayed to a safe level.

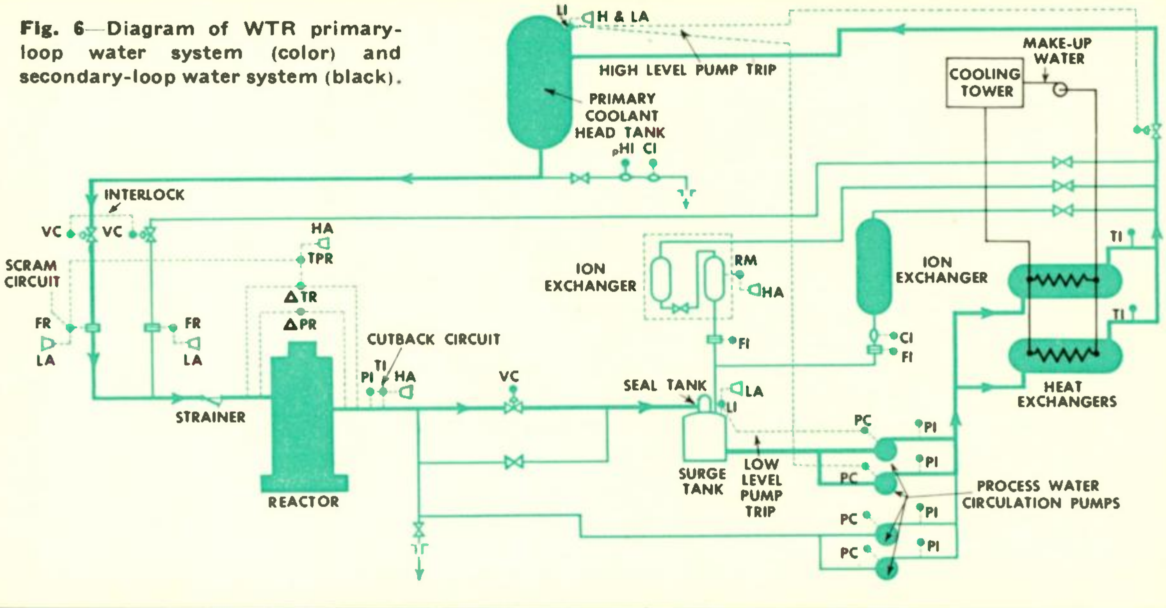
Wastes requiring treatment will be collected in the collection tanks. One tank will normally collect and store the wastes while the contents of the other are being neutralized. The treated contents of the tanks are then pumped to an evaporator. The condensate is pumped to the retention basin when the activity is at safe tolerance levels. The concentrated portion of the wastes will be drained into shielded containers for disposal.

Wastes that require shielding will be either collected for direct disposal by off-site burial, concentrated in small disposable evaporators, or diluted and treated by one of the previously-mentioned methods.

The Westinghouse Testing Reactor is designed primarily for studying physical characteristics of materials exposed to high levels of radiation. Metals undergo a change in structure when they are bombarded by fast neutrons. Physical properties such as hardness, tensile strength, resistivity, and magnetism change. Slow neutrons and gamma rays do not appreciably change the internal structure of metals until extremely high flux levels are reached. However, plastics, insulation, and some organic liquids are affected considerably by slow neutrons and gamma rays. Controlled irradiation can increase hardness, strength, and resistance to the influence of temperature changes. Westinghouse and other companies can use this testing reactor to learn more about these basic properties of materials. Such information will be valuable for normal design of electrical products in the coming Atomic Age. ■

Instrumentation or Control Device	●
Audible Alarm	◁
High Alarm	HA
Conductivity Indicator	CI
Flow Indicator	FI
Flow Recorder	FR
High and Low Alarm	H&LA
Low Alarm	LA
Level Indicator	LI
Pump Control	PC
Pressure Indicator	PI
Radiation Monitor	RM
Temperature Indicator	TI
Thermal Power Recorder	TPR
Valve Control	VC
pH Indicator	pHI
Differential Pressure Recorder	ΔPR
Differential Temperature Recorder	ΔTR

Fig. 6—Diagram of WTR primary-loop water system (color) and secondary-loop water system (black).



mica

MICA, A PRIME INGREDIENT of modern, high-voltage electrical insulations, is something of a paradox: Its application is most modern—there are no better substitutes; but it still depends upon many of the same mining and processing techniques that were employed over fifty years ago when Westinghouse used mica insulation for the first Niagara Falls generators. The continued use of mica is due to its outstanding combination of dielectric and physical characteristics—high dielectric strength, low dielectric loss, and high surface and volume resistivity are inherent; it also has excellent thermal stability, since mica is both infusible and non-inflammable.

Mica is actually a natural film, which nature provides in block form that can be split into thin usable flakes. Of the seven recognized varieties of mica, only two—*muscovite* and *phlogopite*—are of any industrial importance. Chemically, muscovite mica might be called hydrogen-potassium-aluminum-silicate; similarly, phlogopite is a hydrogen-potassium-magnesium-aluminum-silicate. The colors of both types vary considerably. Muscovite, the harder and more used of the two, is commonly found in white, green, and ruby. Phlogopite is found in amber, brown and wine colors. Characteristic red or black stains are a frequent source of trouble, since they may be oxides of iron, manganese, or copper, which impair the insulating properties of the mica.

Although mica is found in all parts of the world, the most easily worked deposits are located in India and Madagascar. The mica-bearing rock is blasted, and mica crystals are separated from adhering rock by hand cobbing, that is, by breaking them apart with a small hammer. The mica is then inspected and sorted according to size and quality. To be of use in high-voltage electrical insulations, the blocks should yield pieces at least one-inch square. The blocks are trimmed with knife, scissors, or saw and sorted into various size grades. They are then split by hand with a knife or similar sharp-pointed instrument into films five to ten thousandths inch thick or into splittings from six to twelve thousandths inch thick. The availability of low-cost labor in these areas makes mica an economical product. In both India and Madagascar, children are taught the art of splitting mica from the age of about six years.

Manufacture of Mica Insulation

While nature has provided an excellent basic insulating material in mica, several subsequent operations are necessary to make it usable. Binders and backing materials must be added for mechanical strength, and bonded under heat and pressure. The processing gives a usable engineering material, but also introduces a variety of problems and difficulties. In the manufacture of mica insulation, the technique of fabrication is equally as important as the quality of the basic materials. Two seemingly identical mica-built materials can differ in dielectric level by a factor of ten depending upon the method and manner of fabrication.

Hand-Building—The hand-built method, where successive layers of overlapping mica flakes are placed by hand and sprinkled with a binding material, is presumably similar to the first mica plate made in India in 1892.

Hand building is used for the best grades of insulating materials that require high dielectric strength and uniform thickness. Layers of relatively large and high-grade mica splittings are placed so that the edges overlap ¼ to ½ inch (see Fig. 2). If the material is to comprise only one layer, the mica must be laid on a backing material that has been treated with a binder to hold the splittings in place. Although the basic method is old, many improvements have been made in backing materials and binders. Present backing materials include synthetic films, varnish-treated paper and cloth, treated or untreated glass cloth, and tissue paper to name a few; several different types of resins are used, ranging from the first used shellac-and-alcohol mixtures, which are still satisfactory for many applications, to the high-temperature silicone varnishes.

The hand-building method is employed largely on mica tape and wrappers. Mica tape is built on a conveyor-type machine usually 18 inches wide. Mica coil wrappers also are usually built in continuous sheets on a conveyor belt, but may be built on stationary tables. They constitute a high-quality insulation, most of them being dielectrically tested in the range of 3000 to 7000 volts.

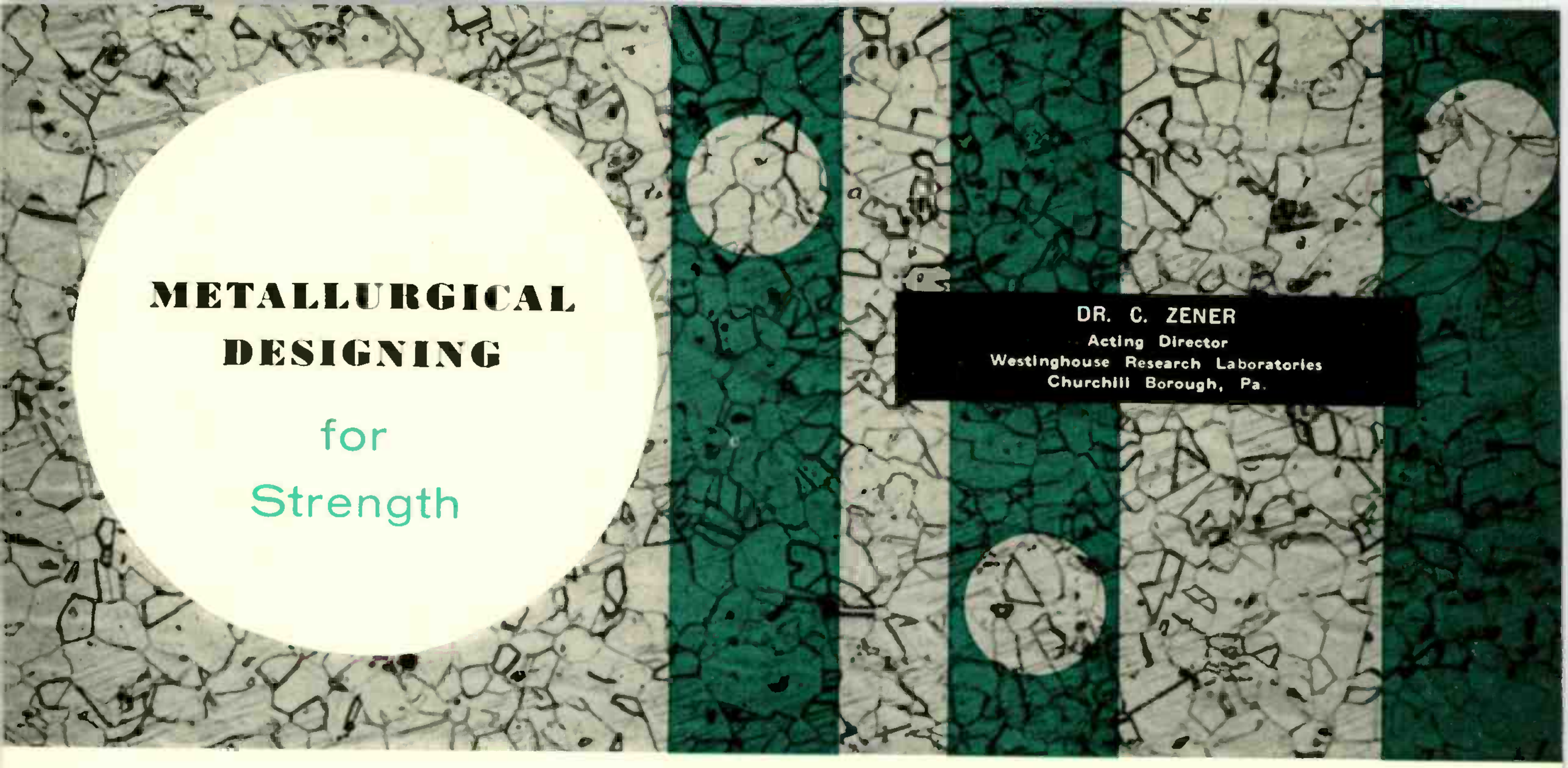
A wrapper is composed of one or more layers of mica, covered on one or both sides with materials similar to those used for tape coverings, or with fish paper. The binders used for wrappers are the same as those used for tapes. In addition, a special low-power factor bond is employed in wrappers to be used in such applications as transformer coils, where the power factor of the insulation is important. These materials are generally thicker than the mica tapes, ranging from 8 to 22 thousandths of an inch. Those built on conveyors are usually 36 inches wide while those built on tables can be made to any convenient sheet size.

Machine-Built Mica Insulation—In early practice, all mica insulation was built up by hand, but increased demand has required the development of mechanical methods for laying the mica flakes. Today, mechanically built materials account for about 80 percent of the raw mica used.

Although some tape is manufactured mechanically, the bulk of the machine-built materials are in plate form, for stamping into shapes, such as commutator insulating segments, or for molding into permanent shapes on special dies. Since machine-built plate is relatively thick, smaller and lower-cost grades of mica flakes can be used than for hand-built insulation. The underlying principle of the mechanical-laying device is shown in Fig. 6.

Mica plate is of two general types, for punching, or for molding. If mica plate is to be punched into shapes, such as commutator segments, it is put into presses and heated under pressure and then cooled. The material is then sanded to obtain the uniform desired thickness, and finally punched.

This article was staff written from information furnished by W. R. Watson, Supervising Engineer, Westinghouse Mica plant, and G. L. Moses, Manager, Services Engineering Department, Transportation and Generator Division.



METALLURGICAL DESIGNING for Strength

DR. C. ZENER
Acting Director
Westinghouse Research Laboratories
Churchill Borough, Pa.

▪ RECENTLY A NEW high-temperature alloy for steam turbines was developed at the Research Laboratories. This alloy is significant in that it has not only the desired high temperature strength and corrosion resistance, but also "built-in" damping characteristics. Perhaps of even greater significance than the material itself, however, is the fact that this alloy was *designed*—not developed solely by the time-honored cut-and-try methods of metallurgy.

The currently used blading material for steam turbines (12 percent chromium steel) has served well for over thirty years. Its high strength has prevented deformation at the red-hot operating temperature of 1000 degrees F; its high corrosion resistance has withstood steam attack, and its high damping capacity has prevented failure by fatigue. However, steam turbines now under construction are intended for inlet temperature of 1200 degrees F, far in excess of the temperature for which our present blading material, or any mere modification, has adequate strength. While other alloys are known that have the necessary strength and corrosion resistance, none of them have the necessary damping capacity. An understanding of the fundamental mechanism of damping enabled scientists at the Research Laboratories to design high-damping capacity into an alloy having the necessary high-temperature strength and corrosion resistance. Thus the costly cut-and-try methods were avoided.

This example illustrates the truism that the more intimately the behavior of metals and alloys is understood, the more rapidly and with less cost can design principles be used to improve their properties and even to develop new types of alloys. In recognition of the importance of understanding metallurgical processes, and of the primitive nature of present understanding, a large fraction of the current effort of the metallurgy department of the Research Laboratories is devoted to obtaining just this understanding, i.e., to the formulation of design principles.

In the electrical industry, metals are used for diverse purposes. They are used as carriers of magnetic flux. They are used as heating elements. In almost all equipment in the electrical industry, metals are called upon to withstand stresses without failure through deformation or fracture. In fact the major demand upon metallurgists is the development of alloys to withstand more and more severe operating conditions, such as higher stresses and/or higher temperatures. Thus the design principles for resistance to deformation and fracture are of extreme importance. Consider then, some of these principles and their underlying concepts.

Atomic Structure of a Metal

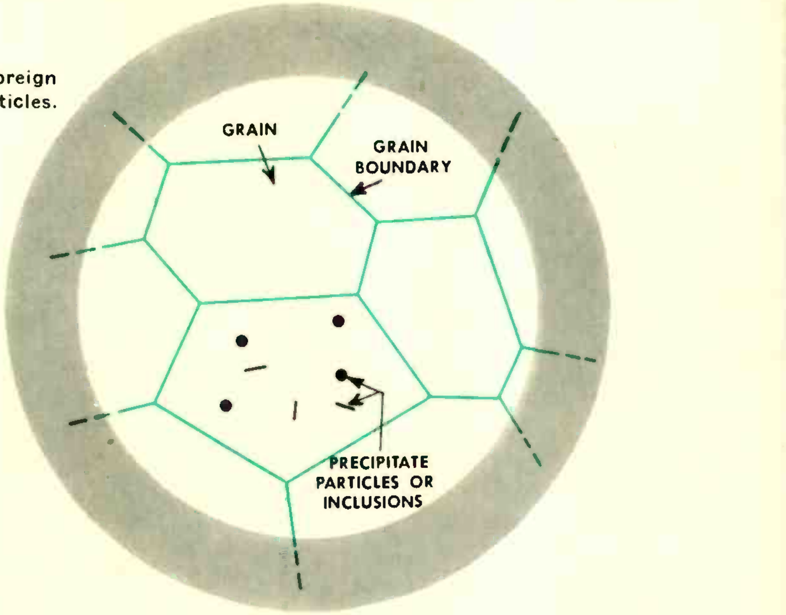
A characteristic feature of a solid metal is the orderly arrangement of the atoms in a three-dimensional network, just as corn in a field forms an orderly arrangement in a two-dimensional network. If the same orderly array extends throughout the entire specimen, the specimen is a *crystal*. Usually the orientation of the orderly arrangement remains nearly constant over only comparatively small regions, called crystallites, or more commonly *grains*, Fig. 1. The orientations of adjacent grains are essentially independent of one another.

Within each grain various types of irregularities occur. Here and there foreign particles intrude. Those foreign particles that were present in the liquid before solidification are known as *inclusions*. Other foreign particles are formed during the cooling of the solid metal from the melt, just as rain drops precipitate on cooling supersaturated air. These are *precipitate particles*.

Even between the foreign particles, the metal is not perfectly regular. Here and there foreign atoms are found. Atoms of an element added intentionally are said to be *alloying* atoms. Those of an element not added intentionally are called *impurity* or *tramp* atoms. Here and there a position where a metal atom should be is found to contain no metal atom. Such a position is called a *vacancy* (Fig. 2).

The relation of foreign atoms to precipitate particles is analogous to the relation of water molecules in saturated air to suspended water droplets. As the temperature is raised, more and more of the precipitate particles go into solution, thereby raising the concentration of the atomically dispersed foreign atoms, just as with a rise in temperature the suspended water droplets will gradually evaporate, thereby raising the concentration of water molecules in the surrounding air.

Fig. 1—Typical grain structure. The foreign particles are inclusions and precipitate particles.



When the alloying atoms are present in a sufficiently high concentration, i.e., approaching 50 percent, they may arrange themselves in an orderly manner. The metal is then said to be ordered. Otherwise it is said to be *disordered* (Fig. 3).

A rather peculiar, but very important, type of irregularity for a two-dimensional array is the termination of a row of atoms, as illustrated in Fig. 4. The consequent distortion of the lattice is confined essentially to the immediate vicinity of the terminus. This vicinity is called a *dislocation*. In a three-dimensional array, a dislocation forms a line, not necessarily straight. That line of atoms which terminates in a dislocation need not remain fixed. As illustrated in Fig. 4, only a slight rearrangement of atoms is necessary in order for a terminating row to interchange roles with a neighboring row. Such a rearrangement of atoms can be thought of as a motion of the dislocation normal to the termination row, a motion which is called a *glide*. A condensation of vacancies at the dislocation will cause the dislocation to move up, the process of evaporation of vacancies will cause a downward motion. Such a vertical motion is called a climb (Fig. 5).

This description of a metal is a static description, appropriate to very low temperatures. Actually at moderate, and particularly at high temperatures, the atoms in a metal are in a constant state of flux. The individual atoms vibrate with the high frequency of the order of magnitude of 10^{12} cycles/sec. The vacancies rapidly roam throughout the metal, resulting in a continual reshuffling of parent and foreign atoms. In this reshuffling, foreign atoms precipitate; other precipitate particles partially redissolve. Dislocations are continually gliding back and forth as well as climbing up and down, with a concomitant condensation or evaporation of vacancies.

Fig. 2—Within each grain the orderly pattern of atoms is broken by impurity atoms and vacancies.

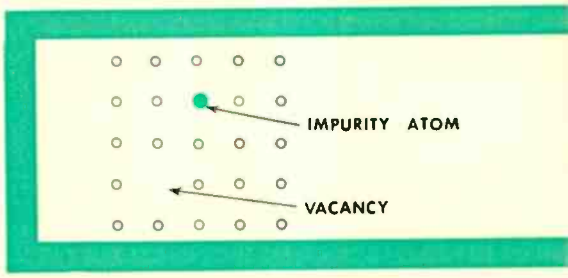


Fig. 3—An ordered metal is one in which the atoms arrange themselves in an orderly pattern. If the concentration of alloying atoms is less than 50 per cent the arrangement is often disordered.

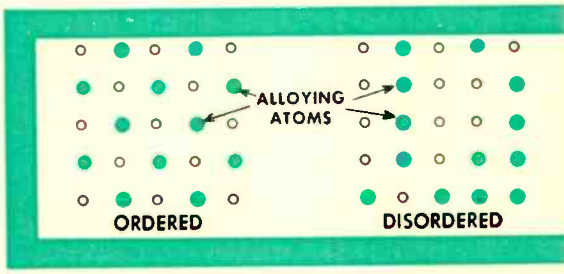


Fig. 4—Glide is the lateral movement of a dislocation, and results in some rearrangement of atoms.

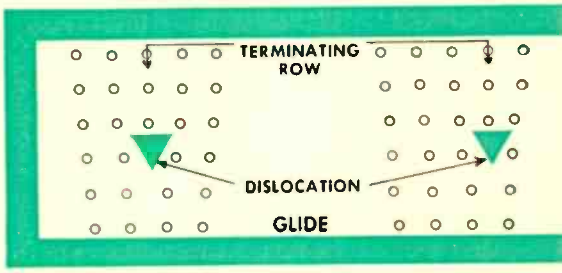
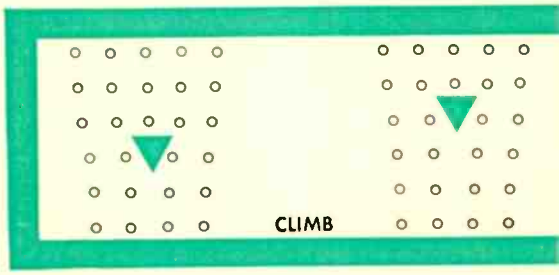


Fig. 5—Climb is the vertical movement of a dislocation and is caused by either condensation or evaporation of vacancies.



Deformation

The atomic mechanism of deformation in metals is best understood by contrasting deformation in metals with that in amorphous materials such as tar. The rate of deformation in an amorphous material is strictly proportional to the applied load, i.e., amorphous material behaves in a viscous manner. As illustrated in Fig. 6, a plot of deformation rate versus load yields a straight line. In marked contrast, the rate of deformation in a metal is essentially zero until a critical load is reached, higher loads resulting in a rapidly increasing rate of deformation. In an amorphous material the load required to cause a given rate of deformation increases rapidly with a decrease in temperature. Thus this load may be doubled by a 10-degree C drop in temperature. In many amorphous materials, such as glass, the load required to produce an appreciable rate of deformation at room temperature is so high that on raising the load the material fractures without observable deformation. Such amorphous materials are said to be brittle. In marked contrast, the load required to produce a given deformation rate in a metal is relatively insensitive to temperature, increasing by only a small factor as the specimen is lowered from room temperature to that of liquid helium.

The significance of this difference in deformation behavior of metals and amorphous materials can best be grasped by considering the actual atomic movements. In both cases an elementary act of deformation takes place by a rearrange-

Fig. 6—Deformation rate of amorphous material and a metal crystal under load.

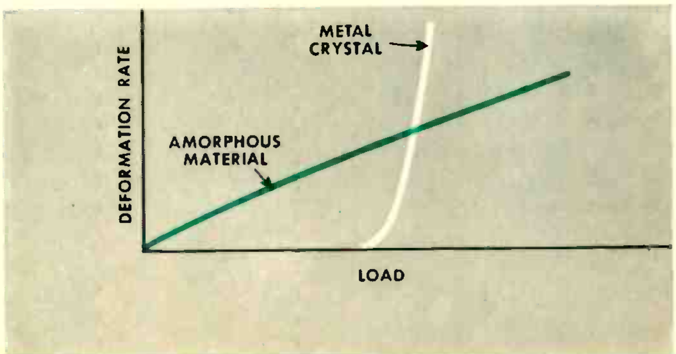
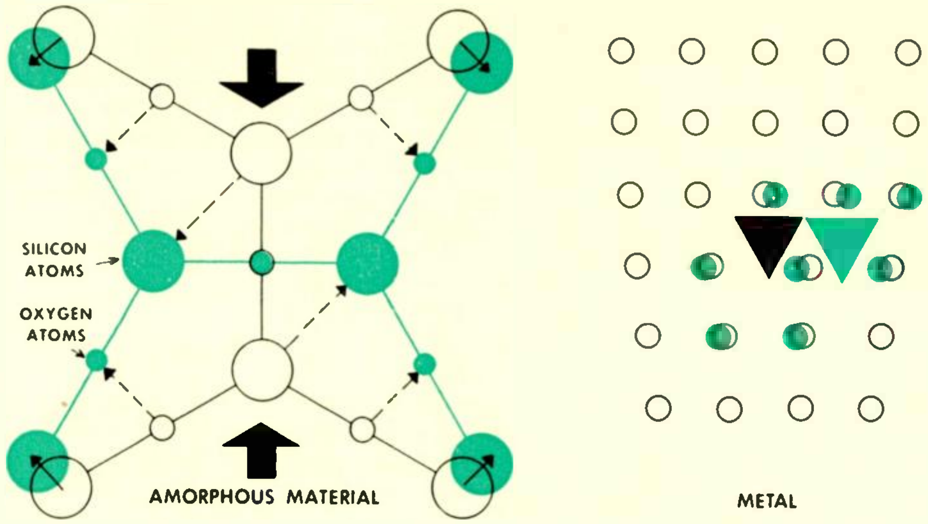


Fig. 7—Large movement of atoms is necessary for deformation to occur in amorphous material, as shown for a two-dimensional glass. In a metal, on the other hand, the deformation may consist merely of the glide of a dislocation, with only slight atomic movement.



ment of atoms in a localized region. Examples of such rearrangements of atoms are given in Fig. 7 for an amorphous material and a metal. In the former, large atomic movements are necessary in order for an elementary act of deformation to occur. Such large atomic movements cannot be induced by an externally applied stress. These large movements can occur only through thermal fluctuations. The externally applied stress can only modify somewhat the size of the thermal fluctuation needed to cause the rearrangement of atoms.

In the case of a metal, an elementary act of deformation may consist merely of the glide of a dislocation by one atomic layer. The associated atomic movements are so small that they can be induced solely by an externally applied stress. No thermal fluctuations are necessary.

In crystals, deformation proceeds mainly via the glide of dislocations. In metals such glide is impeded now and then by various obstacles, such as precipitate particles, grain boundaries, or other dislocations. When the applied stress is not sufficiently large to cause the dislocation to glide through a given obstacle, the dislocation can, given time, climb around the obstacle by the mechanism of condensing or evaporating vacancies, as suggested in Fig. 5. Climbing takes place much more rapidly as the temperature is raised, because the motion of vacancies occurs only through thermal agitation. Recrystallization and creep at elevated temperatures presumably require both the glide and climb of dislocations.

At moderate temperatures dislocations move only by gliding. Impurity atoms, atomically dispersed, exert only a slight retarding action. Their retarding effect upon glide is greatly enhanced by precipitation into particles, essentially impenetrable by dislocations. Impurity atoms tend to be squeezed into dislocations. Such a tendency is operative, however, only at elevated temperatures where the impurity atoms have some mobility. The resulting clogging of dislocations at elevated temperatures presents an impediment both to the glide and climb of dislocations.

At high temperatures, atomically dispersed impurity atoms exert a second, more subtle effect. At such temperatures, dislocations are continually moving to configurations of lower potential energy, resulting in partial mutual annihilation (Fig. 8) and in partial ordering. The overall result is a reduction in the impediments to the motion of other dislocations, i.e., the metal softens. By their clogging action impurity atoms prevent such softening.

All estimates of the fracture stress of perfect metal crystals give a million pounds per square inch or higher, corresponding to an elastic strain of several percent. Our common pure metals cannot be trusted not to fracture at stresses of only one-tenth of this value, or even less. Recent experiments with very perfect filamentary specimens, known as *whiskers*, confirm the theoretical estimate. Thus the fracture in metals as commonly prepared must be blamed on imperfections of one sort or another.

The observed fracture strengths of amorphous materials are also much lower than the theoretical values. At least in the case of glass, this discrepancy can be traced to the presence of small surface cracks. The stress concentrations at the end of the cracks are just sufficient to raise the local stress value to the theoretical strength of the material. Except in unusual circumstances, it does not appear possible to blame premature fracture in metals to surface cracks.

Premature fractures of metals at low stress levels can, however, be caused by either of two types of imperfections, acting singly or together. The first type is a structural imperfection giving rise to local stresses far higher than the overall stress. The second type is the chemical imperfection of a laminar or planar distribution of chemical elements or compounds having abnormally low cohesive strength.

At least under all known conditions, the very act of deformation itself introduces high stress concentrations. Presumably because of the manner in which they are generated, many dislocations are observed to follow one another along a common glide plane. The spearhead of such a cluster advances until stopped by some obstacle. The continued advance of dislocations behind the stopped spearhead builds up a high stress concentration in an attempt, so to speak, to force the spearhead through the obstacle (Fig. 9). This stress concentration will be higher the larger the cluster. Unless otherwise impeded, these clusters will extend clear across the individual grains, from grain boundary to grain boundary. The larger the grains, the higher will be the stress concentration that is induced by the dislocation clusters. These stress concentrations have been calculated at the Research Laboratories. Upon taking them into account, precise agreement has been found with all the measured fracture stresses of pure metals, including iron. Less susceptible to analysis is the stress concentration of a dislocation cluster stopped by obstacles other than grain boundaries.

Whereas the interior of a grain does not deform until the load reaches a critical value, the grain boundary responds to a load in the same manner as a viscous material. More precisely, the regions on the two sides of an element of grain boundary slip over one another at a rate proportional to the shear stress acting across the element, in the manner indicated in Fig. 10. This rate of slip increases rapidly with a slight rise in temperature. But no such relative motion can occur at the junction of these grains. These junctions thereby acquire a high stress concentration. Cracks started at these junctions can then spread throughout the specimen. Metal specimens are susceptible to such cracks under conditions that favor grain boundary slip over plastic deformation in the interior, namely low stresses and high temperatures for a long time. These are just the operating conditions for inlet pipes to steam turbines.

Small amounts of impurities could not appreciably lower the resistance to fracture if the impurity atoms remained atomically dispersed. Many types of tramp atoms have the unfortunate habit of segregating into films enveloping the grain boundaries, these films having only a slight cohesion with the adjacent grains. Now the overall fracture strength of a specimen can be only as high as that of the weakest plane in the specimen. Only minute traces of those elements which then segregate are hence necessary to cause premature fracture. The classic example of the disastrous effects of such films is the segregation of bismuth along the grain boundaries of copper. Unfortunately this segregating tendency is not confined to esoteric elements like bismuth. This tendency is pronounced in the common tramp gases, oxygen and nitrogen, as well as in the common alloying elements silicon and carbon.

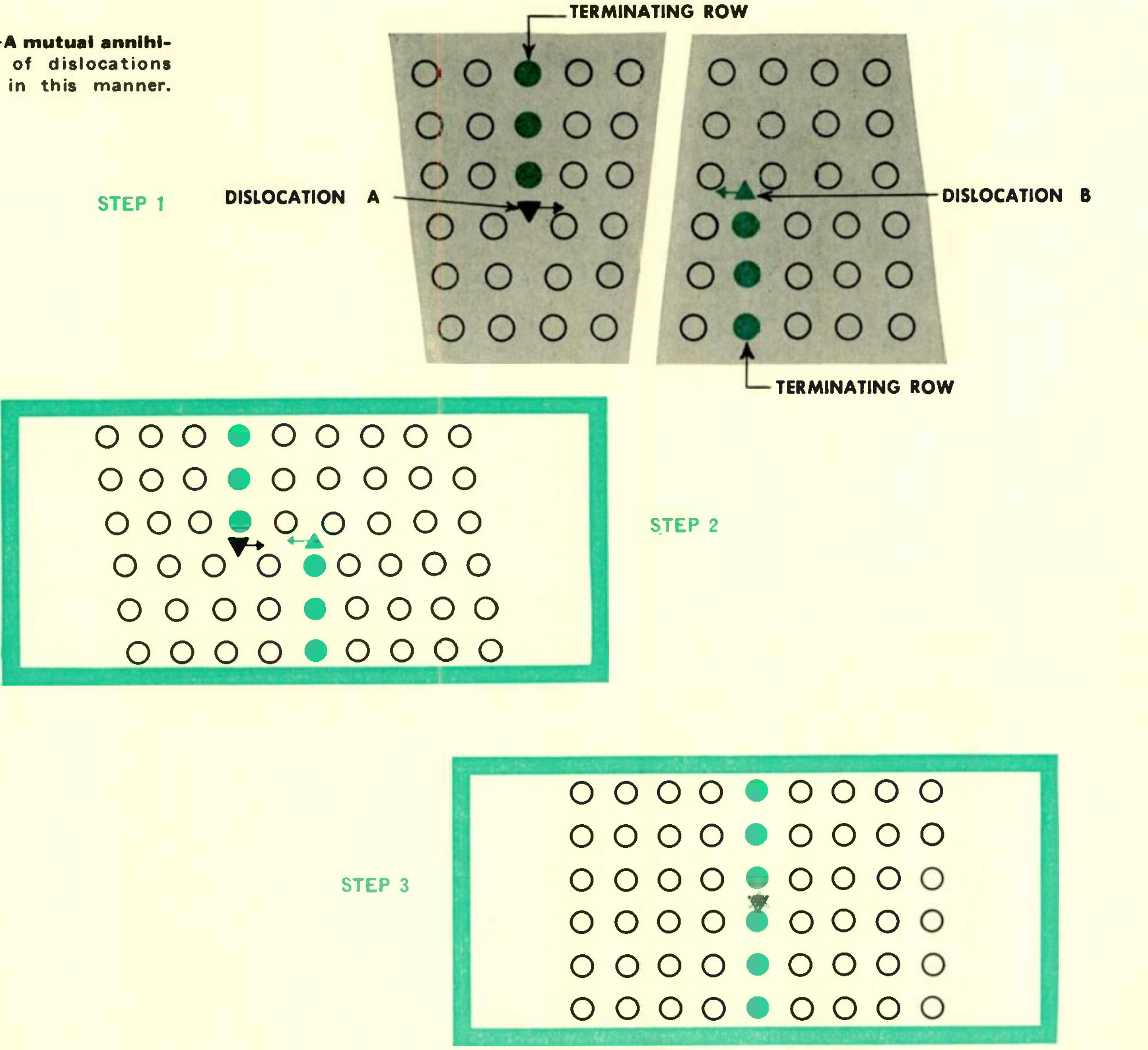
Thus grain boundaries are not only the site of high stress concentrations caused by the very act of deformation itself, but also are apt to be the site for the formation of weak films. The combination of high stress concentration at sites of intrinsic weakness frequently renders grain boundaries the weakest link in a metal structure. Thus minute traces of oxygen or nitrogen embrittle molybdenum, the molybdenum falling apart along the grain boundaries.

Minute traces of hydrogen behave in a particularly treacherous manner in large forgings. These traces of atomically dispersed hydrogen are introduced during steel making. Suppose that a stress is applied to introduce a little deformation, this deformation itself giving rise to tiny cracks too small to propagate under the applied stress. Then the hydrogen atomically dispersed in the specimen gradually diffuses into the cracks, in time building up pressures that finally cause disruptive expansion. This danger of catastrophic failure is not present in small forgings, out of which hydrogen rapidly diffuses.

Design Principles

The appropriate choice of the general type of material for a particular application can frequently be made from obvious

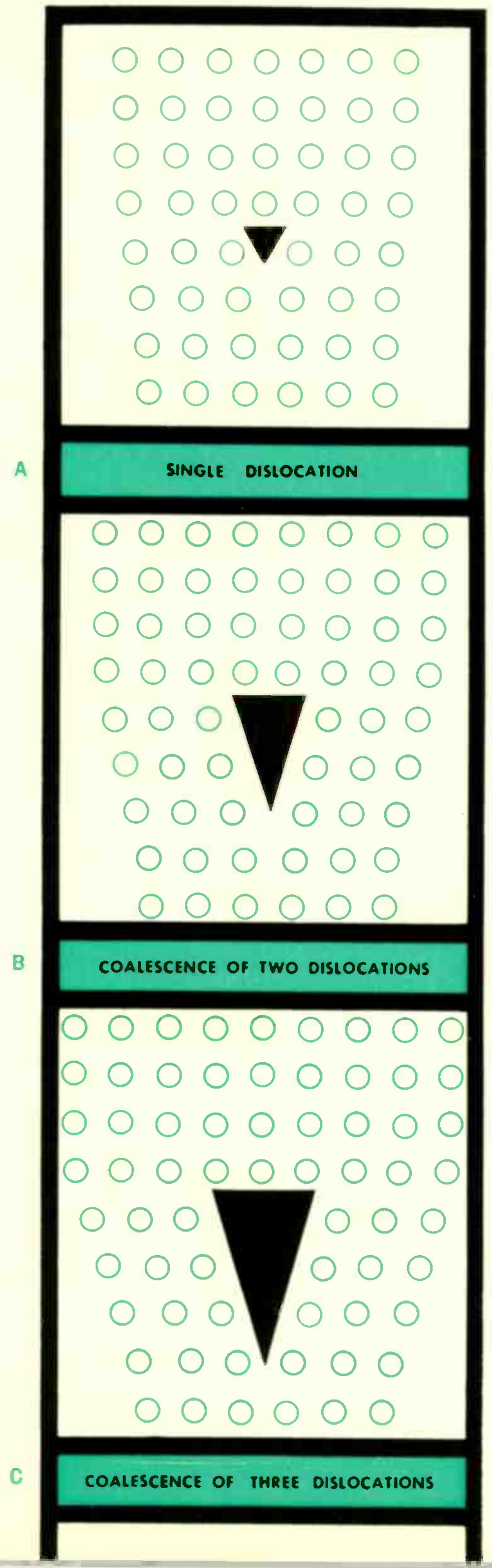
Fig. 8—A mutual annihilation of dislocations occurs in this manner.



considerations. Thus if lightness of weight is important and high-temperature operation is not required, an aluminum-base alloy may be chosen. If the material is to operate at room or only moderately elevated temperatures, an iron-base alloy has many advantages. If the temperature of operation is very high, a base with a high melting temperature, such as molybdenum, is called for. Only after the general type of material has been chosen, and the question of how this base material must be alloyed and processed, is the need for metallurgical design principles encountered.

Irrespective of our particular application, and irrespective of our choice of general types of material, the same basic metallurgical problem is faced. A common requirement is high resistance to deformation, i.e., high strength as measured, for example, by yield strength, or hardness, or stress required to produce a given creep rate. But experience has taught that premature fracture in service may occur with little or no appreciable prior deformation, unless the material has a certain minimum ductility as manifested in the standard tensile test. In service, localized regions of stress concentration arising from notches, scratches, or inclusions are unavoidable. Unless these localized regions are susceptible to considerable plastic deformation and thereby to stress relaxation, fracture will occur before the overall stress level reaches the design level. Experience has also taught that increased strength may readily be gained only at a sacrifice of ductility. This inverse relation between strength and ductility is represented in Fig. 11.

Fig. 9—Stress concentrations can be built up by the coalescence of dislocations, thereby forming micro-cracks.



Increased strength, with a concomitant reduction in ductility, can be obtained in a variety of standard ways, such as by raising alloying content and/or lowering tempering temperature. Increased strength without a concommitant decrease in ductility can be obtained only by recognizing those factors which contribute to premature fracture and then designing the composition and processing of the alloy to minimize the harmful effect of these factors.

As mentioned, certain undesirable tramp elements, in particular the gases oxygen and nitrogen, are prone to form weak films around the grain boundaries. The deleterious effects of the tramp elements will be further minimized by avoiding ceramic crucible contamination through use of a cold-hearth melting technique, such as is done in arc melting or in induction drip pool melting.

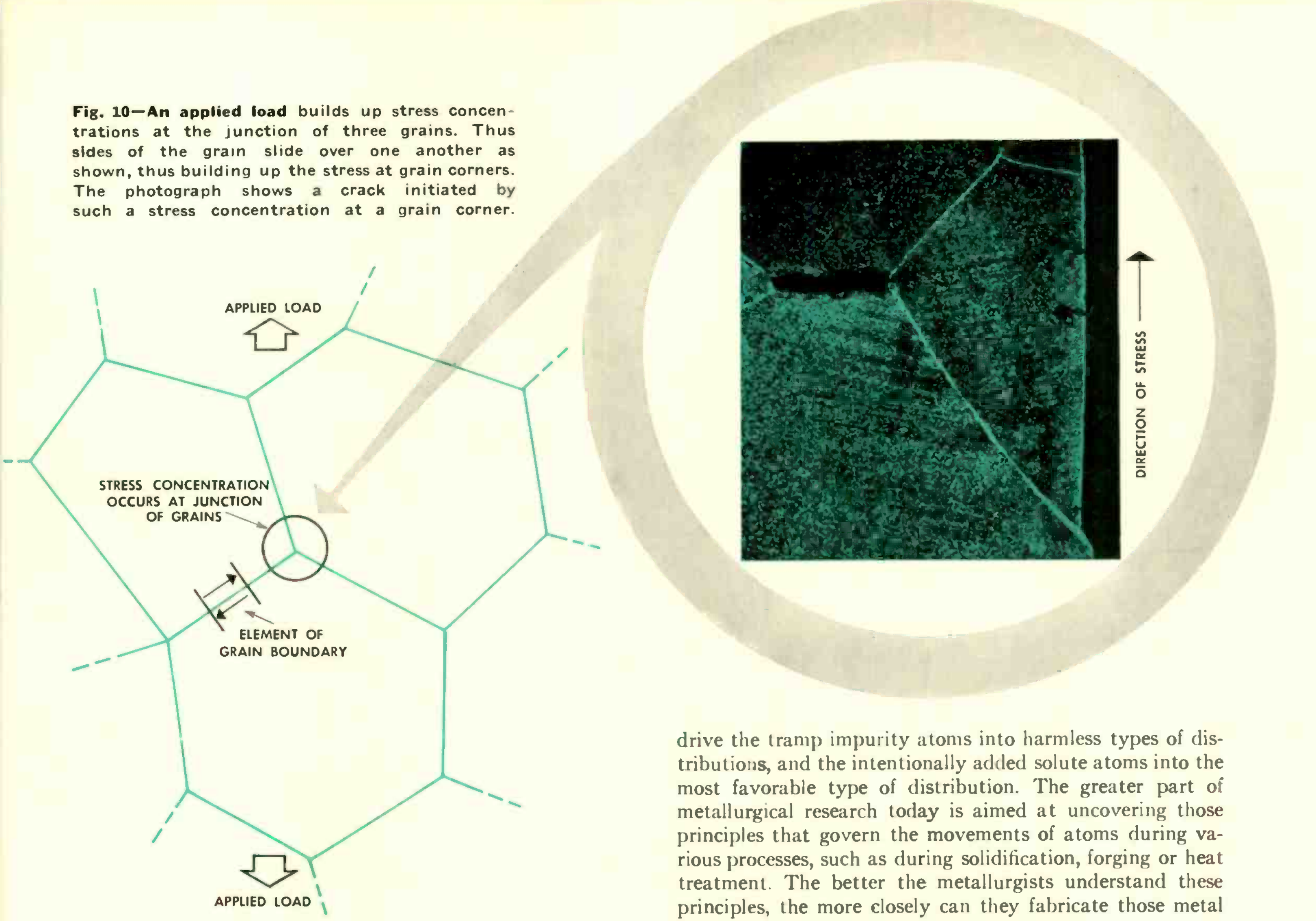
The harmful effects of the contaminating gases may sometimes be lessened by avoiding film formation. Thus if the oxygen is tied up in the form of a refractory oxide, it is rendered essentially harmless.

Improvement in the strength-ductility relation can be obtained not only by minimizing the content of those tramp elements that form weak films, but also by minimizing the stress concentration induced by deformation itself. Stress concentration induced by dislocation clusters impinging against grain boundaries is higher the larger the grains. Reduction in grain size therefore leads to an improved strength-ductility relation.

Another method of lessening these stress concentrations is by the introduction of finely dispersed precipitate particles. Such particles presumably cushion grain boundaries against the impact of the dislocation clusters' spearheads. By introduction of finely dispersed precipitate particles, strength and ductility can possibly be raised simultaneously. Thus the addition of two percent of finely dispersed particles of aluminum to zinc doubles the yield stress and at the same time changes the reduction of area from 25 to 99 percent. A corresponding simultaneous rise in strength and in ductility likely will be achieved in most common alloys when methods are developed for increasing the fineness of dispersion of the hard precipitate particles. For example, such a simultaneous rise has been obtained in Discaloy precipitation hardened alloy by an appropriate combination of working and heat treatment. The conventional method of obtaining finely dispersed hard particles is through precipitation of an intermetallic compound. Less orthodox methods promise the possibility of obtaining even finer dispersion. Examples are internal oxidation and powder metallurgy.

Two primary factors are responsible for a decrease in strength at higher temperaturees. One factor is the gradual decrease in the dispersion of the precipitate particles, technically known as coalescence. Coalescence can be reduced by

Fig. 10—An applied load builds up stress concentrations at the junction of three grains. Thus sides of the grain slide over one another as shown, thus building up the stress at grain corners. The photograph shows a crack initiated by such a stress concentration at a grain corner.

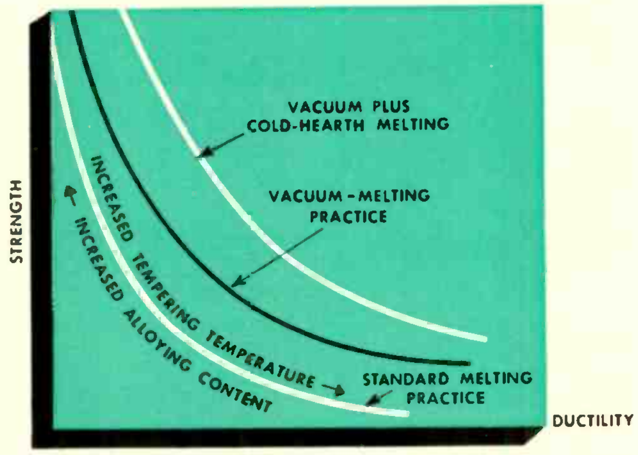


use of precipitate particles having lower solubility and lower mobility. Thus steels hardened by a finely dispersed tungsten carbide phase retain their hardness at higher temperatures than steels hardened by iron carbide. The second factor is the increased mobility of dislocations at higher temperatures, particularly mobility in climbing. The standard way of reducing this mobility, as manifested, for example, through a rise in recrystallization temperature, is by the addition of appropriate solid solution alloying elements that clog the dislocations. It is believed that, for a given concentration, the most effective alloying elements for clogging dislocations are those whose atoms differ most in size from those of the base metal. Thus the order in which one atomic percent of alloying elements raises the recrystallization temperature of iron is Mn, Cr, Mo, V, W, Cb, Ta, the same order in which atomic size differs from that of iron.

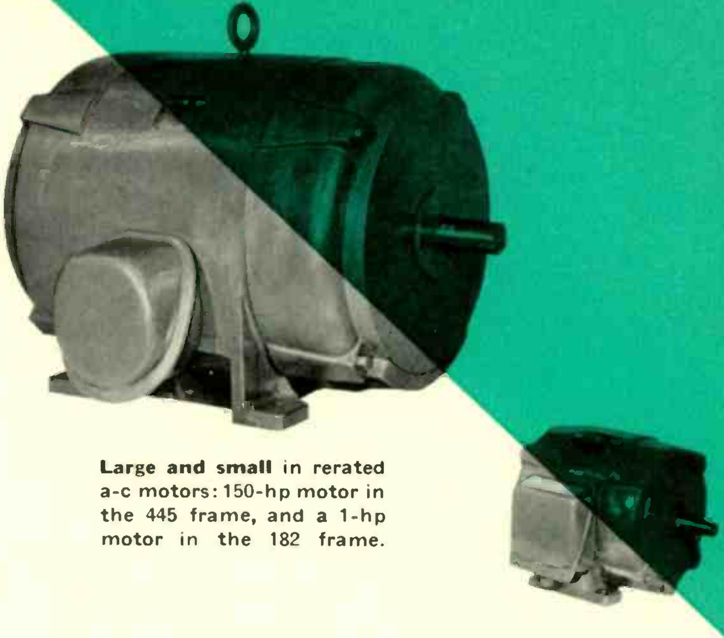
A metallurgist's troubles have only begun once a metal design has been decided upon for a particular application. Unfortunately, he cannot place the atoms layer by layer just as he pleases, like a bricklayer building a wall. When a metal freezes from the melt, the arrangement of atoms is almost beyond his control. Oxides and nitrides have probably segregated along grain boundaries, thereby rendering the ingot brittle. Those alloying elements that have been added intentionally for increased strength may be uselessly dispersed in large precipitate particles, so large as to have little strengthening effect. By using the few available crude tools, such as forging or rolling, heating, quenching, or slow furnace cooling, and various combinations thereof, the metallurgist strives to drive the tramp impurity atoms into harmless types of distributions, and the intentionally added solute atoms into the most favorable type of distribution. The greater part of metallurgical research today is aimed at uncovering those principles that govern the movements of atoms during various processes, such as during solidification, forging or heat treatment. The better the metallurgists understand these principles, the more closely can they fabricate those metal structures designed for particular purposes.

Metallurgical design principles are currently used for imparting properties other than strength, such as corrosion resistance and improved magnetic behavior. The design principles, although admittedly primitive, are still of considerable use in improving old and in developing new alloys. In metallurgy, the possible combinations to form alloys are almost limitless. Only through the perfection of design techniques can we hope to determine with assurance the best metal or alloy for a given application. ■

Fig. 11—Strength and ductility vary inversely. Thus a large increase in strength can be gained only with a sacrifice of ductility, and vice versa.



The rerating program undertaken with small a-c motors now is being extended to larger a-c motors and to d-c motors. The results and effects of the new standards are outlined here.



Large and small in rerated a-c motors: 150-hp motor in the 445 frame, and a 1-hp motor in the 182 frame.

The Significance of
NEW STANDARDS FOR MOTORS

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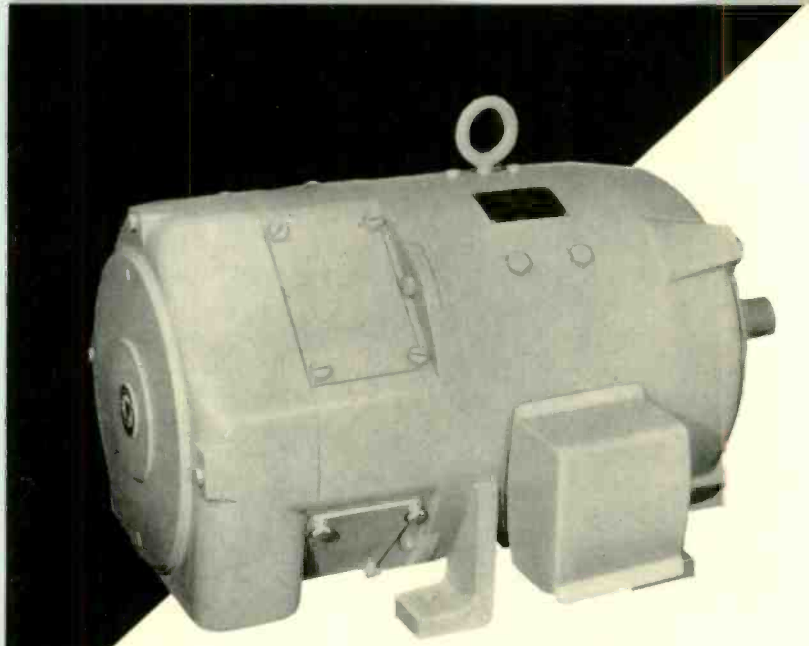
This article is based on a paper presented at the 20th Annual Machine Tool Electrification Forum, sponsored by the Westinghouse Electric Corporation. Buffalo, N.Y., April 17 & 18, 1956.

Several years ago industry-wide standards for small a-c motors were revised. This enabled motor designers to take full advantage of the many developments that had been made in the motor art; the result was a new Lifeline A motor, which is both smaller and lighter than its predecessor for a given horsepower, and has a longer life expectancy and improved performance.

This NEMA rerating program has now been extended to the larger frame sizes of a-c motors, and also applied to d-c motors for the first time. Many benefits will accrue from these new programs.

TABLE 1—NEMA FRAME ASSIGNMENTS

	OPEN—40° C—60 CYCLES				TEFC—55° C—60 CYCLES			
HP	3600 RPM	1800 RPM	1200 RPM	900 RPM	3600 RPM	1800 RPM	1200 RPM	900 RPM
	(DESIGNS A AND B)				(DESIGNS A AND B)			
20	284-U	286-U	326-U	364-U	286-U	286-U	326-U	364-U
25	286-U	324-U	364-U	365-U	324-U	324-U	364-U	365-U
30	324-S	326-U	365-U	404-U	326-S	326-U	365-U	404-U
40	326-S	364-U	404-U	405-U	364-US	364-U	404-U	405-U
50	364-US	365-US	405-U	444-U	365-US	365-US	405-U	444-U
60	365-US	404-US	444-U	445-U	405-US	405-US	444-U	445-U
75	404-US	405-US	445-U	—	444-US	444-US	445-U	—
100	444-US	444-US	—	—	445-US	445-US	—	—
125	445-US	445-US	—	—	—	—	—	—
						(DESIGN A)		
	(DESIGN D OPEN—PROPOSED)							
	5–8% SLIP				8–13% SLIP			
10	—	—	—	—	—	—	—	—
15	—	—	—	364-U	—	—	—	365-U
20	—	—	364-U	365-U	—	—	365-U	404-U
25	—	—	365-U	404-U	—	364-U	404-U	405-U
30	—	364-U	404-U	405-U	—	365-U	405-U	444-U
40	—	365-U	405-U	444-U	—	404-U	444-U	445-U
50	—	404-US	444-U	445-U	—	405-US	445-U	—
60	—	405-US	445-U	—	—	444-US	—	—
75	—	444-US	—	—	—	445-US	—	—
100	—	445-US	—	—	—	—	—	—
125	—	—	—	—	—	—	—	—



This industrial d-c motor is representative of the line designed in response to new NEMA standards.

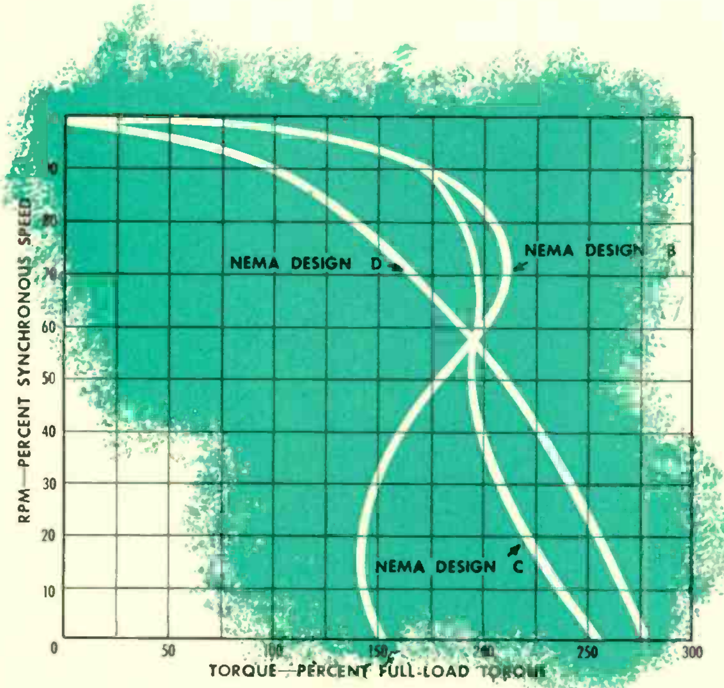


Fig. 1—Typical speed-torque curves for NEMA designs, B, C, and D.

A-C Motors

For a-c motors, the new extended standards cover frame sizes from 364 through 445, which represent, roughly, a-c motors from 40 to 100 horsepower.

From the user's standpoint, the new program will not cause the problems encountered previously when new frame diameters and mounting dimensions were introduced for smaller frames. No new diameters or frame mounting dimensions will be introduced. Changes will be limited to a reassignment of ratings, horsepower, and speed for motors in standard 364 to 445 frame sizes.

For dripproof a-c motors, a simple, practical rule of thumb for determining the new frame for a given horsepower rating is that the new frame size is two frame sizes down from the conventional size. However, this rule does have an exception; it does not apply to these motors in two-pole, 3600-rpm ratings.

Totally-enclosed fan-cooled motors do not follow any such convenient pattern, even though comparable reduction in frame sizes have been made. The relationship between old and new frame sizes is shown in Table 1.

The reassignment of frames has not made any changes in NEMA performance standards, Fig. 1. The limits on starting torque, pull-out torque, inrush current, temperature rise, and other characteristics have not been changed. A dripproof motor for 60-cycle operation will still be rated on a 40-degree rise and enclosed motors on a 55-degree rise. Thus, the new standards will not affect interchangeability. No difficulties will arise in converting from the present standard frame, diameter, and mounting dimensions to the new rating.

Doubtless in many cases the new standards will provide an answer to a redesign problem. Possible examples are the problems created by the current trend toward increased cutting speeds and duty cycles on machine tools, and the necessity for increased horsepower requirements for spindle, table, and feed motors. In the past, to avoid design changes resulting from space limitations, Class H or silicone-insulated motors rated with high-temperature rise have been used to obtain the necessary increased horsepower. Motors built according to the new NEMA standards can ease this problem; where a 50-hp, 1800-rpm spindle motor was used formerly, a four-pole, 75-hp motor can now be used without any change in mounting or space requirements.

The new motors will be similar in design and appearance to the smaller Lifeline A motors (1 to 30 hp). The design features and performance characteristics of the smaller motors will be incorporated in the new ratings to provide a uniform group of a-c motors extending upward through the 445 frame size (see photo, above left), covering, roughly, ratings from 1 to 100 horsepower.

D-C Motors

The new standards adopted for industrial d-c motors (see photo, above right) cover ratings of 1 through 200 horsepower; for generators ratings through 150 kilowatts are involved. No standardized frame assignments are made. However, the new standards for d-c equipment involve several important changes in ratings and performance characteristics.

The field of application for d-c motors has changed materially since original standards were established. Formerly, they were applied for constant-speed drives and wherever direct current was the main source of supply. Occasionally, they were applied to obtain the higher-than-base speeds made possible by weakening the field. At present, the majority of d-c motors are applied on variable-voltage drives and have their own generator source. Recognition of this trend has resulted in a combination of the present constant-speed and adjustable-speed ratings into one design.

Principal changes in the d-c motor standards are: (1) There are no frame assignments. (2) A single table of ratings combines the present constant-speed and adjustable-speed ratings; the table provides for 156 ratings, rather than 502 as before. (3) The new motors have improved dynamic characteristics. (4) Nominal voltage is to be 120 and 240 volts rather than 115 and 230 volts. (5) Class B insulation has been standardized. (6) Dripproof motors can be rated 60-degrees C rise with service factor.

The absence of frame assignments under the new NEMA standards represents no real change in policy, since they were actually rescinded sometime ago. The association's conclusions were that a-c and d-c motors are not used interchangeably, and since d-c applications are usually of a special nature, no advantage exists in having manufacturers build their d-c ratings on the same frame sizes. Generally the frame numbers used with a-c motors will continue to be used on the new line of d-c motors. The ratings, however, will not necessarily fall on the same frame sizes with all manufacturers.

The torque produced by a d-c motor can be much greater than that of an a-c motor of the same rating. A 10-hp d-c motor, for example, can be built on one frame size by one manufacturer and on another frame size by another manufacturer. However, with but few exceptions both will have frame numbers that will line up basically with the NEMA numbering system for a-c motors.

A single table of ratings came about because of a new approach to the rating of adjustable-speed motors. The old system for rating adjustable-speed motors established that an open motor should operate at 150 percent above its base speed with a 40-degree rise. The motor was also rated at the base speed for one hour at a 50-degree rise. The horsepower was tapered, increasing from that at 150 percent of speed to that at 300 percent of base speed, and with a 40-degree rise. This rating at 300 percent of base speed was the next higher horsepower rating, and varied considerably over the line of motors. The adjustable-speed motor on the old arrangement was therefore a somewhat different motor than one designed to operate continuously at base speed with a 40-degree rise.

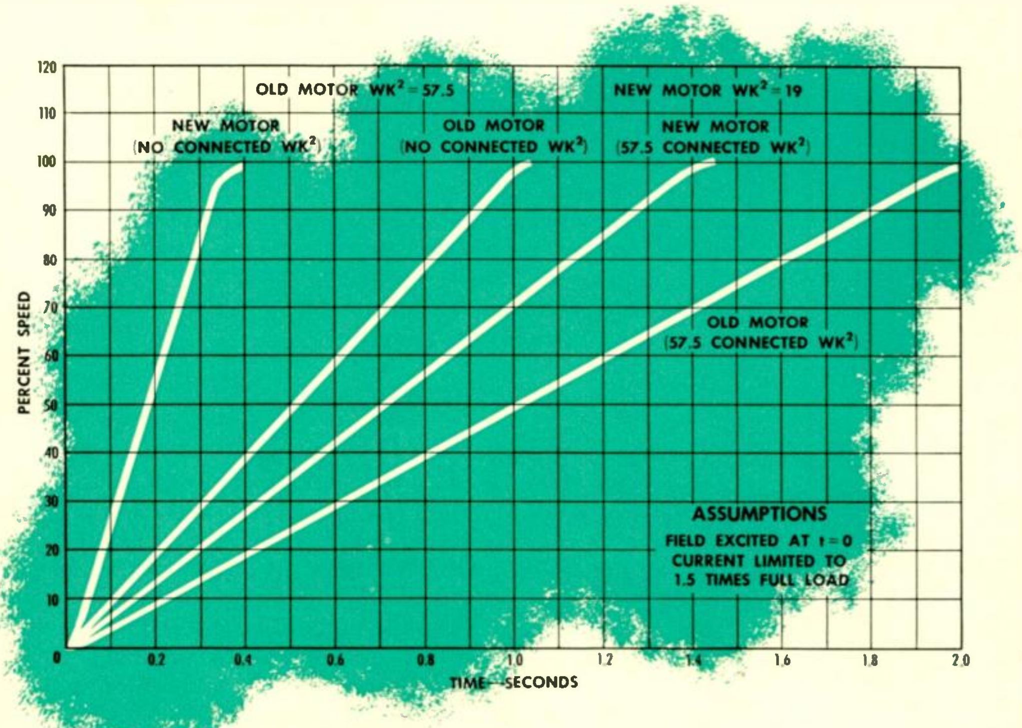


Fig. 2—Relative response of rerated d-c motors and comparable conventional motors.

In the new industrial d-c motor the constant-speed and adjustable-speed ratings are merged. Dripproof motors will operate continuously at base speed with a rise of 60 degrees regardless of whether they are sold as adjustable-speed or constant-speed motors. Adjustable-speed motors will carry 115 percent of their rating at 150 percent of base speed. At three times base speed, or higher, they will carry 130 percent of the rating at base speed. Both of these ratings are at 60-degrees C rise, continuous.

A considerable reduction has been made in the number of ratings in the new d-c line. Where 502 ratings appeared in the old standards, now only 156 ratings are necessary. In addition to combining the constant-speed and adjustable-speed motors into one table, the number of ratings has been reduced by dropping eight base speeds entirely, namely, 100, 150, 200, 250, 350, 450, 575, and 690 rpm. On the other hand, two new base speeds have been added. One new base speed, 650 rpm, now substitutes for obsolete speeds of 575 and 690 rpm, and one, 2500 rpm, was added to fill the gap between 1800 and 3600 rpm.

The relative response of the new line, Fig. 2, compares favorably with that of the old. The use of Class B insulation, plus the use of a longer core length for a given armature diameter, reduces mechanical inertia materially. Basically, the new designs have a slight advantage in time constant of the main field, but this is not truly significant because in any case where a low time constant is desired, the relation of inductance to resistance of a field can be controlled by the design of motor and control. This is, of course, true for either old or new machines.

Although d-c motors usually have been rated at 115 and 230 volts, and d-c generators at 125 and 250 volts, under new standards nominal motor voltage becomes 120 and 240 volts, while generator voltage ratings are unchanged. Earlier, the difference was intended to compensate for line drop, because there was usually a considerable length of conductors between the generator and the motors. This situation is not true for the individual variable-voltage drive where the motor-generator set is usually located near the d-c driving motor. In such cases, the line drop is negligible. Furthermore, in applications where motors are supplied from a constant potential line, users have improved voltage regulation so that the average voltage at the motors is more nearly 120 and 240 volts than 115 and 230 volts.

In considering standards for generators, no change was made in the voltage because new generators very frequently must be operated in parallel with old ones. Furthermore, keeping the line voltage the same as before produces no problems involving capacity of lines.

Regarding Class B insulation, the principal advantage of its use is that, over the entire range, it makes possible smaller motors with lower WK^2 of the armature and lesser fields. This causes motors to be faster electrically. Further, recent advances in Class B insulation—such as enameled conductors—have much significance for the new designs.

The ASA standard for Class B insulation is for a 70-degree rise over a 40-degree ambient temperature for an open or self-ventilated motor. The corresponding limit for Class A insulation is a 50-degree rise over a 40-degree ambient temperature. Since general-purpose motors were assigned a 40-degree rise (with a service factor), a similar margin was used for the new industrial d-c motors. The present revision of the ASA C50 standards shows a 60-degree rise for Class B insulated motors for general-purpose applications. Therefore the same relationship was desirable when using Class B insulation, as had been used with Class A insulation. The same service factor, 1.15, applies to the new line of motors having the 60-degree rise.

These results of the d-c motor rerate program are now being incorporated in motor designs. This program is well planned, and will yield worthwhile results with minimum difficulty. ■

Recent Developments in SILICON POWER RECTIFIERS

DR. R. L. BRIGHT
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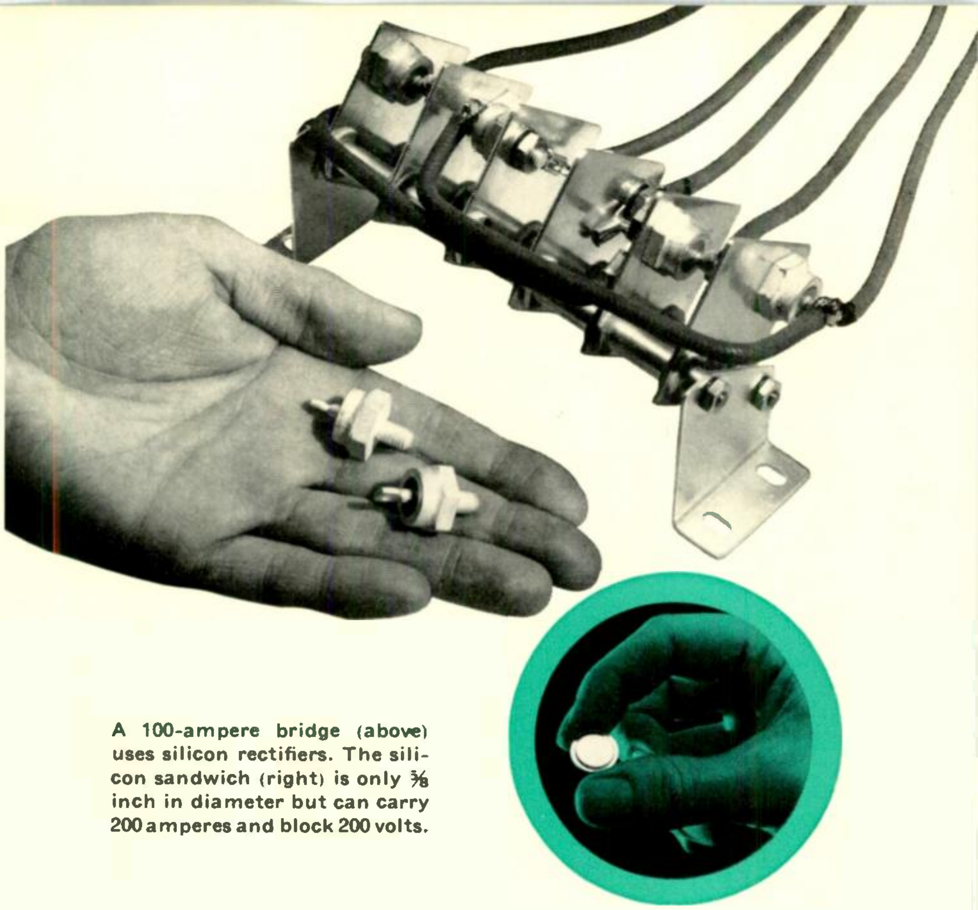

A 100-ampere bridge (above) uses silicon rectifiers. The silicon sandwich (right) is only $\frac{3}{8}$ inch in diameter but can carry 200 amperes and block 200 volts.

■ THE SILICON RECTIFIER has been transformed from a laboratory curiosity to a practical high-power, current-rectifying device within the past year. The advantages of the new silicon rectifier are several: long life with negligible change in forward drop; high peak inverse voltage per cell; high permissible operating temperature; high rectification efficiency; and rugged mechanical construction.

The silicon power-rectifying cells now commercially available are of the alloy-junction type. This unit can be made by placing a thin slice of *n*-type silicon between a piece of aluminum foil and a piece of high-melting-point solder, and fusing this sandwich together in a furnace. The aluminum melts and alloys with the surface of the silicon to form a layer of *p*-type material. The actual rectifying junction is the interface between this thin *p*-type silicon-aluminum and the undisturbed *n*-type silicon.

The current density in a silicon cell is extremely high compared to that of present industrial selenium rectifiers. Whereas selenium is normally rated at about $\frac{1}{3}$ ampere per square inch, silicon is being rated by various manufacturers at 500 to 1500 amperes per square inch, and conceivably 3000 amperes may be practical. Actually, the real current-carrying limit of a silicon junction is determined by the temperature rise of the cell—hence the better the cooling, the greater the current-carrying capacity.

The maximum operating temperature is limited by several factors. For example, temperature must not exceed the melting point of any of the parts. Since leakage usually increases rapidly at high temperatures, this is another limitation. For applications where leakage is not critical, maximum junction temperature is limited to a value necessary to prevent thermal runaway due to power dissipated in the cell during the reverse part of the cycle.

At the present state of the art, the average silicon-rectifier life, and the exact effect of the various factors that influence this life are not known. Although silicon rectifiers have been tested for several thousand hours with almost no failures, the field is advancing so rapidly that new and improved versions are obsoleting the original designs even before life testing can be completed. Many units do not seem to change at all under load tests, while others show a slow increase in leakage. Leakage is generally believed to be the determining factor for the final life of a silicon cell.

The low forward drop of a silicon rectifier combined with the high-peak inverse voltage makes it a very efficient rectifier. Most silicon rectifiers now manufactured have maximum peak inverse ratings of from 50 to 300 volts per cell, and some small diodes are even rated at 1000 volts. Within the coming year, cells with voltage ratings of 500 to 600 volts and current ratings of 100 to 200 amperes are expected. Special low-power devices with inverse-voltage ratings up to several thousand volts may also be forthcoming.

As a consequence of low forward drop, high inverse voltage per cell, and high operating temperature, the silicon rectifier is much smaller than a corresponding selenium unit. For example, a 20-volt silicon assembly may be $\frac{1}{2}$ to $\frac{1}{5}$ the size of a comparable selenium unit; as the voltage rating goes up, the number of selenium plates must increase, whereas a single silicon cell may still be adequate. Thus, at 200 volts, a silicon unit will be only $\frac{1}{20}$ to $\frac{1}{40}$ the size of a comparable selenium-rectifier unit.

At present, silicon bridges are made with current ratings from 1 to 1000 amperes, and with voltage ratings up to 600 volts rms. Higher ratings can readily be built. These rectifiers can be applied to convert alternating to direct current at the point where it is needed for d-c motor drives, or any other application requiring direct current, such as electrolytic machining, plating, etc. In voltage ratings of 115 volts rms and higher, power silicon bridges are now competitive with, and in some cases, less expensive than selenium stacks of equal rating. As a consequence, silicon should soon command a large portion of the industrial rectifier market. ■

A New Concept In Speed and Frequency Control . . . the ELECTRIC GOVERNOR

J. G. GABLE
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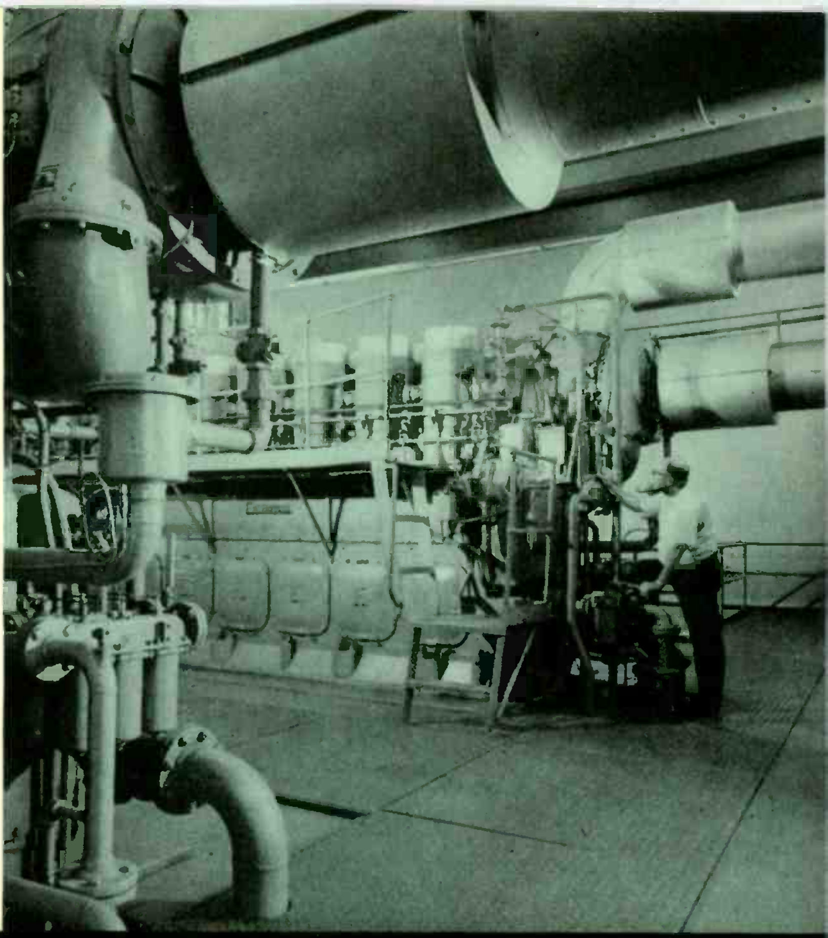


First power plant installation of the electric governor is at the Municipal Power Plant at Tipp City, Ohio (above). The electric governor regulates the prime movers, a pair of Enterprise 1755-hp diesel engines, which drive a pair of 1240-kw generators.

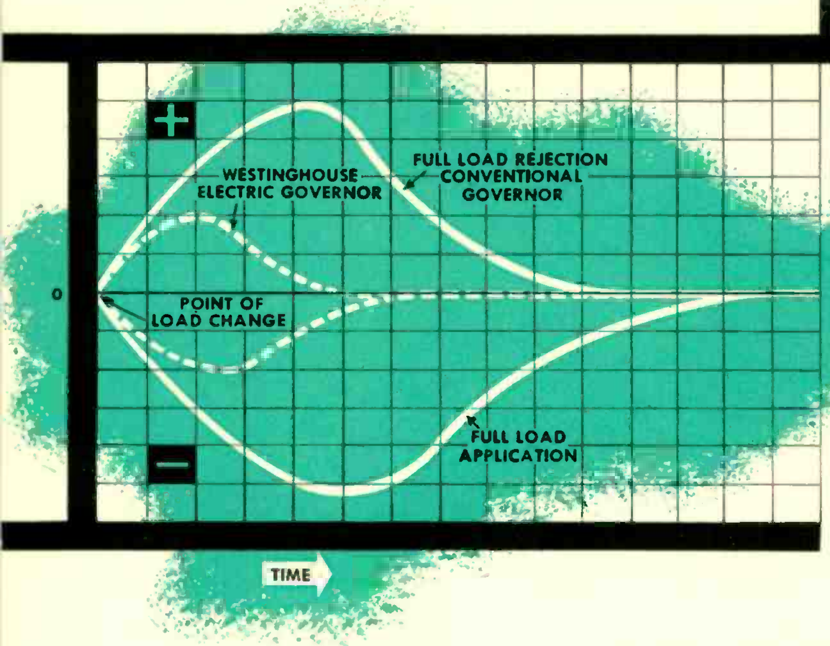


Fig. 1—Comparative speed response of a typical engine-generator set equipped with conventional, and electric governors.

▪ RAPIDLY RESPONDING GOVERNORS are essential for generating closely regulated power with engine-generator sets. A new electric governor achieves this high-speed response through an entirely new concept—anticipation of prime-mover speed change through load sensing. Moreover, the new electric governor permits automatic load sharing by two or more engine-generator sets operating isochronously.

The fundamental difference between the new Westinghouse electric governor and conventional mechanical or hydro-mechanical governors is that while conventional types sense only engine speed, the new electric governor regulates on the basis of frequency (or speed) and also anticipates imminent frequency changes by a continuous sensing of the instantaneous generator load. When a load increase or decrease is sensed, the electric governor acts immediately to forestall any frequency deviations. As a result, the time required to return the system to the desired steady-state conditions is minimized, and frequency deviations are kept within narrow limits, as shown in Fig. 1.

The new governor consists of two basic components—an *electric control unit* and a *hydraulic actuating unit* (Fig. 2). Serving as the information and decision center of the governor, the electric control unit measures three variables: generator frequency, generator load, and engine-throttle position. An electrical summation of these variables is amplified, and applied to the hydraulic actuating unit, which converts the electrical information into proportional hydraulic forces and positions the throttle.

Electric Control Unit

As the center of intelligence for the governor, the electric control unit is contained in a separate ventilated enclosure. Entirely static, it is comprised of such stable components as transformers, rectifiers, resistors, and fixed capacitors. Accordingly, circuits have long service life, and are not affected by shock, vibration, or climatic changes.

Within the electric control unit a *frequency circuit* measures generator frequency, and corrects for any deviation from a set reference frequency. Its primary function is to counteract small frequency shifts at any specific load. Signals from a frequency-sensitive LC circuit and a frequency-reference circuit are compared electrically and any voltage difference then becomes an input error signal to the magnetic amplifier. In operation, the reference voltage cancels the output voltage of the frequency-sensitive circuit when the generator is operating at the desired frequency. When a change in prime-mover speed causes a change in generator frequency, the output voltage of the LC circuit varies above or below the fixed reference voltage and the resulting error signal is magnetically amplified and causes the throttle to be moved in a direction to reduce the error and bring the set back on frequency.

A second circuit within the electric control unit is the *load responsive circuit*, which anticipates prime-mover speed change by measuring generator load. A-c generator loads are measured by small magnetic wattmeters or transformers, which measure phase current and voltage and produce an output signal proportional to the electrical load. Each phase is measured separately and the load signals are added to give the total load, so that phase balance is not required for proper operation. For combination-type 400-cycle engine-generator sets that include a d-c generator as an appreciable percentage of the total load, a d-c current-measuring transductor provides a d-c load signal, which, when added to the a-c load signal, provides a totalizing load signal that indicates the total mechanical load on the prime mover.

The third basic signal developed within the electric control unit indicates throttle position. This indication is provided by a *throttle feed-back system*, which is mechanically coupled to the throttle actuator. This throttle follow-up circuit supplies a voltage that is equal but of opposite polarity to the load-sensing signal. At the instant of load change, the load-sensing circuit develops a signal proportional to the load change. The output signal produced causes the throttle to be moved in a direction to compensate for the load change. As the throttle moves, the throttle circuit furnishes a signal to oppose the original load function. When the correct throttle position is reached, the signals neutralize each other.

Hydraulic Actuator System

The various electrical signals previously described are combined by a magnetic amplifier according to their proper relationship to obtain a single amplified output. The hydraulic actuating system converts this signal to a proportional hydraulic force, which acts through a piston to control the throttle.

In function, the actuator employs an electrical valve which integrates the hydraulic pressure of the supply into two ports that feed the opposite sides of a hydraulic piston or vane in a closed-loop hydraulic system. Under steady-state conditions, these two output forces are equal so the piston is in equilibrium and does not move. But when frequency discrepancies require correction, the push-pull amplifier system causes the valve to unbalance this equilibrium and to raise the pressure on one side of the piston while lowering the pressure on the other side. This unbalance of pressure causes the piston to move. Thus, the position of the piston has no effect on its operation and it can be equalized anywhere within its limits of travel. The linear displacement of the piston or the rotary output of a rotary vane is transferred to the throttle by an appropriate linkage system.

Operating Advantages

The electric control unit provides an operating advantage not previously available, the parallel operation of two or more units on an isochronous basis. If all engine-generator sets are equipped with the electric governors described, internal paralleling control permits all units to run isochronously so that each unit shares its predetermined portion of the total applied load. This is especially important where the maximum load deviations on a system exceed the rating of the largest machine, and frequently droop on increasing load is undesirable. This advantage is made possible by use of the load-sensitive circuit to indicate what percentage of the total load is placed on a particular unit. When the signals from electric governors operating in parallel are compared, any unbalance then operates to return the individual sets to the desired relationship. The electric governor is also provided with a manual control to adjust the individual unit to operate with a zero to five percent steady-state speed regulation. This control permits units equipped with Westinghouse electric governors to be operated in parallel with units with conventional governors.

As a result of the integration of virtually instantaneous electrical circuitry and a highly responsive high-force hydraulic system, throttle change begins in approximately 0.015 seconds, and full travel is completed in an interval as short as 0.1 second after application or rejection of full load. In small, well-designed, high-speed engine-generator sets, this rapid response has produced typical maximum transient speed deviations of less than 1.5 percent, and recovery to steady-state conditions occurs within one second after application or rejection of full load. ■

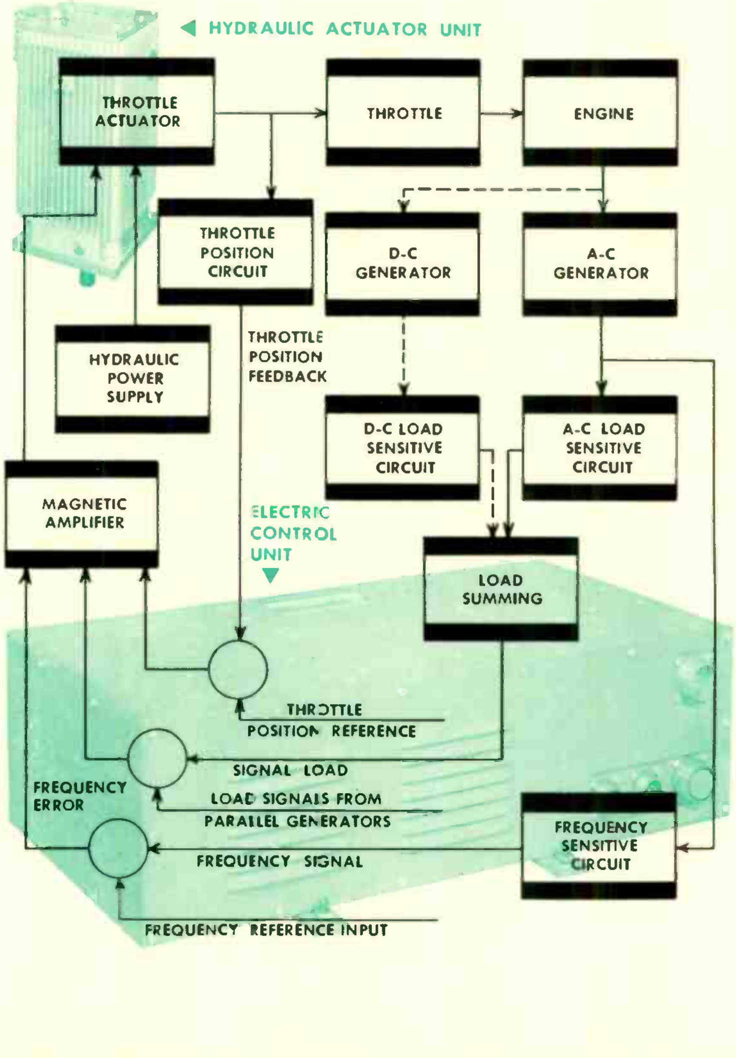
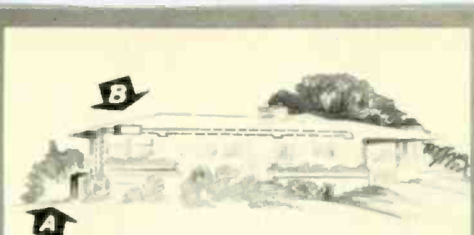


Fig. 2—Operating principle of electric governor: electric control unit measures generator frequency, load, and engine-throttle position, and supplies an electrical summation signal to the hydraulic actuator unit; here, signal is converted to hydraulic pressure, which positions throttle through a linkage system.

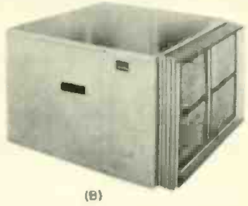
what's *new*



OUTDOOR AIR HEATING AND COOLING UNIT (A), ATTIC INSTALLATION OF HIDE-A-WAY AIR HANDLING UNIT (B)

OUTDOOR AIR HEATING AND COOLING UNIT (A), CRAWL SPACE INSTALLATION OF HIDE-A-WAY AIR HANDLING UNIT (B)

(A)



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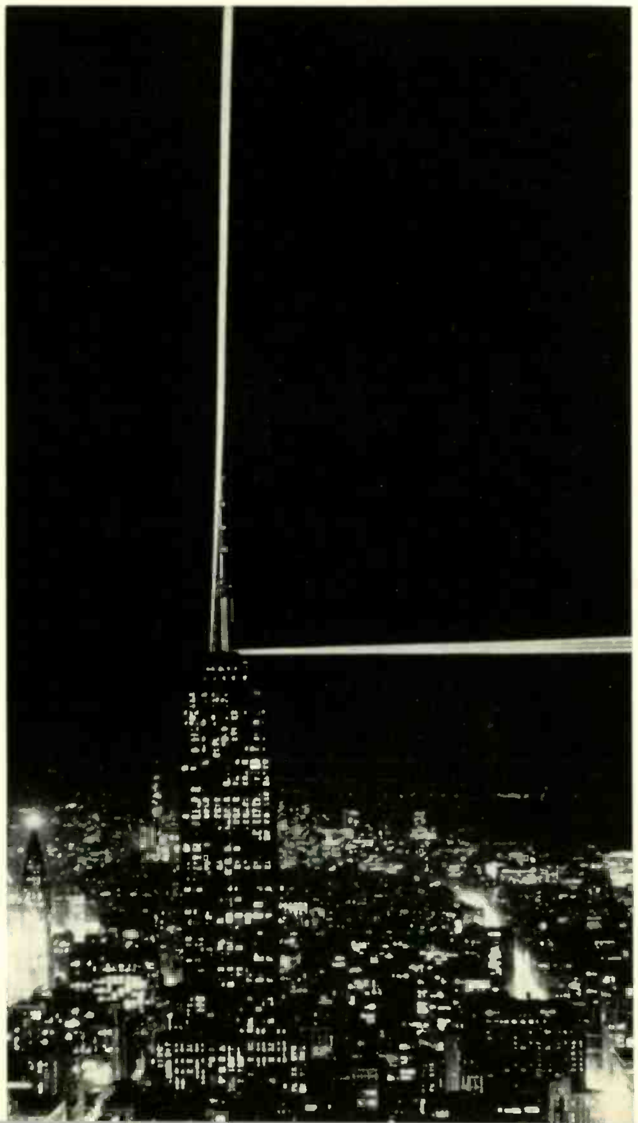


New Installation Possibilities for Heat Pumps

▪ THE INSIDE SPACE required for heat-pump installation is reduced to one-fourth that formerly needed by a new two-package design—an outdoor heating-and-cooling-cycle unit, and an indoor air-handling unit. The new heat pump is designed for homes in the geographical areas of the country most suited for heat pumps, but which are often predominantly bungalow-type residences with no basements. Using no water and depending solely on air for its heating and cooling exchange mediums, the heat pump has proven an extremely economical device for summer cooling and winter heating.

Called the Hideway Heat Pump, the new unit is made in both three- and five-ton sizes. It contains the same operating components that are used in standard single-unit Westinghouse air-to-air heat pumps, such as the "4-way valve" for even heating-cooling changeover.

The inside air-handling unit is 34 by 33 by 22 inches, the outside compressor-condenser unit is 38 by 36 by 29 inches. ▪

Empire State Building Lights The Sky

▪ THE EMPIRE STATE BUILDING will light the skies of much of the northeast through the addition of four mighty searchlights. Installed just above the observation platform, 1092 feet above the streets of New York City, these beacons are powerful enough to be seen under ideal conditions as far away as Boston and Baltimore.

Heart of the searchlights is the 2500-watt short-arc mercury lamps, which in conjunction with the highly polished reflectors, produce 450 000 000 candle power of light per beacon. Combined, the four beacons provide almost two billion candle power of light.

Originally, the searchlight units were carbon-arc lights used as antiaircraft searchlights during World War II. They have been specially modified to house the short-arc lamps.

Temperatures within the searchlights will reach as high as 1500 degrees Fahrenheit. To withstand these extremely high temperatures, the bulbs are made of quartz rather than glass. The quartz is also required to withstand high internal pressures of more than 300 pounds per square inch.

One of the five-foot beacons points straight up. The three others on the world's tallest building are directed outward at an angle of five degrees above the horizontal. They revolve counterclockwise at the rate of one revolution per minute from sundown to midnight. ▪

Supervisory Control for Airport Lighting

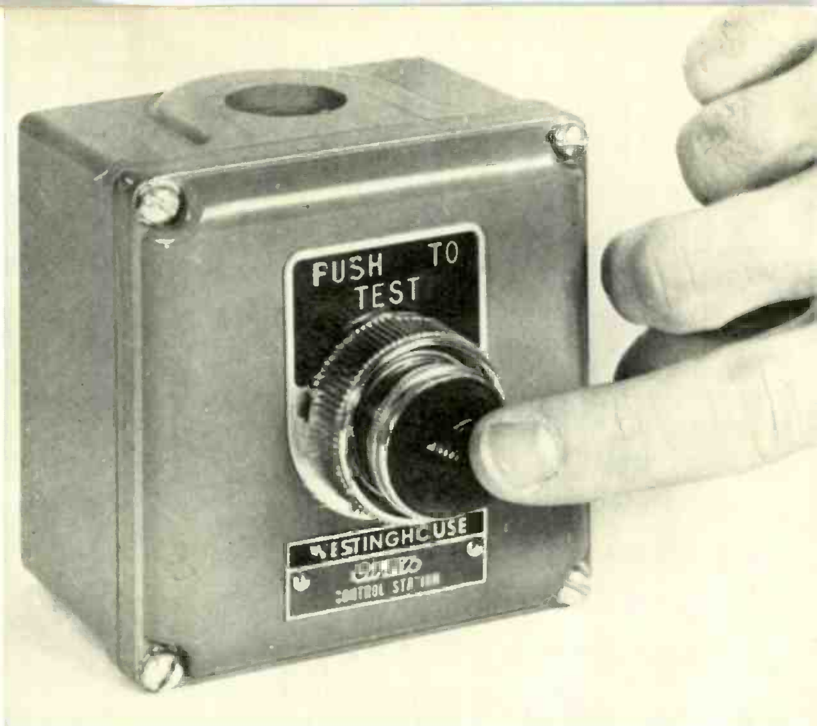
■ THE FIELD LIGHTING SYSTEM for Chicago's new commercial airport, O'Hare Field, is now "supervised" remotely via a supervisory-control system.

During the recent enlargement and rebuilding of O'Hare Field to make the airport suitable for commercial as well as military operations, municipal airport engineers recommended that the control tower be moved to a better spot about 6000 feet across the field. The original airport lighting had, of course, been operated from the old control tower, since the tower operator, in directing air traffic, must frequently vary the lighting. The transformers, switchgear, and other apparatus needed to power and switch the lighting were located in a vault beside the old tower. Underground conduits fed from the vault to approach, runway and beacon lights, and control wires extended from the vault to the tower operator's console.

To move either the vault to the new tower site, with the necessary relocation of underground conduits, or to extend the control wires 6000 feet from the vault to the new tower would have been both expensive and time consuming. Instead, contact has been maintained between the lighting control panel at the new tower site and the old vault with a remote control system and a single telephone circuit between the vault and the new tower. The telephone circuit is leased from the local telephone company.

The remote control system used is a modification of the Westinghouse Visicode supervisory-control system. Normally, this system is employed by electric-utility companies to control remotely-located equipment from a central point.

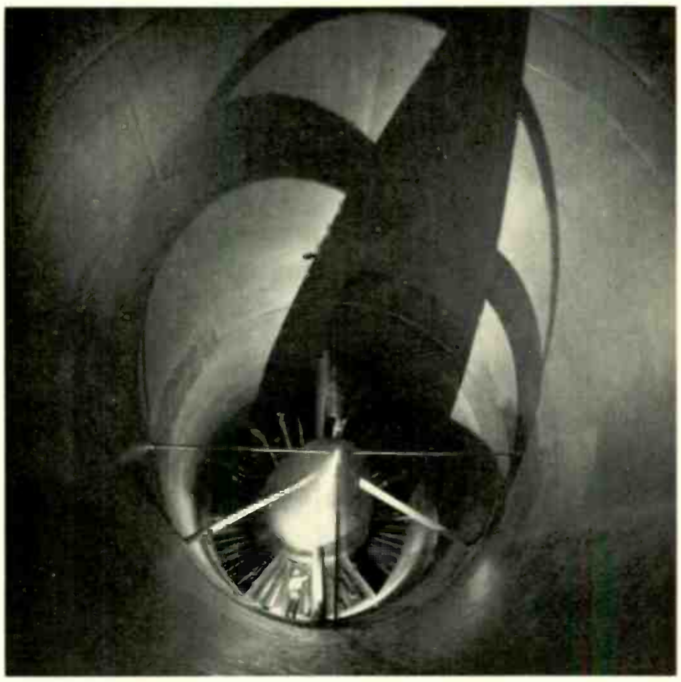
The airport Visicode system consists of two units, one at the vault, and one at the new tower, with a 15- by 30-inch control panel as part of the tower console. On the panel are buttons and lights to control and monitor all the lighting (see photograph). When the tower operator pushes a button, the Visicode unit translates this signal into a code similar to that used in dialing a telephone. It consists of a definite group of pulses associated with the button pushed. The Visicode unit sends these pulses over the telephone wire to the Visicode unit in the vault. This unit counts the pulses and automatically translates them into a signal that causes the designated switch to close. After the switch has closed, another coded signal is sent back from the vault through the Visicode units to the panel. A lamp on the panel then indicates to the operator that that switch has closed. By simply pressing the proper buttons, the tower operator can by remote control: select any runway; select the approach lights at either end of the runway; adjust the brilliancy of the lights; and switch on or off the various wind indicator, and obstruction lights. ■



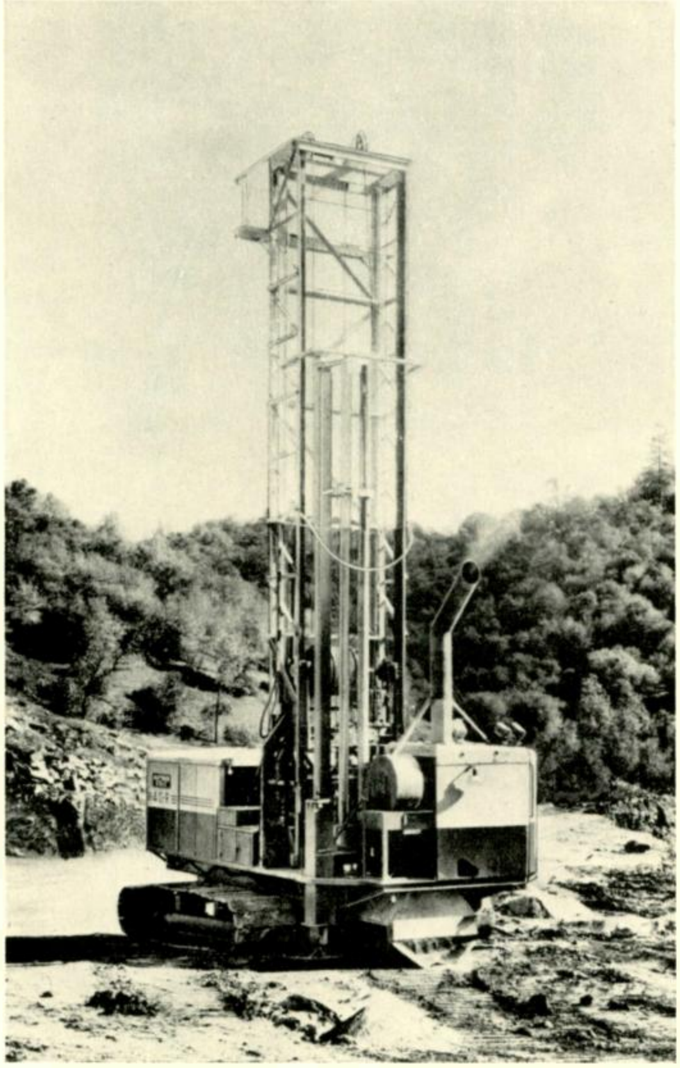
When control circuit trouble is suspected, a new "push-to-test" oil-tight indicating light permits the machine operator or maintenance man to determine whether an unlit indicator lamp means circuit trouble, or is merely the result of lamp failure.

By pressing the lens of the new indicator light, the operator transfers the lamp from its normal circuit to a separate built-in lamp test circuit. If the lamp is functioning, it will light normally, an indication that trouble shooting is in order. If it fails to light, the lamp is easily replaced.

The new push-to-test indicating lights are designed for 110-, 220-, and 440-volt applications. Open, cover, or panel-mounting units have dimensions identical to standard units of corresponding types.



Largest axial-flow compressor ever built is this three-stage compressor, which provides the airflow for the transonic circuit of the Propulsion Wind Tunnel at the U. S. Air Force's Arnold Engineering Development Center, Tullahoma, Tennessee. This view from the downstream end of the huge Westinghouse-built compressor shows the 63-foot streamlined nacelle that encloses the end of the drive shaft. The transonic circuit of the Propulsion Wind Tunnel will test full-scale operating jet engines, or large-scale aircraft and missile models at testing velocities ranging from 500 to 1000 mph.



Electric Motors and Generators Drive Construction Rigs Along St. Lawrence Seaway

▪ LIKE EVERY ASPECT of the St. Lawrence Seaway, the methods and equipment for its construction are big and imaginative. This big rotary blast-hole drill, now at work on the Seaway site, has roughly the same function as conventional air-driven drills, but other resemblance is slight.

This one, made by Bucyrus-Erie, has diesel-electric or full-electric power plants. Its husky rotary and hoist-propel motors and generators, supplied by Westinghouse, are of a type developed to take the severe punishment of steel-mill applications. A total peak of 200 horsepower is available to power the drill during drilling and movement about the site. With each rotary and hoist-propel motor energized from its own generator, the operator can attain smooth and precise control by adjustment of generator voltage output. In turn, the generators are belt driven by a diesel engine or by a 150-hp electric motor, fed from local power lines at 440 or 2300/4000 volts.

In operation, the rotary blast-hole drill can attain high production of smooth straight holes up to nine inches in diameter. Up to 22½ tons of force can be brought to bear on the bit for maximum cutting in hard formations as air blast cleaning removes cuttings from the hole. ▪

New Material For Super Permanent Magnets

▪ A NEW MAGNETIC MATERIAL—virtually 100 percent pure manganese-bismuth—promises to yield more powerful permanent magnets. The magnetic properties of manganese-bismuth are so promising that future design, construction, and performance of many present-day devices employing permanent magnets may be affected.

Although the superlative magnetic properties of pure manganese-bismuth have been predicted for several years, the form of MnBi that best exhibits these properties could not be made pure enough to realize its potential abilities. A new method of preparation recently developed gives, on a laboratory scale, a new and highly magnetic form of manganese-bismuth. The process originated in the magnetics and solid-state physics department of the Westinghouse Research Laboratories. Improvements in the original technique, and investigation of permanent magnets made from the new magnetic material, are now being made by materials engineers (see back cover).

Super-pure manganese-bismuth is prepared in the following manner: manganese and bismuth are ground together to extremely small size under an inert atmosphere of helium gas. The helium prevents the powdered materials from catching fire spontaneously, which they would do on exposure to air. The mixture is then sealed in a glass vessel under low-pressure helium. Using precise temperature control, the manganese and bismuth are united chemically at a temperature slightly less than 520 degrees F, the melting point of bismuth. The resulting product, virtually 100 percent pure MnBi, is reground to a fine powder. These particles are imbedded in a plastic matrix, oriented in a powerful magnetic field, and molded to shape.

Perhaps the greatest advantage of MnBi magnets is their unusual resistance to demagnetization, which is at least 10 times better than most commercial magnets available today. The new magnets derive many of their unusual properties from being powder-type magnets; each individual MnBi particle, about 40 millionths of an inch in diameter, is itself a tiny magnet. The particles are "insulated" from one another by the plastic binder, or matrix, in which they are imbedded. Once magnetized, each particle adds to the total magnetism. The resulting higher resistance to magnetization suggests many advantages of MnBi magnets. For example, such magnets would not be adversely affected by external magnetic fields, which would make them especially promising for electric meters where stray magnetism from large electrical equipment is often encountered.

This high resistance to demagnetization of pure MnBi could result in a whole new assortment of permanent magnets having novel shapes and uses. It makes practical permanent magnets in a wide variety of shapes, particularly in the form of thin wafers or disks.

Previous conventional materials for permanent magnets are notoriously difficult to handle. They must be machined to shape and are extremely hard and brittle. Manganese-bismuth magnets, however, can be easily drilled, tapped, and cut—even with a penknife if a suitable plastic binder is selected. Consequently, expensive machining operations can be eliminated; magnets can be cast or molded, possibly even extruded, into any shape desired. Manganese-bismuth magnets thus possess the fortunate combination of extreme 'formability' plus those magnetic characteristics that make unusual shapes practical. Because the plastic binder is an electrical insulator, manganese-bismuth magnets are nonconductors. These facts suggest possible new applications for the magnets. ▪

personality profiles

J. G. Gable • *M. A. Schultz* • *M. E. Knudson* • *John C. Ponstingl*

Dr. C. Zener • *R. L. Bright* • *Vincent L. Carissimi*

• This is a fitting issue for the appearance of *J. G. Gable*—this month marks his tenth-year anniversary with Westinghouse, and his second year as manager of the electric-governor project, of which he writes in this issue.

Gable joined the company in 1946 after serving in the armed forces in Europe as a signal officer from 1943 to 1946. A graduate of Carnegie Tech in 1940 with a BSEE, he worked with an industrial firm in both engineering and sales prior to joining the armed forces.

He came with Westinghouse as a design engineer in the Control Engineering department, then located in East Pittsburgh, and stayed with the department when it was transferred to Buffalo a year later. He was appointed a section manager in 1951, and a subdivision manager a year later. Exactly two years ago this month, Gable assumed responsibility for engineering, manufacture, and sales of the electric-governor project.

• The second appearance of *M. A. Schultz* in the ENGINEER comes almost on the heels of his first entry in the May 1956 issue. This time he talks about the Westinghouse Testing Reactor, of which he was made project engineering manager in August 1955. This new job has involved Schultz in a myrid of administrative problems, ranging from recruitment of technical manpower for design and operation of the testing reactor, to radiation-sewage disposal. These new responsibilities leave Schultz with one chief regret—little time to delve into engineering design problems.

• *M. E. Knudson*, author of the article on the motor rerating program, is a native of Minnesota. He graduated from the University of Minnesota in 1930, with a BSEE, and then joined the Graduate Student Course at Westinghouse. His next stop was in general sales for three years, and then to the Chicago office, where he handled first the metal-working industries, and then the food industries. In 1952 he was transferred to the Industrial Department in East Pittsburgh as manager of the Steel Mill and Metal Working section. In late 1954 he moved to Buffalo, as manager of the Motor Sales Department, his present position.

As a youth, Knudson earned extra money in a rather unusual manner. For most of his years in college and high school he spent his spare time on the race track as a jockey. Now, although he is still an excellent horseman, his prime recreational interest is fishing.

• *John C. Ponstingl* has been wrestling with control problems since he came with Westinghouse on the Graduate Student Training Course following graduation from Case Institute (BSEE) in 1941. His first stop was the Control Engineering department, where he worked on a variety of control applications, ranging from submarines to wind tunnels. These studies resulted in several patents for Ponstingl for submarine and other marine applications.

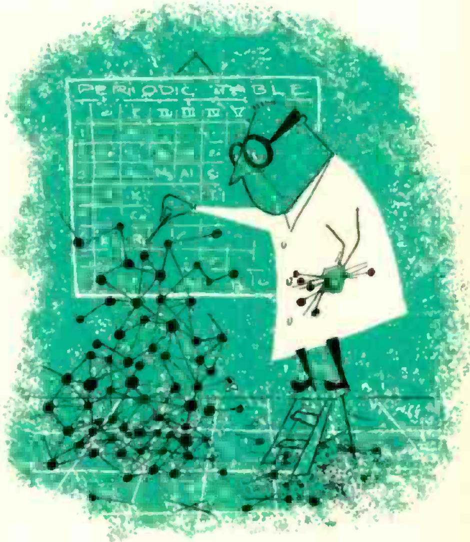
In 1949, Ponstingl switched to the Consulting and Application group, and moved to the company's Cleveland office. He was made the district industrial control engineer in 1952, and a year later became engineering supervisor for the Cleveland district, his present position.

Although his article on braking in this issue marks his first appearance on these pages, he has written a number of comprehensive articles on control subjects for industrial magazines. Ponstingl is also very active in engineering association activities. This was evidenced last year at the 1955 Annual Meeting of the Cleveland Engineering Society, when he was awarded the Gold Emblem for the most outstanding service to the society that year.

• Doing an encore in this issue is *Dr. C. Zener*, acting director of the Research Laboratories. Zener's subject is the fundamental principles underlying metallurgical design for strength.

• Prior to joining Westinghouse in 1953, *R. L. Bright* was a member of the electrical engineering staff of Carnegie Institute of Technology. As a matter of fact he is a graduate of Tech, having earned three degrees there—his B.S. in mathematics in 1946, an M.S. in electrical engineering in 1947, and a D.Sc. in electrical engineering in 1950. Since joining Westinghouse, Bright has largely been concerned with solid-state devices and circuitry—a field in which he already has over thirty patent applications.

• The Shur-Temp range-surface control system was transformed from a working prototype into a production design in record time—just eleven weeks. Coordinating the overall project, to which several company divisions have contributed, was *Vincent L. Carissimi*, recently appointed supervising engineer of long range development for Bryant Electric Company. Carissimi is a graduate of Rensselaer Polytechnic Institute (1949), and came with Bryant, a subsidiary of Westinghouse, in 1953.



Super Permanent Magnet Material

Highly purified manganese-bismuth—a new magnetic material that promises to yield more powerful permanent magnets —bursts into a fiery "waterfall" when scattered in air. Since it catches fire spontaneously on exposure to air, the finely ground powder must be prepared and processed in an inert atmosphere of helium gas. (Right) A sample of highly purified manganese-bismuth is weighed by remote control.