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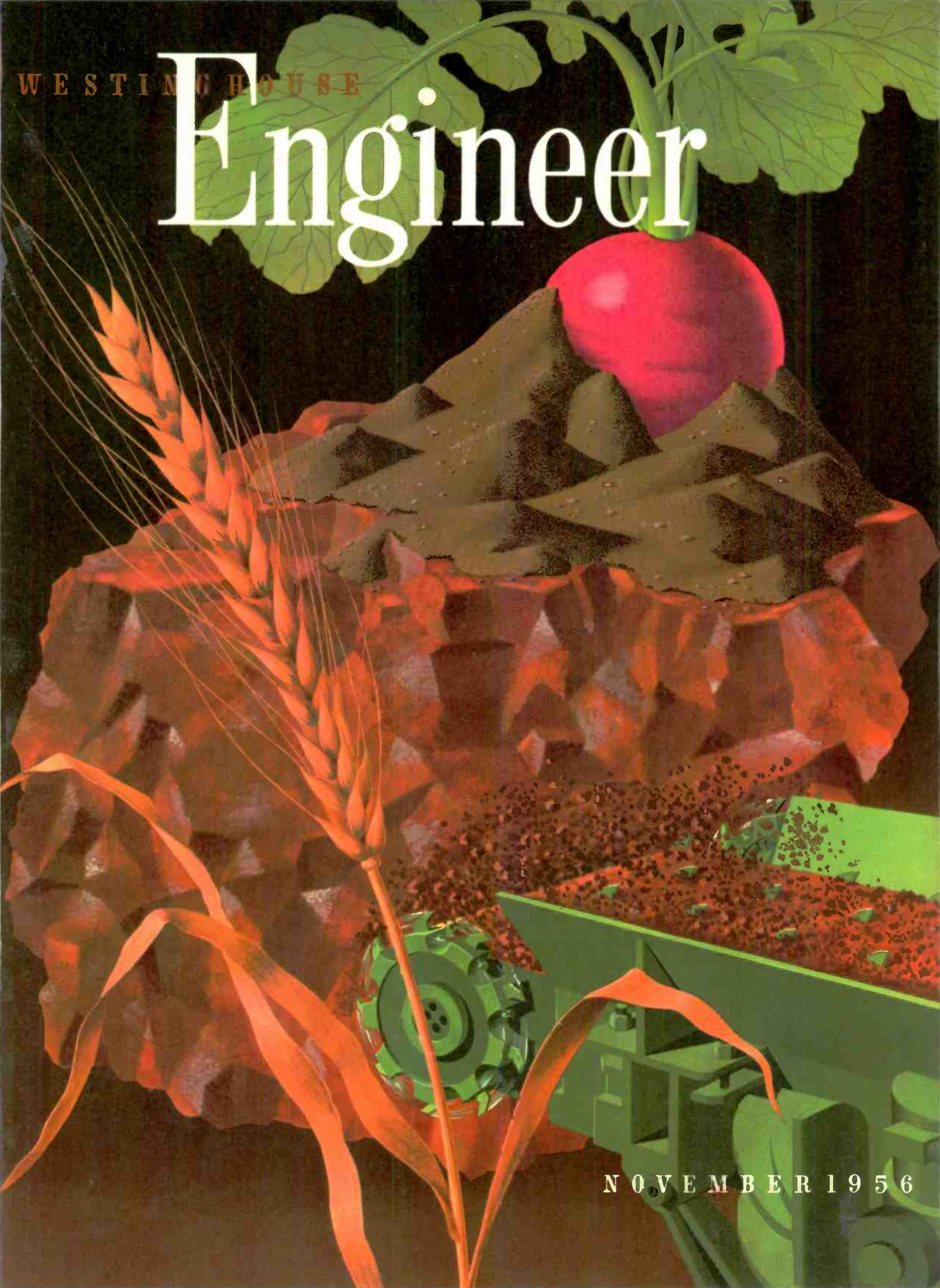

NOVEMBER 1956

Reaching for the Extremes

Today's scientists are, quite literally, going to "extremes" to gain information. On the scales by which quantities and qualities have long been measured, scientists are in many instances working close to the ultimate. On the temperature scale, for example, temperatures of a few tenths of a degree from absolute zero are no longer unusual.

Some of this is based on the demands of new engineering frontiers. But also, from a purely scientific standpoint, behavior at extremes often gives a clue to behavior under more normal circumstances. Thus in temperature, pressure, purity, and many other variables, scientists are working at or near one extreme of the scale.

One thing that these facts point up is the importance of facilities and devices to the modern scientist. Possibly at no time in history have they been as important as they are today. For as the scientists' knowledge of the unknown increases, so does the scope and complexity of the facilities he needs to uncover new knowledge, or to prove his theories.

As pointed out on page 175 of this issue, the facilities provided in a modern laboratory, such as the new Westinghouse Research Laboratories, vary from the seemingly commonplace to the highly uncommon. However, these facilities, complete as they are, are but a base on which to build. In an increasing number of cases, the scientist must develop—perhaps even build—complex apparatus to achieve a specific goal. For example, a few years ago, scientists at the Research Laboratories were trying to obtain a higher vacuum than previously possible. This entailed special experimental equipment.

Then came the point when the scientists were convinced that the vacuum they had obtained was better than their measuring method showed. The next step—prove it. This they did, by developing a new device to measure vacuum; this showed that their results were far better than their original measurements indicated. Coincidentally, it also resulted in a new vacuum gauge, now widely used.

In purity, scientists have been able to make pure iron crystals so perfect that no defects can be detected in their structure. These crystals, incidentally, have strengths approaching a million pounds per square inch, many times the strength of ordinary iron. In the field of semiconductors, purity has reached the point where impurities account for but one part in several million, or more. And these are but a few instances where scientists are reaching for extremes. Accuracy and speed of measurement also offer many examples. True, there are also many areas in which scientists have, in effect, hardly moved toward the ends of the scale; but most of these areas are receiving increased attention, and progress will certainly be made.

A scientist's job is to make the unknown known. But while his basic objective is to uncover new facts, often the route and the vehicle by which he can reach these facts is not obvious. In his exploration of the unknown, the modern research laboratory and its facilities have become his basic vehicle, the vehicle by which he can approach closer to the extremes of every variable with which he deals.

R. W. D.

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In This Issue

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THE COVER

A radish, a turnip, or a beet? Cover artist Dick Marsh symbolizes the plant life that benefits from potash, recovered from deep underground.

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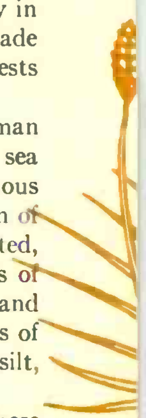
POTASH for Plant Life

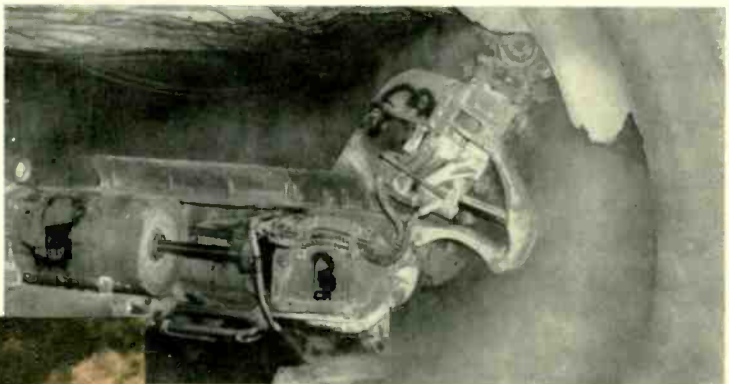
The editors acknowledge the assistance and cooperation of Mr. Jack Sitton, public relations counsel for the operating companies in the Carlsbad area.

Many centuries after man discovered fire, he found that ashes from his fire promoted plant growth. He could cook on his fire, fertilize his crops with the ashes, feed the fertilized crops to his livestock, and thereby return food to his fire. This was a forerunner of the vast potash fertilizer industry of today.

Early production of potash consisted of burning hardwood in iron pots, adding lime, leaching with water, and evaporating the solution to dryness; the remaining "pot ashes" was potash. Its production was a thriving industry in colonial times when the American colonies developed a sizable export trade to England producing potash from wood ashes. However, as Eastern forests were cut, this source of supply of potash was rapidly reduced.

Fortunately, nature began producing potash millions of years before man and his fire. During the Permian age, some 200-million years ago, the sea covered a large portion of what is now the southwestern United States. Various types of salts crystallized on the bottom of this inland sea, and as its water evaporated, vast layers were built up over millions of years. Eventually, the waters receded and the layers of salt were buried to depths of hundreds and thousands of feet by silt, sand, and rocks.



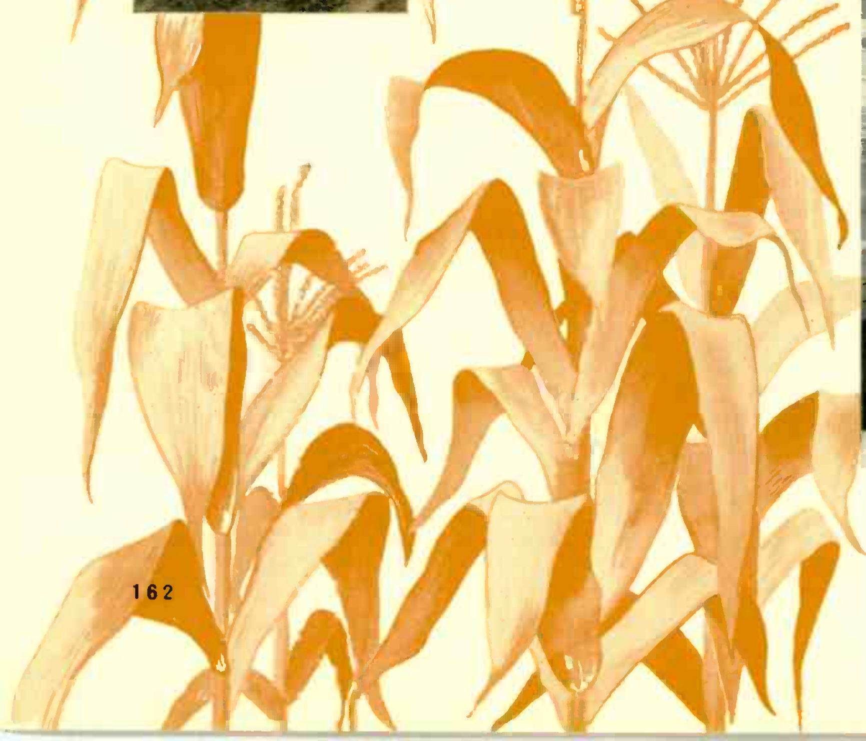


Deep underground, continuous mining machines "eat" their way through sylvite ore.

Photographed by Harold M. Lambert

Today, the recovery of potash from these underground salt deposits is a 75-million dollar industry. Although some potash is also recovered from inland salt lakes, more than 90 percent of the potash refined in the United States today is mined from this rich Permian basin. Present producing ore beds are further concentrated in a comparatively small area east of Carlsbad, New Mexico, since a commercial grade of potash has been found in only this small part of the Permian salt beds.

The word *potash* today denotes a chemical combination of the element potassium with one or more other elements. These potassium compounds are as important to life as air and water. Ninety percent of the potash mined and refined in southeastern New Mexico goes into fertilizer, as potash is one



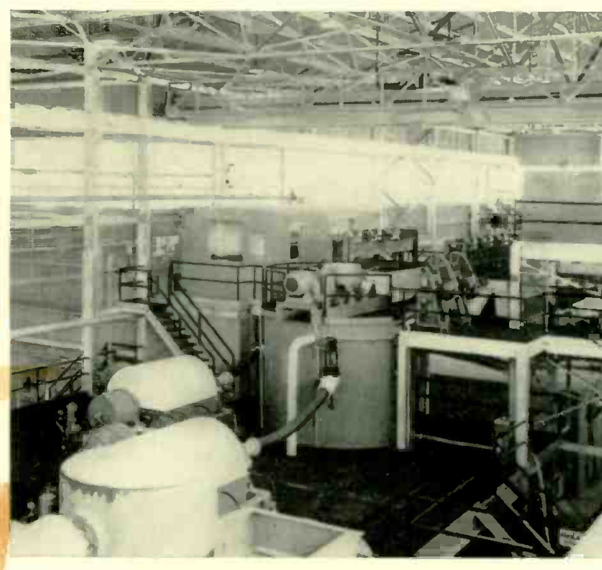


Fig 1.—Interior view of a potash refinery. Shown are flotation cells (center, background), centrifuge (center, foreground), and surge tank (center tank).

of the most important plant foods. The great bulk of potash products for the fertilizer industry are made from potassium chloride or potassium sulfate. There is no substitute for potash in agriculture, and its importance as an essential plant food cannot be overemphasized. It is not only necessary for plant growth, but helps to regulate the intake of other minerals necessary for normal plant growth.

Potash is also important in the manufacture of many other vital products and processes. Potassium chemicals in one form or another end up in liquid oxygen, plastics, television tubes, sewage treatment, paper, soap, insecticides, pharmaceuticals, including antibiotics. Caustic potash (potassium hydroxide) is used in vat dyes for dyeing rugs and draperies. Potash is used in all sizes of batteries, and in high-quality glass, enamels, artificial gems, certain explosives, and pottery.

It is also used as a catalyst in making high-octane gasoline, for manufacturing matches, and disinfectants. It is used in numerous processes, such as etching, leather tanning, printing, lithography, recovery of metals from their ore, tempering of metals, pickling foods, and waterproofing fabrics. Potash is indeed one of our most vital minerals.

The potash industry as we know it today started with the discovery and development of Permian-age mineral deposits in Germany in 1865 (similar to those later discovered in the Carlsbad area). The German potash industry was the sole source of this vital mineral for American agriculture and industry up to the outbreak of World War I, when a search was initiated for possible potash sources in the United States. The Permian basin deposit in the Southwest is geologically similar to those of Europe, and logically directed the search for potassium to this area. Although exploratory core drilling was carried on by the U. S. Geological Survey, the first commercial deposit was located in 1925 by the Snowden and McSweeney Company, which was exploring for oil east of Carlsbad. Subsequent drilling has delineated large deposits of various potassium salts. The principal potash-bearing material found was sylvite ore (a mixture of potassium chloride and sodium chloride), the raw ore from which Carlsbad potash is produced.

As a result of the discovery, the United States Potash Company was formed to develop the deposit. Today there are five companies[1] operating in southeastern New Mexico. They are producing crude ore at a rate of about 8 000 000 tons a year.

A typical headframe over a mine shaft, where ore is raised to the surface.

[1] In order of appearance, U. S. Potash Company (now a division of United States Borax & Chemical Corporation), Potash Company of America, International Minerals & Chemical Corporation, Duval Sulphur and Potash Company, Southwest Potash Corporation. National Potash Corporation is scheduled to begin production in 1957.

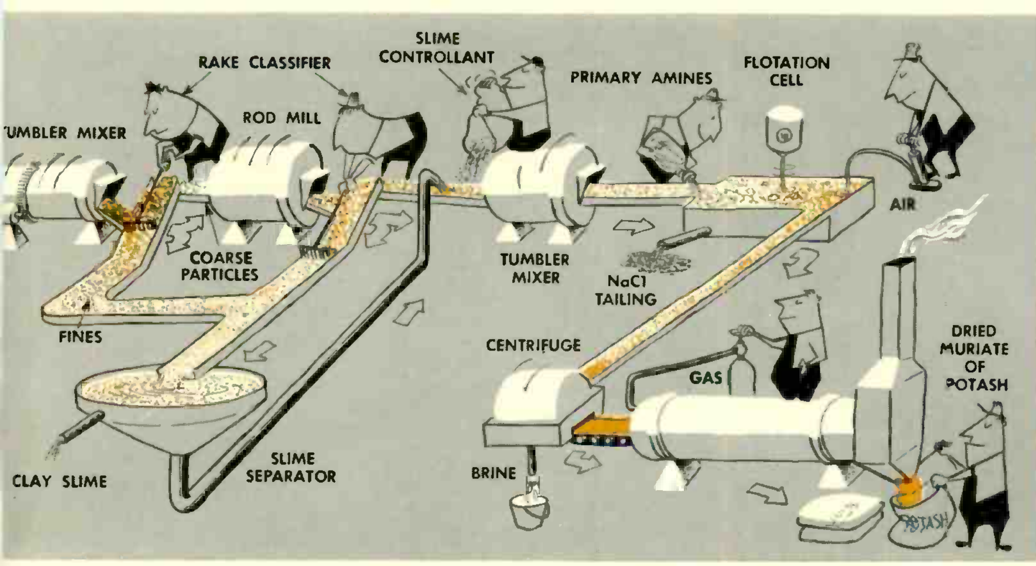


Fig. 2—Simplified flow diagram of potash refinery. Since each producer employs a sufficiently different concentration process to make generalization difficult, the process shown is approximate.

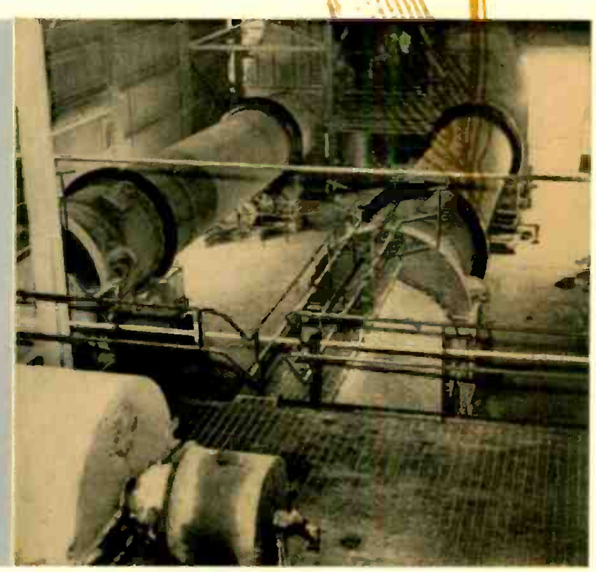
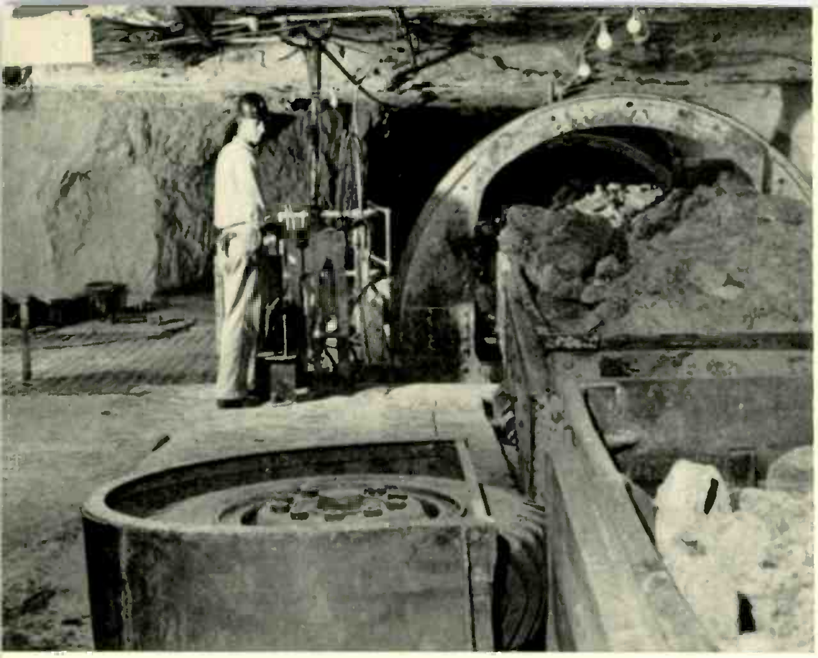


Fig. 3—Flotation concentrate is filtered with centrifuge machines and transported by conveyors to large dryers (background) where it is dried to a finished product.



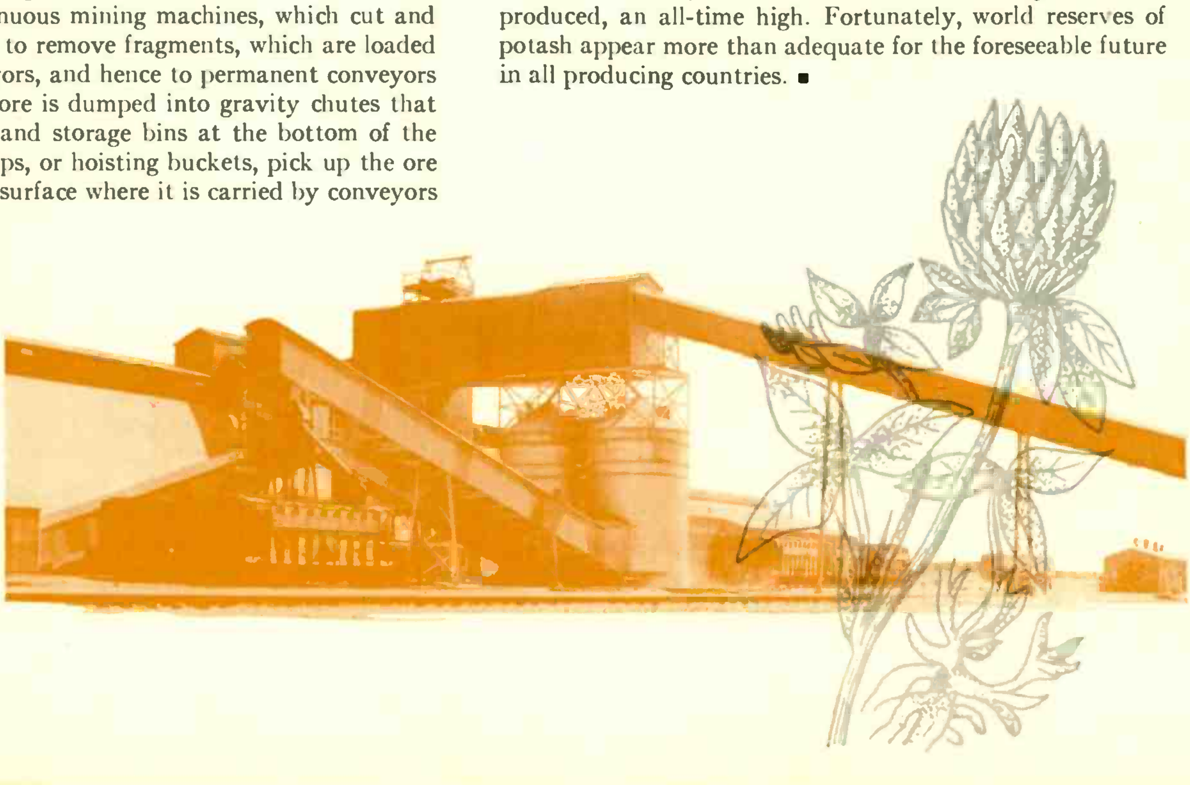
Ore dumped from train by rotary dump into coarse ore pocket.

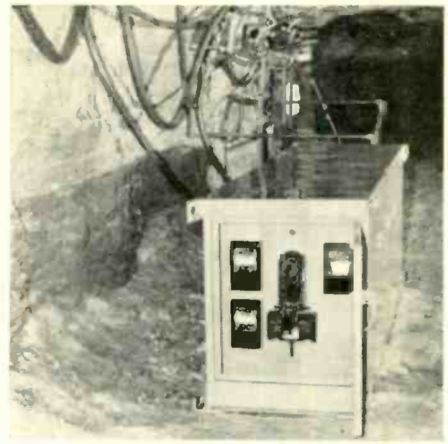
The ore body, outlined by surface drilling, is generally horizontal. Since the potash ores were laid down in solid beds, with no structural faults or intruded boulders to cause slips or falls, underground tunnels and rooms do not require supporting timbers. The room-and-pillar method of mining is used. Under this plan, the mining area becomes a checkerboard with rectangular rooms mined out and pillars of ore left to support the overburden. Above the pillars lies a solid bed of rock salt 200 to 700 feet thick. This, too, was laid down by the evaporating seas of the Permian age in solid unbroken mass, and acts as a giant beam to support the ceiling of the potash mines, 750 to 1800 feet below the earth's surface. Underground drifts and tunnels are wide, high, well-lighted passageways leading off through a pastel-tinted world with no timbers or dripping water. Potash mining is free from many hazards customarily encountered in mines, and there are no noxious gases, no explosive dusts, no danger of silicosis.

The potash mines and refining plants run at full production 24 hours a day, with three shifts of men carrying on the uninterrupted cycle of mining, concentrating, and refining. Deep in some of the mines, undercutting machines bite into the ore, electric drills bore blasting holes, and loading machines gulp up quarter-ton fragments of blasted ore at a bite. Other mines now use continuous mining machines, which cut and claw at the ore body to remove fragments, which are loaded onto portable conveyors, and hence to permanent conveyors or shuttle cars. The ore is dumped into gravity chutes that carry it to crushing and storage bins at the bottom of the mine shaft. Here, skips, or hoisting buckets, pick up the ore and convey it to the surface where it is carried by conveyors to the crushers.

The ore from the mine, a crystalline mixture of potassium chloride, sodium chloride, and some two percent other impurities, must first be reduced in size to unlock individual crystals, and the crystals then reduced to dimensions suitable for separation by flotation. An accompanying problem to size reduction is the production of extremely fine particles, which are detrimental to both separation and marketing. To minimize the production of fines, crushing is conducted in stages commencing with the roll crushers in the mine, which reduce the ore particles to less than five inches. This material moves by belt conveyor to and through the surface crushing plant where it is further reduced by screening and crushing stages to a maximum particle size of $\frac{1}{8}$ inch, which constitutes the refinery feed to the crushed-ore bin (see flow diagram). As the material enters the refinery, it is slurried in a brine. The brine is saturated with the ore constituents and hence acts only as a carrier. To provide a suitable feed for flotation, the ore must be properly sized and also have all clay slimes physically removed or chemically rendered inert. The ore is first wet ground to a final size less than 1/20 of an inch. Following wet grinding, the clay slime is removed and the ore pulp is conducted to the reagent conditioning section. Here, a slime controllant is added to render inert any remaining clay. The next step is the addition of the sylvite collector and frother. The reagent used is a primary amine manufactured from beef tallow. The amine, ignoring the sodium chloride, seeks out potassium-chloride crystal surfaces and is selectively absorbed thereon. The chemical nature of the amine forms a new water-repellent, air-loving potassium-chloride crystal surface. This reagentized pulp is conducted to flotation machines where it is suspended and aerated. The ascending air bubbles affix themselves to the hydrophobic surface of the potassium chloride, lifting them to the surface where they are removed in the form of a highly mineralized froth. The sodium chloride remains in suspension and is drawn off from the cell bottom. The flotation froth product is dewatered and fed to a gas-fired rotary kiln, for removal of remaining moisture. The resulting dry product (muriate of potash) contains a minimum of 95-percent potassium chloride.

In years to come, potash production will become even more important. As the earth's population increases, productivity of farmland will have to be increased by means of chemical fertilizers. Each year, domestic production of potash is on the increase. In 1955, over 3-million tons of refined potash were produced, an all-time high. Fortunately, world reserves of potash appear more than adequate for the foreseeable future in all producing countries. ■





An underground portable switch house.

POWER for POTASH

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and

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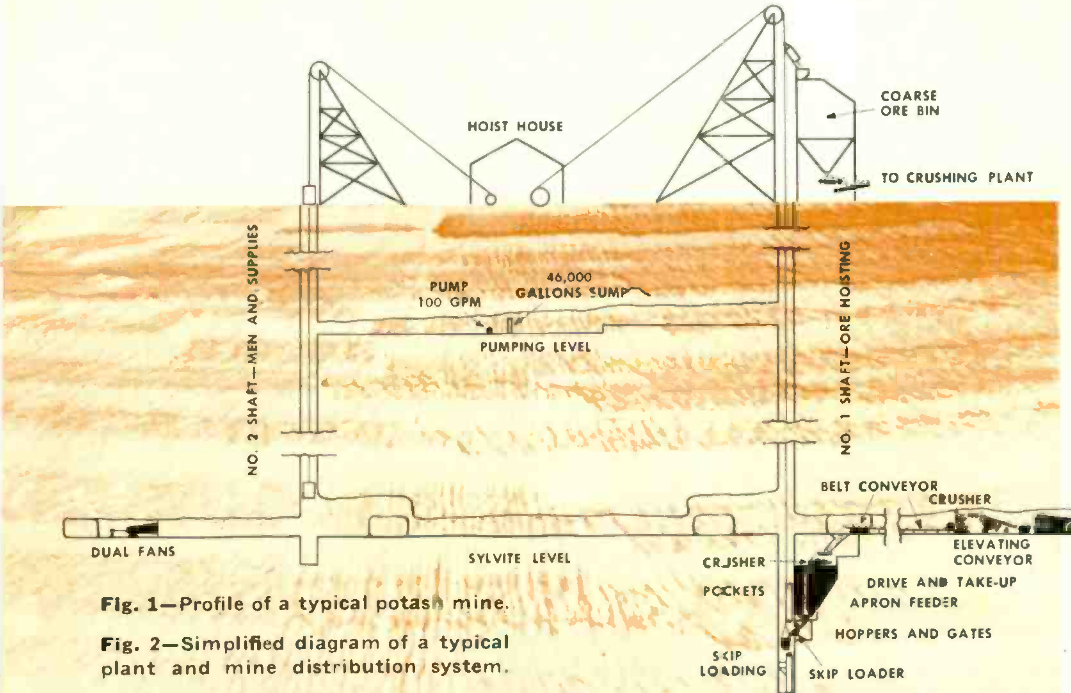


Fig. 1—Profile of a typical potash mine.

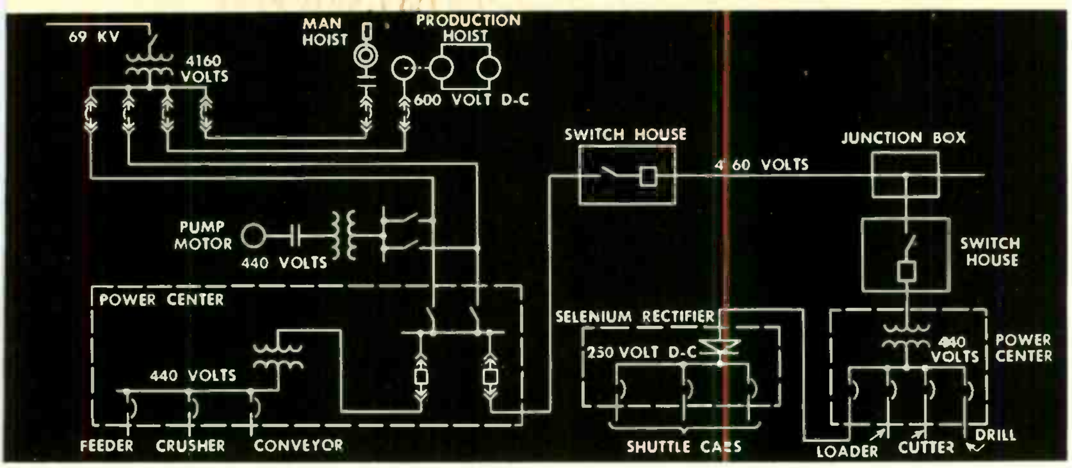


Fig. 2—Simplified diagram of a typical plant and mine distribution system.

The discovery of a major deposit of potash ore in the desert area of southeastern New Mexico in 1925 presented a combined challenge to the mining and electrical industries. Here 750 to 1800 feet below the surface of a desolate, windblown desert was a bountiful supply of much-needed material. Shafts had to be sunk, the ore mined, transported to the foot of the shaft, hoisted to the surface, and processed to produce a commercially attractive product. Energy, and plenty of it, was required to economically perform these tasks. The convenience, economy, and safety of electrical energy compelled its use.

A major factor in the design of the electrical system is the "two-faced" electrical nature of potash ore. When dry it is non-conductive, non-corrosive, and being crystalline in nature can be easily cleaned from equipment by blowing. However, the ore is hygroscopic and, once moist, becomes both conductive and corrosive. This side of its "character" remains quiescent for long periods in this arid location, but strikes suddenly when severe atmospheric changes occur or processing equipment leaks develop. Therefore, electrical equipment must be adequately protected, and kept clean to prevent grounds and short circuits, with consequent loss of production.

Plant Distribution

A main substation is provided by the electric utility to transform incoming electrical energy from 69 kv to 2400 or 4160 volts and, in a few instances, to 12.47 kv for plant use. Power is distributed to the hoisting and processing equipment "topside", and

Control center in a refinery.

Photographs provided by Duval Sulphur & Potash Company, International Minerals & Chemical Corporation, Potash Company of America, Southwest Potash Corporation, United States Potash Company Division of United States Borax & Chemical Corporation.

Shuttle car unloading into dumping pocket.

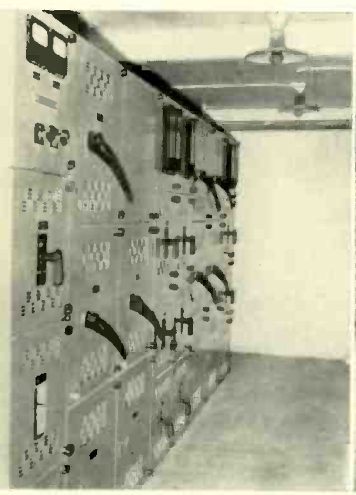
underground to the mine equipment serving the working face, which may be several miles distant. Throughout this distribution channel, the greatest caution must be given to continuity of service; upon this feature depends the safety and comfort of personnel, the quality of product, and profitable operation.

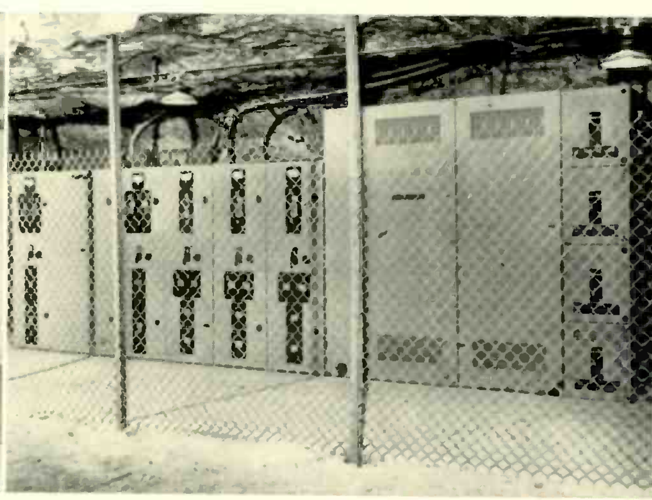
The main substation generally has two output feeder breakers, each serving one underground or two overhead lines into the plant. The vulnerability of overhead lines dictates a double overhead circuit compared to a single underground cable circuit.

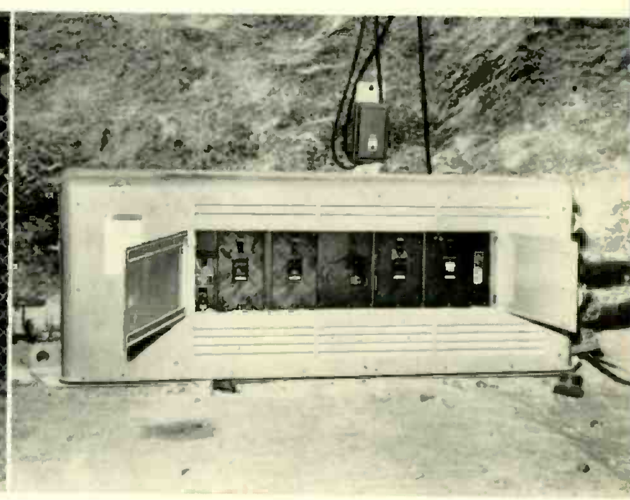
The distribution systems in potash refining plants are characterized to a large measure by the initial size of the operation and the period in which they were installed. Generally, power is fed into one or more main buses by the multiple feeders from the main substation. From this point, simple radial distribution systems have served the many refinery load centers and those underground at mining operations. However, such radial systems lack flexibility and do not provide continuity of service should defects develop in feeders, transformers, or switching equipment. Coming into more general use are modern radial systems that provide primary or secondary selectivity. Primary selective radial systems have multiple feeders in parallel to the load centers, where selective switching permits operating the load from either of two available feeders. With a secondary selective system, continuity of service is further assured by duplicating power-center transformer facilities.

The practice of carrying multiple feeders into the mine is developing. Extension of the working faces several miles from the bottom of the original shaft calls for establishment of remote shafts for men and supply portals. One or more "high-lines" can be run above ground to such a shaft, or to a bore hole, and a high-voltage cable run underground at that point. Several of these supply feeders can be tied together to form an underground primary distribution "network", thus achieving a high degree of protection against outages caused by faults on the primary distribution system.

For certain electrical loads, continuity of service is extremely critical. To serve these loads, an emergency section of the main bus is established. This section is connected to the main bus during normal operation through a bus-tie circuit breaker. However, during main-bus power failure, the tie breaker is opened and the emergency bus section energized from local auxiliary generating equipment. The emergency bus restores electrical energy quickly to at least one of the mine hoists and such critical items as ventilating-fan pump systems. In certain ore-processing equipment, such as classifiers







Power center in a refinery.

An underground substation.

Underground portable mine power center.

and thickeners, power outages can result in solidification of the material requiring costly "digging out" procedures. Such loads are also placed on the emergency bus.

Energy received from the power plant bus is transformed to either 440 or 220 volts for motor-driven machinery. The transformation is frequently performed by power centers—unitized combinations of high-voltage breakers or switching equipment, transformers of appropriate capacity, and low-voltage switchgear for distributing the energy at utilization voltage to multiple feeders.

High-voltage protection consists of either high-voltage circuit breakers, fused or unfused load-break disconnect switches, fused or unfused magnetizing current-break switches, or a combination of both switches and breakers. Switches are mounted in a cubicle integral with the power center, circuit breakers in matching cubicles.

Low-voltage circuit protection and switching equipment is physically located on the opposite side of the transformer. It consists of air circuit breakers of the drawout type, and network protectors where the distribution system dictates their use. Instrumentation and relaying are included to suit the operating practice of each operation.

The location of the power center and the operating conditions determine the type of transformer construction. Dry-type transformers offer the advantages of lighter weight and reduced space requirements over liquid-filled types. They are the most popular type for indoor applications. For outdoor applications and those indoor locations where severe atmospheric conditions exist, liquid-immersed transformers can be used. These are of the askarel- or oil-filled type. If the power center is located indoors, askarel-filled transformers can be used without the provision of expensive vaults and other fire-preventive features required with oil-immersed types.

With the transformer located outside, it is throat connected to the low-voltage switchgear through the building wall. This reduces indoor mounting space to a minimum and provides flexibility for adding low-voltage distribution switchgear.

Underground Distribution

Originally, common practice was to transmit power down the mine shaft at 2300 volts and transform it underground to 240 volts for a-c mining equipment and for rectification for d-c traction apparatus. However, as the faces advanced from the bottom of the shaft such a distribution system, particularly the radial type, required large, costly cables to maintain adequate voltage regulation. This has led to the use of 4160 volts as the popular distribution voltage in underground workings, and in at least one mine, power is taken to the bottom at 12.47 kv. The introduction of higher powered face equipment, such as continuous miners, has required an increase in working-face voltage. Present utilization of 440 volts results in cables of smaller size, reduces power losses, and improves voltage regulation at the machines.

The transformation of energy from distribution voltage to utilization voltage is done underground with equipment that functions like the power centers previously described for mill distribution. However, operating conditions dictate specially designed equipment. Underground power centers are designed to withstand physical abuse in the active working area, to have adequate ventilation in confined spaces, and with appropriate dimensions for lowering through the mine shaft. Although the equipment may operate in underground areas with increased headroom, it may have to pass through low areas when advancing to follow the working face. The low height of some of the ore deposits necessitates a maximum height of about three feet.

For underground service, power centers with dry-type transformers are used. The high-voltage compartment on the input end of the unit contains the cable-connecting plug and, if desirable, an oil-immersed disconnecting device. A 600-volt panelboard of fixed molded-case air circuit breakers is mounted at the opposite end of the equipment. Feeders served from these breakers are taken out through connecting receptacles at the end of the unit.

Frequent movement of the power centers is necessary to keep them within reasonable distance of the working face. The units have self-supporting, skid-type bases and are placed directly on the mine floor. The power center is placed on a dolly for transporting over the mine rail system if major distances are to be traveled. With plug-and-receptacle type disconnecting means for both high- and low-voltage connections, the units can be readied quickly for movement from one location to another.

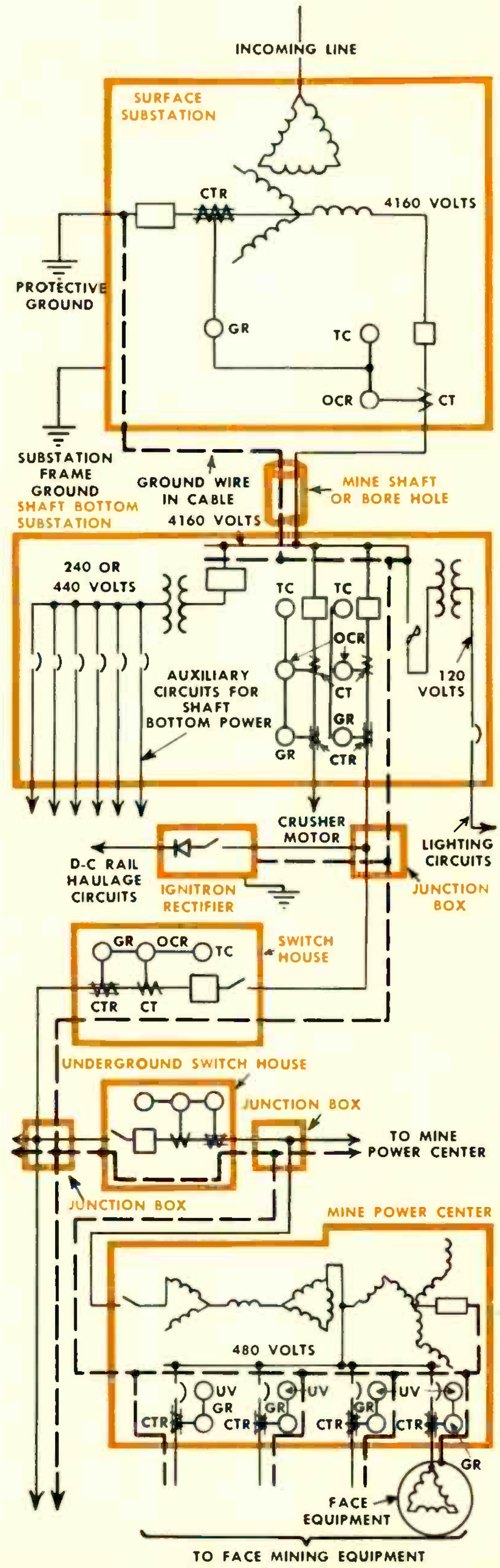
Underground power centers are provided in ratings from 112 to 500 kva. The transformer is connected 2400-volt delta or 4160-volt wye on the high-voltage side, and 240- or 480-volt delta on the low-voltage end. Two $\pm 2\frac{1}{2}$ percent voltage-adjusting taps are provided. Power-center ratings are appropriate for serving a working mining unit, which usually consists of drilling and cutting equipment or one of the modern continuous mining machines together with appropriate loaders, shuttle cars, and perhaps conveyor or car-loading apparatus. The d-c operated shuttle cars are supplied from the mine rail haulage trolley system or, in those mines using conveyors, through dry-type selenium rectifier units operating from one of the 440-volt feeders of the power center. The remaining equipment is operated by three-phase alternating current.

For 480-volt face equipment, means of limiting voltage to ground of machine frames is required. This is accomplished by the use of a ground-protective scheme, that limits machine frame-to-ground voltage rise during a fault to a value considered not dangerous to personnel, and by deenergizing the faulty circuits as quickly as possible.

The following system was developed originally to meet these requirements and is still used in many applications: The main-power center secondaries are grounded through a current-limiting resistor. When secondaries are wye connected, the neutral

Fig. 3—Grounding system for electrical equipment in potash mine.

CT—Current Transformer
CTR—Ring-Type Current Transformer
OCR—Over-Current Relay
GR—Ground-Protection Relay
TC—Trip Coil
UV—Under-Voltage Trip Coil



point is grounded to the frame of the power center through a resistor that limits maximum ground fault current to 5 amperes. On units with delta-connected secondaries, a zig-zag grounding transformer derives a source of ground current, and the current-limiting resistor is connected between the neutral of this grounding transformer and the power-center frame. From the frame side of this resistor a ground wire is carried to a ground trip coil of each feeder breaker and hence through this coil to the frame of the machine supplied by the breaker. The power wires to the machine and the ground wire are carried in the same cable. The incoming high-voltage cable to the power center also carries a ground wire, which is connected to the power-center frame.

At surface substations, a protective ground is established and the substation transformer secondary is grounded through a current-limiting resistor to the protective ground. The establishment of a low-resistance protected ground at the surface is more easily accomplished than underground. In effect, the ground wire of the high-voltage cable brings the ground point to the ground-wire terminal of the 480-volt grounding resistor. In the event of a phase-to-frame fault on a 480-volt machine at the face, the fault current is limited to 5 amperes by the resistor. Voltage to ground of the machine frame is therefore held to a maximum of 5 amperes times the ground-wire impedance in the cable, which for cable lengths anticipated is 10 volts or less. The ground trip coil to which the ground wire of the face machine is connected trips the breaker at 3.5 amperes, and has a continuous rating of 5 amperes.

Underground machine shop.

Further refinements of the general grounding system have subsequently been made. In recent installations, the grounding system employs a "ring" or "doughnut" type ground-detecting transformer and relay. The three power conductors of a load feeder pass through the iron opening of this transformer and the ground wire is carried outside the iron core. The secondary winding of the transformer is connected to a relay, and the relay contacts connected in the under-voltage trip-coil circuit of the breaker. For a phase-to-frame fault on the face equipment, ground-fault current passes through one of the conductors in the iron core and returns by the ground wire outside the iron core. This causes a voltage in the secondary winding of the transformer, which operates the ground-current relay and trips the breaker.

When unbalanced a-c loads occur, or single-phase loads where no ground fault is present, no voltage is developed in the secondary of the ground-detecting transformer because current that passes through the opening in one direction also returns through the same opening.

This general scheme is useful in most cases where the a-c ground wire is subject to d-c currents. In those installations with both a-c and d-c power, misoperation of the breaker due to d-c currents in the ground wire is prevented since there is no tripping element in series with the ground wire.

Haulage of ore from the mine face to the shaft bottom area of the production hoist is accomplished by either mainline conveyor or underground rail systems. Conveyor systems are operated with squirrel-cage motors and industrial-type starters at 440 volts. The starters have full- or reduced-voltage starting, overload and low-voltage protection, and air contactors.

For underground rail-haulage systems, d-c mining locomotives operate from a 275-volt d-c trolley. Rails are bonded to supply a low-resistance return path. Formerly, direct current was obtained by motor-generator sets located in underground rooms. More recently, the operating economies and the maintenance-free features of the ignitron rectifier have made it an almost universal underground d-c supply. These rectifiers are a coordinated assembly of equipment on three cars of appropriate dimensions to be lowered through the shaft and moved about readily. The first car contains the main incoming a-c circuit breaker and an auxiliary transformer with fuse disconnects to supply low-voltage alternating current for rectifier auxiliaries and lighting. The second car contains the rectifier transformer, and the third houses ignitron rec-

Table I—Typical Face Equipment Drives

MACHINE	HORSEPOWER	MOTOR TYPE	CONTROL
Drill (Jumbo)			
Drive	26	Squirrel Cage NEMA B	Full Voltage Start
Fan	.75	Squirrel Cage NEMA B	Full Voltage Start
Cutter	50-75	Squirrel Cage NEMA C	Full Voltage Start
Loader			
Drive	50	Squirrel Cage NEMA D	Full Voltage Start
Pump	6	Squirrel Cage NEMA B	Full Voltage Start
Shuttle Car			
Traction	Two 10	D-c Series	Series Start—Parallel Run Dynamic Brkg.
Conveyor			
Hyd. Pump	10	D-c Compound	Full Voltage
Continuous Miner			
Cutter Motor	Two 65	Squirrel Cage SPCL	Full Voltage Start
Hyd. Pump	10	Squirrel Cage NEMA B	Full Voltage Start
Conveyor	Two 3	Squirrel Cage SPCL	Full Voltage Start
Tramming	Two 7.5	Squirrel Cage SPCL	Full Voltage Start
Fan	5	Squirrel Cage NEMA B	Full Voltage Start

Table II—Typical Refinery Equipment Drives

MACHINE	HORSEPOWER	MOTOR TYPE	CONTROL
Crusher	75-125	Squirrel Cage NEMA C	Full Voltage Start
Rod Mill	150-250	Synchronous Wound Rotor	Full or Reduced Voltage Start Secondary Resistance Starting
Classifier	15	Squirrel Cage NEMA B	Full Voltage Start
Flotation Cells	5-7½	Squirrel Cage NEMA B	Full Voltage Start
Conveyors	3-75	Squirrel Cage NEMA B or C	Full Voltage Start
Kiln	15-40	Squirrel Cage NEMA C D-c Compound	Full Voltage Start Adjustable Voltage
Centrifuges	150	Wound Rotor	Secondary Resistance Starting
Fans	40-250	Squirrel Cage NEMA B Synchronous	Full Voltage Start or Reduced Voltage Start

tifier tubes, the d-c output circuit breaker, and the cooling system for the rectifier tubes.

With the long rail hauls and grades encountered in the mine, minimum voltage drop must be maintained on the trolley circuit to permit maximum utilization of locomotive capacity. This calls for careful location and movement of rectifier stations, since advancement of working faces changes the electrical demand of the haulage system.

The production hoist is the vital link transporting ore from the base of the shaft to the surface. These hoists are generally of the balanced type, with two skips operating in a vertical shaft at speeds up to 1600 feet per minute, and with loads up to 13 tons. Such a hoist has a capacity of approximately 15 000 tons per three-shift day.

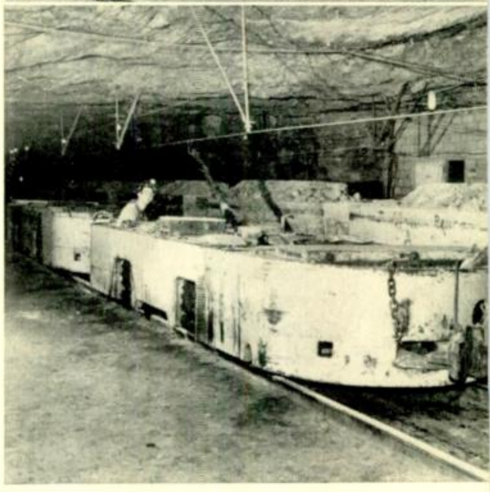
These production hoists are generally driven by adjustable-voltage drives employing reversing d-c motors, each with its associated d-c generator. The generators are driven by synchronous-type m-g sets. Eighty-percent power factor synchronous motors are used to provide power factor correction within the plant system.

Control of these adjustable-voltage systems incorporates rotating speed regulators that provide flat speed-torque characteristics at the desired operating speeds. Current-limit regulators provide the desired torque for acceleration and retardation. These are of the rotating or magnetic-amplifier type. The use of a torque-limit feature not only assures proper torque throughout the accelerating period to provide lively performance, but also protects the mechanical system of the hoist against excessive stresses.

Automatic operation of production hoists can be incorporated with a skip making a trip after it has been loaded at the bottom. The load is automatically dumped at the top, and the hoist waits until the companion skip is filled.

At shift-change time, the production skip may be converted to a man skip and operated under manual control at reduced speed to bring men to the surface and take the next shift into the mine. However, those miners working remote from the shaft bottom generally assemble at one of the auxiliary man-and-material hoists located nearer the working faces. These hoists are, in most instances, driven by a-c wound-rotor motors with full magnetic reversing control. They are of smaller capacity than the production hoists and are under the control of an operator.

Rotary dump for dumping ore into a crusher bed.



Electric mine locomotive.

Ore Processing

When ore reaches the surface it is conveyed either to the appropriate storage bins or directly into the processing operation. Throughout milling and refining processes, the ore is handled numerous times on conveyors of various lengths. These conveyors generally are driven by line-started squirrel-cage motors operating on the 440-volt system.

One of the first refining processes is primary grinding followed by further grinding of ore in a ball or rod mill. Such mills usually are driven by synchronous motors—80-percent power-factor machines provide power-factor correction.

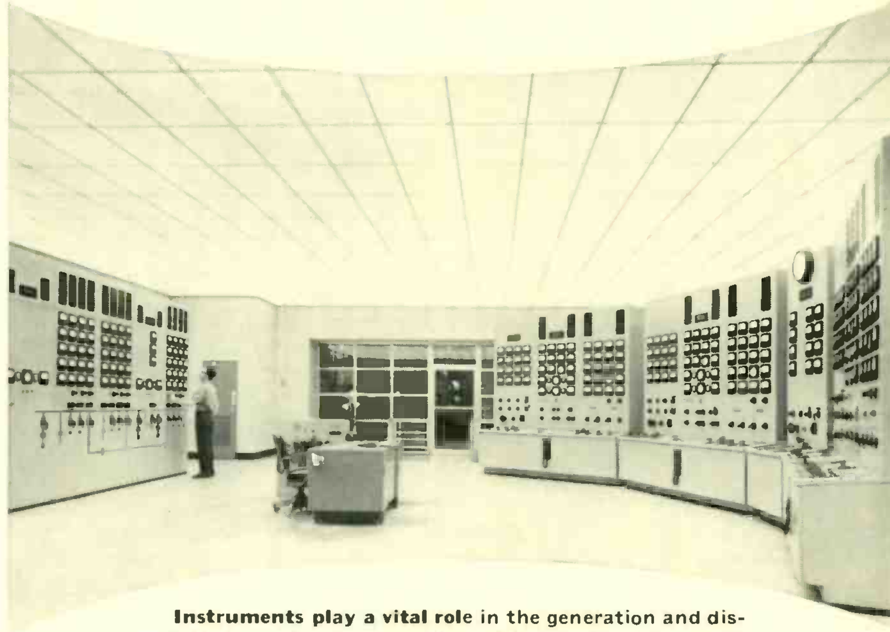
Many of the treating processes use flotation cells, in which a finely crushed mixture of ore and brine combined with certain chemical reagents is placed in tanks, agitated and caused to froth by the insertion of air bubbles at the bottom of the tank. The flotation cells usually employ squirrel-cage motors of 5- to 7½-hp rating.

After refining, the final product is filtered in a centrifuge, and then dried in large kilns before being placed in storage or directly prepared for shipment. A large portion is shipped in bulk, either in covered hopper or box cars; the remainder is bagged.

Throughout the mill processes, certain major concentrations of electrical load are best served by a control center. The control centers group all of the industrial magnetic controllers in one location, each in an individual metal cubicle for easy access and ready interconnection. Controllers are of the full-voltage or reduced-voltage type and incorporate disconnect switches or air circuit breakers as desired. Lighting distribution panelboards can also be included in control centers. The drives are controlled from pushbuttons on the doors of individual compartments, assembled at a centralized control desk or located at each drive. With much of the interconnecting and main wiring done at the factory, and terminals available for the interconnecting wiring to the drives themselves, control centers materially reduce installation cost and time and, after installation, promote better and more economical maintenance.

With such a large system of electrical drives and with processes so dependent upon electrical equipment for continuity of operation, operating companies have established effective preventive-maintenance programs. These incorporate regularly scheduled checks of all equipment, maintenance of adequate records, and an adequate supply of spare parts. Thus from the utility substation to the storeroom, the electrical supply and drive systems are safeguarded in every feasible way to provide the utmost in safety, flexibility, and continuity of service so that electrical energy assists in producing potash 8760 hours each year. ■

NEW DEVELOPMENTS IN INSTRUMENTATION



Instruments play a vital role in the generation and distribution of power, as evidenced by this bank of meters at the Elrama Station of the Duquesne Light Company.

J. C. NYCZ, R. C. MacINDOE, and U. L. SMITH
Instrument Engineering Department, Westinghouse Electric Corporation, Newark, New Jersey

▪ Through the eyes of instrumentation, the production and distribution of more than 500-billion kilowatts a year is regulated and controlled. In the generating station, such quantities as voltage, current, power factor, watts, vars, and frequency are measured and often recorded for each generator. These same quantities, in varying combinations, are measured on the station bus, the generator substation, distribution substations, and ultimately at the load. Thousands upon thousands of instruments are required for this purpose. Here then, are some of the means by which designers improve the "vision" of the modern instrument.

Four major requirements must be considered in the design and selection of electrical indicating instruments; these are readability, accuracy, reliability, and space required. The first is rather obvious since the prime object of the instrument is to impart intelligence. To obtain this intelligence, the user must read the indication as quickly and as accurately as possible. To comply with national and military standards, switchboard instruments must be accurate within one percent of full-scale rating under specified operating conditions and must be within specified limits under various operating influences, such as frequency, wave form, temperature, and power-factor variation.

Reliability covers many phases: The instrument must be stable and not drift in accuracy with time, temperature, or other external influences; it must be fairly free of maintenance problems; if service is required, the instrument should be easy to service, and remain in good condition. The final requirement is particularly important to the user whose application requires many instruments on one board; usually, all the instruments needed should be located as closely together as possible so that an operator can read a large number from a central location. Space taken by instruments for an electric utility application determines the size of the switchboard in the control room, the size of the control room itself, and to some extent, station size.

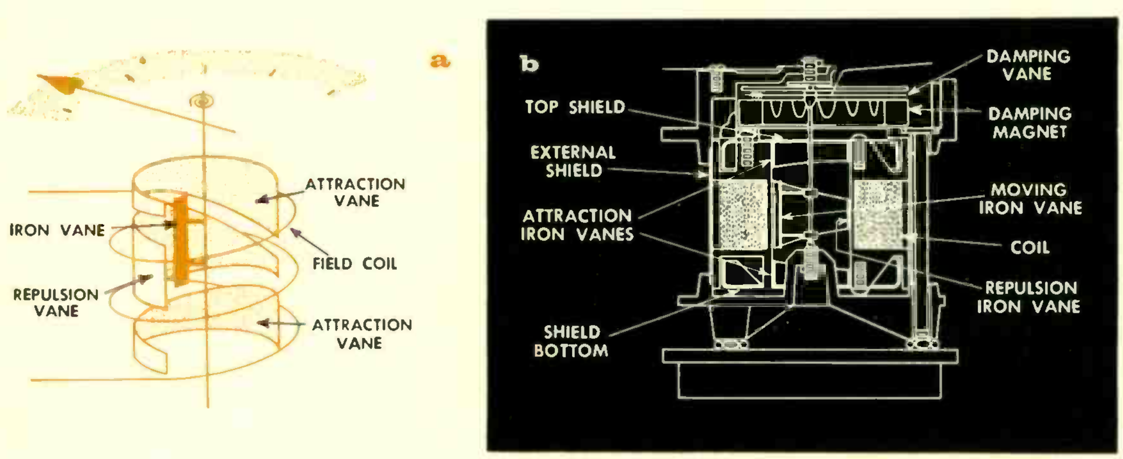


Fig. 1—(a) Moving-iron mechanism is based on repulsion of like magnetic poles, attraction of opposite. Iron vane is repelled from wide end of stationary repulsion vane when both are magnetized by field coil; vane is attracted by attraction vanes as it deflects toward them. (b) Cross-sectional view of Westinghouse moving-iron mechanism used in ammeters and voltmeters.

Circular-Scale Instruments

To meet all of the various requirements encountered, two general types of switchboard instruments have been developed, both in the one-percent accuracy classification—a 90-degree type and a 250-degree type.

The 90-degree instrument is the older of the two. Because of the smaller travel arc of the pointer, its major advantage is its relative simplicity. The improvements made over the years have led to an extremely stable instrument—one that maintains its accuracy over extended periods of time and in the face of adverse external conditions such as handling, temperature, and severe overloads received in service.

The 250-degree instrument (24 Line) is a more recent development, which offers the advantages of smaller size with maximum readability. These instruments originally were developed for the Navy during the second World War and are used almost universally for marine applications. Since the war, the commercial "full-view" design of these instruments has been widely accepted for industrial use. More recently, still further major improvements have been achieved through more efficient design, new materials, and manufacturing techniques. For example, the use of new alloys for the permanent-magnet moving-coil types has increased the torque-to-weight ratio of the moving system by approximately 30 percent. Similarly, major design advances have been made in the 24-line a-c ammeters and voltmeters, and also in the 24-line synchroscopes and power-factor meters.

Moving-iron Mechanism—Ammeters and voltmeters that use the moving-iron type mechanism (Fig. 1a) have undergone a complete redesign. The stability of the instrument has been improved by decreasing the weight and number of parts. The moving-element design was changed from a nine-piece unit to a three-piece unit, which is assembled by a die-casting process; the moving element is now a single unit with no organic materials to vary with time and temperature. The torque-to-weight ratio has been increased by almost 100 percent. This was accomplished by reducing the mass of material, and by using more efficient magnetic material in a redesigned magnetic circuit.

By arranging the magnetic circuit and properly shaping the magnetic components (Fig. 1b) the scale has been made substantially linear from 20 percent of full scale to full scale. In addition to providing a more linear scale, the more efficient magnetic circuit increases the torque developed by the moving element, which also aids in making for a more stable design. The increased torque and magnetic arrangement also result in lower error due to stray fields. The error caused by an external field of five gausses is only 0.8 percent, as compared to 1.6 percent for the previous design. Frequency error and wave-form influence have been minimized and enable operation on higher frequency, such as 400 cycles.

Rotating-vane Mechanism—The rotating-vane mechanism for the synchroscope (I-24) and power-factor meter also has been improved (Fig. 2). By redesigning the mechanical arrangement of the top and bottom bearings so that the concentricity between the moving element and the stator iron is held very close, a more linear scale on the power-factor meter is obtained and the synchroscope rotates more smoothly.

Operating torque was increased for the reasons given above and because the magnetic coupling of the vanes and stator was increased. In addition, the stator winding is now machine wound, in contrast to a hand-wound stator used in the old design, which improves consistency of the scale and smoothness of rotation.

A major consideration for synchroscopes is the ***pull-in*** and ***pull-out*** frequencies. These terms refer to the difference in frequency of the two sources being synchronized, at which the instrument will start rotating and stop rotating. By increasing the magnetic coupling and torque and by improving the rotation and dynamic characteristics, the pull-in frequency of the new design has been increased from 1.5 cycles to 2.5 cycles, and the pull-out from 4 cycles for the old design to 7 cycles for the new design.

By use of a compact condenser and an optimum size inductance to phase split the single-phase voltage applied to the three-phase stator, the instrument is self-contained. This is important to the user because of the space required for the external box formerly used on single-phase instruments.

Transducer-Type Frequency Meter

In conventional frequency meters, the instrument mechanism forms a part of the circuit. The cross-coil type, the moving-iron type, and the vibrating-reed type all have mechanisms built specifically for these meters; and these units have little other commercial use. This means that manufacture and service of these instruments require special tools and stocks of parts for each different size and type. In the transducer-type frequency meter the frequency circuit is separated from the indicating mechanism. The transducer unit converts cycles into d-c voltage. Any size or type of d-c indicating or recording voltmeter can be used to measure the transducer output by calibrating the dial or chart in cycles.

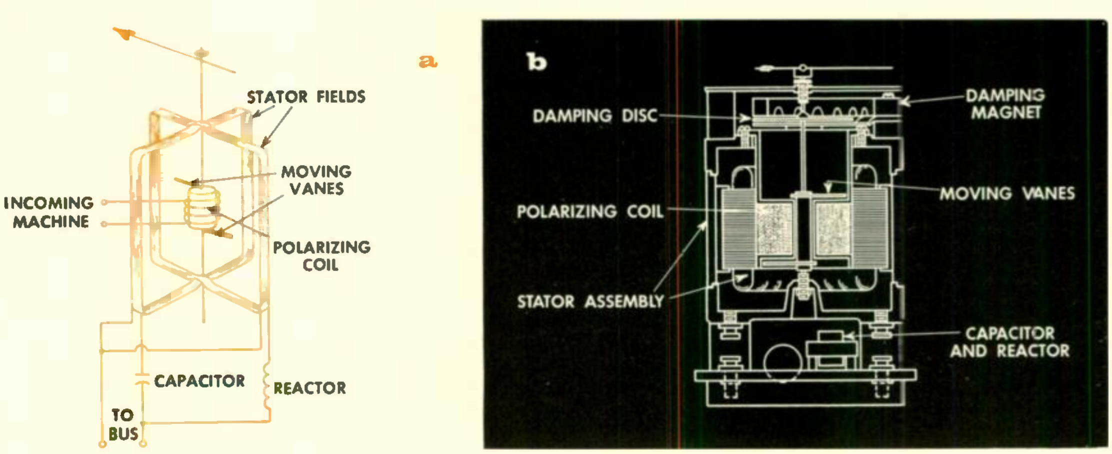


Fig. 2—(a) The stator fields of a rotating-vane mechanism are connected to the station bus through a reactor and capacitor, which produces a "rotating" stator field. Rotating vane is magnetized by polarizing coil from the incoming machine. If frequencies of machine and bus are the same, vane will take a stationary position where the field of the vane is zero at the same instant that the field from the stator is zero. The position will indicate difference in phase. If frequency is not equal, vane will rotate in a "fast" or "slow" direction. (b) Rotating-vane mechanism used in Westinghouse synchroscope and power-factor meter.

Several advantages are provided by this development: (1) standard d-c indicating or recording voltmeters can be used merely by adjusting the instrument calibration to match the transducer output; (2) any size or shape of instrument can be used; (3) ranges as narrow as 59 to 61 cycles can be built, but broad ranges such as 50 to 70 cycles are just as practical; (4) the transducer can be furnished for any basic frequency such as 50, 60, or 400 cycles; (5) only one size and type of transducer is needed for any basic frequency; (6) the scale is nearly uniform over the entire range; and (7) the necessity for tooling, building, and stocking of mechanisms used only for frequency meters is eliminated.

The circuit is shown in Fig. 3a. Two parallel off-resonance circuits are employed; each circuit has an inductance, capacitance, resistance, and rectifier, with rectifiers connected to give full-wave rectification. One leg of the parallel circuit is adjusted for resonance below the scale at approximately 48 cycles; the other circuit is adjusted for resonance above the scale at approximately 72 cycles. The current-frequency relation for these circuits is shown in Fig. 3b. A d-c instrument reads the difference in currents with the null or balance point near the center of the scale. Actually, the null point is located at 60.5 to 62 cycles, depending on the range, so that when the circuit is de-energized, the pointer rests off the 60-cycle or base-frequency point.

Different frequency ranges are obtained by using voltmeters with different ranges. For a 50- to 70-cycle range, a center-zero, 0.5 milliampere d-c instrument is used with a series resistance of about 6000 ohms. Different values of resistance are used for other ranges. Calibration is obtained by adjusting the series resistance to match transducer output.

In circuits of this kind, the d-c output is influenced by changes in line voltage except at the central point where the output value is zero. To make the entire scale independent of voltage change, a saturation-type regulator holds voltage constant over a range of 100 to 130 volts in line voltage.

Four basic transducer units are made for these frequency meters: For 60 cycles, a commercial unit and a Hi-Shock unit will cover ranges 58–62 to 50–70 cycles; for 400 cycles, a commercial unit and a Hi-Shock unit will cover ranges 380–420 to 350–450 cycles. The operating characteristics of the commercial units and the Hi-Shock units are the same. Hi-Shock units are larger and heavier than commercial units and are required only on certain military installations.

Recording Instruments

New direct-acting recording instruments (Type 44) have been developed to meet the increasing demand for a versatile, high quality, and compact design. This includes three completely new instrument mechanisms: (1) permanent-magnet, moving-coil mechanism for d-c rectifier-type, and transducer measurements; (2) attraction iron-vane mechanism for alternating currents and voltages; and (3) iron-core electrodynamic mechanism for wattmeters and varmeters.

Movement torques developed by these elements are far in excess of the usual values. Whereas conventional recording instruments operate with movement torques as low as 50 centimeter-grams (measured on the basis of 360-degree deflection), the new mechanism operates between 150 and 160 cmg. This permits an exchange of the excess torque-producing ability for reduced instrument temperatures and burdens.

Increased operating torque also makes possible two other important features—rugged movements that will withstand heavy-duty use, and improved response time from over one second to less than $\frac{3}{4}$ second. The latter improvement, however, accentuated the problem of continuity of pen inking on deflections across the chart. In former designs with relatively slow instrument response time and pen travel, the pen had little tendency to skip on the chart. A newly-designed pen mechanism was required to prevent skipping at the increased pen speeds. The writing pen is mounted on knife-edges near the front of the recorder and is designed so that its center of gravity is above the knife edges. On a quick swing of the pen arm, the centrifugal force acting on the center of gravity of the pen develops a torque that makes the pen tip press down on the paper with greater than normal pressure. Thus, the faster the pen moves, the greater the pen-tip pressure. For

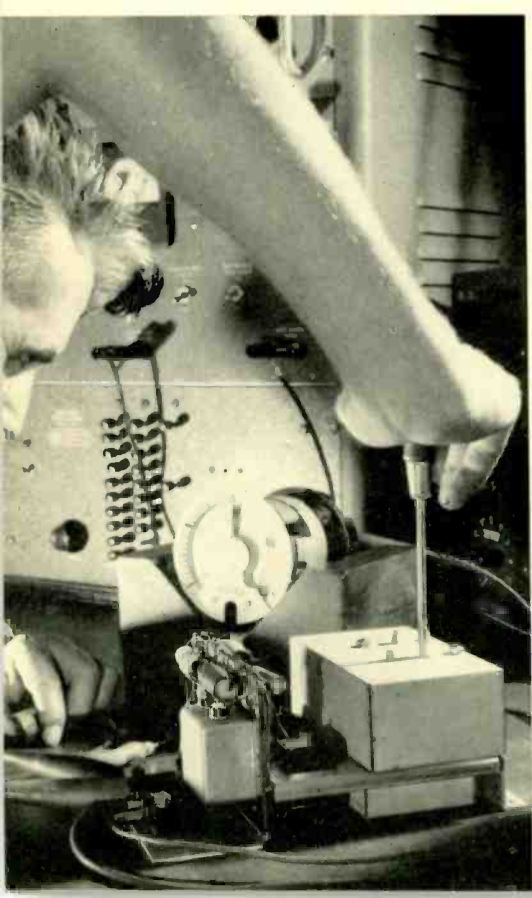


Fig. 3a

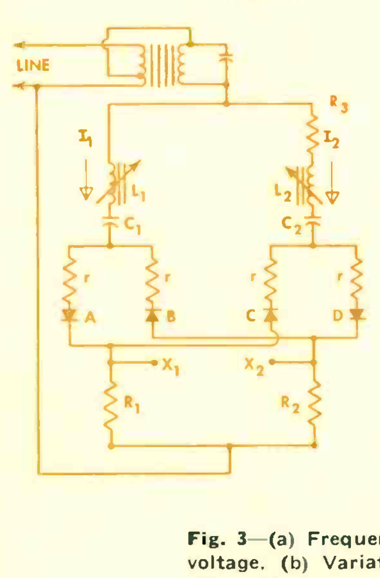


Fig. 3b

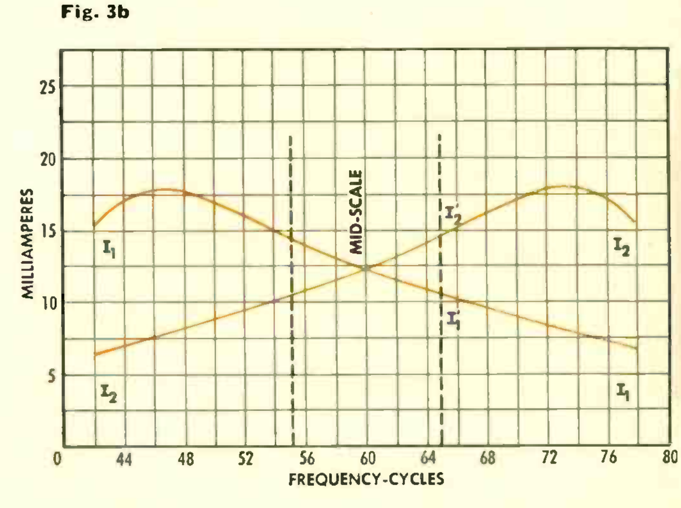


Fig. 3—(a) Frequency transducer circuit converts frequency to d-c voltage. (b) Variation of branch currents with frequency change. (Photo) Frequency transducer circuit is adjusted for use with a d-c milliammeter, which has been calibrated to read frequency in cycles.

Skilled technicians assemble instruments with watch-like precision.

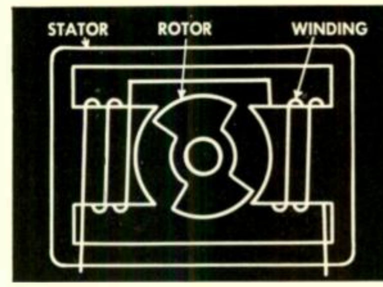


Fig. 5a

Fig. 5—(a) Magnetic circuit of attraction-iron mechanism for alternating voltage and current measurements. (b) Torque-producing ability curves of attraction-iron mechanism for various ampere-turns. From these curves, scale distribution, operating torque gradient, and saturation characteristics are derived. (c) Typical scale distribution. (d) Saturation characteristic curve.

sudden excursions of the pen up to half-scale deflection, the static pen-tip pressure required is substantially zero. For full-scale deflections, the required static pen-tip pressure is about 20 milligrams, which is only half the pen-tip pressure required for continuous inking of conventional pen designs.

Moving-coil Mechanism—For the permanent-magnet, moving-coil mechanism, full use was made of the high air-gap flux possible with Alnico-V magnets. Full-scale sensitivity has been increased from 0.025 watt for previous designs to 0.0025 watt for the new standard high-torque design. This made possible recording-ammeter operation from 50-millivolt shunts instead of the previous 100-millivolt units, and voltmeters with 1000-ohms-per-volt sensitivity. For high sensitivity applications, the power consumption can be reduced to 0.001 watt by reducing the spring torque, and air-gap flux can be increased by eliminating the magnetic adjusters.

The most novel feature of the design is the use of one-piece laminations for the air gap, core, and pole-piece regions of the magnetic circuit, Fig. 4b. These laminations are easily-manufactured to a high degree of accuracy, assuring consistent uniformity and stability in the air-gap flux and the resultant linear scale distribution. The design also permits removal of the moving-coil assembly without disturbing air-gap flux. In conventional designs, this operation usually requires removal of a portion of the magnetic circuit with a resultant loss of air-gap flux, so that the magnets must be remagnetized after re-assembly.

Another feature of the new design is the magnetic shunts, which can be adjusted over a range of 40 percent; this can be used to modify calibration, or to accommodate a wide range of shunt-lead lengths.

Attraction-iron Mechanism—The attraction-iron principle of operation was selected for the mechanism used for a-c voltmeters and ammeters because of its inherent simplicity, high magnetic efficiency, general performance, and high overload capacity, both thermal and mechanical. The arrangement of the magnetic circuit is illustrated schematically in Fig. 5a. It consists of one-piece stator and one-piece rotor laminations, with the operating coils pre-wound and slipped into the stator.

The magnetic efficiency of a moving-iron mechanism is defined as the difference of the inductance at full-scale deflection and the inductance at zero scale divided by the former. Heretofore, magnetic efficiencies have ranged from 10 to 25 percent; the new mechanism has an efficiency of 35 percent.

The performance of any mechanism can be determined from a study of its torque-producing ability. Knowing the desired full-scale torque and angular travel of the moving element, the torque-producing ability curves (Fig. 5b) can be used to select an operating region that affords the most consistent scale distribution and operating-torque condition. The degree of magnetic saturation also can be determined from the torque-producing ability characteristics. Since maximum flux density in the iron occurs at full-scale rotor position, data from the 60-degree position is crossplotted, as shown in Fig. 5d, to indicate the relative degree of saturation. The

Fig. 5b

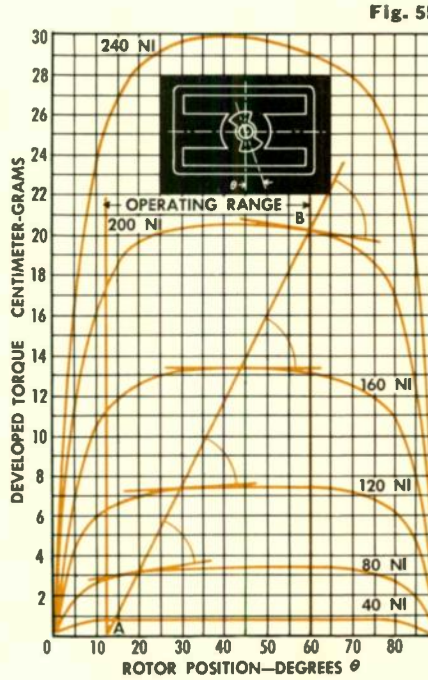


Fig. 5c

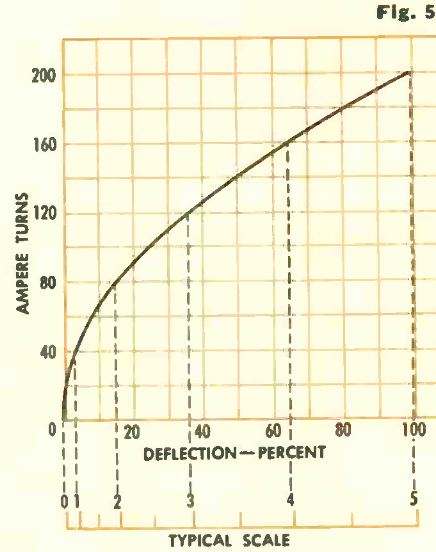
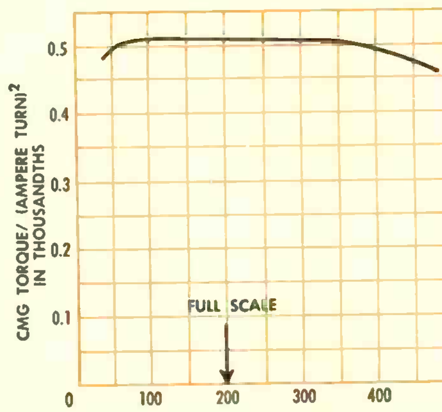


Fig. 5d



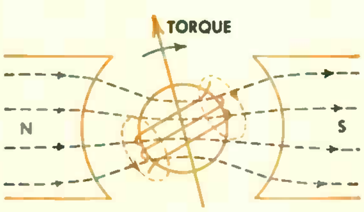


Fig. 4a

Fig. 4b

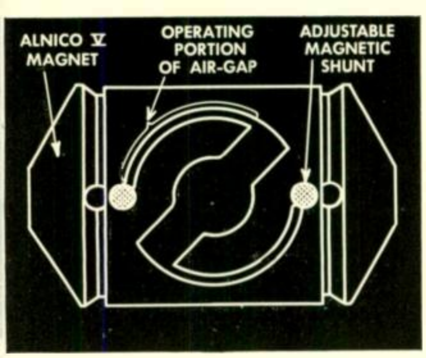


Fig. 4—(a) Fundamental principle of permanent-magnet moving-coil mechanism. Flux produced by current in coil acts in magnetic field to produce torque. (b) Modern magnetic circuit of permanent-magnet, moving-coil mechanism uses one-piece lamination and adjustable calibration shunts.

continuation of the flat region of this curve beyond the full-scale point shows that the iron is operated well below saturation. This assures freedom from wave-form variation error.

The square-law torque characteristic of the attraction-iron mechanism results in extremely high torques during over-load conditions. This would normally result in violent deflection of the pen and severe mechanical stresses in the moving element. These effects are eliminated by mounting the rotor iron so that it is free to rotate on the shaft. The rotor is biased against a stop on the moving element by an auxiliary spring. Any sudden overload permits the high torque developed in the rotor to deflect it quickly to the full-scale point. The auxiliary spring then moves the remainder of the moving element system to the full-scale position free of any violent torques.

Iron-core, Electrodynamic Mechanism—For measuring watts and vars, the iron-core electrodynamic type of mechanism was selected because of its high efficiency and high torque attainable with the inherent close magnetic coupling of the electrical circuits. The mechanism as developed for this recording instrument has the magnetic circuit built up of one-piece laminations, as shown in Fig. 6b. As in the case of the permanent-magnet moving-coil lamination, this assures consistently uniform scales of linear distribution.

The magnetic-circuit structure of one element is built up of two equal stacks of laminations, spaced to permit assembly of the moving coils. In the past, common practice was to use compensating coils with iron-core electrodynamic mechanisms, connected in series with the potential coils to cancel the effects of solenoid forces. By reversing the two stacks of an element and by careful development of the shape of the laminations, the element has an inherently constant self-inductance of the moving coil over its entire range of operation. Solenoid forces are reduced to zero and "voltage error" or deflection of the instrument with only the voltage circuit energized is eliminated.

Another unique feature of the voltage element is the splitting of the moving coil of each element into two separate coils. This permits the use of the astatic connection, in which the current is made to flow in the active sides of both coils in the same direction, thereby canceling the effect of uniform stray fields upon the mechanism.

The superior performance of the new mechanism is shown by the temperature-rise curves of Fig. 6c. An instrument calibrated for 500 watts operating at 120 volts will have a maximum temperature rise of 8 degrees C in the potential coil and 6.5 degrees C in the current coil. This low-temperature rise means that calibration can be changed over a wide range of scale conditions without changing coils or otherwise rebuilding the mechanism. The performance of this instrument under various conditions of power factor is shown in Fig. 6d.

Size and Convenience

Control-room space is a costly factor in electric utility operations. As generation and distribution facilities expand, more and more space is required for instrumentation facilities. Consequently, miniaturization has been employed wherever practicable; the 250-degree, full-view face makes smaller sizes possible with increased scale length and readability. Instrument designers have made service and maintenance operations and adjustments easier by providing more convenient accessibility. For example, sensitivity and scale-distribution adjustments on circular-scale instruments are made from the front of the instrument simply by removing the cover and dial mask. Service operations on recording equipment, such as loading and re-rolling the chart, or cleaning and servicing the inking system are quickly performed. A high level of performance, and simplicity of operation and maintenance assures accurate measurements and records of system operations. ■

Fig. 6a

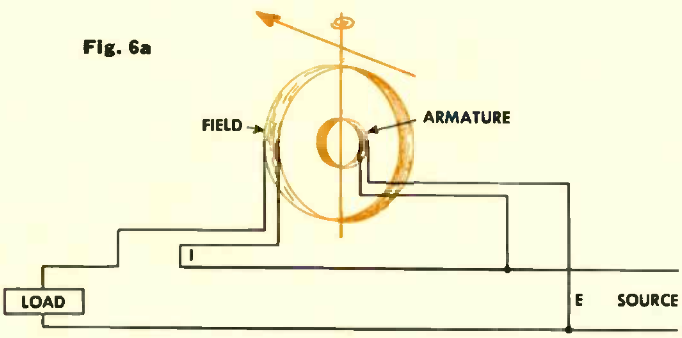


Fig. 6b

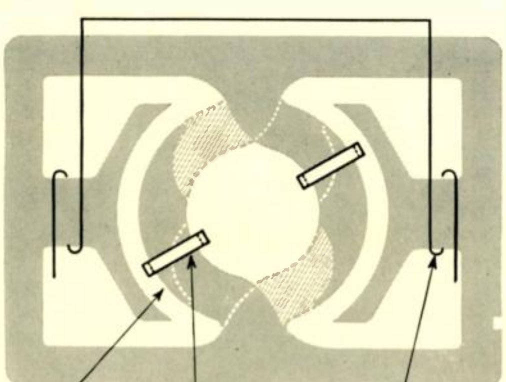


Fig. 6c

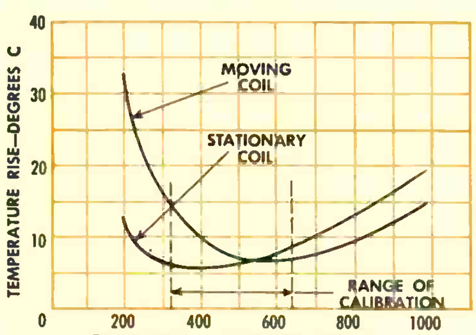


Fig. 6d

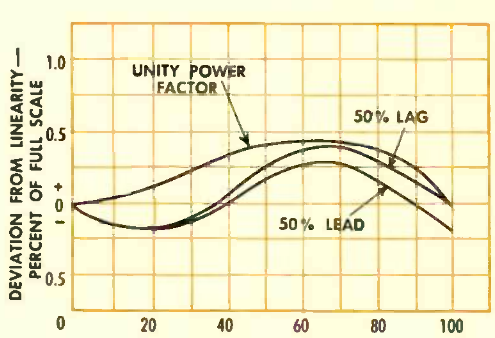
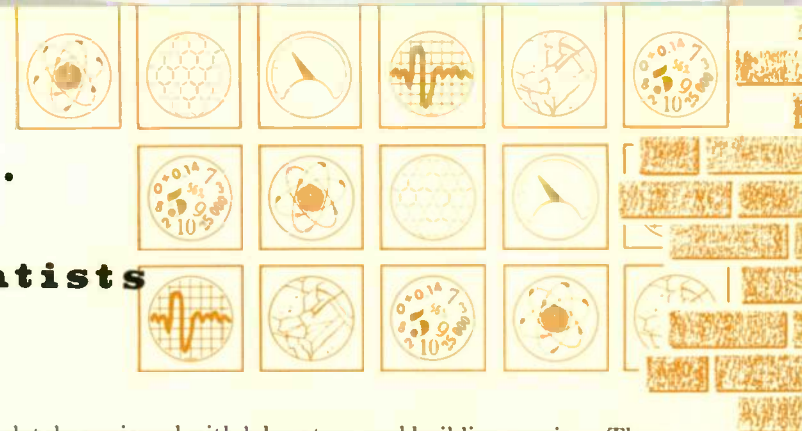


Fig. 6—(a) Principle of dynamometer movement. Torque produced is proportional to product of current in field coil and voltage across armature coil. (b) New magnetic structure for electrodynamic mechanism uses two equal stacks of laminations spaced to permit assembly of the moving coils. (c) Temperature rise of moving coil and stationary coil of electrodynamic mechanism at rated voltage and for currents determined by the various watt calibrations. (d) Performance of electrodynamic mechanism under various conditions of power factor.



NEW LABORATORIES . . .

Modern Vehicle for Scientists

A modern research laboratory is geared to provide the necessary facilities for scientists quickly, efficiently, and as completely as possible. This, in a large diversified laboratory, is a big order. In the complex world of modern science, the needs are not all simple.

Space-wise, the scientist must have a laboratory well adapted to his particular area of research. Often the space must have flexibility as to size and arrangement. Certain facilities should preferably be "within arm's reach," such as water, common gases, electric power, and the many other elements used in experiments. Also, special equipment must be available for his use—devices such as electron microscopes, mass spectrometers, diffraction cameras, and the many other intricate devices necessary to many experiments. More often than not, he must have specially built equipment to perform an experiment; the means of constructing this equipment must be at hand. Sources of information must be available on current and past research in his particular field. The scientist must have places to meet with fellow scientists, so that information can be freely exchanged. He needs all this, and much more.

Singly, these are relatively simple requirements. But combined they are sometimes more difficult to achieve, especially when the laboratory is active in broad fields. Even different branches of the same basic field, such as physics, often have far different laboratory requirements.

However the importance of these requirements, no matter how deceptively simple, cannot be overlooked. For one thing, the pace of research depends to a large degree on whether or not the necessary "tools" are available. All of the tools are important, from the supply of oxygen piped to the individual laboratory to the most complicated experimental apparatus.

The new Westinghouse Research Laboratories, dedicated in September, was designed to fulfill these requirements. The Laboratories are designed on a modular basis. In this case a module is the smallest repetitive unit of space that is completely equipped with laboratory and building services. These modules can be combined in separate laboratories of various sizes to suit the needs of individual departments. Actually there are three basic modules—two different sizes for laboratories, and one for offices, conference rooms, drafting rooms, and similar spaces.

Both laboratory modules are six feet wide. One is 19 feet deep, the other 25 feet. Thus, modules can be combined to produce laboratories in any multiple of six feet wide. Each module is self-contained as far as services are concerned (see diagram). All services—electric power, telephone, heat, hot and cold water, compressed air, vacuum, natural gas, nitrogen, oxygen, and hydrogen—are contained in the exterior wall. When space requirements are determined, branches of these services are provided in walls perpendicular to the outside walls, or in island service strips. Side walls of all modules are movable, which makes for maximum flexibility.

The new Laboratories are well-equipped with other necessary facilities. For the scientist building a special apparatus for an experiment, a machine shop, a carpenter shop, and a glass-blowing laboratory can provide most of his special needs. Numerous conference rooms of varying sizes are available for small seminars, and for larger groups an auditorium, complete with a projection booth and other essential aids, will seat about 250 people. A complete reference library—a virtual necessity for research—contains some 30 000 volumes and subscribes to about 500 periodicals. A cafeteria seating 240 persons makes the building almost a self-contained research "city".

Special facilities are a story in themselves, and too numerous to mention in detail. Among others are low-temperature facilities capable of carrying on experiments within a few tenths of a degree of absolute zero, a high-voltage laboratory, a technology laboratory equipped with metals processing equipment, chemical analysis devices, and other specialized apparatus of many types.

Although research without modern laboratory facilities may be possible, each year it becomes less feasible. Every probe into the unknown produces more unknowns, and brings with it new problems of experimentation. Without the necessary tools, research would proceed at a much slower pace. ■

(continued)

1—RESEARCH LIBRARY, an essential element to any well-equipped facility, contains some 30 000 volumes and subscribes to some 500 periodicals, including many in foreign languages.

2 and 3—MACHINE SHOP AND GLASS-BLOWING FACILITIES supply scientists' needs for test apparatus.

4—AUDITORIUM has a seating capacity of 250, and complete facilities for movies and slides. Projection booth at left, out of picture, has equipment for 16- and 35-mm film, as well as for slides. Behind the curtain on the stage are sliding panels containing blackboards; behind the sliding panels is the movie screen.

5—THIS PHYSICS LABORATORY is typical of the facilities at the new Research Laboratories. Even the relatively simple experimental set-ups shown here hint at variety of standard and special equipment needed.

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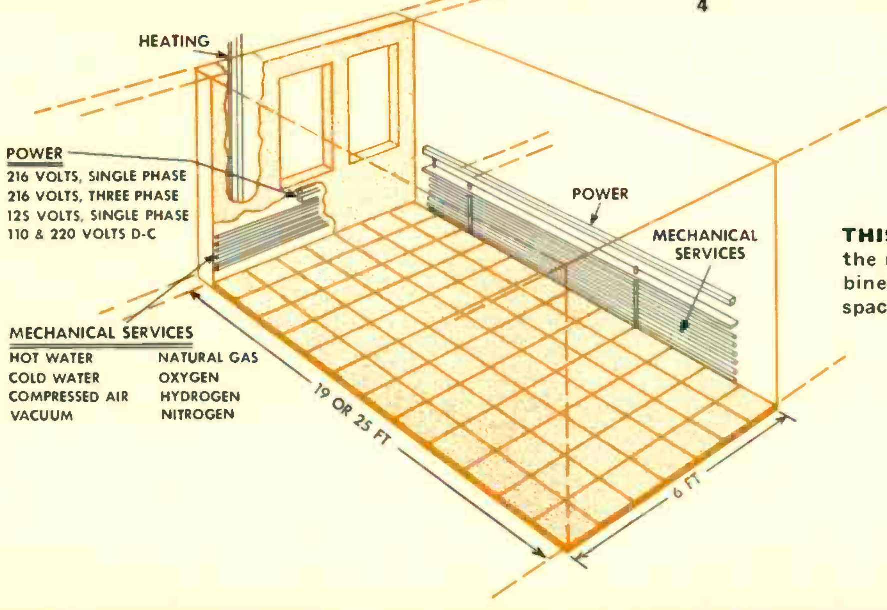

THIS LABORATORY MODULE is typical of those at the new laboratory. Several such modules can be combined to form one large facility. Office and drafting spaces are also modular, of slightly different design.

6—SPECIAL APPARATUS is typified by this laboratory-built high-temperature vacuum furnace. Experimental alloy in the furnace is heated to a temperature of 5000 degrees F. The furnace is used in a long-range program aimed at developing high-temperature alloys for the future.

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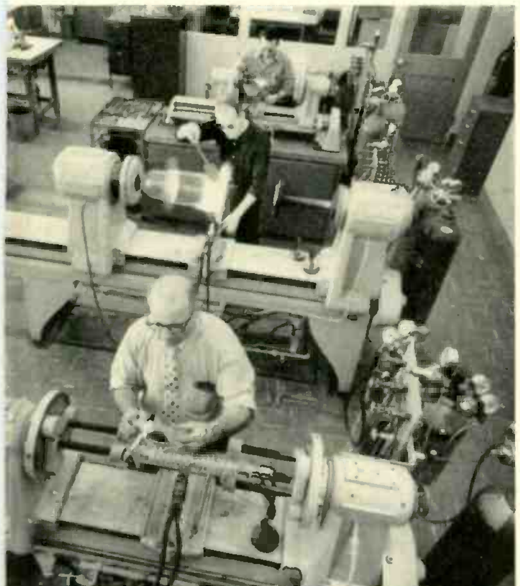

6

New Developments at the Laboratories

A test-pattern background silhouettes the Ebicon, a new type television camera tube being developed at the Westinghouse Research Laboratories. The tube operates on a new principle of electron multiplication, and promises to be 100 times more sensitive than the standard tube used in tv cameras.

Electroluminescence provides the light in this room. Walls and ceilings are made of panels no thicker than ordinary window glass, which provide light from man's newest source of artificial light.

This is Automex, a new "electronic brain" that can differentiate between right and wrong decisions and profit from its mistakes. Pictured is the set-up of a problem analagous to a man trying to climb a mountain in total darkness; the computer is required to get to the top in the least number of steps and the shortest time.

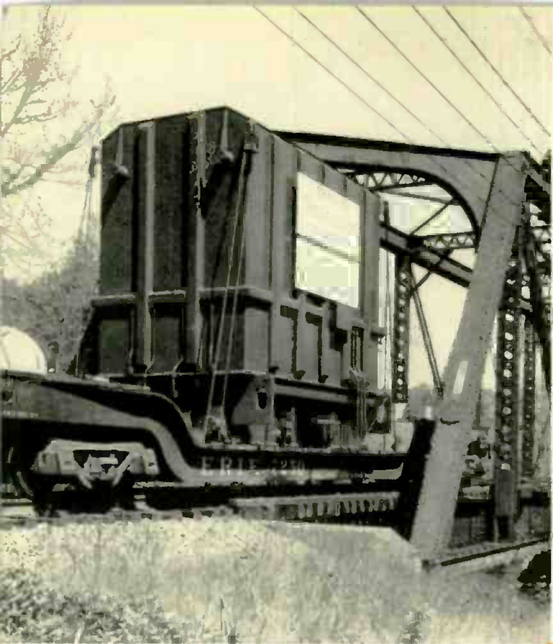

Fig. 1—A 220 000-kva, 161/17-kv, three-phase generator transformer loaded on railway car for shipment.

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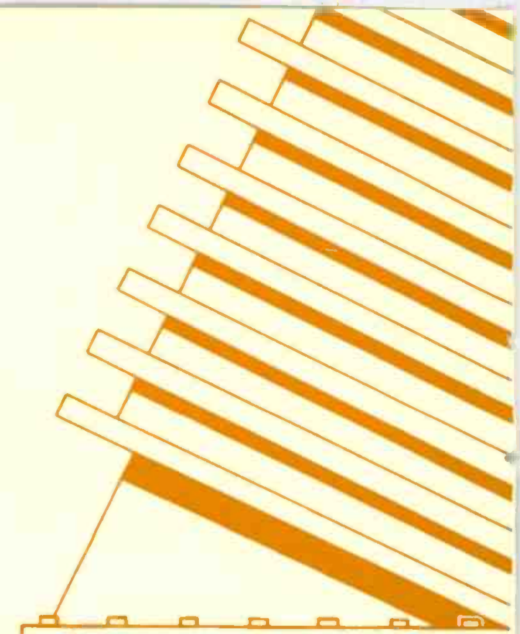
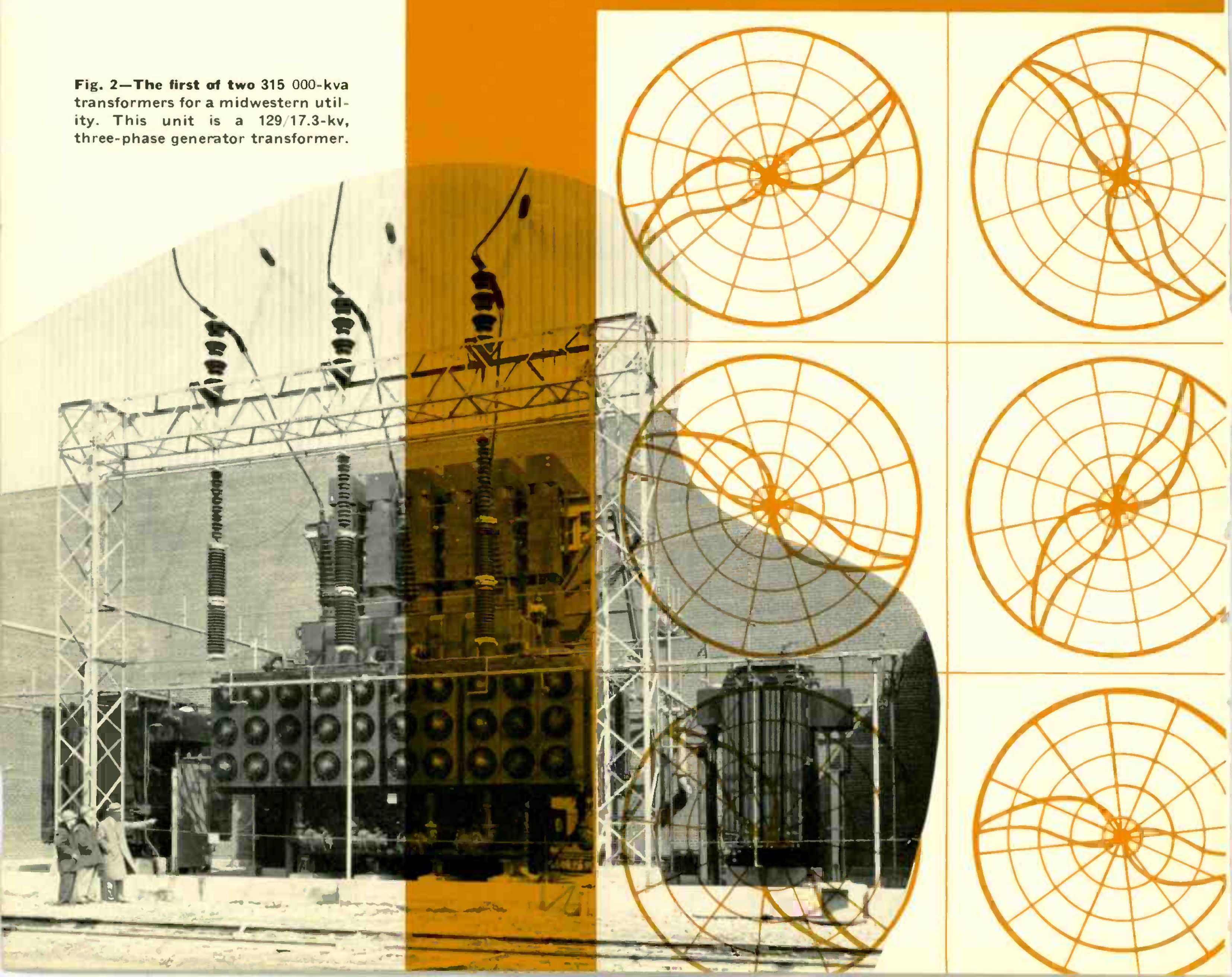


Trends in Power Transformers

Fig. 2—The first of two 315 000-kva transformers for a midwestern utility. This unit is a 129/17.3-kv, three-phase generator transformer.



TODAY'S POWER transformers clearly reflect the rapid growth in the use of electric power. Records are being made and broken frequently in transformer rating. Concurrently, new developments are being introduced to expand the usefulness and simplify the application of these modern power transformers.

At present, no single type of design fills the bill for the complete range of transformers necessary to meet modern requirements for power and distribution circuits. Therefore two basic designs—the shell-form and the core-form—have been applied to best advantage. For ratings greater than 15 000 kva and for voltages higher than 138 kv, shell-form construction has many desirable features; for power transformers from 250 kva through 15 000 kva and voltage ratings through 138 kv, experience has shown that core-form construction is most suitable. Consider, then, some of the recent developments in these basic types.

Developments in Shell-form Transformers

Kva Rating—A phenomenal increase in transformer ratings has characterized the last few years—and is still continuing. A mere 10 years ago the first unit rated 100 000 kva was built. Yet in 1952 several 190 000 kva units were constructed. By 1954 the maximum rating had risen to 220 000 kva (Fig. 1). In 1955 the first of two 315 000-kva generator transformers was shipped (See Fig. 2). Now on order are additional units ranging from 325 to 380 mva. This means nearly a four-fold increase in 10 years. These units are all full-winding transformers. In the field of autotransformers two record-setting 400 000-kva units have already been shipped. A view of the core-and-coil assembly of this 330-kv design is shown in Fig. 3.

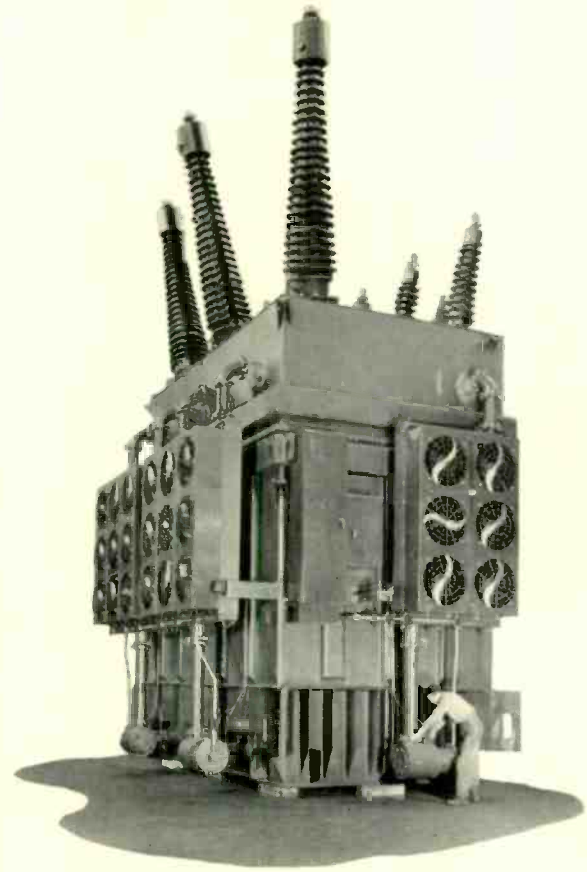


Fig. 4—One of the first 150 000-kva, 330-kv, three-phase autotransformers, built in 1953.

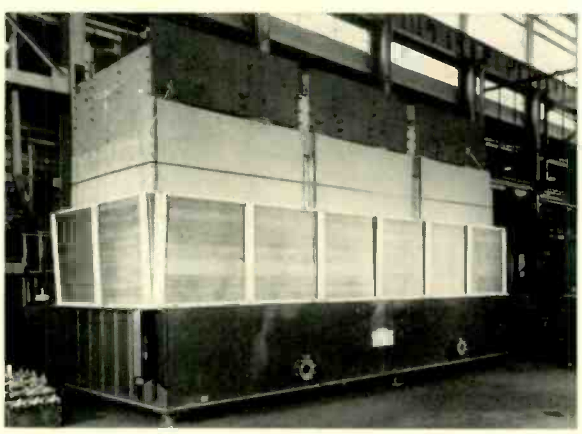


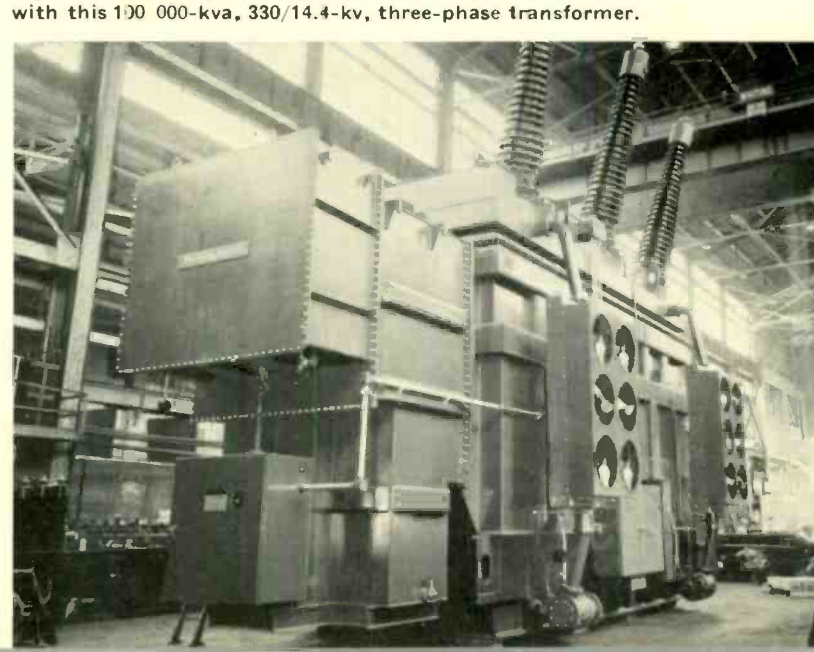
Fig. 3—Core and coils of 400 000-kva, 330-kv autotransformer.

This tremendous increase in rating has necessitated rapid advances in transformer technology. Fortunately, these advances—in materials, processing, and design techniques—have been forthcoming. Corona-free insulation, involving the placement of solid insulation parallel to equipotential surfaces, reduced internal clearances as well as eliminating corona. Oriented electrical steel provided a higher quality material capable of handling higher flux densities, thus reducing core weight while decreasing the core loss. Directed-flow high-volume forced-oil cooling, with its more efficient heat transfer, reduced copper requirements while decreasing hot spot temperatures. Finally, the shell form-fit design, by integrating the structure of the core and coils and the tank, reduced weights and dimensions, while increasing mechanical stability and structural strength. These four major advances have contributed greatly toward making the present higher rated units possible within reasonable limits of both size and weight.

The trend to larger individual ratings has been stimulated by the economics inherent in large single units. These include lower initial cost per kva, lower installation costs, and finally, lower operating costs because of lower loss per kva of rating. These economies, coupled with the growing recognition of the inherent reliability of modern power transformers, have greatly accelerated the increase in unit ratings.

Voltage Rating—A milestone in higher operating voltage was set in 1935 when the first units were built for the Los

Fig. 5—Tap-changing-under-load equipment is included with this 100 000-kva, 330/14.4-kv, three-phase transformer.



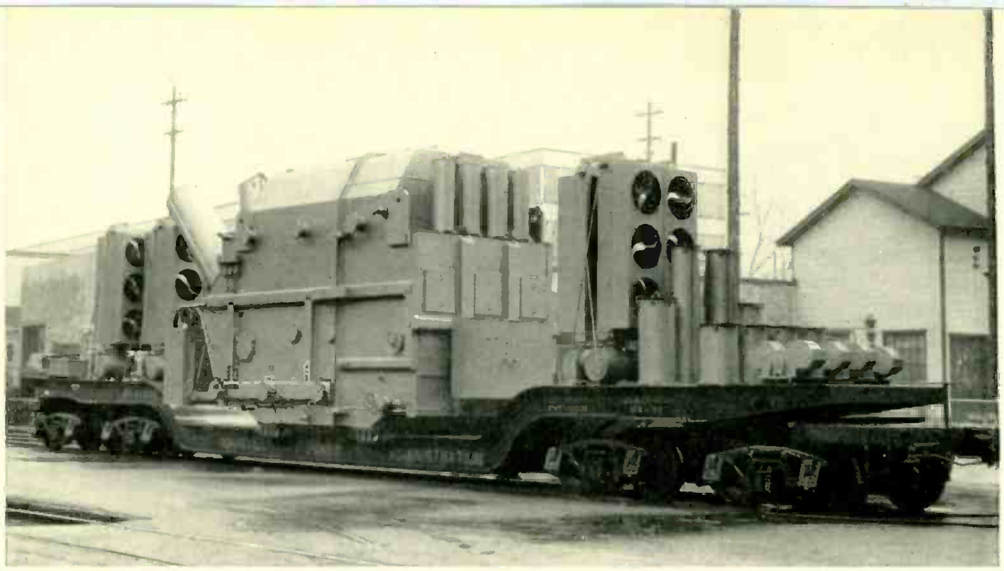


Fig. 6—Railway portable transformers also are reaching new sizes. This is an 83 333-kva, 220/115/13.2-kv, single-phase power transformer.

Angeles-Boulder Dam transmission line. These units brought the operating voltage to a new high of 287 kv. In 1946 experimental units were built for use up to 500 kv and were installed at Brilliant, Ohio. These were part of an experimental extra high voltage installation involving transmission lines, switches, breakers, and associated station equipment. The transformers were in active use for several years.

Nevertheless, as far as commercial installations in this country were concerned, 287 kv remained the highest operating voltage for 18 years. Finally, in 1953, the limit was raised to 330 kv when the first 330-kv, 150-mva autotransformers were built (Fig. 4). A total of 12 of these units have been built since that time. These autotransformers were followed by a series of generator transformers and transformers with tap-changing-under-load equipment (Fig. 5). All in all more than 5 000 000 kva of 330-kv power transformers have been built by Westinghouse.

Although the step to 330 kv was more spectacular, the trend to higher voltage on existing systems is just as significant. Systems originally 69 kv are now being boosted to 115 or 138 kv. Systems at 138 kv are being boosted to 230 kv. In general, the larger blocks of power being generated and transferred between systems have necessitated these increases in operating voltage.

Reduced BIL—One deterrent to increased operating voltage has been the increase in cost of terminal equipment, such as transformers, with increase in operating voltage. The continuing trend toward reduced insulation levels for higher operating voltages has markedly decreased the cost differential involved. Reductions in BIL of one level in the range of 115 to 161 kv and one and one-half levels of 230 kv and above are now common practice. Reductions of two BIL levels have been supplied in those cases where system grounding and operating voltages permit. For example, most new 138-kv designs are now insulated for 550 kv BIL and several are in operation at 450 kv BIL. Similarly, most negotiations for new 230-kv transformers are for 825 BIL, while some are for 750 BIL. This reduction in BIL level and its attendant reduction in cost has undoubtedly accelerated the trend to higher operating voltages.

The trend toward lower BIL has been made possible by the continued improvement in lightning-arrester characteristics. As a result, transformers with reduced BIL today can usually be provided with more protection against lightning surges than was possible 20 years ago with full BIL insulation. Reduced level insulation, especially two-step reduced insulation, does require investigation of possible low-frequency system overvoltages. This establishes whether the proper arresters can be applied and whether sufficient margin in low-frequency strength is available.

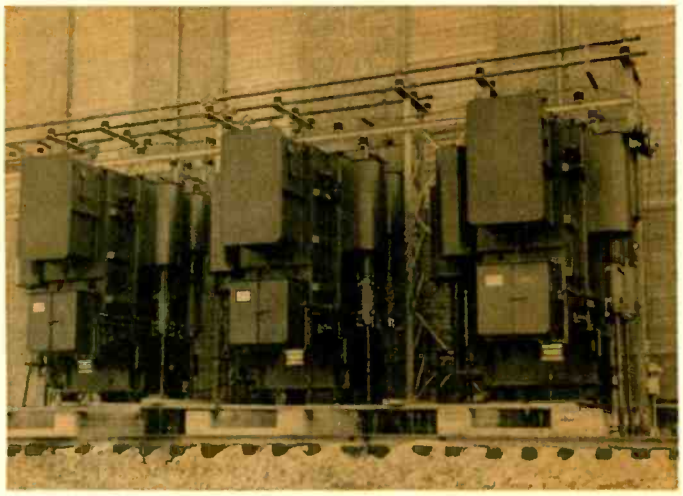
Autotransformers—The use of autotransformers has been increasing steadily. Since only part of the through kva undergoes any transformation, the size, weight, losses, impedance, and cost are lower than that of a comparable two-winding transformer. The savings in cost is most favorable where a minimum of taps are used. With the continued trend toward increased operating voltages, autotransformers are often used as ties between systems or portions of systems at different operating voltages. When used as an interconnection between transmission lines at different voltage levels, the series impedance of the lines tends to compensate for the lower through impedance of the autotransformer. The 150 000-kva, 330-kv autotransformer in Fig. 4 is used as a tie between an existing 138-kv system and a new 330-kv system.

Another application of autotransformers is to provide small differences in voltage in portions of an existing system. The 400-mva unit in Fig. 3 represents an application of this type.

Mobile Transformers—Paralleling the general increase in power-transformer activity has been an increase in mobile or portable transformers. These fulfill a double purpose. Primarily, they are used as standby units to permit regular maintenance schedules on existing installations without loss of service. At the same time these units serve as emergency spares in case of field troubles.

Since mobile units are frequently moved over public highways, their size and weight must be kept within specified limits. The same advances that have kept the size and weight

Fig. 7—A bank of single-phase transformers with oilostatic termination chambers. These are 26 000-kva, 115-kv transformers.



of "super" rated units within reasonable limits are used to the full extent in building larger and more effective mobile units today. One additional advantage of the shell form-fit design that favors its use on mobile units is that it can be mounted horizontally with bushings at each end. This greatly reduces the height of mobile units, permitting them to stay below critical overpass clearances on the highways.

A new trend in mobile units is the railway portable power transformer. In this application the railway car is designed expressly for the power transformer and its accessories. The unit can then be moved to different parts of a system by rail with minimum delay. One design of this type, shown in Fig. 6, is an 83 333-kva single-phase unit. Another design is a 50 000-kva three-phase unit (Fig. 10).

Oilostatic Cable Terminations—While oilostatic cable lines have been brought into power stations for some time, usually they have been terminated at some point separate from the equipment being fed. A new development is an oilostatic termination chamber for power transformers. In this arrangement the transformer bushings are mounted in oil-filled pockets on the side of the transformer. The bushings act as seals between the high-pressure cable oil and the low-pressure transformer oil, in addition to their normal function as winding terminations.

Several power transformers have been built with these oilostatic terminations. An installation of a bank of single-phase units is shown in Fig. 7. In this case both the 46- and 115-kv windings have oilostatic termination chambers.

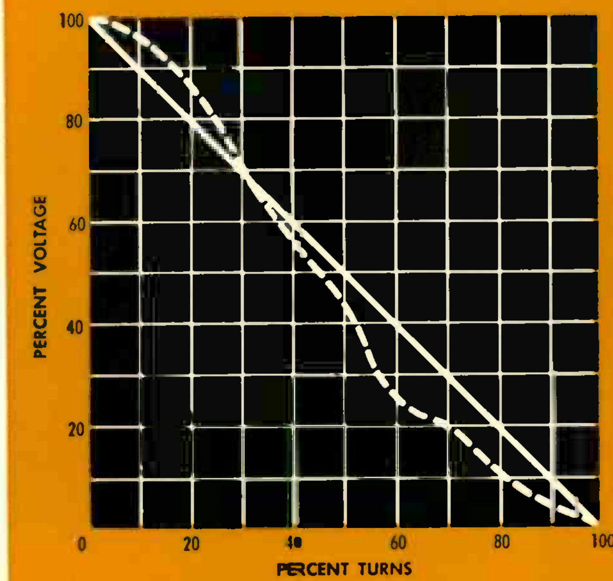


Fig. 8—Initial impulse voltage distribution curve for a low ground capacity (Lowgrocap) winding.

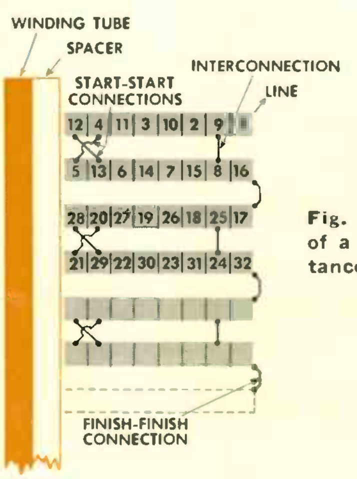
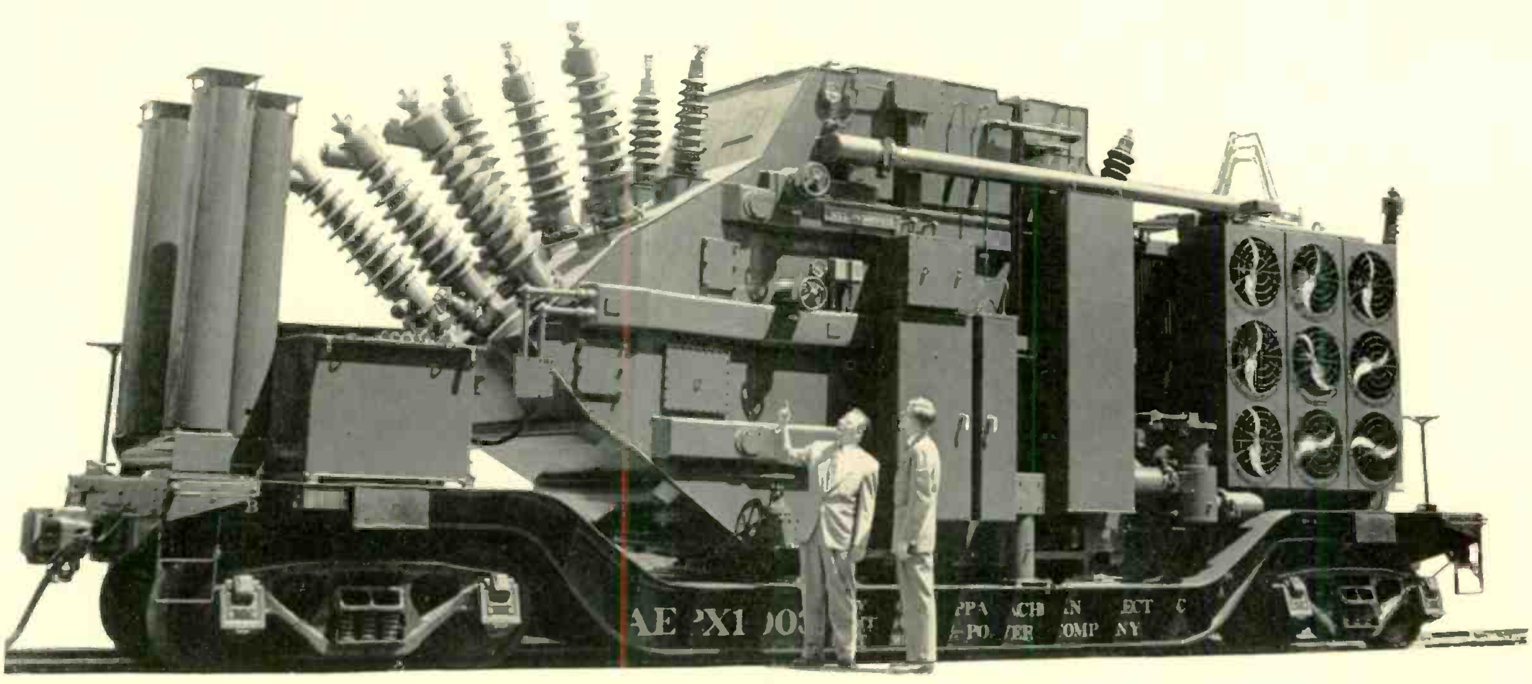


Fig. 9—A sectional view of a high series capacitance (Hisercap) winding.

Developments in Core-Form Transformers

New Types of Windings—For the 250–333 and 500 kva, single phase and all three-phase ratings up to and including the 750 kva, and in all voltage classes up to and including the 34.5-kv class, a completely new design of winding called Lowgrocap is being used. When calculating the surge distribution of a transformer, the designer must take into consideration three inherent capacities of the transformer. These are: coil-to-coil capacity; layer-to-layer capacity; and the capacity-to-ground. The surge distribution factor is directly proportional to the square root of the ground capacitance divided by the sum of the coil-to-coil and the layer-to-layer capacitance. The distribution factor should be kept as low as possible and

Fig. 10—This is a three-phase, 50 000-kva, 132-kv railway portable transformer.



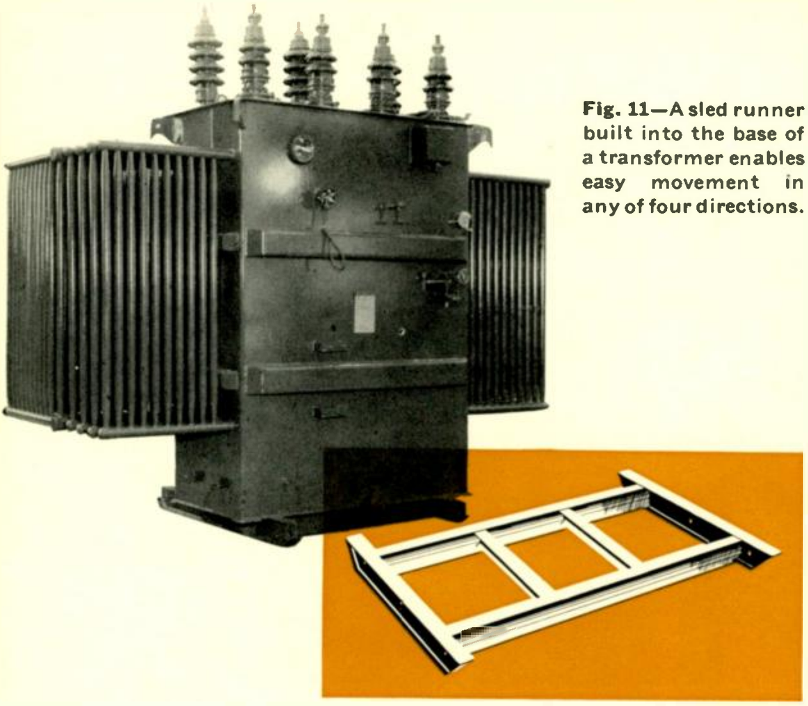


Fig. 11—A sled runner built into the base of a transformer enables easy movement in any of four directions.

this is accomplished by the Lowgrocap design. This winding, as its name indicates, is designed specifically to have a low ground capacity, which gives ideal surge-voltage distribution across the winding. A typical voltage distribution curve for this type of winding is shown in Fig. 8.

The mechanical structure of the Lowgrocap transformer has been greatly simplified by the use of maple for the supporting members and lead supports. This has made it possible to reduce the weight of these ratings by ten percent.

For the large kva sizes and for voltages above 69 kv the Hisercap winding has proved superior to other types of windings. By a unique method of winding, the turns are arranged to greatly increase the series capacitance, which also gives uniform distribution of surge voltage across the winding.

A sectional view of part of a Hisercap winding is shown in Fig. 9. The series capacitance of two of these sections is many times greater than the turn-to-turn capacitance in two of the conventional pancake sections. The two high-series-capacitance sections are similar to two wound-type capacitors connected in parallel with a voltage between the electrodes equal to half the voltage between sections. There is also series capacitance between the sections that are connected finish finish. This is in parallel with the turn-to-turn capacitance and adds to it, thereby increasing the series capacitance.

To check the balance of the dielectric characteristics of these transformers, many of them are being impulse tested as a regular quality control procedure. This test is essentially the same as the impulse test recommended by ASA, that is: one reduced full wave, two chopped waves, and one 100-percent full wave. The main difference is that a positive and negative tolerance of five percent on the voltage amplitude is permitted. This test is applied to line leads of each winding, and complete records, including oscillograms, are taken.

Oil Maintenance—Moisture in the oil of a transformer can soon lead to insulation failure. When moisture is present it tends to collect at the lowest point of the transformer tank; oil samples must be taken from the place where moisture is likely to collect. A sump in the bottom of the tank from which oil samples can be drawn provides a means of collecting the moisture and affords a means of accomplishing complete drainage of the tank when this is necessary.

The only internal parts of a transformer that are subject to deterioration under normal operating conditions are the oil and insulation. To combat this, many schemes for oil protection have been used, such as open air breathers, dehydrating breathers, conservators, gas oil seal, sealedaire, sealed tank and inertaire. For the past 12 years a number of transformers have been on life test to prove the effectiveness of these various schemes. These tests have proved that sealing the transformer to exclude oxygen is the most effective.

New Bushing Designs—Two new designs of bushings are now available for application to power transformers. The type RJ bulk-type bushing consisting of a one-piece porcelain with a solid stud clamped to it is being used for voltage classes through 15 000 volts. The outstanding feature of this bushing is the metal flange, which is fastened and sealed by rolling the metal into grooves in the porcelain. This eliminates any porcelain shoulders, and any mechanical strains produced by clamping the flange on the gasket seat are not transmitted to the porcelain (Fig. 12).

The ASA standards now specify the physical dimensions of bushings for voltage classes 22 000 through 69 000 volts. Solder-seal condenser bushings for these voltage classes now meet all of the requirements of the ASA standards.

Three-coat Paint System—To protect the steel cases of transformers against the elements, they are now painted with a remarkable paint called Coastal Finish. Coastal Finish is a three-coat paint system consisting of the primer, intermediate, and finish coats. The primer or first coat is composed of a vehicle giving good adhesion and chemical resistance to salts, acids and alkalis. The second or intermediate coat is the key to the remarkable performance of Coastal Finish. The vehicle of the second coat is composed largely of alkyd resins with some additions of phenolic resins. The pigment is composed of mica flakes that overlap each other in the film to produce a "shingle roof" effect, which wards off moisture and oxygen. The mica also increases the heat stability as much as ten times at elevated temperatures. It also improves the coverage on sharp edges, thus reducing the tendency to corrode at these points. The third or final coat is composed of resins and pigments to withstand the elements and provide good appearance when new and after weathering has taken place. Under comparable conditions this finish has twice the life of any other finish commonly used on transformers.

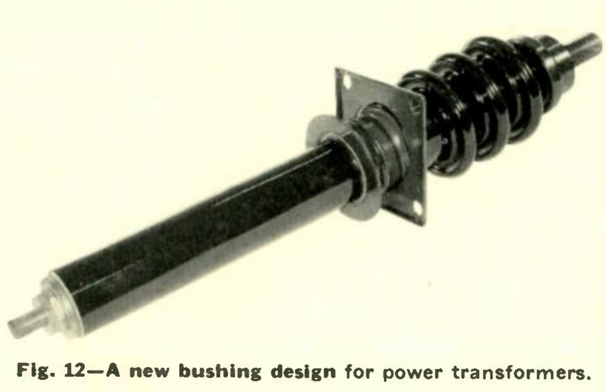


Fig. 12—A new bushing design for power transformers.

Conclusions

Power transformers are an indispensable element in the vast systems that channel electric power from generator to ultimate user. As such they are affected by changes that occur in electric utility practice, and by the increasing amounts of power transmitted. Advances in design and construction such as those outlined have made it possible to keep power transformers in pace with system requirements. ■

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DISTRIBUTION SYSTEM PROTECTION

A slight flicker of lights during a thunderstorm goes almost unnoticed to the majority of electricity consumers. Yet to the knowing, it is reassurance that a potential service outage may have been avoided. A lightning arrester detoured a stroke to ground, or a circuit recloser isolated a short circuit caused by a falling branch. These are typical examples of modern protective devices that insure service continuity on distribution circuits. Since distribution systems represent about half of the capital investment of the electric-utility industry today, the protection of distribution equipment and circuits warrants serious consideration. Many automatic devices have been developed specifically for radial distribution systems to improve service reliability and reduce operating costs, yet without seriously increasing construction costs. Typical of these devices are lightning arresters, fuse cutouts, automatic circuit reclosers, and automatic line sectionalizers.

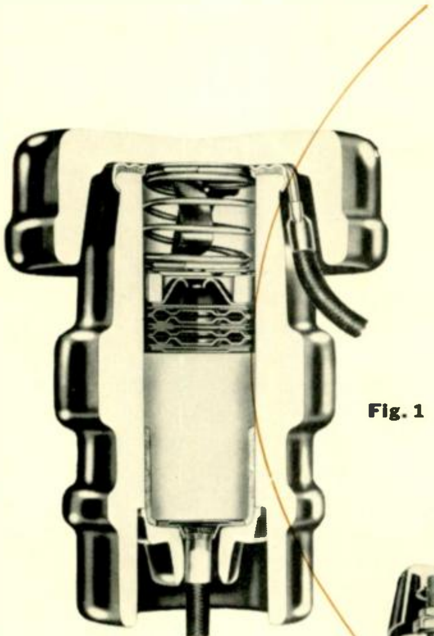


Fig. 1

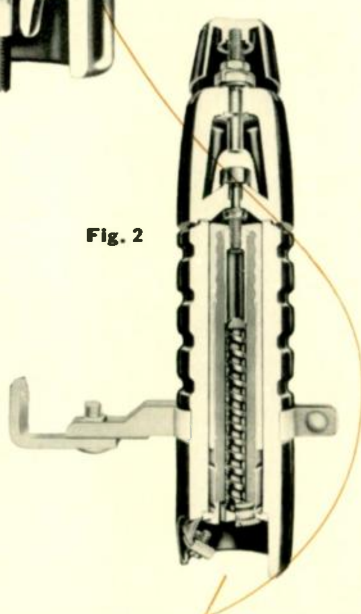


Fig. 2

Fig. 1—Autovalve arrester operation can be seen from this cutaway view. Isolating gap sparks over when lightning surges occur. Autovalve block becomes a good conductor while discharging high lightning surges, but limits current at line voltage to values readily interrupted by the quench gaps.

Fig. 2—In expulsion-type arrester, top series gap isolates arrester from the line, but sparks over when lightning surges occur. If a power-follow arc results, it is transferred from the original straight-line sparkover path to the much longer helical path in the spiral filler. The resulting higher arc voltage limits power-follow current and forces current zero, interrupting power-follow current.

Lightning Arresters

When lightning strikes a circuit, extremely high transient currents result. If impedance restricts these currents, the resulting high voltages may puncture or flash over insulation. Lightning arresters have been used for many years to prevent surge-induced damage to equipment. Distribution circuit arresters can be compared to very fast automatic switches connected line-to-ground. Normally, the lightning arrester is an open circuit, but will close at some predetermined voltage to provide a bypass for flow of surge current around insulation so that high voltages will not develop. The arrester reopens when the voltage has dropped, interrupting the flow of power system current which follows the surge current through the arrester to ground, thereby preventing interference with the supply of power to users.

The terms *valve* and *expulsion* are descriptive of the operation of the two basic distribution-arrester types. The valve arrester utilizes non-linear resistance elements and gaps to control the flow of current, while the expulsion type employs a blast of gas produced when the arc contacts gas-evolving materials to interrupt the power-follow current.

The valve arrester contains a series of gaps that sparkover at a predetermined voltage, and Autovalve blocks, which limit the voltage to a safe value while passing surge current to ground. After a surge has passed, the Autovalve blocks limit the power-follow current, so that it can be interrupted by the arrester gaps (Fig. 1).

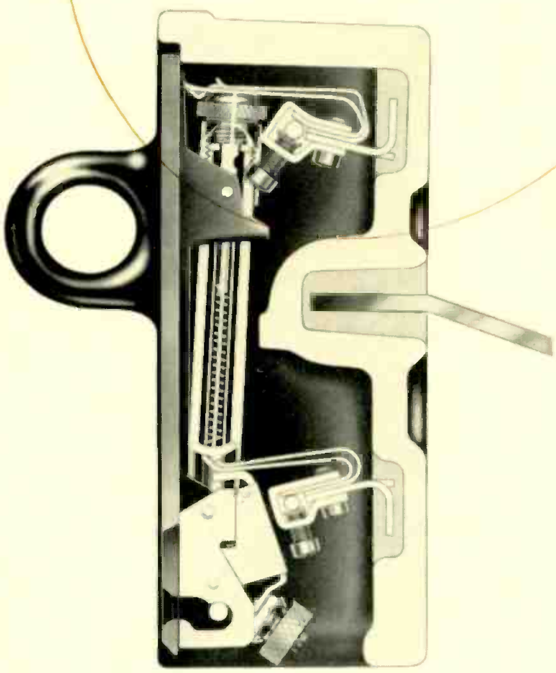
The operating characteristics of the expulsion arrester result from its unique mechanical construction (Fig. 2). During normal system operation, the arrester is isolated from the system by a series gap. When a surge voltage sparks over the series gap, the surge current takes the shortest path to ground. The arc extends from the top electrode to the bottom electrode through the space between the bore of the fibre tube and lands of the spiral filler. Power-follow current follows the surge current to ground, generating gas from the fibre tube and filler. The discharge of this gas along the spiral path of the filler carries along with it the power-follow arc. The arc path is thereby elongated to approximately four times the original sparkover distance and causes an increased arc voltage; as a result, current interruption takes place in a fraction of a half cycle of system voltage.

Fuse Cutouts

The occasional occurrence of short circuits on distribution systems is inevitable. Fuses are intentional "weak links," installed to interrupt fault current before damage to other circuit components can occur. Judicious selection and placement of fuses minimizes the loss of service caused by a fault at a particular location.

A fuse link is a length of flexible cable connected to a fusible element de-

Fig. 3—Enclosed fuse cutouts can be used for distribution-system equipment or circuit protection. Fuse link clamped under the lower knurled nut holds toggle mechanism in restraint. When the fuse link blows, toggle mechanism is released, allowing door to drop open. This action is aided by the 20-degree angle from vertical at which the cutout is mounted. Enclosed cutouts are rated up to 7800 volts, with current-interrupting capacities up to 14 000 amperes, symmetrical.



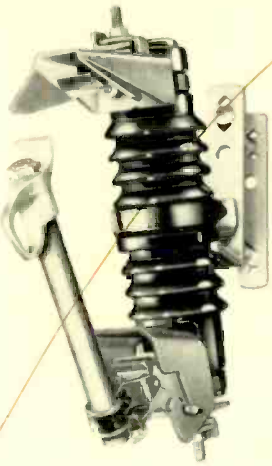


Fig. 4—Open dropout cutouts (Type DX) can be applied for distribution system equipment or circuit protection plus disconnect or load-break applications up to 15 000 volts. Its continuous-current rating is 100 amperes, with a 200-ampere disconnect-blade rating. The unit's interrupting capacity is 5000 amperes maximum.

signed to melt in response to overcurrents. Fuse links are generally interchangeable and can be used in variety of fuse cutouts. Fuse-link designs have tended toward a certain degree of standardization to permit interchangeability between the various current ratings and various equipment manufacturers.

However, standardization in cutouts ends with the fuse links—there are many styles of cutouts, and application problems dictate the need for two distinct types, the enclosed and the open cutout (Figs. 3 and 4).

The *enclosed* fuse cutout is a porcelain enclosure with unexposed contacts and line terminals designed to receive a fuse holder, which is generally a fibre tube fixed to an insulated hinged door. The door is generally removable to allow convenient fuse link replacement. The enclosed cutout is used primarily where the exposure of live parts would be objectionable.

The *open* cutout performs the same functions as the enclosed cutout. It consists of an insulator, which supports the hardware, contacts and line terminals. A fuse holder installed between the two stationary contacts completes the fusible circuit for the protection of distribution lines or equipment. The open cutout (Type DX) has a very effective load-break attachment. By pulling down on the operating lever, the fuse link is broken within the fuse tube, interrupting the load current as in a regular fuse-blowing operation. The load-break device requires little effort when breaking even the largest link that is used in the cutout. The link is stretched to insure interruption even at low currents. Contact pressure is maintained during the entire link elongating and breaking operation because the force applied to break the link keeps the cutout closed.

Fuse cutouts protect circuits against outages caused by apparatus failures. They are also frequently installed to sectionalize portions of circuits that may experience faults. The protection thus achieved is positive, but has the disadvantage that cutouts, which usually are one-shot devices, do not distinguish between permanent faults and those faults that can be cleared by momentary current interruptions. Because of their simplicity and resultant low cost, millions of fuse cutouts are in use, and many more are installed each year.

Automatic Oil Circuit Reclosers

A majority of faults other than those caused by equipment failure can be cleared by momentarily interrupting the current.

Experience has shown that of the faults cleared by opening and reclosing circuits, a high percentage are cleared by the first opening, and a few additional faults are cleared by the second opening. Further re-opening or reclosing of the circuit results in very little additional benefit. A major improvement in service continuity can be obtained by utilizing automatic apparatus, which will clear all temporary faults or localize permanent faults. The search for a device to provide reclosing operations and avoid the nuisance of line lockouts following temporary faults led to the development of oil circuit reclosers. These devices utilize bimetallic elements or series-connected solenoids to operate oil-immersed circuit interrupters.

Several newer reclosers are shown in Fig. 5. These "dead-tank" reclosers are designed for operation between 2300 and 15 000 volts with continuous

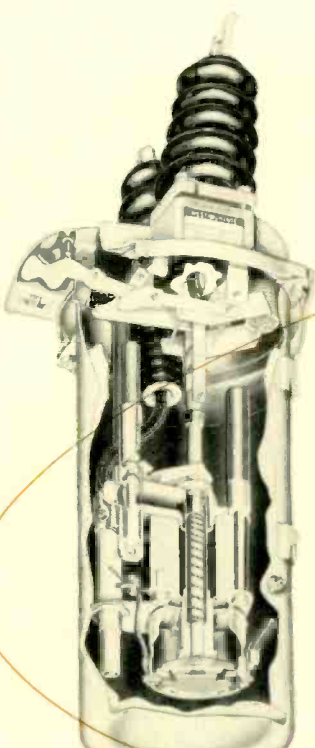


Fig. 5a

currents ranging from 5 to 100 amperes and a maximum interrupting rating up to 2000 amperes.

Proper application of reclosers to a distribution system insures that no service interruptions due to temporary faults will occur and that permanent faults will be limited to the smallest possible portion of the circuit. For example, when both reclosers and fuses are applied in a distribution circuit, fast initial operations are desirable when faults occur. This will minimize damage to fuses during temporary faults. After the first or second instantaneous operation, time-delayed operations are required to insure proper fuse blowing rather than recloser lockouts on permanent faults in fuse-protected sections of the distribution system.

The mechanical features necessary to obtain a predetermined sequence of instantaneous and time-delay operations are built into the recloser. Series solenoids detect overcurrents and provide operating power. An operation-counting member is combined with a time-delay element to provide such operating characteristics as: opening time inversely proportional to fault current; predetermined sequence of instantaneous and time-delayed operation, and a predetermined number of reclosures before lockout.

As higher interrupting and continuous current ratings are developed, reclosers are being applied to heavier circuits where three-phase installations are frequently encountered. Three-phase reclosers provide lockout of all three phases in case of permanent faults. Their individual pole units trip independently, but a preset number of successive operations of any will lock out all three phases.

The largest recloser extends the continuous-current rating to 400 amperes, and the maximum symmetrical interrupting ratings up to 6000 amperes (Fig. 7). Simultaneous tripping or closing of all three poles is accomplished

Simplified one-line diagram of a typical distribution circuit illustrates use of reclosers, sectionalizers, load-pickup switches, fuse cutouts, and lightning arresters.

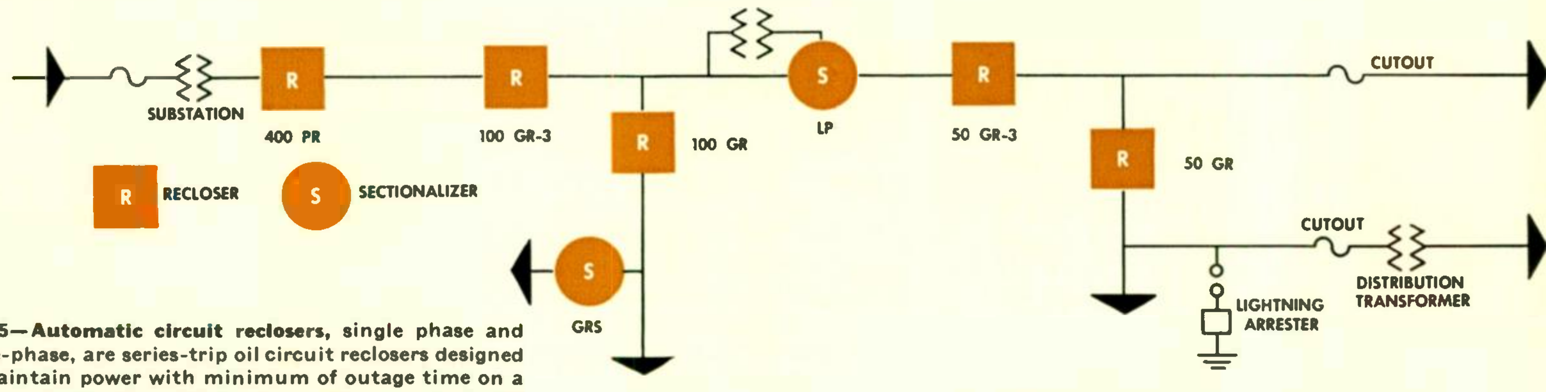


Fig. 5—Automatic circuit reclosers, single phase and three-phase, are series-trip oil circuit reclosers designed to maintain power with minimum of outage time on a rural and suburban distribution system up to 15 000 volts. When an overload or short circuit occurs, the reclosers instantly trip and automatically reclose after a short time interval. If the fault persists, this operation repeats until the recloser automatically locks open after the fourth trip. Maximum interrupting capacity of the 50-GR and 50GR-3 is 1200 amperes symmetrical.

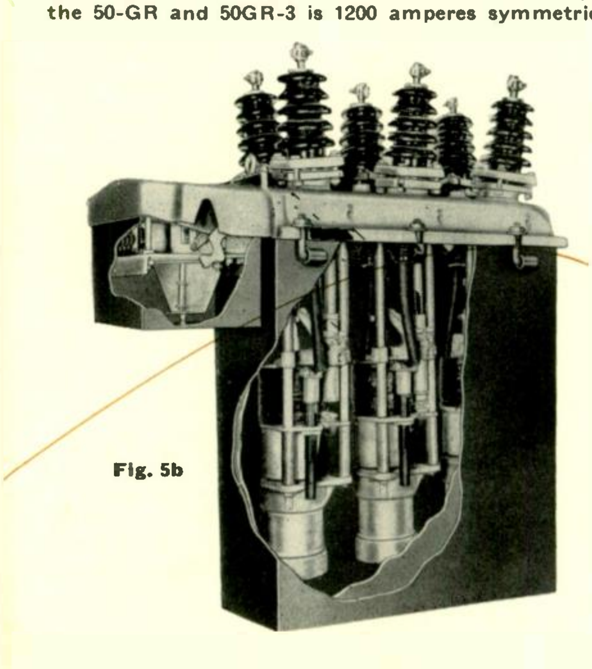


Fig. 5b

by a single motor-driven mechanism. Operation of all three poles at each operation assures clearing of every temporary fault. Overcurrent tripping time-delay devices are used with the recloser, and controlled independently of the motor mechanism. This permits a wide range of sequence, time-current-curve adjustments to permit coordination with other reclosers and with fuse cutouts. A series solenoid in each phase operates to trip open the recloser mechanism. Movement of each trip linkage is retarded by a pneumatic timer, in which a diaphragm forces air to escape through a needle valve. The effect of temperature changes on time delays is negligible. Instantaneous operation settings for the recloser are obtained by disconnecting the trip linkages from the timers.

The 400-ampere recloser is designed to accommodate multi-ratio bushing current transformers, which facilitates the application of relay-controlled tripping. This recloser can be applied to distribution systems that require ground-fault protection, differential protection, or other relay schemes. The unit comes ready for pole or substation frame mounting. A tank lifter, load instrumentation, and control auxiliaries are available.

Automatic Line Sectionalizers

Reclosers can be used to protect an entire distribution system, so that no line lockouts can be caused by temporary faults. Such applications are expensive, but can be justified economically. However, the same degree of

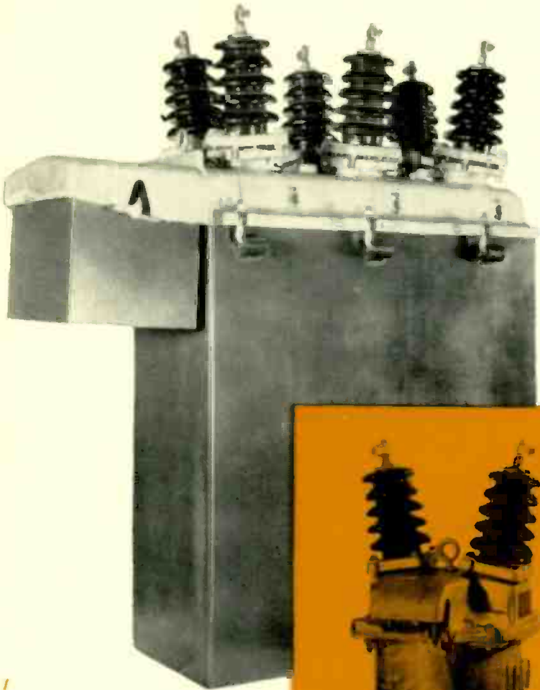


Fig. 6b

Fig. 6a

Fig. 6—Automatic circuit reclosers (Type 100-GR and 100-GR-3) are series-trip oil circuit reclosers designed for application on distribution systems up to 15 000 volts, 60 cycles. They have continuous-current coil ratings ranging from 25 to 100 amperes, with a maximum interrupting capacity of 2500 amperes, symmetrical. The Type 100-GR is a single-pole recloser while the 100-GR-3 is a three-pole recloser.

service reliability can be provided by replacing some of the reclosers with automatic line sectionalizers. The sectionalizer has a lower cost achieved by omitting the fault-current interrupter and the tripping time-delay mechanism. This sectionalizer (Fig. 8) is a 15-kv oil switch with a series-coil operated "brain" that recognizes excessive currents, counts the number of times such currents are consecutively interrupted and opens when a predetermined count is reached.

Sectionalizers must be used in series with reclosers or reclosing circuit breakers that interrupt and reclose when faults occur to actuate the counting member in the sectionalizers. The sectionalizer offers several advantages over a fuse: (1) It will not open on temporary faults, regardless of current duration. (2) It has no time-current characteristic subject to damage by previous faults or current surges. (3) It is an oil switch and can be used to break load for routine sectionalizing.

Cold-Load Pickup Switches

Even the extensive use of reclosers and sectionalizers does not preclude the possibility of permanent faults and the possible need for intentional outages for maintenance or construction. In many instances, service is difficult to restore after an outage. Difficulty occurs particularly when a large portion of the connected load on heavily loaded circuits consists of automatically controlled equipment such as refrigerators, pumps, air conditioners, etc.

For example, on a distribution circuit having 100 refrigerators installed, one-quarter of them probably will be operating at the same time. Simultaneous starts will be very infrequent. Thus during normal operation, random sequencing of operating times of the connected loads insures that only a portion of the total possible load is actually operating at a given instant. This diversity permits installation of distribution-circuit equipment that cannot carry all the connected load operating simultaneously. However, when a given circuit is de-energized, diversity decreases and is almost completely lost after 20 minutes. Loss of diversity and the fact that most electrical devices require starting currents higher than their continuous operating currents make it difficult to re-energize "cold" circuits without having the overcurrent protective devices operate. Therefore, many circuits require manual sectionalizing to divide them into parts that can be successfully picked up individually.

The load-pickup switch (Fig. 9) was developed for those circuits where re-energization difficulties have been experienced or are anticipated. This switch is controlled by built-in voltage-sensitive elements that cause its contacts to open at the end of a selected time delay following loss of circuit voltage. The switch remains open during the remainder of an outage and recloses at a predetermined time after voltage reappears. Hence, load-pickup switches automatically sectionalize a circuit into parts, which are successively reconnected when the circuit is re-energized. Proper application will keep the maximum currents low enough to avoid operation of the reclosers or circuit breakers, and makes manual switching unnecessary. Field experience has demonstrated automatic restoration of service to a circuit that had previously required as long as four hours to pick up manually.

Tripping time of the switch is controlled by an air-escape timer, and closing time delay is obtained from a socket-mounted, electrically heated, bimetallic strip relay. The required control power is taken from a distribution transformer on the source side of the switch.

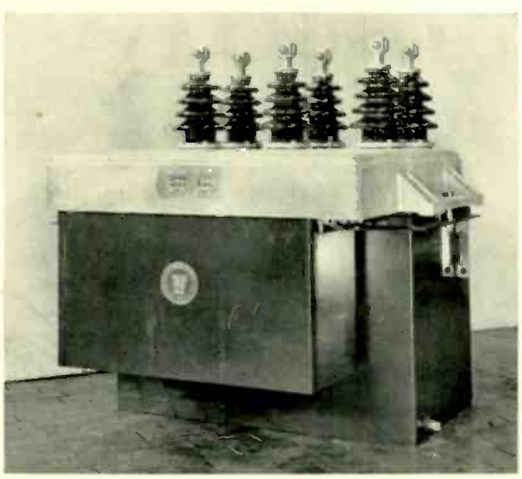


Fig. 7—This three-pole recloser (Type 400-PR) is designed for substation or line application on distribution systems up to 15 000 volts, 60 cycles with a maximum 6000-symmetrical-ampere interrupting capacity. For series or overcurrent tripping, continuous current coil ratings range from 25 to 400 amperes. Ground trip, shunt trip, or other relay protection schemes may be applied. The recloser can be frame mounted for substation applications, or pole mounted for line application.

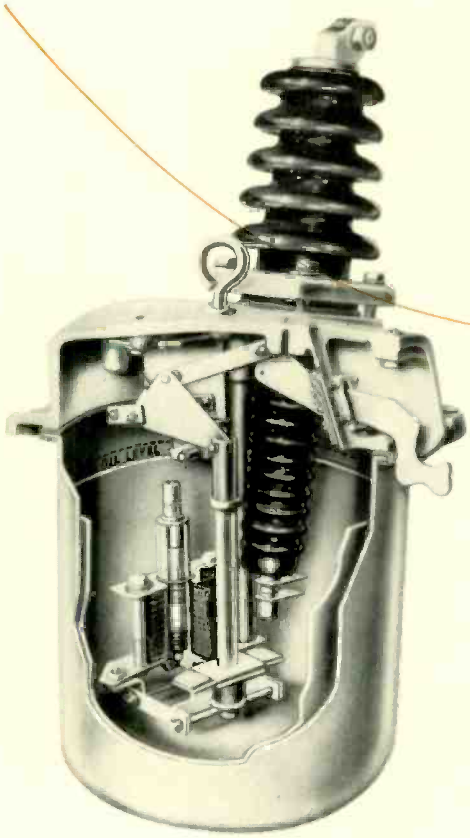


Fig. 8—Automatic line sectionalizers (Type GRS) are automatically tripped, single-pole oil switches, which are tripped open by a fault-current counter operated by the opening and closing of the preceding recloser or reclosing circuit breaker. Tripout can be preset to occur after either the third, second, or first operation. Sectionalizer contacts are tripped open only when the circuit has been opened by the preceding recloser, so that a fault interrupter is not required in the sectionalizer. Sectionalizers are available in ratings from 5 to 40 amperes, 15 000 volts, with a momentary rating of 6500 amperes symmetrical.

Distribution System Protection

To improve service reliability to the consumer at minimum cost, proper and efficient use of the available distribution system protecting tools (reclosers, sectionalizers, cutouts, load-pickup switches, and lightning arresters) require thorough data covering system characteristics at many locations on the distribution circuit. Each system contains many variables, making it difficult to cover all applications here. Economics dictate the type, and number and location of protective devices needed. The selection is determined by type of fault and system outage time, revenue losses, and evaluated customer good will. Several fundamental requirements must be met when coordinating protective devices: (1) The protective device must have sufficiently high voltage rating. (2) The continuous-current rating must be adequate. (3) The interrupting and momentary rating of a device must be greater than all faults that can occur beyond it. (4) The minimum short-circuit current at the end of the section protected by a device must be high enough to operate it. (5) Consideration must be given to coordination of the time-current characteristic of series-connected devices. If distribution systems are subject to outages, and service continuity is important to reduce costs, protective devices can be found.

Solutions to many of the problems confronting distribution system designers lie in the use of the apparatus recently made available. Many types and ratings of distribution-circuit protective devices have been developed to solve specific problems. The one feature common to all of the devices described is that they are tools that aid in making power distribution more reliable, and more economical.

As acceptable standards of service reliability become more stringent and voltage and current levels are raised, additional new apparatus will be required. Developments will include increased ratings, combinations of existing devices, and radically new designs not even resembling those presently used. There is no end in sight to the demands for new types of distribution equipment. ■

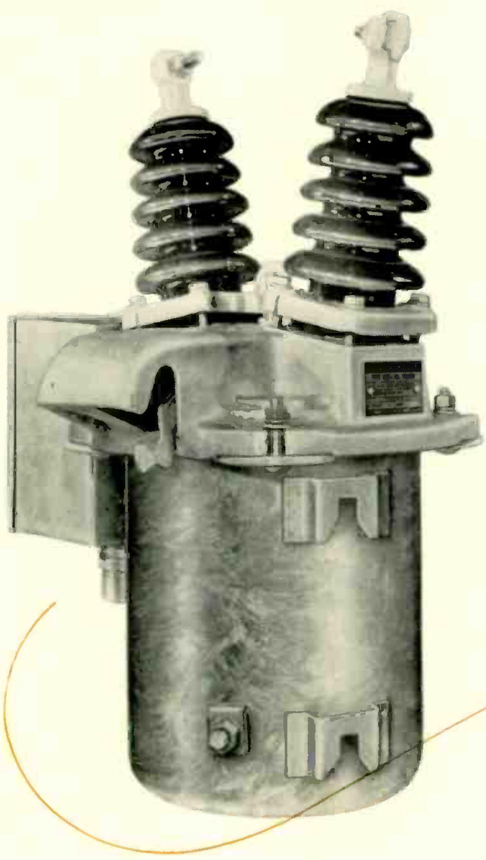
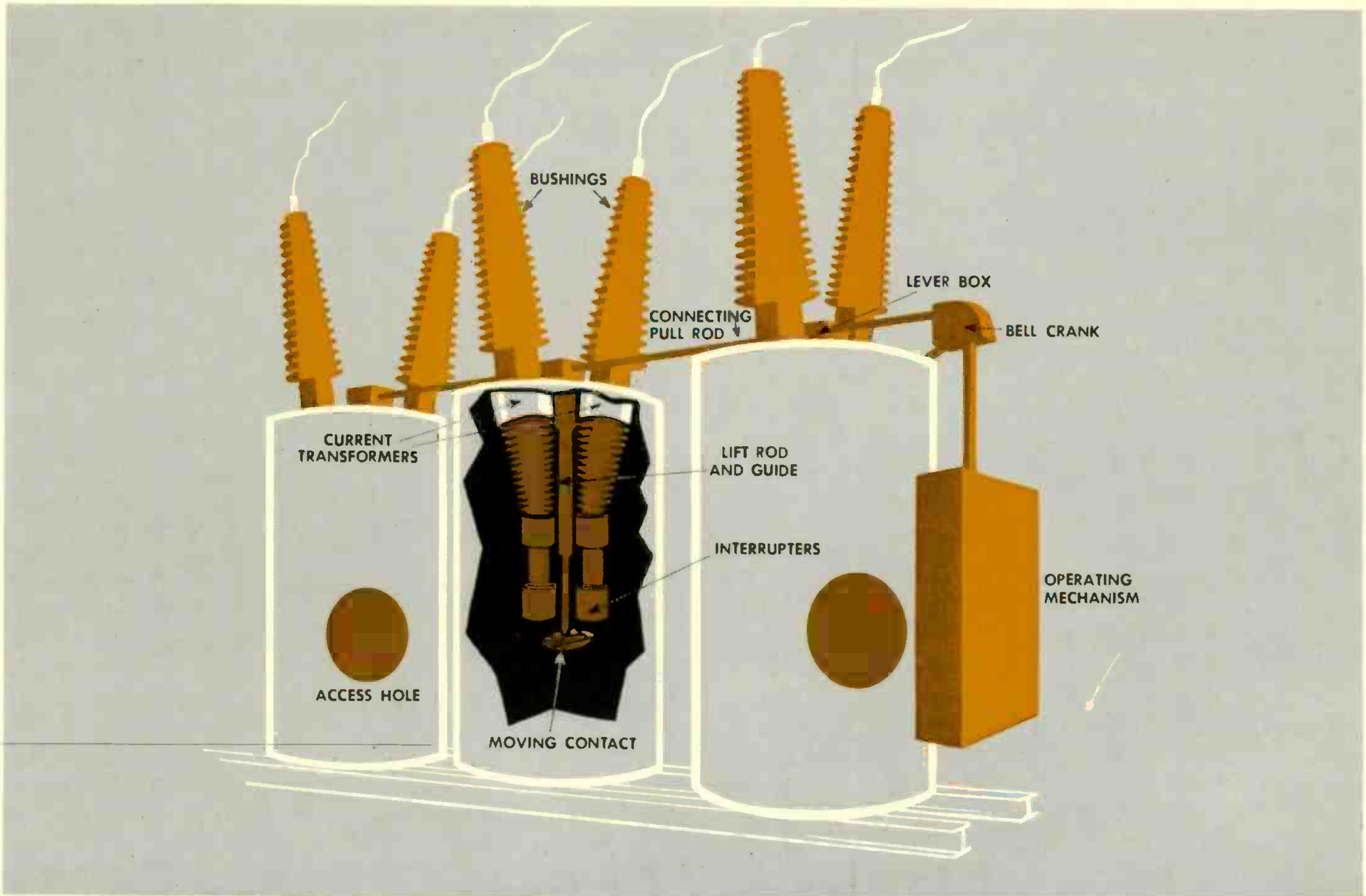


Fig. 9—Load-pickup switch is a 200-ampere, 15 000-volt cold-load pickup switch, which automatically sheds and picks up load as a function of voltage and time. It also can be used as a 200-ampere load-break switch. The LP can be used as a single-pole device for crossarm or direct-pole mounting, or three poles can be channel mounted for three-phase use. It has a momentary rating of 6500 amperes symmetrical.



Rebuilding Oil Circuit Breakers

from 3500 Mva to 10 000 Mva

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TREMENDOUS INCREASES in short-circuit currents over the past few years have presented power-system operators with the real problem of matching circuit-breaker capacities to system requirements. Fortunately, advances in interrupter design and efficiency, together with liberal size of most older circuit-breaker designs permits substantial up-rating by in-place revamping.

This was demonstrated recently by the modernization and up-rating from 3500 mva to 10 000 mva of two 161-kv Westinghouse breakers at a substation connected to the TVA system. The field work was done by the regular maintenance personnel. Tests on the completed job, with new operating mechanisms and roller bearings throughout, demonstrated the ability of the circuit breaker to open in three cycles and reclose rapidly.

These breakers had originally been installed some 12 years ago and had seen substantial service. Revamping to such a high capability required major changes—replacement of almost everything in the tanks but the current transformers. Surge suppressor chambers were welded into the tanks to absorb the shock pressures of the new rating. Bushings were replaced with new heavy-duty type "O" condenser bushings. New roller-bearing lever and linkage system, and pneumatic operating mechanism were installed and a manhole was cut into the tank wall for convenient entrance.

After rebuilding, tripping operation, timing, and other characteristics were checked and adjusted, and the breakers released for service.

Fig. 1—Simplified diagram of a circuit breaker, showing the parts replaced (in color).

Advantages of Rebuilding

Revamping not only costs less than a new breaker of the required capability, but requires less time because parts can be procured more quickly than the entire breaker. Doing the work on the spot with available construction and maintenance personnel also provides excellent opportunities for training. The modern operating characteristics attained eliminate the problem of finding a place where an old breaker can be reinstalled without modification, and saves moving expense.

This program grew out of the rapid increase in TVA generating capacity during the past 20 years. This growth has required almost continuous review of the adequacy of existing 161-kv breakers. When their ratings are exceeded, four corrective methods are investigated: (1) Install bus reactors. (2) Revise line connections to permit split-bus operation. (3) Replace existing breakers with breakers of adequate rating. (4) Rebuild existing breakers to a suitable higher rating.

Bus reactors have not been installed at any of the generating plants on account of cost, space, and operating factors. Split-bus operation is used in two of the steam generating plants where the duty is such that the largest available breaker at this time, 10 000 mva, was not adequate. This type of operation has disadvantages in flexibility.

Replacement or rebuilding of breakers has been used extensively. At present, a total of 357 breakers, furnished by three manufacturers, of the 161-kv class are installed in 20 hydro and 6 steam plants. Of the 113 breakers installed in the hydro stations, 72 percent have been revamped to higher interrupting capacity, and 27 percent have been transferred from other stations where they were replaced with new breakers of increased rating. (There is some duplication in these figures since a large part of the transferred breakers have had improvement parts installed.) In addition, a large number have been transferred to step-down substations.

All of the 1500-mva and many of the 2500-mva breakers originally installed have been improved to the 3500, 5000, or 7500 mva rating. In these cases the original bushings were not replaced, and except for the one installation where breakers were revamped to 7500 mva, the pole-top boxes were not replaced. In practically all cases, solenoid-type operating mechanisms were replaced with pneumatic-type as required by the heavier contact loading, or to reduce interrupting and reclosing times.

The relative costs of improving existing breakers as compared to replacing with new breakers varies widely as illustrated in the following tabulation. Case A covers the installation of new interrupters, lift rods with guides, and operating mechanism. Case B requires the installation of new pole-top lever boxes as previously described in addition to the parts required for Case A. Case C is similar to B, except new replacement bushings are required to obtain the required mechanical strength. (All costs are stated in per unit of new breaker cost of the required rating.)

	Case A	Case B	Case C
Existing breaker rating—mva	1500	3500	3500
Required breaker rating—mva	5000	7500	10 000
INSTALL NEW BREAKER OF REQUIRED RATING			
New breaker cost f.o.b. site	1.00	1.00	1.00
Install on existing foundation	0.04	0.03	0.03
Total installed cost	**1.04**	**1.03**	**1.03**
Net salvage value, replaced breaker	0.24	0.57	0.54
Total net cost	**0.80**	**0.46**	**0.49**
IMPROVE EXISTING BREAKER TO REQUIRED RATING			
Improvement parts cost f.o.b.	0.34	0.38	0.65
Install parts	0.05	0.06	0.06
Total installed cost	**0.39**	**0.44**	***0.71**

*0.58 if credit for replaced bushings is taken.

For case A, it is advantageous to improve existing breakers, particularly since it would be very difficult to find a suitable location for the 1500-mva rating.

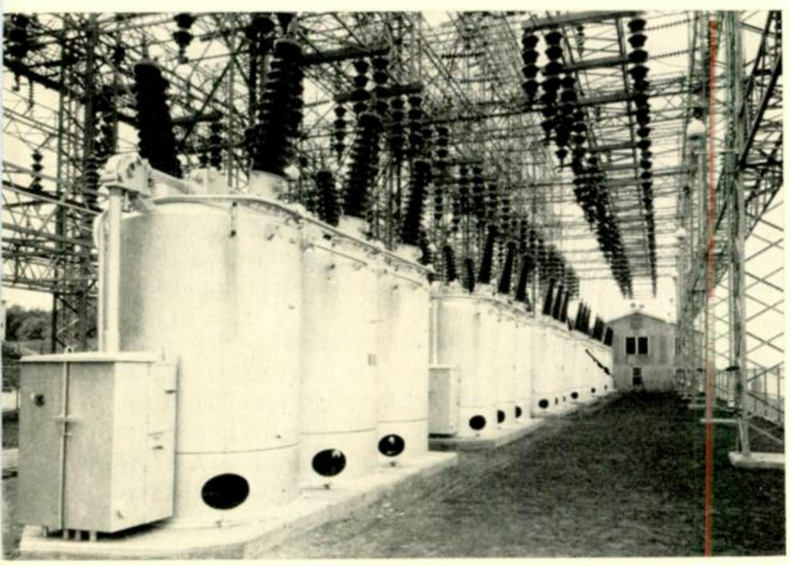
For Cases B and C, the existing breakers should be replaced if their high salvage value can be realized at other locations; otherwise improvement parts should be installed.

The book value of the replaced parts is recognized in accounting procedures but is neglected above since they are usually scrapped. For Case C, however, credit for the replaced bushings may be in order.

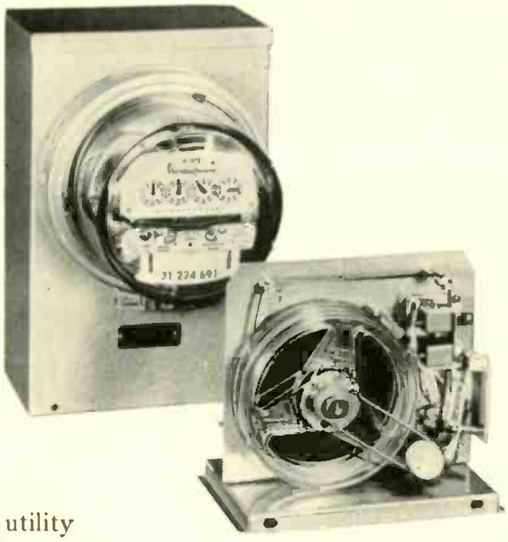
In addition to the cost saving resulting from revamping existing breakers, revamping proves advantageous not only from the standpoint of increasing interrupting capacity but also in obtaining modern interrupting and reclosing time performance. It may not be too attractive to transfer a breaker with obsolete operating characteristics even if a location is found where the interrupting capacity is adequate.

Also, less time is required to obtain improvement parts than to obtain a new breaker. It also permits on-the-spot rebuilding, using available construction and maintenance personnel. This provides excellent opportunities for training the personnel responsible for operation and maintenance. ■

Some 161-kv oil circuit breakers before revamping. Operating mechanism and housing were replaced, manholes added, and new interrupters installed.



what's NEW



This compact magnetic-tape recorder installed at the customer's service records demand data as load and time impulses on standard reusable magnetic tape.

Load-Survey System

A radically new system for load surveying on utility systems transfers data from a recorder installed at the customer's service to punched cards, eliminating any need for human interpretation and its risk of errors. The new system draws upon basic techniques of modern information handling to make the data gathering and the data processing virtually an automatic process.

The new survey system was developed to meet the need for a reliable but highly accurate method of studying effects of increasing residential loads on utility systems. Current forecasts indicate average residential loads are to double within the next ten years. As use of electric heating, air conditioning, and other domestic electrical equipment increases, utilities require more timely and accurate data to foresee the effect on system load curves. This new load-survey system is intended to furnish this data.

A complete survey system includes a compact recorder that transcribes load and time quantities as impulses on magnetic tape, a translator that interprets these impulses as demand values, and a summary card-punching machine (such as IBM's type 526) to transcribe the demand values to standard cards. Since all functions except data gathering are concentrated in the translator and the card-punch machine, which are central-office equipment, the recorder is sufficiently simple, rugged, and compact for field installation without interference with normal metering.

At the customer's service, the recorder unit records time and load impulses on standard 600-foot lengths of dual-track magnetic tape. At a recording speed of 9.4 inches per hour, standard tape lengths permit a 32-day survey run without attention to the device. Outages will be indicated by a clock, and neon lamps are used to give a visual indication that impulses are being recorded.

The recorder will be made in three forms: (1) a socket-type unit containing a 15- or 30-ampere Type DS meter; (2) a socket-type unit with provision for retaining the customer's original meter in service; and (3) a separately housed recorder unit for connection by cable to 3-wire, 120/240-volt "A" base meters.

After the survey has been run and the tape is brought to a central location for play-back, the translator unit totals and converts time and load impulses into demand values. Tapes are processed at 3¾ inches per second when 15-minute demand intervals are desired, or at 7½ ips for 30- or 60-minute demand intervals. A 32-day, 600-foot tape can be processed, accordingly, in 35 minutes or 18 minutes.

From the translator, plug-in connectors carry demand values directly to the card-punch machine, where survey data is punched on cards that have been pre-punched with other pertinent survey information, such as survey number, customer identification, day, period of day, date and month, and the demand multiplier. Pre-punching is performed by a control unit that processes 30 cards per minute after one card is punched manually.

After demand values are punched each completed card then bears all significant data for a definite survey period. Since each card accommodates 16 demand intervals, one card is adequate for a four-hour survey period when the demand interval is 15 minutes. At this interval, 2880 individual demand readings taken during a one-month survey run can be contained in 180 cards.

Though the format of cards to be used will be determined by the requirements of the survey, a representative card has been designed by Westinghouse for general use. When processed, demand values are automatically printed as numerals for each of the 16 demand intervals. In the center of the card, printed numerals and punches show the full date, the day, the period, identification of the survey and the customer, and the demand constant. ■

The lightning protection afforded by a properly grounded steel building is well understood by engineers and others familiar with electrical phenomena. Unfortunately, most prospects for small steel buildings, designed for use on farms and in rural areas, are not electrical engineers. To offset the often heard belief, "... steel buildings attract lightning ..." the Armco Steel Corporation demonstrated the safety of their all-steel buildings in the Westinghouse high-voltage laboratory. In the test shown above, the building was filled with hay, and "struck" with lightning. In another demonstration, a man stood in the building. Both hay and man came through the tests unscratched. (Incidentally, the man was an electrical engineer.)

"Big Maggie" Has Good Eyes

The most powerful shipborne radar set ever put in service has been installed on the cruiser *Northampton*, a Navy command vessel for directing the firepower of a task force. At the heart of this most powerful radar set is a magnetron; nicknamed "Big Maggie," this tube delivers to the radar antenna the powerful pulses of r-f energy needed to search out enemy planes over 400 miles away. At peak power, "Big Maggie" delivers over ten million watts.

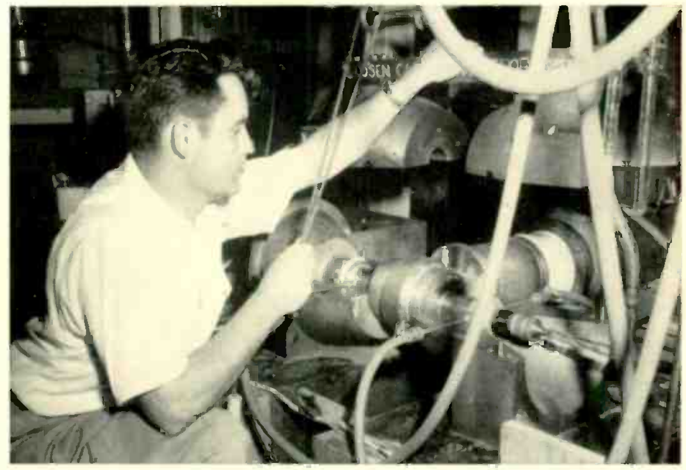
"Operation Maggie" started in 1947 when the Navy, foreseeing the imminent need for long-range radar in fleet and home-based operations, sponsored the tube development. The goal was a magnetron with a power capacity at least ten times that of existing World War II magnetrons.

Since radar range is proportional to the fourth root of the *average* radiated power, a substantial increase is required to produce a significant increase in range. For example, radiated power must be increased sixteen times to double effective radar range. The transmitted radar signal consists of pulses of r-f energy. The duration of each pulse is determined by the minimum detection distance. Each pulse is followed by a much longer empty period. This period is determined by the maximum detection distance. Hence, average power could be increased only by very large increases in pulse power beyond conventional levels. To further complicate matters, the inherent build-up time of the electro-magnetic field in the tube had to be decreased well below conventional values at the operating frequency, while still maintaining the required stability and efficiency.

This meant that engineers had to undertake considerable pioneering work to come up with a magnetron capable of generating the long pulses of extremely high power required—a ten millionth of a second is a long time to handle over 10-million watts—in a volume about the size of a football. The complete tube alone weighs only about 60 pounds; its permanent magnet weighs some 300 pounds.

The new magnetron operates as a sealed oscillator, employing water and mild forced-air cooling. No pressurizing or auxiliary gas insulation is needed.

An accomplishment in itself is the power supply for the magnetron. It must supply peak input power pulses of about

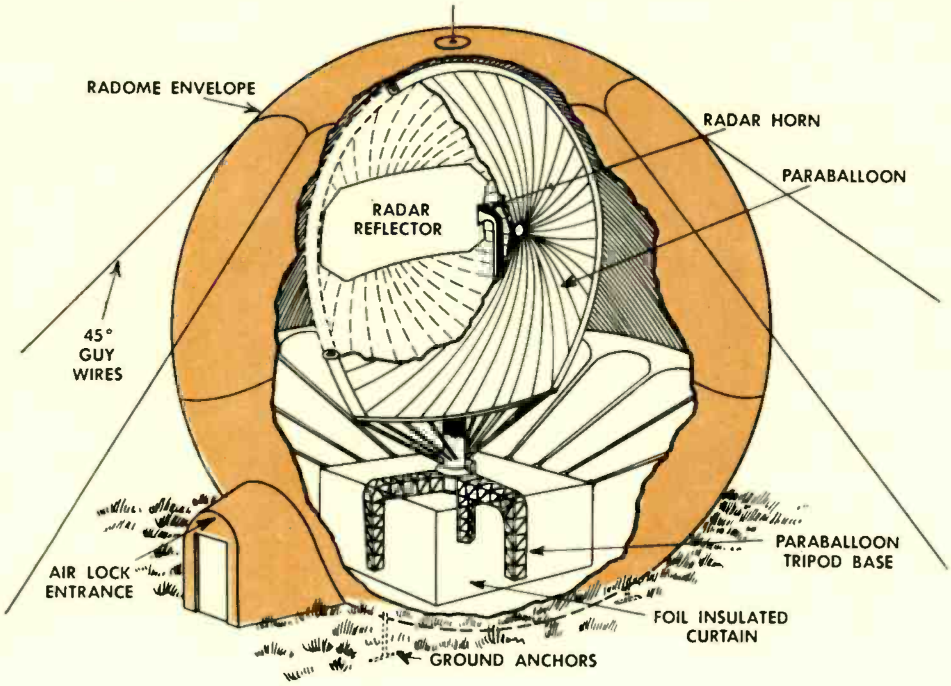


A large electromagnet with split pole pieces supplies a powerful magnetic field, which together with electric fields inside the tube, interact upon electrons emitted from the cathode to produce the ultra-high-frequency signal in this ten-million-watt magnetron.

23 megawatts at 60 000 volts. These rectangular pulses are converted by the magnetron into "bundles" of ultra-high frequency energy for radar purposes. Testing equipment for evaluating the new tube was another project requiring considerable engineering effort.

Many new technological developments and manufacturing processes of major proportions were required to make possible the giant magnetron telescope. New methods for the vacuum-tight brazing of stainless steels and the fabrication of large metal-ceramic and metal-glass seals are among those which have made practical a tube with power-handling capabilities far in excess of anything achieved by magnetrons before.

After successful laboratory tests in 1953 "Big Maggie" and its associated equipment underwent performance tests in the port of Boston. First tests surpassed expectations for distance-scanning; radar operators monitoring a radar screen aboard a warship were said to be surprised when, to the south, they could observe air traffic arriving and leaving New York City's La Guardia Airport, and to the north, the rugged coastal terrain of Nova Scotia. ■



New Powerful Mobile Radar to Strengthen Defense Networks

An extremely lightweight, mobile radar set of revolutionary design and long range has been developed for the U. S. Air Force. The key development is the radar antenna, called the Paraballoon antenna. The radar was developed to detect high-flying aircraft and to play a vital role in strengthening the defense networks of America and its allied nations.

The Paraballoon antenna is made from a vinyl-coated fiberglass fabric. This fabric was chosen because of its high modulus of elasticity and consequent low stretch. To form the assembled antenna, two paraboloids of revolution 30 feet in diameter are joined together at their rims and inflated to less than 0.02 psi above the surrounding pressure. When inflated, the two paraboloids are stabilized by a 16-inch diameter fabric tube that is incorporated into the rim of the Paraballoon antenna and inflated to 10 psi.

To form the 30-foot wide by 20-foot high reflector, a sheet of Mylar that has been coated with aluminum by vapor deposition is attached to the inside of one paraboloid. The thickness of this aluminum deposit is about one-millionth of an inch. The uncoated fiberglass fabric will not obstruct radar beams as it is transparent to all radio-frequency energy.

The fabric paraboloids are cut off at the bottom to provide a suitable area for attachment to a folding structural magnesium base. Assembly is accomplished with quick-operating fasteners. The entire base, which is 20-feet long, 8-feet wide and 5½-feet high, is supported on a bearing and driven at 6 rpm by a ¼-hp, 400-cycle induction motor. The bearing is mounted on a tripod at a height sufficient to provide work space beneath the antenna, where the balance of the radar equipment is located. The complete antenna system weighs only 1690 pounds.

An air-supported radome—lightweight, sectionalized, and designed to erect directly on the ground—protects the radar and electronic equipment, operating personnel, and the Paraballoon antenna from high-winds and ice-loads.

The radome is designed so that temperatures ranging from 65 degrees F below zero to 140 degrees F above and wind velocities of 125 mph will cause no interference with antenna rotation. Air-pressure inside the Paraballoon antenna is maintained greater than air-pressure inside the radome by a fixed amount. This is necessary to maintain the close tolerances needed on the surface of the reflector and prevent any distortion of the radar transmission and reception pattern. Entrance to the radome is through a pressure-lock door. Air-pressure in the radome—approximately 0.17 psi above atmospheric pressure—does not cause discomfort to operating personnel.

Mounted directly on the ground and stabilized by ten guy wires, the radome is secured to specially developed ground anchors that are adaptable to all types of soil. Tests conducted at the Cornell Aeronautical Laboratories Inc., have shown these anchors to be capable of withstanding continuous pulls up to 3000 pounds when imbedded in sandy soil.

During erection, the 24-foot diameter base circle of the radome is covered by a ground seal cloth to prevent air-leakage through the ground. A magnesium-grating floor provides a walk from the air lock to the electronic equipment in the event that frozen ground is thawed by the radome heating units. The radome is sectionalized into five side panels and one crown piece for ease of transport and erection. Total radome weight is about 1400 pounds.

Blowers with sufficient capacity and suitably flat pressure-volume characteristics are used for both the Paraballoon antenna and the radome housing. Wide variations in the amount of air-leakage from either inflated area will not result in large pressure changes. This, coupled with rip-resistant fabric, makes the complete system insensitive to minor tears caused by wind-blown objects or gun-fire. Specifically, more than fifty 20-mm projectiles can pierce both the antenna and the radome without affecting normal operation.

The assembly of the complete system can be quickly accomplished with no special erection fixtures. A trained crew of 20 men can set up the entire radar system in two hours.

The radome can be deflated and unzipped into sections and the associated supporting structures collapsed. As a result, the entire antenna system can be dismantled in a matter of minutes and packed in shipping containers of small volume. Fully-packed shipping containers weigh about 200 pounds each, and can be easily handled by two or three men.

The "lollypop" shaped Paraballoon antenna can be erected and dismantled an unlimited number of times. Even after repeated rough handling, it will retain its desired reflector contour when inflated. When the antenna is packed in special air-lift cases, air-drops of an entire radar set are feasible.

Rome Air Development Center, under direction of Headquarters Air Research and Development Command, recognized the need for a high performance radar for the use of the Tactical Air Command, and awarded Westinghouse a contract for a complete study of the problem. With the aid of Cornell Aeronautical Laboratories, Inc., the Paraballoon antenna resulted. Of all antennas studied, only the Paraballoon antenna meets the exacting and rigid electrical performance and mobility requirements.

Four 50-foot Paraballoon antennas are now being manufactured by Westinghouse for the armed forces. Two are for the Air Force and two for the U.S. Marine Corps. ■

personality profiles

S. Bennon and G. R. Monroe • *L. R. Sellers and Ralph O. Bonine*
L. Chabala and T. J. Herter • *J. C. Nycz, R. C. MacIndoe, and U. L. Smith* • *B. E. Rector and C. B. Risler*

• In 1937 when *S. Bennon* joined Westinghouse he was assigned to large power transformer engineering. Today, he is a section manager of that same department. But, wait! A lot has happened in the interim.

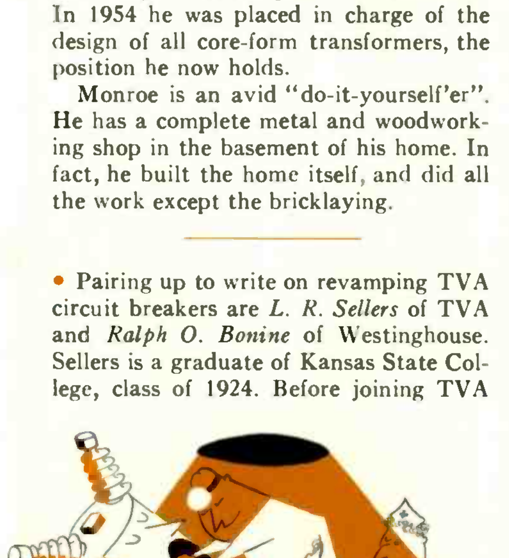
Bennon joined the company after gaining his MSEE from the University of Pennsylvania. Almost immediately he went to work on reducing sound levels of large power transformers. Came the war, and Bennon was needed to design Navy torpedoes. This job carried him to Pearl Harbor, among other places; his work in developing a new type of electric torpedo also won him a "Silver W," a Westinghouse award for outstanding accomplishment.

After the war Bennon returned to sound level problems. In 1949 he switched to distribution transformer problems, when he was made a section manager in that engineering group. In 1951 however, Bennon returned to power transformers as a section manager, the position that he now holds.

Bennon's co-author, *G. R. Monroe*, came to Westinghouse from the campus of the University of Utah, from which he earned his BS in EE in 1928. He worked first as a tester in the Transformer Division, then transferred to the engineering department in 1930. Here he worked as a design engineer until 1941, when he was appointed section manager in charge of the design of small power transformers. In 1954 he was placed in charge of the design of all core-form transformers, the position he now holds.

Monroe is an avid "do-it-yourself'er". He has a complete metal and woodworking shop in the basement of his home. In fact, he built the home itself, and did all the work except the bricklaying.

• Pairing up to write on revamping TVA circuit breakers are *L. R. Sellers* of TVA and *Ralph O. Bonine* of Westinghouse. Sellers is a graduate of Kansas State College, class of 1924. Before joining TVA he had gained a background in electric utility work through experience with an electrical equipment manufacturer and an electric utility. In 1936 he became a member of the TVA Design Section in Knoxville. His present responsibility includes supervision of the electrical specification and procurement section. In his off-duty hours Sellers' principal hobby is music; he is an accomplished clarinetist and has been a member of the Knoxville Symphony since 1936.



Bonine is a Carnegie Tech man. He came to Westinghouse in 1925, and since then has been concerned with many aspects of circuit breaker design, testing, and installation. After five years in switchgear testing, he became foreman of a circuit breaker testing facility in 1930. In 1942 he transferred to circuit breaker engineering, and has since represented the section on field installations and maintenance of large outdoor oil breakers all over the United States.

• *L. Chabala* came to Westinghouse in 1950 with an EE degree from the University of Michigan. While on the Graduate Student Training Program, he attended the Electrical Design School. He then joined the Distribution Apparatus Department in East Pittsburgh. Here, he has worked with reclosers, switches, and sectionalizers, which has resulted in about 30 patent disclosures, of which 11 have resulted in patent applications. He is presently responsible for the design of load-pickup switches and sectionalizers.

T. J. Herter received his BSEE from Notre Dame in 1950, but decided to stick around an extra year for an ME degree. During this final year of graduate work, Tom acquired some valuable industrial experience working nights at an automotive plant. Tom came with Westinghouse on the Graduate Student Training Program in 1951. From here, he went on the consulting and application engineering training program, and then to an electric utility C & A engineering assignment in the Baltimore office. The first of 1955, he transferred to his present position of product engineer traveling the Atlantic, Central, Northeastern, and Southwestern regions for the Switchgear Distribution Apparatus Department.

• *J. C. Nycz* graduated from Newark College of Engineering in 1939 and came to Westinghouse through the cooperative course which Newark College had at that time. After a brief stint as a laboratory technician, he was made a design engineer on recording instruments in 1942. About a year ago, he was appointed to his present position of section manager of switchboard and portable indicating and recording instruments.

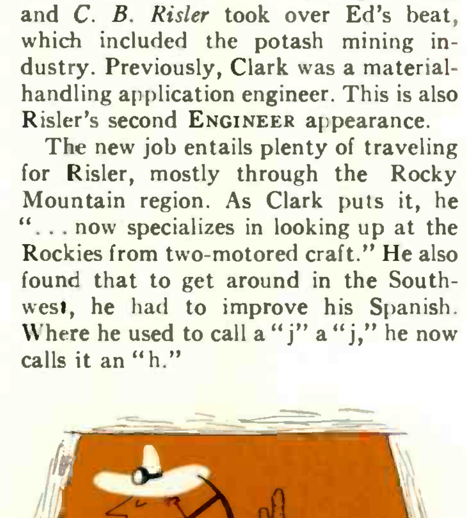
R. C. MacIndoe came to the Meter Division from the Graduate Student Training Course in 1946 after several years with the U. S. Armed Forces during World War II. He's a graduate of Brooklyn Polytechnic Institute, 1942. Bob is a senior design engineer on switchboard, portable, and indicating instruments.

U. L. Smith is the "dean" of the Meter Division's instrument design engineers, coming to the instrument engineering department from the Graduate Student Training Course following his graduation from the University of Missouri in 1925. Uel has had wide experience in practically all of the various lines of Westinghouse instruments.

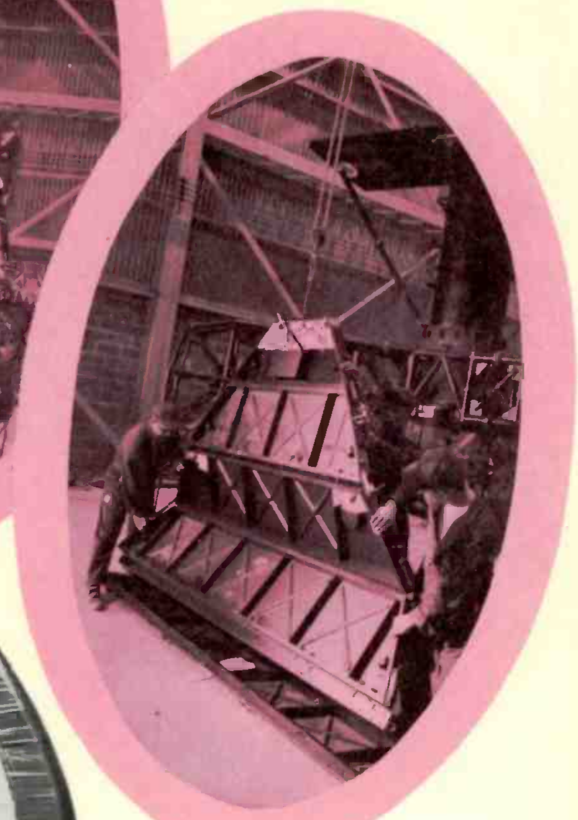
• *B. E. Rector's* journalistic efforts are staying in step with his progress on his ten-acre farm east of Pittsburgh. Last year, when he wrote of taconite processing (reclamation of iron from a previously marginal ore) he was also engaged in reclaiming his land from the brush. Now, as he busily spreads chemical fertilizers over the cleared ground, he writes about potash mining and processing.

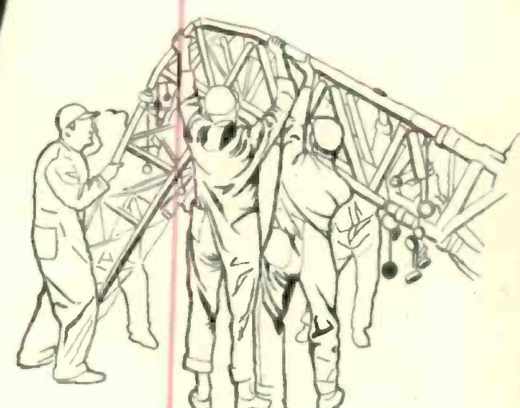
In December 1954, Rector was made manager of the mining, petroleum, and chemical section of Industry Engineering, and *C. B. Risler* took over Ed's beat, which included the potash mining industry. Previously, Clark was a material-handling application engineer. This is also Risler's second ENGINEER appearance.

The new job entails plenty of traveling for Risler, mostly through the Rocky Mountain region. As Clark puts it, he "... now specializes in looking up at the Rockies from two-motored craft." He also found that to get around in the Southwest, he had to improve his Spanish. Where he used to call a "j" a "j," he now calls it an "h."









This revolutionary radar antenna, developed for the Air Force by Westinghouse, is literally blown up like a balloon. Called a Para-balloon antenna, the unit is extremely light-weight and sectionalized. It can be assembled or dismantled by a crew of nine in several hours, packed in a few cases weighing only 200 pounds each, and air-dropped into tactical areas for the detection of enemy aircraft.