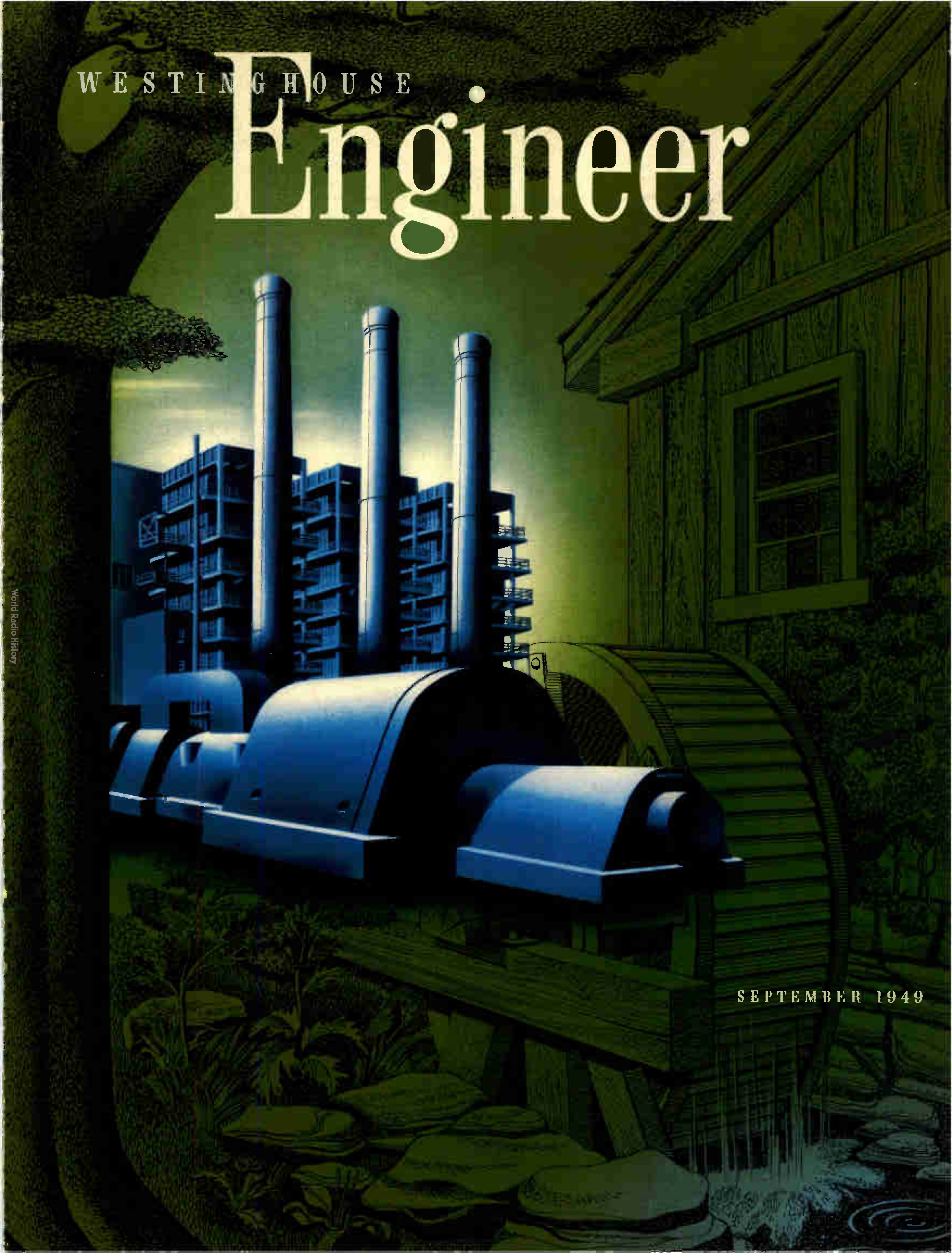
WESTINGHOUSE

Engineer



SEPTEMBER 1949

Vertical Transportation—Mammoth, Progressive, but Unnoticed

At sleepy eight a.m. on any weekday the lobbies of the buildings in Rockefeller Center are as devoid of people as Coney Island on a brisk January morning. But an hour later the hustle and bustle that has been rapidly swelling in streets, subways, trains, and buses suddenly overflows into office buildings and stores. People who have just left various forms of horizontal transportation are now whisked quickly, smoothly, and quietly to their floor destinations by vertical transportation. The size and traffic of this transportation system is amazing. In the Rockefeller Center system alone there are 215 elevators. In one day they carry a quarter-million passengers—a figure roughly equivalent to the combined population of Salt Lake City and Atlantic City. And this is done rapidly; one bank travels at a speed unequalled in building elevators elsewhere in the world—a fast 1400 feet per minute.

But this is only one vertical transportation system in one city. In 1948, the more than 200 000 elevators in the United States carried over 17 billion passengers, as many as trains and buses combined. A sizable transportation system!

Yet out of this tremendous number of passengers probably only a small minority realize its full extent. Probably no other form of transportation is as much taken for granted, and as little understood.

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Vertical transportation was born centuries ago because of man's desire to get places quickly and with the least amount of physical effort. Forty years ago vertical transportation systems, specifically elevators, had gone mechanical. In fact the hydraulic system then in use seemed to be the ultimate in vertical transportation. By contrast, electrical systems, then in their infancy, were considered poor and their operation rough. But with the appearance of gearless traction motors in 1915 there began a long series of developments that have led to ultramodern systems in which cars glide, sometimes operatorless, up and down shafts with smooth, comfortable operation, their schedules and movement controlled at every step by an electrical brain that almost senses traffic demand.

All types of elevators have undergone drastic changes. The variable-voltage control of elevator speeds in 1922; the first precise control of car leveling through the main drive motor in 1923; the Rototrol speed regulator; Quota Control, the first system to render uniform service to all floors during traffic rushes; and finally Selectomatic, the magic brain that controls whole banks of elevators as a unit, directing with a preciseness, speed and wisdom far beyond the capabilities of a human dispatcher—all these innovations and a great many more have contributed to the prompt service, smooth operation, and fast speeds of the most modern elevator systems.

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Vertical transportation is not limited to the more familiar passenger elevators. Freight, as well as human cargo, is carried with efficiency and dispatch. Freight elevators as big as 40 feet square carry loads up to 40 000 pounds in warehouses, hospitals, and stores. Some are more specialized, such as those used aboard aircraft carriers. A revolutionary new type of hydraulic plane lift was built by Westinghouse during the war for carriers of the Essex class. Prior to this time, carrier elevators had been located right smack in the middle of the takeoff area, which left a gaping hole when the elevator was at hangar-deck level. Moreover, there was always the possibility of a direct shell or bomb hit on the elevator while it was at the hangar-deck level. Westinghouse engineers undertook the design of a deck-edge elevator, hung over the side of the carrier, out of the way of landing operations.

The problem was little less than terrific. Supported from only one side, the 73-ton elevator platform must still be able to lift 30 000 pounds, and operate despite the roll of the ship, or the poundings of waves and weather. But the final requisite was the clincher. The whole elevator platform had to be collapsible against the side of the ship. The elevator built to these specifications is now standard equipment on aircraft carriers.

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Elevators have no monopoly in the vertical transportation field. For some applications, especially where large volumes of people are to be carried only a few stories, modern electric stairways have come into wide use. They have several advantages—they can transport tremendous numbers of people over short distances in a brief time, even though their speed is not comparable to that of elevators. They are continuous, which means no waiting. For example, the largest moving stairway system in an office building is one recently installed in the John Hancock Mutual Life Insurance Company's new building in Boston. Sixteen of these modern stairways extend from the basement to the eighth floor, and serve as the primary means of transportation for these floors. During the rush hour, with all stairways operating in the down direction, they are capable of moving as many as 5000 people to the street floor in 15 minutes.

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Electric stairways are bringing about significant changes in building usage. Once the space from the second floor up was less desirable for stores and banks. Now, with moving stairways, the upper floors are as accessible as the first floor, with the result that buildings can be more profitably utilized. A bank in Oakland, California, has moved to the second floor, releasing its space on the first floor for stores. A one-story department store has utilized its roof as a parking area, using electric stairways to carry customers to and from the store. A restaurant in New York has expanded its capacity by utilizing the basement as a dining area, to which passengers are carried on moving stairways. All these, and many more examples, serve to illustrate that electric stairways, by their convenience and speed, are increasing the value of building space that was once less desirable. Another little-known advance for vertical transportation!

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What the future holds for vertical transportation depends largely on trends in architecture, and upon the ingenuity of elevator engineers. If buildings grow higher, making greater elevator speeds desirable, the present high of 1400 feet per minute can be raised; here passenger comfort is one of the controlling factors. This is partially dependent upon the acceleration and deceleration rather than actual speed. Mine elevators travel at speeds upward of 2000 feet per minute, but here passengers do not object to the slight physical discomfort during acceleration and deceleration. Stairway speeds could be increased above the 125 feet per minute limit now allowable. This again is a matter of passenger comfort and convenience. Controls for elevators may also undergo drastic changes, if the necessity arises. A tiny one-foot model, built solely for demonstration purposes, responds to spoken commands—and in two languages. Elevator engineers believe that such voice control is not feasible in full-scale commercial installations, but the model nonetheless demonstrates the fact that there are plenty of possibilities yet to be explored. Future developments, like previous ones, will undoubtedly be relatively unknown to the riding public. But the "taken for granted" aspect of vertical transportation is in itself a silent compliment to a system that is so quiet, smooth, and rapid that passengers are hardly aware of its efficiency.

WESTINGHOUSE Engineer

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On the Side

The Front Cover—Suggested by the description in this issue of the Sewaren power station, the cover by Richard Marsh depicts a generalized view of modern power generation through an etching of a power plant of a century ago.

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The Back Cover—Every small boy has played with a toy hoist, which he fills with sand until a certain weight is reached, whereupon it moves and dumps its load automatically, returning for another load. Now 12-ton versions of these are at work in mines. At the working level the coal is automatically loaded into the skip and weighed. When the weight reaches 12 tons, a gate closes, stopping the flow of coal. The hoist then automatically rises to the surface, unloads at the tipple, returns for another load, and repeats the cycle. The maximum capacity of the hoist is 700 tons of coal per hour (one cycle every 62 seconds) from a depth of 710 feet. The hoist is driven by a 1250-hp d-c motor, supplied by a 1000-kw m-g set, the entire system being Rototrol-controlled. Its maximum full-load speed is 2485 fpm.

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The experimental microwave installation (see the May 1949 issue) has completed 4000 hours of service without unintentional interruption. The microwave equipment is used in conjunction with a frequency-sharing audiomultiplexing arrangement, which can provide seven voice channels spaced on a single carrier. One unique feature of the multiplexing equipment is its master tuning fork, which is so stable that no adjustments are necessary.

The contents of the *Westinghouse* ENGINEER are analyzed and indexed in the INDUSTRIAL ARTS INDEX.

In This Issue

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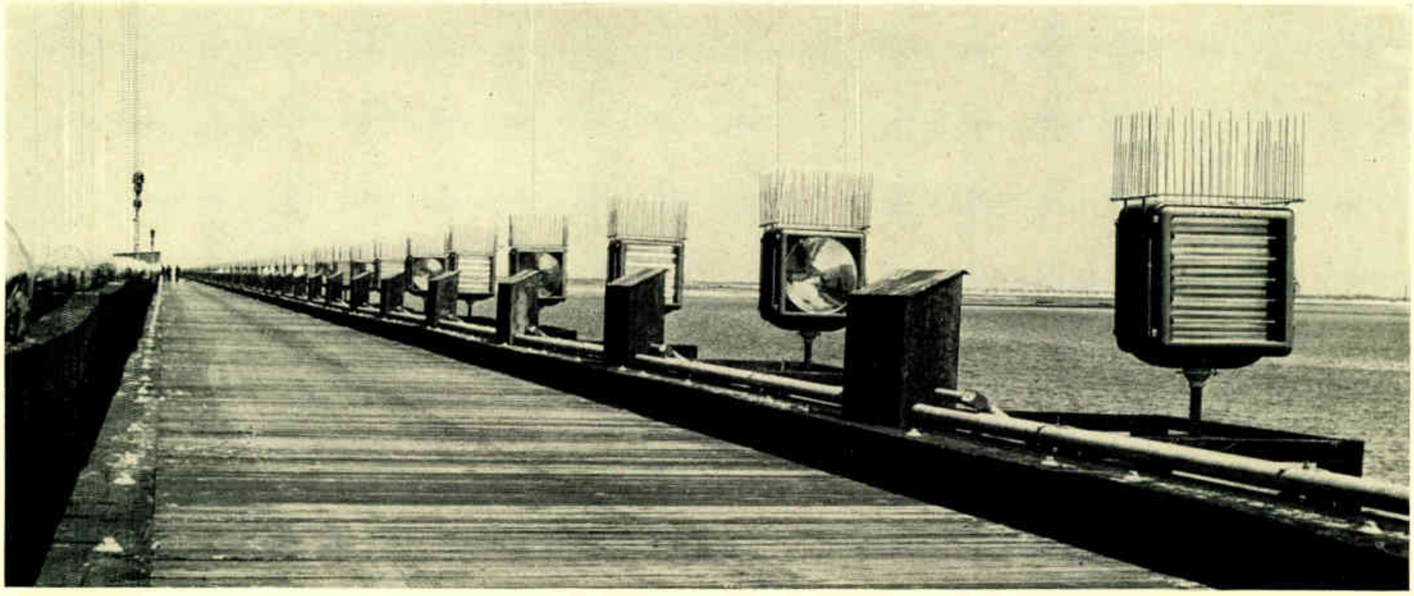


Airport *Approach Lighting* for Landings

"Soupy" weather doesn't help sate the financial appetite of commercial airlines one bit. Below certain minimums of visibility their planes cannot operate, for reasons of safety. This has created an increasing need for improved landing aids. Two approach-lighting systems recently tested by the Civil Aeronautics Administration will, in conjunction with available electronic devices, help solve the problem. The groundwork for all-weather flying has been laid.

William C. Norvell, *Manager, Aviation and Marine Lighting Sales, Westinghouse Elec. Corp., Cleveland, Ohio*

Snow, rain, and fog may not deter the postman from delivering the mail, but they do cause delays and schedule disruptions in airline operation—and all too often from the airlines' viewpoint. In fact, the restricted visibility brought about by these conditions is today the most serious operational difficulty faced by the airlines. For safety reasons, flights must be routed around fields that are "closed in," with the attendant passenger inconvenience and added operational costs involved in landing at other than the scheduled field. Lighting and electronics engineers are currently developing and improving upon various schemes that may lead to all-weather flying.

To eliminate dangerous landings, the Civil Aeronautics Administration has established for each airport certain "weather minimums" below which landings cannot be attempted. An average minimum might be "¾ mile - 500 feet," meaning that the forward visibility must be at least ¾ mile and the ceiling height at least 500 feet. Various factors influence this minimum, such as: length of runway, altitude of the airport, clearance of the obstructions in the approaches to the field, the electronic landing aids available, and the types of lighting alongside the runway and particularly in the approach.

These weather minimums are an expensive safety feature. They cause cancellations, which are costly not only because of the loss of revenue, but because of the added cost of handling and rerouting passengers. Schedules must be revised, which usually produces the evil of "deadheading" planes to get them where they are needed after the cancellation of normal schedules. Probably the greatest—although intangible—loss is the attitude of the many passengers who will not fly if sureness of arrival time is important. Many potential passengers still use ground transportation rather than take a gamble, however small, on a flight that may be delayed by weather. Thus, the increased maintenance of schedule brought about by better landing aids will go far toward adding to airline revenue, as well as safety.

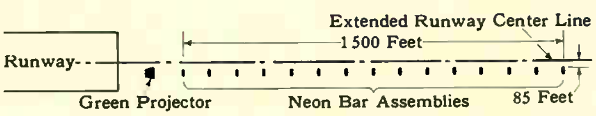
The battlefront for reducing these weather minimums is found in the techniques of producing better aids for low visibility landings. Radio, of course, plays a prominent part. The CAA has standardized on the Instrument Landing System (ILS), and installs the equipment at airports having scheduled commercial operations of sufficient importance to merit the use of such a system. The Air Force and the Navy use the Ground Controlled Approach System (GCA). The ILS system, with its projected radio signals, forms a glide path that is shown on the plane's instrument panel and interpreted by the pilot. The GCA depends upon radar search equipment, with a ground crew locating the plane and instructing the pilot where to fly and land.

The arguments pro and con for each system are many; however, it is agreed that with either system, the pilot should be able actually to see where he is going to land before he attempts to do so. While completely "blind" landings are not unusual, they are executed only as a test or in a distinct emergency. No commercial pilot would consider making such a landing with a load of passengers unless he was forced to do so.

The complexity of the radio equipment, for either ILS or GCA, and the consequent possibility of error, demand that the pilot actually see the approach and runway pattern before he makes his landing. This final visual check has been the "missing link." When proper lights are installed alongside runways and in approachways, the present weather minimums can be drastically reduced and a giant stride made toward the complete maintenance of all airline schedules.

Ten years ago the CAA standardized on a system of approach lights known as the "neon ladder" system, shown in Fig. 1. This consisted of 15 red neon-lamp bars, each about six feet long, installed perpendicular to the extended centerline of the runway and spaced 100 feet apart. This single row of lights was located 85 feet to the left of the extended centerline for visibility to the pilot, and extended 1500 feet into the approach zone. The neon lamps and reflectors produced about 1000 candlepower, which could not be seen over 200 feet in thick weather. They are now being replaced by more effective lights. A system of high-intensity approach lights must reach out through the thickest weather to give the pilot an unmistakable visual check on his position when he is in the approach portal to the runway.

Figure 1

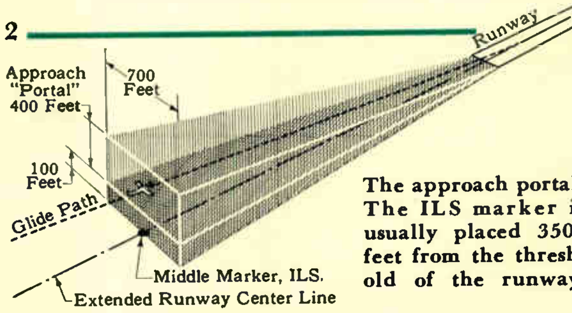


The neon ladder system of approach lighting. A green projector marks the end of the row of lights.

During the last eight years of experimentation with the ILS on airports serving commercial airlines, sufficient testing has been done to determine the average deviation of the plane from the perfect approach. This calculated average deviation shows that the pilot will be somewhere in the approach portal (Fig. 2) when he is over the ILS middle marker, which is usually 3500 feet from the runway threshold. At an average speed of 140 mph, his turning radius, especially in larger aircraft, will not allow him to make sudden corrections. Thus if the pilot is to make a safe landing he must be able to pick up at this point some visual identification that will enable him to line up, both vertically and horizontally, in the correct glide path to the runway.

This visual indication must first provide positive identification of the fact that he is in the approach to a runway and, for that reason, the lights must be immediately distinguishable from lights on highways or other configurations of lights at or near the airport. Recommended practice calls for the pilot to fly the aircraft down the radio glide path, which requires his concentration on the instrument panel. The co-pilot should study the scene ahead. As soon as he sees the approach lights, he notifies the pilot, who then changes over from instruments to "contact" flight. An approach-light system should provide all the necessary information to permit the pilot to complete the landing by visual methods as in clear weather. In order to indicate the relation of the aircraft to the runway, the lights must tell the pilot the distance from the runway threshold, the altitude, the deviation from centerline, and the tilt of the plane with respect to the earth, otherwise known as "roll" guidance. These requirements for the most part can be fulfilled by arranging the light fixtures in proper configurations. However, for the best approach-lighting system the

Figure 2



The approach portal. The ILS marker is usually placed 3500 feet from the threshold of the runway.

lights themselves must satisfy other important requirements:

1—They must be bright enough to be seen in heavy daylight fogs, which, with the high level of background (threshold) brightness, is the worst visibility condition. This, of course, requires a light source of very high candlepower.

2—They must not be a source of glare, for this would completely destroy the pilot's "dark adaptation." This problem can be overcome by adjusting the intensity of the lights for the different weather conditions, and by controlling the distribution so that the pilot receives the peak candlepower only when he is some distance from the unit.

3—The system must have an adequate spread to cover the entire "approach portal," since the plane may be anywhere in this area.

4—The light itself must be suitable for installation on terrain that may rise or fall away from the runway threshold.

No single system or lighting unit yet devised fulfills all these requirements perfectly. Various systems have been advanced that, from a theoretical point of view, seemed to do the job. However, in an effort to test such installations, the Air Force, Navy, and the Civil Aeronautics Administration formed a joint committee, which administers the Landing Aids Experimental Station at Arcata, California. All systems of approach lights are tested under flight conditions at this station before being given final approval.

This particular location was chosen due to the prevalence of heavy fogs from August to November. These fogs are scientifically analyzed for density, uniformity, and particle size for each test flight. Recordings are made of conversations between pilots and control-tower operators, and standardized procedures are worked out in advance of each test. The flights are most frequently made with ILS as the radio aid and with

Figure 3

The Slope-Line approach system. For simplicity, only 12 fixtures are shown, instead of the 60 ordinarily used in the system of this size.

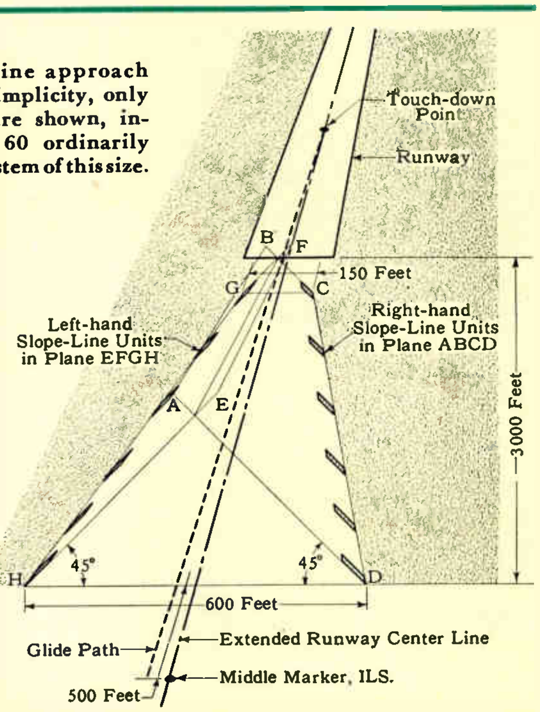


Fig. 4—The ILS instrument panel. ILS brings the pilot to the inner radio marker, at which point he can see the approach lights.

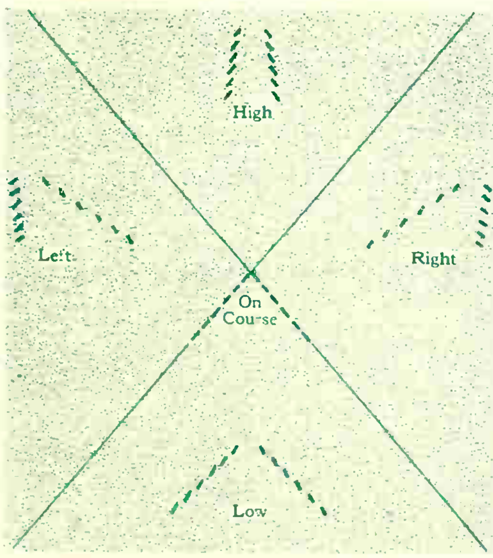


Fig. 5—A pilot's view of the Slope-Line system. Only when he is exactly on the approach course do the lights appear in straight lines as in the center. Other views show the lights as they would appear from points to the left or right of the correct course, or too high or too low.

recorded monitoring by GCA. Thus, a record is made of what the pilot saw, and where the plane actually was at all times during the approach. This represents the most comprehensive attempt to date to collect test data during actual operations.

Five systems were tested and evaluated prior to the 1948 fog season. While all of them represented a great improvement over the neon-ladder system, none was judged adequate to permit a drastic reduction of present weather minimums. Two more systems were tested during 1948. The first of these is the "Slope-Line" system, developed by CAA engineers at the Experimental Station at Indianapolis, Indiana. The second was a single row of flashing neon and krypton lights developed by Westinghouse.

The CAA Slope-Line system consists of sixty 14-foot bars, each containing a line of ten 250-watt sealed-beam lamps with special lenses. A row of lighting fixtures is arranged on each side of the extended centerline of the runway, as in Fig. 3. Bars in each row are paired; each pair is spaced 100 feet apart along the approach lane. Bars are mounted at a 45-degree angle to the ground, with the lower end farthest from the centerline. Since the glide path slopes downward to the runway at about three degrees, the fixtures in each successive pair outward from the runway are placed laterally farther apart or elevated to enable them to aim at the glide path. Normally, the fixtures are mounted at ground level.

This system of approach lighting is based on the optical effect that is produced by the series of bars. When the plane is on the correct glide path, they appear as two continuous straight lines of lights, converging toward the touch-down point, as in Fig. 5. When viewed from a point above or below, or to one side of the glide path, the individual 14-foot bars show as segments instead of as a continuous line, giving an "echelon" effect in each of the two lines. The pattern thus

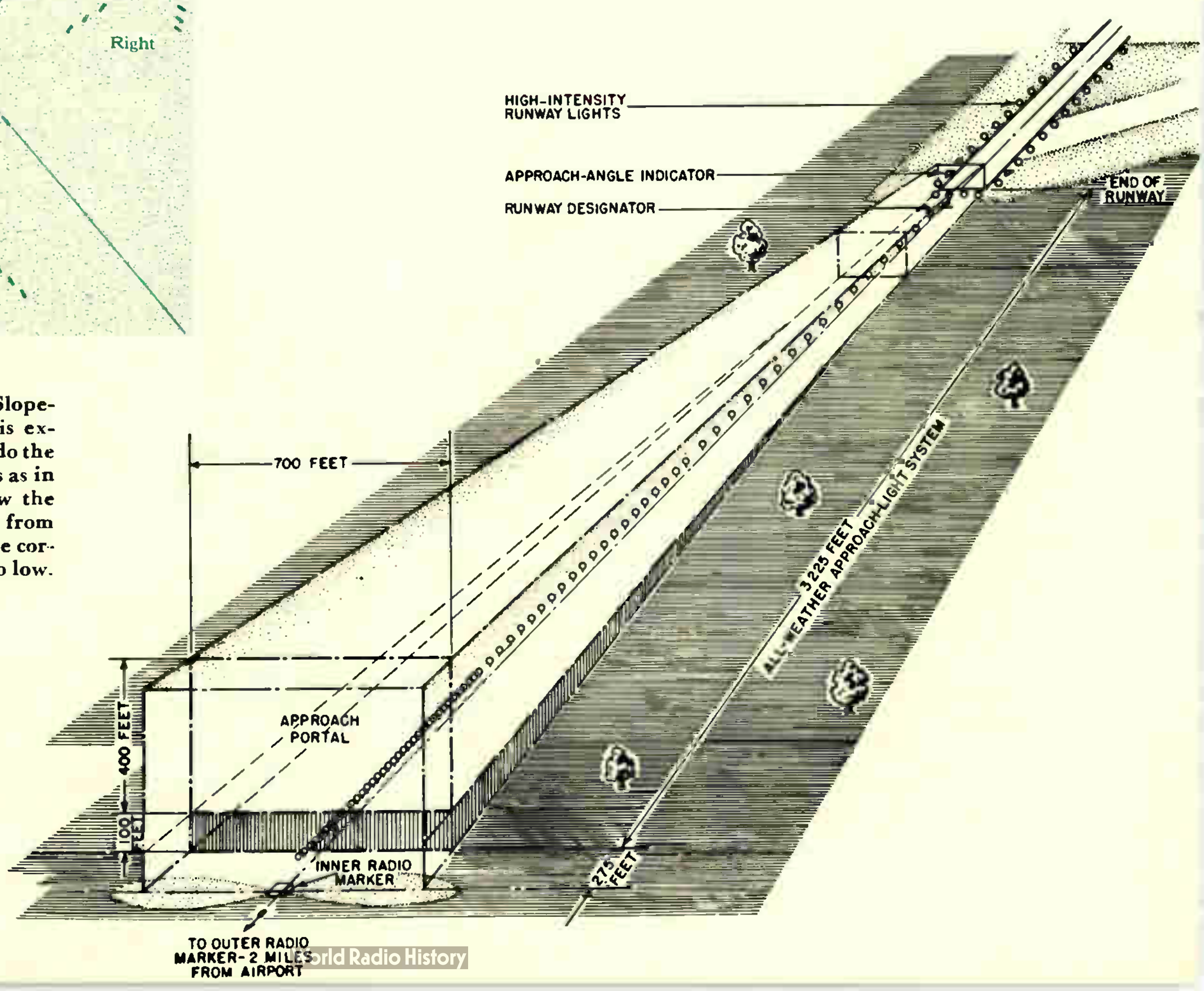


Fig. 6 →
The Westinghouse system of flashing lights, showing their relative position in the approach portal.

depends on the position of the aircraft with respect to the two rows of lights and, if the aircraft is not on the glide path, indicates by its appearance the direction of the necessary correction to return to the glide path.

Each lamp provides about 80 000 candlepower, with a spread of 7 degrees vertically and 35 degrees laterally. This system has been successfully tested down to one-eighth mile forward visibility. Five brightness steps are used for varying weather conditions. The system provides good altitude, centerline, and distance guidance. Altitude (roll) guidance is judged to be fair. As to whether the important matter of "identification" is adequate is still controversial and may not be settled until the next fog season permits additional testing. While the pattern of the two rows is distinctive, especially when viewed from off the glide path, the candlepower may not be adequate under conditions of very low visibility when only a portion of the system can be seen. As a result of the superiority of this system in fulfilling a large part of the requirements, it was chosen as the new standard system by action of the Munitions Board in May, 1949.

The Westinghouse system of krypton and neon lights, shown in Fig. 6, was not completely tested at Arcata. However, partial tests showed that they provide a high degree of identification due to the flashing characteristics of the lights. A single row of these krypton lights was installed at each of the six "Airlift" airports in Germany for facilitating bad-weather landings.

Each krypton lamp fixture, Fig. 8, consists essentially of a 24-inch reflector with a krypton lamp, which is about the size of a cigarette, at its focal point. This optical system provides a peak candlepower of over three billion. However, the flash exists only 17 microseconds and is too short in duration to have a blinding effect on the pilot. The spread is approximately nine degrees. A lower step of brightness is provided for conditions of better visibility.

The flashing neon lights, Fig. 7, are used between each krypton unit. They supplement the krypton lights by providing a wider spread for circling guidance under marginal weather conditions. These units flash at either 100 thousand or 10 million candlepower and can be burned steadily at lower intensities.

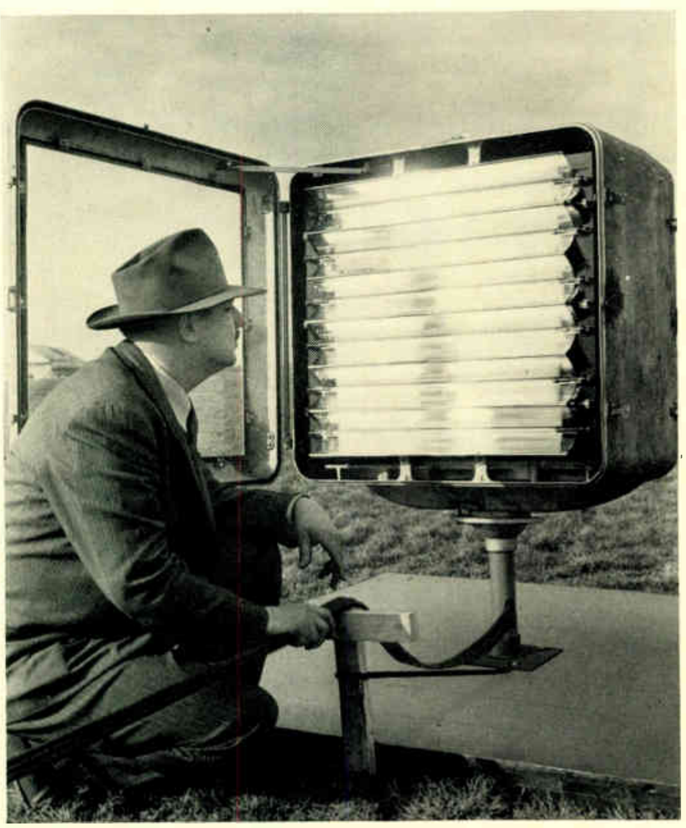
Under the worst visibility conditions both krypton and neon lamps are operated at maximum intensity. At the other extreme, such as on a clear night, only the blaze units are operated, providing a relatively faint line without glare. Between extremes, the lamps operate at various intensities.

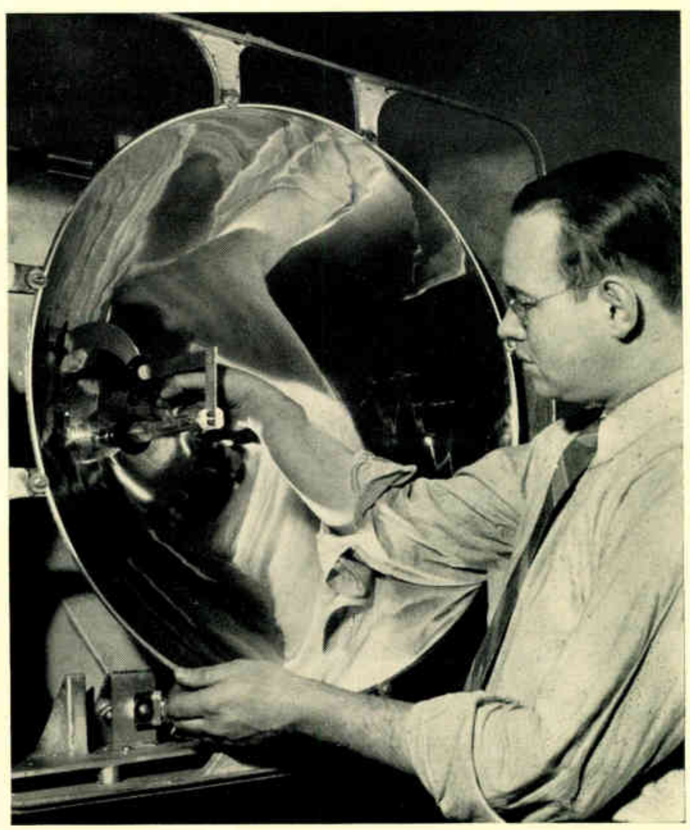
These lights are installed in a single row of alternating krypton and neon units, as shown on page 130. The Arcata tests indicate that this row should be on the extended centerline of the runway and that spacing should not exceed 50 feet. The lights flash successively, starting at the outermost unit. This gives the appearance of a stroke of lightning traveling down the line toward the runway threshold, and provides positive indication to the pilot that he has entered an approach lane. This flashing cycle is repeated 40, 60, or 80 times a minute, as desired, the traveling stroke providing good centerline guidance. These flashing neon and krypton lights can be used to supplement other systems, such as the Slope-Line, or whatever added identification is required.

These improvements in approach lighting will not result in immediate drastic reductions of "weather minimums," since pilots will have to become conversant with these newer types of lights. However, wherever these lights are installed, landing operations in conditions of marginal weather can be conducted with a higher degree of safety. Undoubtedly the groundwork has been laid for all-weather airline operation.

Figure 7 **Figure 8**

At left, the blaze unit of the Westinghouse approach system; right, the flashing unit with the tubular krypton lamp in the center.





The CSP Power Transformer for single-circuit distribution.

Transformers—Adapted for Distribution Substations

Consideration of transformers for substations as separate from the other station components is disappearing. The trend has been toward coordination or integration of the transformer, in design and arrangement, with the other equipments to accomplish a given function. This has led to transformers that are specially adapted for substations.

E. A. Thompson
Substation Transformer Section
Westinghouse Electric Corporation
Sharon, Pennsylvania

Substation transformers are of two general classifications: those for single-feeder and those for multi-feeder service. The Westinghouse transformer used on single feeders is a packaged substation and is designated the CSP (completely self-protecting) Power Transformer.

This CSP power unit combines all the functions of a single-circuit substation in a single housing. Even facilities for dead-ending the lines can be included. The merits of such single-package construction are several. Obviously, purchase becomes a matter of a single order. One manufacturer assumes complete responsibility for the entire substation. The engineering for both construction and erection is greatly reduced. The ground area required for a unit assembly is much less. Because it is more compact and better looking, the CSP Power Transformer is acceptable in many residential areas where conventional substations would not be tolerated. Such a unit assembly can be relocated readily as load growth changes.

The CSP Power Transformer is built in all standard three-phase ratings with primary voltages from 12 000 to 66 000, and secondary voltages from 2400 to 13 200, and are oil cooled. Standard capacities range from 1000 to 3000 kva.

The equipments included to give coordinated protection of the power circuits are: high-voltage, line-type arresters; protective links (fusible elements) connected in the high-voltage circuit between the high-voltage bushings and the windings; taps for changing under load; a thermal relay to permit loading by copper temperature; a circuit breaker in the secondary for disconnecting and fault protection; and relaying and metering equipment.

An externally operated, no-load tap changer connected to 2½-percent taps in the high-voltage winding permits adjustment of the feeder voltage to meet average load requirements. A built-in load tap changer with 32 steps, each of ⅝ percent, automatically maintains constant voltage within a range of ± 10 percent, either at the substation bus or, with the aid of a line-drop compensator, at the load center.

An auxiliary transformer furnishes power for the load tap changer. This transformer, and cooling fans when used, are housed with the Rectox-operated circuit breaker. The potential and current transformers for metering and relaying are also so housed. Fuses of the boric-acid type are used on the primary of the potential and auxiliary transformers to protect them against short circuits, and remove them from the power circuits in case of internal trouble or short circuit of the low-voltage leads.

Ordinarily low-voltage leads are brought out through the cover. Lightning arresters are mounted on the cover adjacent to the bushings. The standard design permits some variations in arrangement, however. For example, low-voltage leads can leave by underground cable, or high-voltage lines can emerge through an oil-filled terminal chamber or to a disconnect switch arranged for cable connections.

Multi-Feeder Substations

Substations for service where more than one distribution feeder is required have the switchgear* and transformer housed separately and connections enclosed in a housing near their top. These are Unit Substation Transformers.

Standard three-phase, oil-filled, unit-substation transformers are available in ratings from 750 to 5000 kva with primary voltages from 13 200 to 66 000, and secondary voltages from 2400 to 13 200.

Multi-feeder substations have all the features of protection and operation as described for single-feeder substations. The core-and-coil construction for multi-feeder substation transformers is the same as that of CSP Power Transformers.

Standard unit-substation transformers may have the high-voltage terminals brought out through the cover, or through a throat into high-voltage switchgear. All standard unit-substation transformers are made with the low-voltage throat on the right when facing the tap changer or fitting side. When the substation is double ended, i.e., with a transformer on each end of the low-voltage switchgear, the two transformers are alike. One transformer is simply turned around and bus transpositions made in the switchgear.

These substation transformers, when the foundations are suitably designed, are interchangeable. Busbar heights and throats of switchgear have been standardized for each voltage class. Differences in height between the transformer bushings and busbars are adjusted in an air terminal chamber, which is part of the transformer. Because of this transition section, transformers of all ratings of a given low-voltage class are de-

*"Switchgear for Unit Substations" by B. K. Smith and P. R. Pierson, Westinghouse ENGINEER, May, 1949, p. 87.

signed for the same bus height; therefore, they are mechanically interchangeable. This feature permits shifting smaller units to new locations and installing larger sizes when switchgear buses and breaker ratings are adequate. Particular care is taken in the design of the transition compartment to eliminate solid metal-to-metal connections between the transformer and the switchgear. This avoids transmission of sound from the transformer to the switchgear housing, which might act as a sounding board.

Features of both CSP and Unit-Substation Transformers

Because both CSP and unit substations are frequently located in residential areas, their sound level is minimized. Several steps are taken to achieve this. The core legs and yoke are proportioned to avoid undesirable harmonic frequencies produced by magnetostriction. The core-and-coil assembly is mounted in the tank so that the sound is not transmitted to the case. The iron is worked at low inductions. When substations are to be located near hospitals, particular attention is given this factor.

All these substation transformers have a considerable inherent short-time overload capacity available for handling peak loads or emergencies. This desirable extra capacity can be utilized with a new factory-coordinated, winding-temperature relay (TRO), which (1) starts the fans, (2) gives a warning, and (3) trips the circuit breaker as the hot-spot temperature of the winding increases.

A new protection link provides interrupting capacities much greater than previously obtainable. This link is mounted on the lower end of the high-voltage bushings to fuse and disconnect the transformer from the incoming lines on the occurrence of internal fault or the failure of other devices to clear secondary faults. It functions on the well-known De-ion grid principle. This device may permit the omission of oil circuit breakers on the high-voltage side or avoid mounting of fuses in a dead-ending structure.

A new no-load tap changer (RS) is smaller in size than previous tap changers of the same rating. It thereby permits smaller transformer tanks that require less oil and are easier to handle. A distinctive feature is its positioning device, which does not require accurate alignment of the connecting shaft. One complete turn of the handwheel is required for each tap position, and full contact pressure is maintained for 30 degrees on either side of the dial position. The operating handle can be brought out of the tank wall between tubes or coolers through a pipe welded in the tank wall.

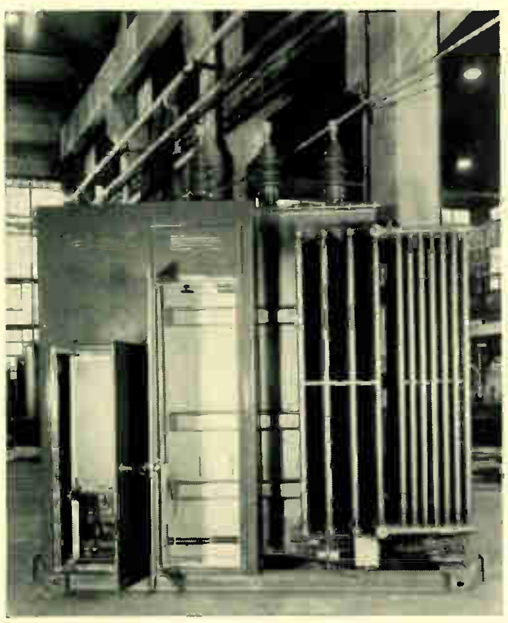
A new load tap changer (type URS) with larger capacity (400-amp rating) is now available. In many ratings, the need for series transformers is eliminated, thus reducing the size of the case and lowering the losses. The tap changer features a completely oil-immersed unit with direct motor drive through geneva gears to give quick-break action of contacts without shock or impact, and without springs. New contacts, of arc-resisting and wear-resisting alloys, are designed to give exceedingly long wear without replacement. The tap changer is completely sealed against moisture, because it is sealed against in-breathing. Controlled out-breathing is permitted to prevent excessive pressure resulting from continued tap-changer operations. Less filtering of tap-changer oil is required to keep down moisture and avoid bad effects on dielectric strength.

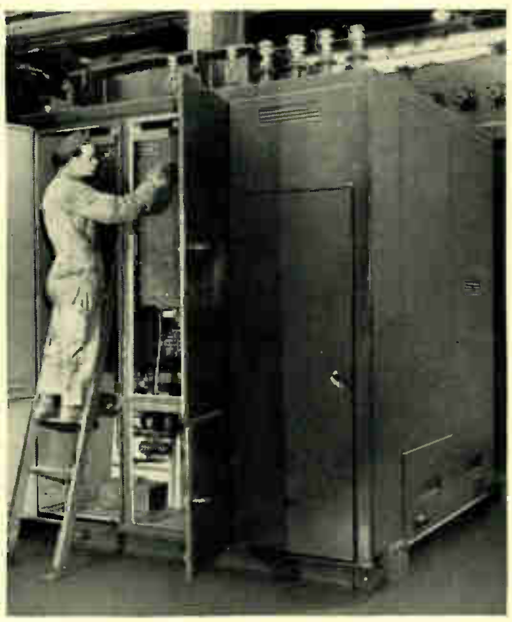
Some devices tend to increase the usefulness of the transformers; others, such as the mechanical relief device, serve as a form of insurance. This new device, which acts more quickly and is more reliable than the diaphragm, prevents rupture of the tank in case of a flashover within the tank. The relief device, the protective link, and the inert-gas seal act as a team to minimize damage or fire in case of a flashover.

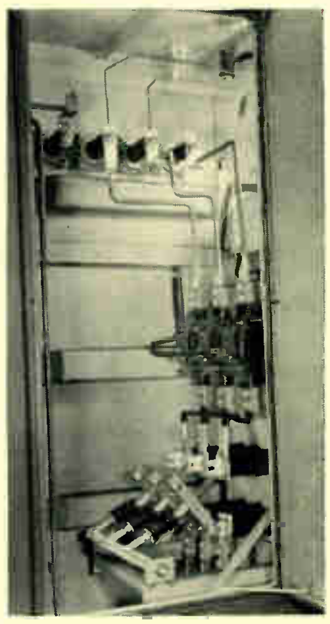
Other recent developments contribute to the ease of maintenance and permanence of CSP and Unit Substation Transformers. Among these are a high-visibility dial for oil gauges and thermometers, an oil gauge with a dial that can be removed without lowering the oil or breaking the transformer seal, and a thermometer that is also removable without breaking the oil seal. A rust-preventing undercoat similar to that used on automobiles is applied to the tank bottoms.

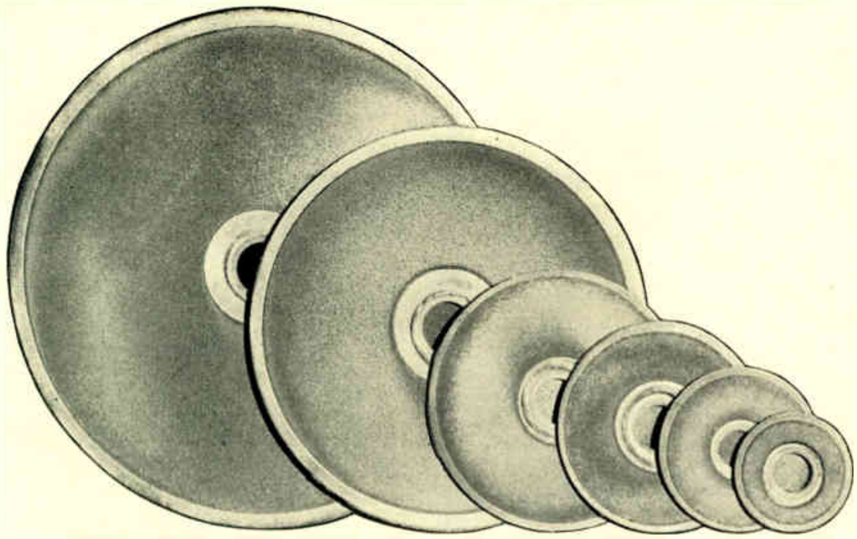
All these new features are combined with Hipersil core construction, Sealedaire, and Inertaire system of oil preservation and other features well known on power transformers. They are coordinated in such a manner that each small part contributes its particular bit to excellent performance.

A CSP Power Transformer, rear and front views respectively, and the compartment at the rear of the circuit breaker.









The characteristics of selenium rectifiers, whether in operation or "on the shelf," change importantly with time. These changes, which determine the actual quality of the rectifier, cannot be predicted simply by testing new stacks. Hence, only life tests lasting several years give absolute proof of the quality of rectifiers.

Factors in Judging *Selenium Rectifiers*

I. R. Smith, *Manager, Rectifier Engineering, Westinghouse Elec. Corp., Buffalo, New York*

"Selenium rectifier" is a general term, embracing the products of a number of manufacturers. No two of these are made in the same way, there being at least four different basic processes, with numerous variations of each. Furthermore, any one producer may make several varieties having dissimilar characteristics. Hence, general statements as to the characteristics of the "selenium rectifier" may be misleading, for what is true of one type may be untrue of another.

All selenium cells have, of course, one common characteristic—all offer a much lower resistance to current in one direction than to current in the other—which enables them to rectify. However, the overall quality of selenium rectifiers depends on several factors:

1—Forward resistance, or resistance to current in the forward direction.

2—Reverse resistance, or resistance to current in the reverse direction.

3—Conversion efficiency (or efficiency of rectification).

4—Effect of aging, whether in service or "on the shelf."

5—Temperature characteristics.

6—Life.

Since all rectifiers "age" (that is, change in characteristics with time, temperature, and operation), comparison of rectifiers only on the basis of their performance when new is futile. These changes include aging under load and "un-forming," which is a gradual decrease in reverse resistance while the rectifier is idle. (Upon application of d-c reverse or a-c voltage to such a cell, the rectifier "re-forms," usually in a second, or less.) It is important then to examine rectifiers not only as to their initial characteristics, but also as to their characteristics after service and over a long period of time.

Forward Resistance

Forward resistance is determined best by passing a specified direct current, corresponding to the full load rating, through a cell in the forward direction and measuring the voltage drop, Fig. 1, at a given ambient temperature. Various makes of new 18-volt (a-c) cells were tested at 0.34 ampere per square inch of active area, the average rated full-load current density, and 25 degrees C ambient temperature. The voltage drops varied from 0.75 volt to as much as 1.4 volts. Naturally, the lowest voltage is preferred, since this gives the best regulation. Westinghouse cells have a maximum test limit of 0.9 volt at 25 degrees C ambient. Production ranges between 0.75 and 0.9 volt, with an average at about 0.84 volt.

Another method of measuring forward resistance, which, however, can be used only on full-wave stacks, or on half-wave stacks in a full-wave connection, is the short-circuit test of Fig. 2. The d-c terminals are short-circuited through an ammeter and sufficient alternating voltage is applied to the a-c terminals to pass the rated direct current through the ammeter. This alternating voltage, then, is that required to overcome forward resistance, leakage (reverse) current at this

A laboratory arrangement for life-testing selenium rectifiers.

low voltage being so small as to be insignificant. The forward voltage is about 11 percent higher than obtained with the d-c measurement, since the voltage read is rms instead of average.

To determine how forward resistance changes during service under load, a comparative test was made by continuously operating representative makes of rectifiers at 110-percent rated voltage and rated current output. The units were mounted side by side on the same panel, so that all were subject to the same ambient temperature, and run for 20 000 hours (2¼ years). At the end of this period, forward resistances were measured by the a-c short-circuit method. The results varied considerably, with resistance increasing in one case as much as 265 percent. The average increase was about 50 percent with Westinghouse stacks increasing 10 percent.

Reverse Resistance

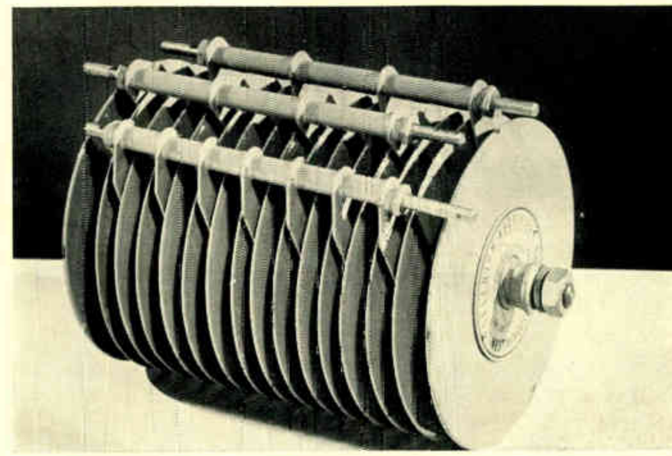
Reverse resistance is difficult to evaluate, because of the peculiar behavior of the selenium rectifier. A test similar to that used on copper-oxide cells, that is, measuring the reverse (or leakage) current at a given d-c voltage impressed across the cell in the reverse direction, may not have any meaning, partly because the cell may start "forming in" (re-forming) as soon as voltage is applied. Also, reverse resistance may not be the same under such a test as when the cell is carrying load, because current in the forward direction affects reverse resistance noticeably.

One common method of checking full-wave stacks is to apply rated alternating voltage with the d-c circuit open, Fig. 3, and to measure the input current, which of course is reverse current. Again, it is not necessarily identical to the current during load, but it serves as an indication. On such a test, a wide range of results may be obtained on different makes of rectifiers, the lowest being perhaps 10 milliamps per square inch, or less, and the highest as much as 100 milliamps; Westinghouse stacks fall in the first quarter of this range.

Again, it is of interest to see what happens to these rectifiers in operation. Measurements of reverse resistance during the 20 000-hour load test were very erratic, values swinging over wide limits. Conclusions would vary, depending on when comparisons were made. For example, the reverse currents of one stack in successive readings several thousand hours apart were 100, 30, 100, and 19 milliamperes.

In general, it appeared that the units with the worst record as to forward aging showed up best as to reverse resistance, and vice versa, although there were exceptions. For example, the Westinghouse stacks, whose forward resistance increased 10 percent, had a reverse current about 50 percent higher after 20 000 hours than when new; other stacks that aged 100 percent in the forward direction showed a 25-percent decrease in leakage current; stacks that aged 265 percent in the forward direction showed a 95-percent reduction.

Reverse resistance, however, while indicative to some extent of rectifier quality, is only one factor in overall performance. Life tests demonstrate that it is not as important as forward resistance and forward aging.



Individual cells of different sizes (shown on opposite page) and a complete stack (above).

Conversion Efficiency

The most important single criterion of rectifier performance is conversion efficiency, the ratio of d-c watts output to a-c watts input. It depends, of course, on the forward and reverse resistances and the corresponding losses. Naturally, low conversion efficiency means higher operating temperature, aside from the extra power cost.

On a long-time basis, the Westinghouse process seems to produce the stacks with the highest efficiency. Even though initially other types may be better, the low degree of forward aging is the controlling factor. Over the 20 000-hour test, Westinghouse efficiency decreased by the smallest percentage and, at the end of the test, was the highest. Conversion efficiency for the eight makes of rectifiers tested varied from 63.5 to 71 percent when new (single phase) and from 44 to 65 percent after 20 000 hours; Westinghouse stacks showed 70 percent initially and 65 percent ultimately.

Shelf Life

In addition to aging during operation, aging when on the shelf is also important. On-the-shelf aging includes un-forming and changes in either forward or reverse resistance.

As far as forward and reverse resistances are concerned, tests indicate that shelf aging has very little effect on Westinghouse rectifiers. No change at all is noticeable during the first nine months. After another year (21 months total) forward resistance increased eight percent, which affects output less than one percent. Reverse resistance decreased nineteen percent, but this is insignificant, having no discernible effect on output.

Figure 1

The d-c test (Fig. 1) and the a-c test (Fig. 2) for measuring forward resistance; Fig. 3 shows the test for reverse resistance.

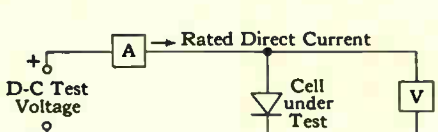


Figure 2

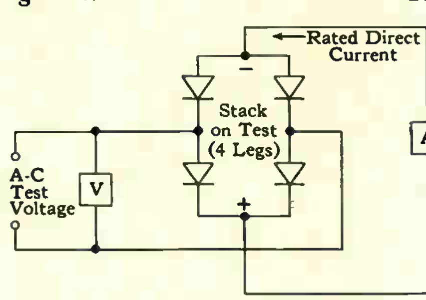
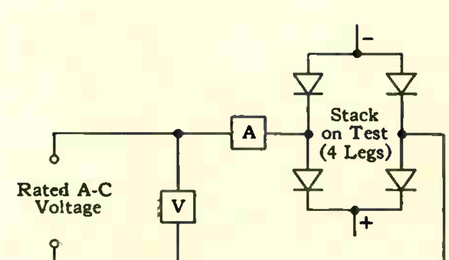


Figure 3



The un-forming experienced during storage is sometimes the limiting factor in shelf aging. As an indication of un-forming, oscillographic tests were made on several makes of rectifiers, first in 1944 on new units and then again in 1947 on the same units, which had been on the shelf in the interim. No voltage was applied to the stacks, except during the brief tests. The tests were made by applying rated a-c voltage to each rectifier (whose d-c terminals were open) and recording on an oscillograph the initial peak of the current input and the approximate time to re-form to normal (during which the current decreases). Results showed interesting differences.

The stacks, when new, drew leakage currents whose initial peaks ranged from a minimum of 0.7 ampere per square inch (for Westinghouse stacks) to a maximum of 3.8 amperes for other types. Westinghouse stacks re-formed in 15 cycles; others in up to about 90 cycles. After three years on the shelf, Westinghouse stacks showed an initial peak current of 1.4 amperes (double the value when new), and re-formed again in 15 cycles. The initial peak currents of other types were from three to nine times their peaks when new, the highest being 21 amperes, with about the same increase in re-forming time, the longest being 360 cycles.

For most applications high initial leakage current and time required to re-form are unimportant. However, on highly intermittent duty, selenium rectifiers used in d-c blocking circuits could cause faulty operation of sensitive relays. Applications such as this should be studied carefully from every standpoint before a selenium rectifier is selected.

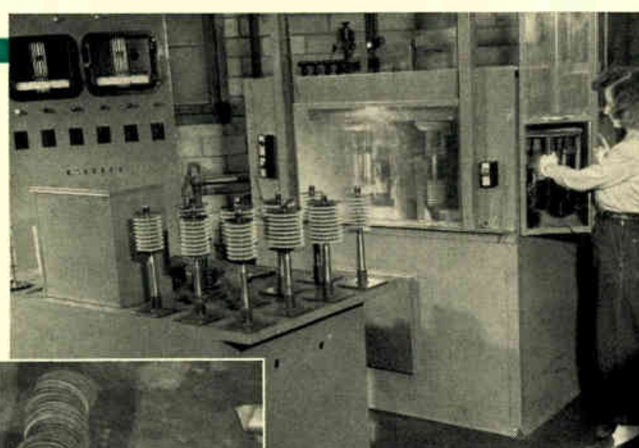
Temperature Characteristics

Most types of selenium cells employ a sprayed-on positive electrode of an alloy that melts at 103 degrees C. If, for any reason, the rectifier reaches this temperature, the alloy melts and runs off and the rectifier's usefulness is ended. This temperature limit has been greatly increased in Westinghouse cells by the use of a high-melting-point alloy, which does not soften below 175 degrees C. Many stacks of this type have operated for thousands of hours at cell temperatures up to 125 degrees C, which enables handling special high-ambient applications, as required for some military or naval equipments. The alloy also provides a reserve to take care of excessive temperatures occasionally encountered in operation.

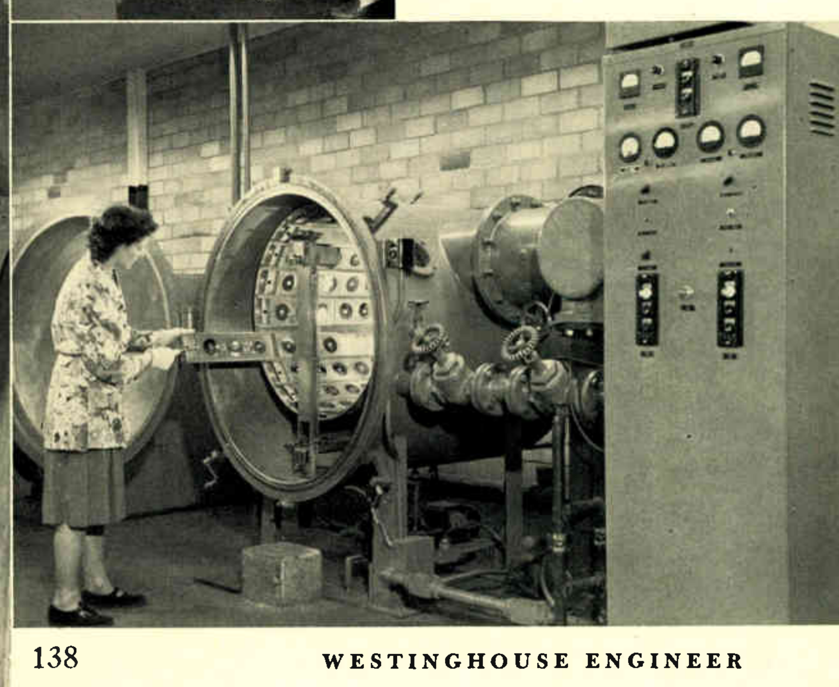
Life

Westinghouse rectifiers have now operated on laboratory life tests continuously for 4½ years (40 000 hours) with very satisfactory performance. The increase in forward resistance due to aging of these units still does not exceed 15 percent, a good indication that they should operate for many more years without trouble. Rectifiers with higher rates of aging may be expected to have shorter life. High rates of forward aging mean lowered conversion efficiency, increased losses, and hence higher temperatures, which accelerates aging, again increasing temperature. The process is cumulative to rectifier

Degreasing of the aluminum blanks (below) produces the thoroughly clean surface necessary for application of subsequent coatings. One side of the blank is then sandblasted to roughen the surface slightly, which improves the contact and adherence of selenium. . . .



. . . A light coating of metal is electroplated onto the sanded surface, after which the selenium is deposited by spinning the cells in a molten bath (left). Following inspection, the barrier layer is condensed onto the surface of the selenium in this high-vacuum chamber (below). Each cell is then masked to prevent a short



destruction unless a stable condition is reached.

Manufacture of Selenium Rectifiers

The individual selenium rectifier cell is a synthetic rectifier comprised of four components bonded into an integral unit. These components are the base plate, the selenium coating, the barrier layer, and a sprayed metal coating.

The base plate is usually of aluminum, 30 to 40 mils thick, though it may be of steel. The selenium, usually "doctored" to get low resistance, is deposited on one side of the base plate in a tightly adherent layer several mils thick. Deposition may be accomplished by any of several methods, such as, for example, by evaporation, by hot pressing, or by spinning in a bath of molten selenium. The barrier layer is obtained by depositing a suitable material on top of the selenium in a layer of molecular dimensions, or by chemically changing the nature of the top surface of the selenium. The last component—the metal layer—is sprayed on over the barrier layer, forming a coating several mils thick.

Exact heat treatments are used to crystallize the selenium layer, followed by electrical formation of the barrier layer. Formation increases the reverse resistance of the layer, without materially affecting the forward resistance, thus increasing the cell voltage rating.

Processing should be carried on under practically laboratory conditions. Not only is it necessary to control closely all materials and all parts of the process, but all contamination, such as from dust, must be avoided. In the Westinghouse plant, for example, processing is done in an air-conditioned room, with both temperature and humidity control. Dust is removed by mechanical filters, and a Precipitron, giving the ultimate in cleanliness. Daily quality control checks, weekly accelerated life tests, plus many long-time load runs, are needed to produce a rectifier of maintained high quality.

Manufacturers differ in their methods of applying the selenium layer to the base plate, in the "doctoring" of the selenium, in the make-up and application of the barrier layer, in the make-up of the sprayed metal layer, in heat treatment, and in the method of forming the barrier layer. So it is not surprising that resulting cells should differ in characteristics.

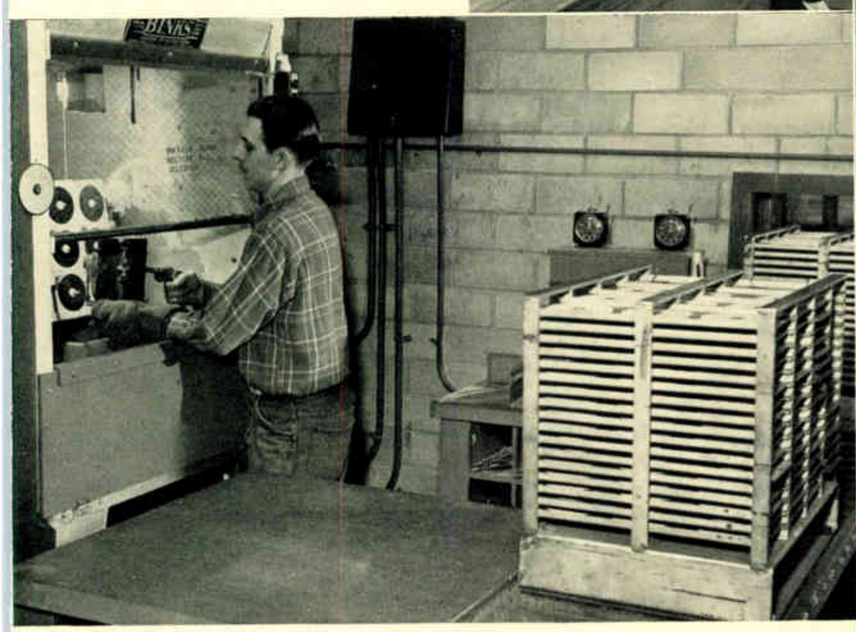
Conclusion

The rectifier business is a constantly changing one. Hence, the picture presented here is always subject to change. The use of high melting alloys for the positive electrode, for example, may become more prevalent.

However, whether or not such improvements have been realized can be determined only by testing over a long period of time. In spite of accelerated aging tests, an "improved" selenium rectifier or an "improved" technique cannot be proved for several years, because the differences disclosed by life tests cannot in any way be predicted by snap tests on new stacks. Users generally cannot make extensive life tests, but they should know the effects of time and operation on rectifiers.

circuit around the edges. The high-melting-point alloy is sprayed on (below), and the masks removed. Each cell is now complete as to components, but the process is not. The cells must be heat-treated to change the selenium layer to crystalline structure and then formed-in electrically (right). . . .

. . . The cells are tested, assembled into stacks (below), and re-tested. The rectifiers are now ready for installation. Selenium rectifiers provide d-c power at high or low voltages, ranging from as low as six volts to several thousand, and for a variety of industrial purposes.



Stories of RESEARCH

X-ray Diffraction at High Temperatures

As far as the scientist is concerned there is still much unexplored territory to be "mapped." For, unlike the face of the earth, which is fairly well known and reasonably constant, the structure of most solid materials is far from constant. Since the characteristics of most materials depend to a large extent upon the structural position of atoms within their boundaries, "mapping" is of the utmost importance in ascertaining the properties of materials under different physical conditions.

Like many geographical measurements the locating of atoms in a structure must be done by indirect means. One such method, x-ray diffraction, is based upon the "reflections" of x-rays from atoms within a solid. This principle, discovered by Laue in 1912, has been widely applied by research scientists. The x-ray diffraction camera is one instrument built to utilize it.

X-ray diffraction cameras now commercially available allow the study of materials at temperatures up to about 1000 degrees C. However, temperature is a factor that greatly affects atom structure, and since the present trend in many fields is toward higher and higher operating temperatures, exhaustive studies must now be made in these upper ranges. A new camera, designed and built at the Westinghouse Research Laboratories under the direction of the late Dr. J. W. Hickman, pushes the upper limit to greater heights—up to 2000 degrees C.

The camera consists of a hollow, metal cylinder, about two feet high, with an 8½-inch diameter. The top half removes to disclose the inner workings of the camera, and the high-temperature heating equipment; the sample being studied is mounted in the very center. X-rays are produced externally, beamed through a beryllium window in the side of the cylinder, and strike the sample. Reflecting rays pass through a peripheral slit in the cylinder and strike a sensitive film mounted behind it, recording a pattern that indicates the atom arrangement of the sample.

Several features of this new camera are outstanding in addition to its high-temperature operation. Associated equipment makes it possible to maintain a certain atmosphere in the camera, or to change its composition, without disturbing the photographic action. Thus one gas can be removed and another substituted without opening the camera or interrupting the study. Also, unlike most cameras of this type, several exposures can be taken without opening the camera. Film can be adjusted from the outside of the vacuum chamber, and a total of five exposures can be taken on one strip of film. A larger than usual radius gives greater resolution of lines in the pattern obtained.

One useful application of this camera is in studying the atom arrangement and rearrangement in various metals and alloys. For example, there is still considerable speculation as to exactly what happens to a heating wire when it is subjected to cyclic applications of current throughout its life. Both an electron diffraction camera, for the study of surface reactions, and the x-ray diffraction camera, for the combined wire and oxide study, are used in this work. In applying the x-ray camera to this use, a sample wire is mounted, the cover sealed, and then an auxiliary device takes over to turn the current on and off at specified intervals. Diffraction pictures are taken during each "on" period, so that a complete record is obtained of the step-by-step changes in the oxide structure that forms throughout the life of the wire. By studying these pictures scientists hope to discover exactly what structural changes take place.

This is but one use for the x-ray diffraction camera. The atom arrangement of almost any solid, with the exception of a few amorphous materials like glass, can be determined. Thus it is useful not only in observing changes in arrangement under different temperature and atmosphere conditions, but also in identifying solids, and in determining the state of order of a metal.

A specimen is placed in the diffraction camera. X-rays scattered from it will pass through the metal foil, and impinge upon film.

Emission Mountains from Platinum

The discovery by DuFay in 1725 that the area surrounding a hot body was a good electrical conductor touched off a series of further discoveries that led eventually to the modern electronic tube. Since that date it has been found that all metals, heated to a sufficient temperature, give off electrons. This thermionic emission is the basis for many electronic tubes. But science often applies a principle knowing only "how" it works, leaving the more difficult "why" for later and more detailed examination. Thus, although the theoretical emission characteristics of most metals are by now well known, scientists are still puzzled by the "whims" of some metals when actually tested as emitters.

In recent experiments with platinum, supposedly an excellent grid material because of its low emission, research engineers of the Westinghouse Lamp Division discovered that emission differed tremendously from theoretical values at certain temperatures. They started their tests with ordinary platinum, and observed rather high emission characteristics over a wide range of temperatures. Deciding that this might well be because of the impurities in the metal, they substituted chemically pure platinum—more than 99.9 percent pure. At last their results seemed more reasonable. As they raised the temperature gradually, they found that initially emission was erratic and a little high; but as the temperature was increased to 1400 degrees C it became more stable and corresponded closely to theoretical emission values. So far so good. But from then on the results were strictly unorthodox. As they began to lower the temperature, the emission displayed alpine tendencies. Below 1100 degrees it shot to mountainous peaks that decayed slowly with time. These peaks became successively higher as the temperature was reduced further, until at 905 degrees the emission reached an instantaneous peak value of Matterhorn proportions—over two billion times greater than the calculated values for pure platinum at this temperature. Puzzling behavior to say the least! But as they continued, they discovered the source of this mysterious emission.

By coating part of the inside of the tube containing the platinum emitter with a phosphor, they were able to observe the action of the metal as the temperature changed. Tiny spots of light on this phosphor coating told them that the emission was originating from a few minute pin points on the metal, rather than from a general area. This action could lead to but one conclusion. Despite the near perfection of the chemical purity of the platinum, the infinitesimally small impurities—so small that their composition could not be detected spectrographically—were causing the erratic emission. Apparently these minute impurities "boiled" to the surface only under certain definite temperature conditions, and provided sudden bursts of emission as they reached the surface. The exact composition of these foreign substances is still not definitely known, but it seems likely, in view of the emission curves obtained with these samples, that the material is one far removed from pure platinum on the emission scale—i.e., one with very high emission characteristics.

Imprisoned Light

LIGHT that enters a gas-filled tube is sometimes given a rigorous workout before being allowed to escape. For example, certain wavelengths of monochromatic light that strike mercury vapor are "bounced" from atom to atom for a period of several hundred microseconds. By usual standards, of course, a hundred microseconds is not a long interval; but considering the speed of light, and the rapidity with which most atomic reactions occur, this "imprisonment" is comparable to a long-term jail sentence.

As a part of a long-range fundamental study of the interrelationships between atoms in gas discharges—appropriately titled "interatomic physics"—this reaction is under intensive study at the Westinghouse Research Laboratories by co-workers Dr. Daniel Alpert, Dr. Theodore Holstein and A. O. McCoubrey. Current aim of their experiments is to find out more about one phase of this phenomenon—so-called "resonance radiation," which is the re-emission, at the same wavelength, of light absorbed by an atom.

Resonance radiation was first discovered in 1912 by R. W. Wood, who noticed that when monochromatic light in the ultraviolet region (2537A) was directed at one portion of a mass of mercury vapor, it spread to other parts. Since this action was not due to the movement of atoms, he concluded that it was the result of single absorptions and re-emissions by the mercury atoms. Later investigations showed that actually the light was absorbed and re-emitted hundreds of times before it finally escaped the gas. However, until 1947 when Dr. Holstein published his theory* on the imprisonment of resonance radiation in gases, there was no adequate theoretical description of the phenomenon.

At present, Alpert, Holstein, and McCoubrey are making the first accurate measurements of the time interval required for monochromatic ultraviolet light in the 2537A region to escape from mercury vapor under various gas-pressure conditions. Ultraviolet light, alternately turned on and off by a rotating wheel, passes through a monochrometer; the resulting monochromatic light strikes a tube filled with mercury vapor; radiation from this tube is captured by a photomultiplier and the information, in the form of a decay curve, is displayed on the screen of an oscilloscope. Pressure in the vapor tube is controlled by varying its temperature. Experimental results obtained thus far agree closely with those computed from Holstein's theory.

Experiments so far have used only ordinary mercury; later the recently available 198 isotope of mercury will also be used. This isotope is expected to imprison radiation over five times as long as ordinary mercury.

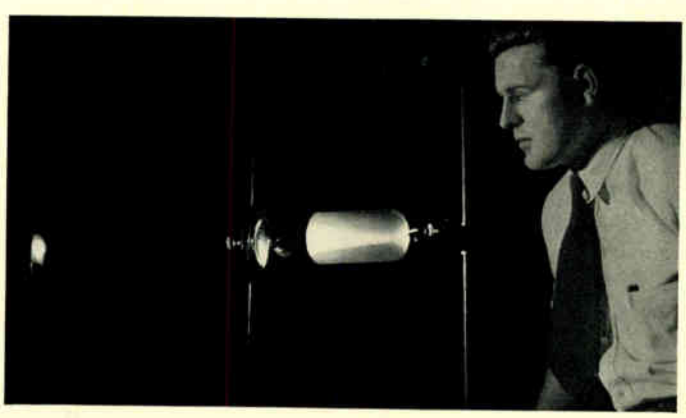
Factors other than vapor pressure affect the escape time of incident radiation. Small amounts of air introduced into the mercury cause a quenching action, decreasing the intensity of escaping radiation. Apparently collisions between the excited atom and a foreign gas molecule cause the excitation energy to be given up to the foreign molecule, preventing the excited atom from radiating. A study of this phenomenon is also planned.

Although the radiation escape time after the removal of excitation is the specific factor being measured in most of these experiments, the results also apply to imprisonment while the tube is still externally excited. In some cases this is the more important consideration. For example, the fact that a fluorescent lamp emits light for a split second after the voltage is removed is of no particular significance, either from an electrical or a psychological standpoint. But resonance radiation and its escape time is of vital importance during the "on" period of the lamp, since light output of the fluorescent lamp depends upon the amount of 2537A radiation produced. Thus, a thorough knowledge of resonance radiation may lead to improvements in the efficiency and characteristics of fluorescent lamps.

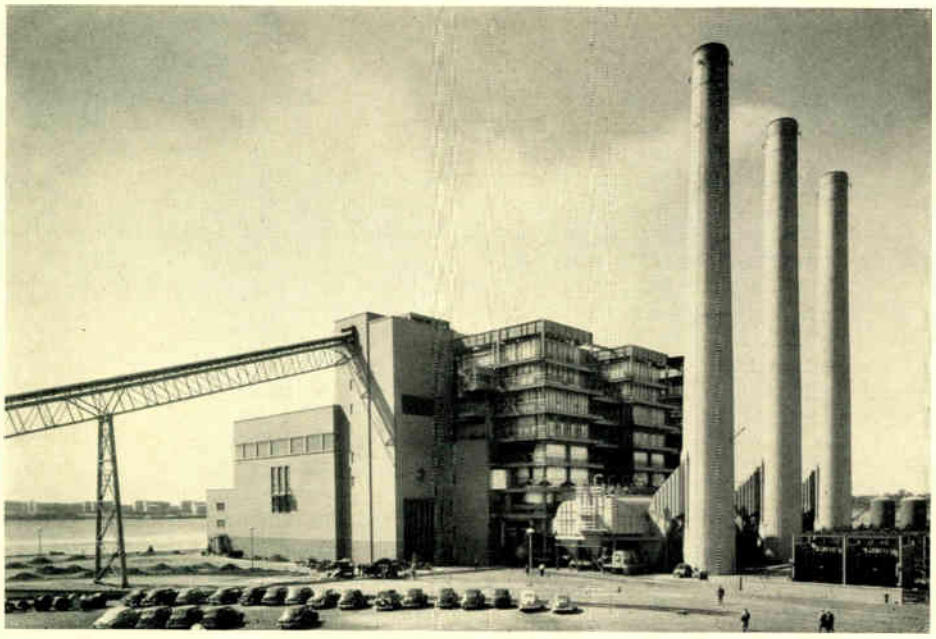
On the other hand, the time delay after removal of voltage is of extreme importance in some other electronic devices, such as the thyratron, where a continuance of excitation even for a few microseconds may be of significance.

Since the phenomenon of resonance radiation is not limited to mercury vapor, improvements in other gas-discharge devices may also be expected. But regardless of the practical significance, this investigation will increase man's knowledge of one of the electrical engineer's most useful tools, the electric gas discharge.

*"Imprisonment of Resonance Radiation in Gases," by T. Holstein, *The Physical Review*, Vol. 72, No. 12, Dec. 15, 1947, pp. 1212–1233.



Resonance light from the left is invisible to the camera until it strikes the vapor-filled tube. Atomic absorptions and re-emissions then scatter it in all directions. In picture at right, decay of resonance radiation is measured. Decay curve appears on the screen.



During a year in which the installed capacity in the United States is growing some ten percent, many power plants are being built anew or expanded. One wholly new generating station is Sewaren, in which several novel practices are being given a full-scale trial. The performance of this station, which features the hottest of steam temperatures, large 3600-rpm turbine generators, semi-outdoor-type boilers, centralized control, and an all-electric auxiliary drive, will be watched with interest for many years by utility engineers.

Sewaren Station—A Pioneer Power Plant

Only infrequently does a utility have the occasion to build a new central station from the ground up, unencumbered by previous construction. Hence, when this opportunity was presented, the engineers of Public Service Electric and Gas Company (of New Jersey) built into Sewaren Generating Station their most forward thinking. Sewaren, with its many innovations, accentuates the fact that the power industry, despite the immutability of generating principles, is ever dynamic and changing.

Public Service has long distinguished itself in promoting bigger—and hotter—3600-rpm turbine generators. In 1932, for example, it installed at its Burlington Generating Station one of the first turbines to operate at 825 degrees F, the previous limit being 750 degrees. The generator, rated 18 000 kw at 3600 rpm, was at that time the largest high-speed unit, albeit small by today's standards. It was built for topping service (its 200-psi exhaust is fed to three turbines), then almost a new concept. It was also among the first installations to utilize welded high-pressure piping.

In the years since the Burlington installation, the utility has continued to pioneer in higher temperatures, its efforts culminating at Sewaren last fall, when it placed in service the first two turbine generators to operate at 1050 degrees F. The turbines, which have a nominal rating of about 100 000 kw, are among the largest capacity, high-speed (3600-rpm) units in operation. They are to be followed by two more, one of which will be rated 125 000 kw.

Sewaren's significance is not founded on superlatives alone, on "hottest" temperatures and "largest" capacities. Its other equipments and its overall plan and design have many novel and important features. As a result of these improvements, the complete four-unit station will cost approximately 132 dollars per kw and will operate with a plant heat rate of approximately 10 000 Btu per kwhr, figures importantly low to power utility men.

Prepared by L. H. Berkley, from information furnished by F. P. Fairchild and P. A. Salmon of Public Service Electric and Gas Company.

The Steam Equipment

That Sewaren exemplifies modern station design becomes apparent as one approaches the main building, situated on the New Jersey coast, across the salt-water Arthur Kill from Staten Island. First to catch the eye are three semi-outdoor-type boilers, which strike even the layman as unusual appurtenances of power-plant construction. But to utility engineers, these boilers are extraordinary in that they are the largest and among the first semi-outdoor boilers located so far north. The building encloses only the front and part of one side of each boiler. This design reduced building dimensions and saved about one million dollars in construction cost for the first three units. Also, the heat and dirt entering the turbine and control rooms from the boiler room are lessened, reducing the ventilation problem and facilitating good housekeeping in these areas.

Sewaren is laid out on the unit system. With this scheme, each generating "unit"—coal pulverizers, boiler, turbine, generator, transformer, and all auxiliaries—is complete in itself and practically independent of others. Such a plant is less expensive than one having, for example, three or four interconnected boilers for the two turbines, but it is considered satisfactory, largely because of the reliability of the boilers.

The first three boilers for Sewaren Station were constructed by Combustion Engineering-Superheater, Inc. Each boiler is of the three-drum, radiant type, rated 1500 psig at 1050 degrees F, with a continuous capacity of 850 000 pounds of steam per hour and a four-hour maximum capacity of 950 000 pounds. The fourth boiler will supply steam at the same initial conditions, but it will be arranged for reheating. The steam flow will be about the same, but because of reheating the turbine will deliver a greater output.

The furnace is of the wet-bottom type, from which the molten ash flows continuously into a water-filled tank; it is then disposed of by hydraulic pumping. The furnace is fired from all four corners with burners that can use pulverized coal, oil, or gas, or a combination of all three, whichever is most economical. Final steam temperature is controlled by a damper that by-passes part of the furnace gases from the primary superheater to the economizer, which preheats boiler water, affording maximum utilization of heat. Each boiler has a combination mechanical-electrostatic flue-dust collector that removes 95 percent of the total weight of fly ash.

Of the two turbines now in operation, Sewaren No. 1 is a Westinghouse tandem-compound machine rated 110 000-kw maximum, with a double-flow low-pressure exhaust. It is served by a 50 000-square-foot Foster Wheeler condenser and is designed to operate most efficiently at a load of approximately 95 000 kw, at which the theoretical plant heat rate is approximately 9900 Btu per kwhr. No. 2 is a General Electric unit, also rated 110 000-kw maximum. It, too, is a tandem-compound machine, but with a triple-flow exhaust. It is served by a Foster Wheeler 60 000-square-foot condenser and is designed to operate most efficiently at a load of approximately 105 000 kw, at which its heat rate is about 9750 Btu per kwhr. No. 3, scheduled for operation this year, will be a duplicate of No. 2 turbine.

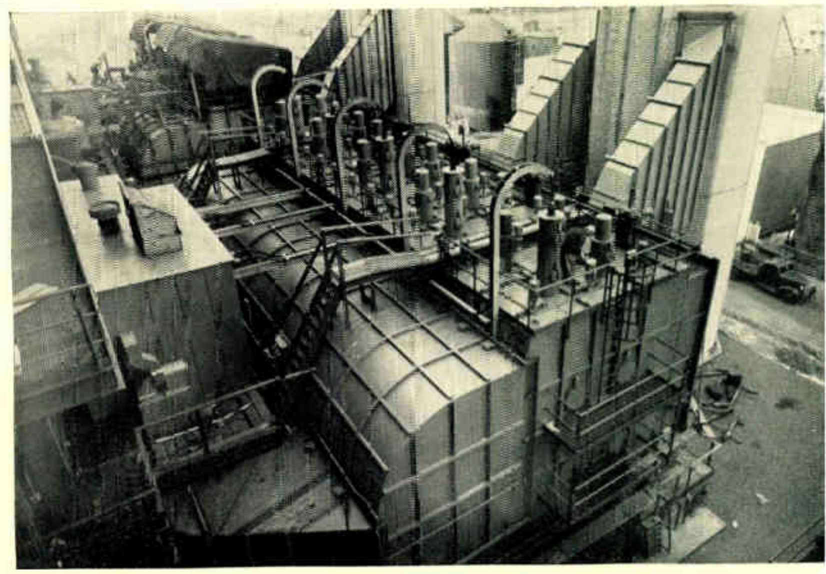
No. 4, scheduled for operation in 1951, will be a Westinghouse unit rated 125 000 kw. It will be similar to Nos. 2 and 3, except that it will be arranged to use steam reheated to 1000 degrees. It will be served by a 65 000-square-foot condenser and will operate most efficiently at a load of 115 000 kw, at which its heat rate will be approximately 9400 Btu per kwhr. This turbine will be among the largest in rating of 3600-rpm machines, and a significant mark in the return of the reheat cycle.

The Sewaren turbines, particularly interesting to utility engineers because of their high temperature, high pressure, and high capacity at high speed, posed particularly difficult problems to their designers for precisely these same features. One of the most difficult resulted from the 1050-degree steam conditions, which required the use of steels new to turbines. These steels were used for the steam chests (which contain the regulating valves), the piping, the nozzle chambers, the nozzles, and the first stage of impulse blades of the rotor; these parts are in contact with high-temperature steam. This steam comes directly from the superheater, which also presented a difficult problem for the same reason. The solutions were found in several stainless-steel alloys, containing various quantities of chromium, nickel, molybdenum, and other elements. For example, in the Westinghouse turbine, the steam chests and nozzles are of 18-8 chrome-nickel, stainless steel.

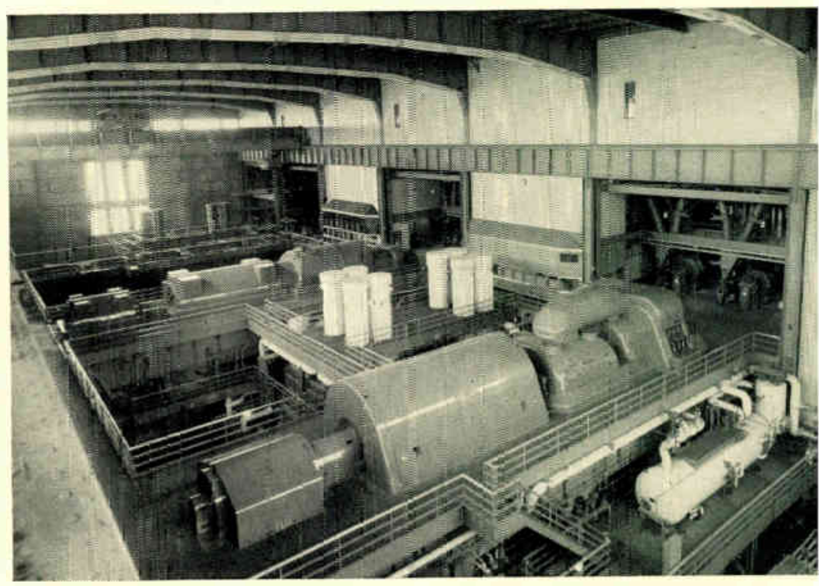
The use of special steels in piping and turbine components raised problems when these metals were welded to lower alloy steels, because of their dissimilar coefficients of thermal expansion. One concerned the connection of the throttle housing of high chrome-nickel steel with the steam piping of low chrome-moly steel, whose coefficient is about 33 percent lower. The junction was finally made with the aid of a special transition piece containing the two materials welded together along a longitudinal seam.

Similar problems occurred on the turbines themselves, whose various sections are constituted of different alloys, determined by the temperature of each. The difficulties were surmounted by welding, at the points of lowest stress, relatively thin, flexible members, which permit expansion and contraction with temperature changes.

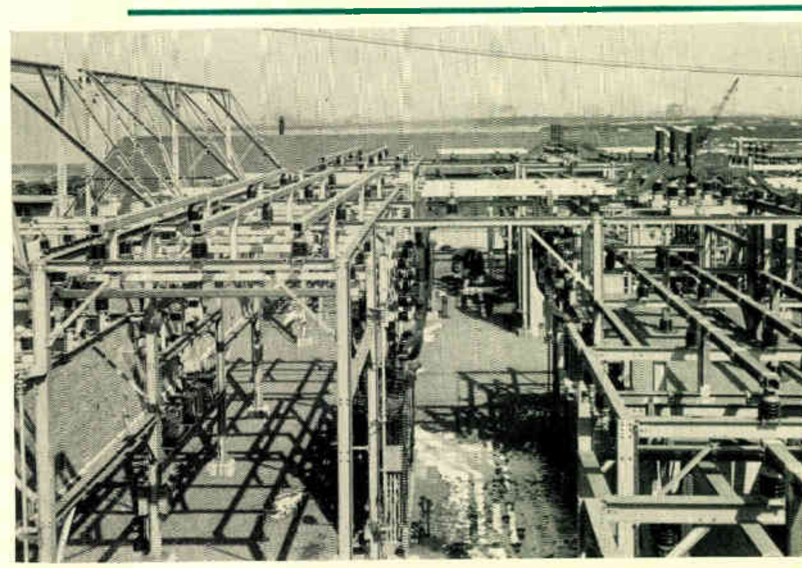
Another difficulty was the development of a suitable 23-inch-long turbine blade for the last low-pressure stage on the rotor. The radial length of blades in the last row limits the volume of steam flow and, therefore, the economical capacity of the turbine. The lack of a blade of the necessary 23-inch length was a factor that retarded the development of a single-

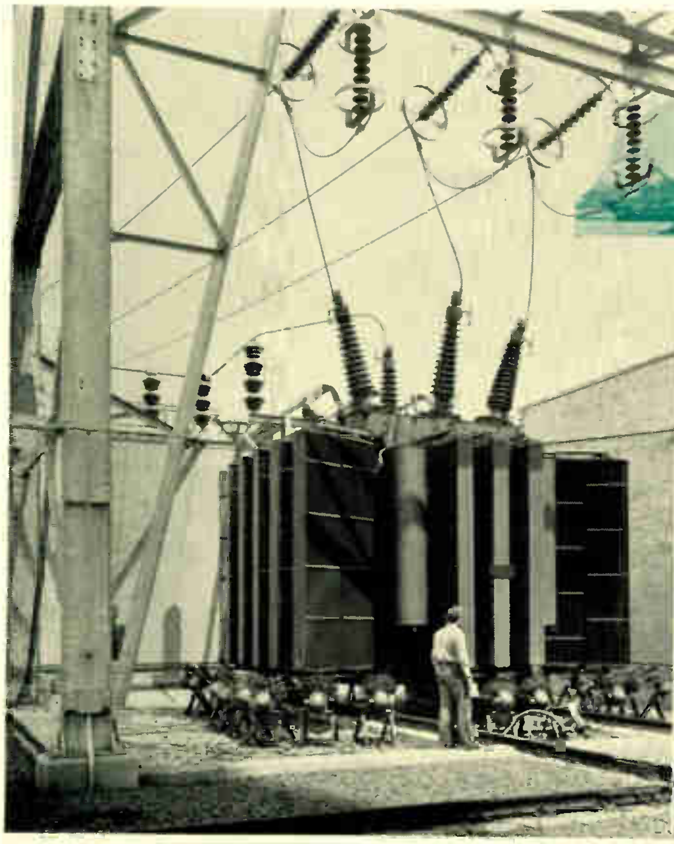


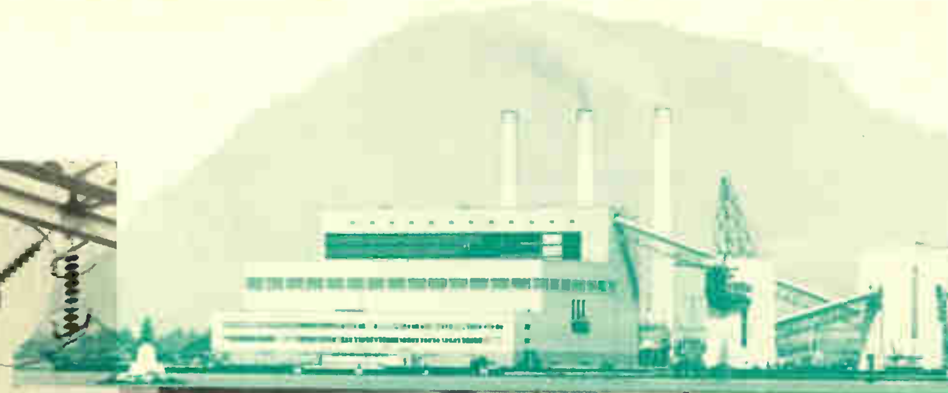
The mechanical-electrical flue-dust collectors (above) remove 95 percent of the total weight of the fly ash.

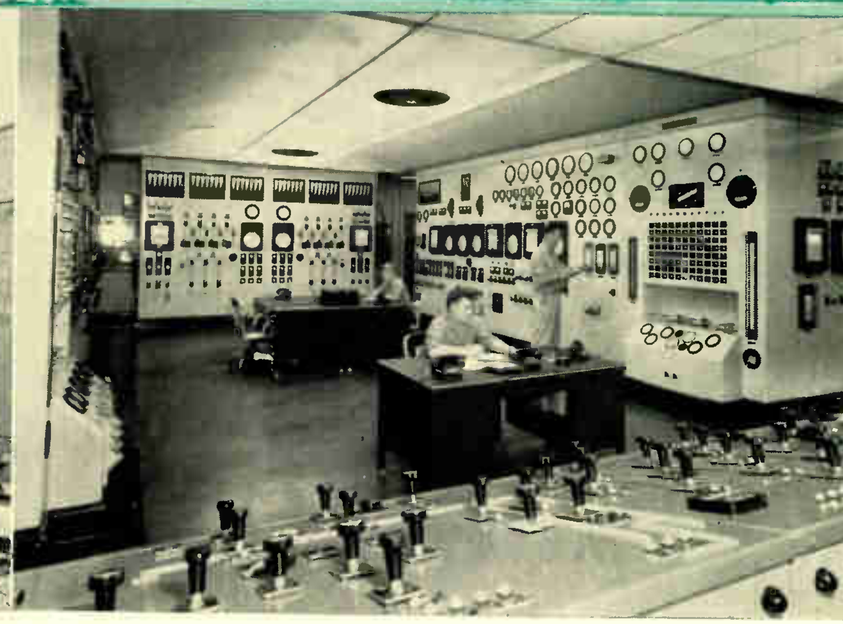


Incandescent and fluorescent lighting combine to give the turbine room (above) an intensity of 22 foot-candles. Welded buswork in the transformer yard (below).









This 3-phase, 85 000-kva (maximum) transformer steps up the voltage to 132 kv. It is triple rated, forced-air and forced-oil cooled.

One control room, showing the electrical bench board in the foreground and mechanical panels around the other three sides.

shaft, 100 000-kw, 3600-rpm condensing turbine generator.

The blade had to meet a number of exacting requirements. It had to be of sufficient strength to resist the enormous centrifugal force of 16 000 times its own weight, and yet carry its normal steam-pressure load. When mounted on a 42-inch-diameter disk (in the case of the Westinghouse machine), and rotated at 3600 rpm, the blade has a tip speed of 1380 feet per second, well in excess of sonic speed. But the requirement that, under conditions of full load and speed, the blade must not vibrate excessively, so as to cause failure, is even more exacting. To meet this specification, it had to be of precise proportions and composition, so as not to have a harmful resonant frequency that is a multiple of sixty cycles. The blade was developed only after several years of extensive testing of experimental models mounted on wheels and rotated at high speed. The blade is of a chrome-iron alloy, long standard for turbine construction.

That the use of 1050-degree steam for power generation will be successful is indicated by the fact that both turbines have operated for almost a year without major difficulty.

All-Electric Auxiliary Drives

Another innovation at Sewaren is the exclusive use of motor-driven auxiliaries—instead of steam-driven. Most power plants use boiler steam for air ejectors (for removing air from condensers), for soot blowing (cleaning the boilers), for driving the auxiliary oil pumps and the reserve boiler feed pumps, and for other purposes. Much of this steam is discarded after use because it is uneconomic to recover or to return to the condenser, or for other reasons. It must be replaced by make-up water, which of course must be treated and distilled before it is pumped to the boiler. Excessive use of make-up water is undesirable, first because it is expensive, and, second, because it increases contamination, however slight, particularly in high-pressure boilers.

At Sewaren, steam from the boilers is used only to run the main turbines; the steam is then condensed and returned as water to the boilers. Most of the functions normally assigned to auxiliary steam are accomplished by other means. One problem in eliminating the use of auxiliary steam was in the substitution of motor-driven vacuum pumps for steam-jet ejectors. Before proceeding with this radical departure from customary practice, such a pump was tried at Public Service's Marion Generating Station for about a thousand hours. The test revealed some minor difficulties with separation of water vapors coming from the condenser, from the pump lubricating oil, but proved the application feasible. Consequently, vacuum pumps (of the positive-displacement rotary type) are being given a full-scale trial at Sewaren.

Soot blowing, which normally requires a large volume of steam, is done by compressed air.

The traditional steam turbine driving a reserve boiler feed pump was eliminated, a step justified by the inherent reliability of the auxiliary generators and of the squirrel-cage induction motors driving the boiler feed pumps. These motors are rated 2000 hp at 3600 rpm and are of the totally enclosed, recirculating-air-cooled type.

Also discarded at Sewaren is the steam-driven auxiliary oil pump. The system used is comprised of a full-capacity a-c motor-driven pump, backed up by a smaller a-c motor-driven auxiliary pump (normally used for lubrication when the turning gear is operating), and further backed up by a still smaller d-c motor-driven pump supplied with current by the station battery. The latter pump has enough capacity to provide lu-

A view of No. 1 boiler, which is over 123 feet high, from the foot of the stack. The flue-dust collector appears in the foreground.

Coal is brought into the main building by this conveyor, one of a system of eight belts. The capacity is 600 tons of coal per hour.

brication for bringing the turbine generator to a stop should both a-c motor-driven pumps become inoperative.

The advantages of all-electric auxiliary drive are: (1) reduction in the quantity of make-up water to less than one-half percent, (2) elimination of the auxiliary steam header at the boiler, the pressure-reducing valve, and much steam piping, and (3) facilitation of central control of the station, another Sewaren feature. Auxiliary steam, used only for heating fuel oil and the building, and for mixing chemicals for water treatment, is supplied by the evaporators or, in the event of complete station shutdown, by a small unit-type heating boiler.

Electric power for running the motor-driven auxiliaries and for other local uses is supplied by 7500-kw, 80-percent power factor, 2400-volt auxiliary generators, one coupled to each main generator. To isolate each unit system from external disturbances, the auxiliary generators are never paralleled with each other or with the main generators. If an auxiliary generator loses its voltage for any reason, the load is automatically transferred to auxiliary transformers energized from an outside supply. Throw-over in the reverse direction, required after restoration of voltage to the auxiliary generator or when starting the turbine generator, is done manually.

Excitation of each generator is provided by an m-g set energized from the auxiliary supply. The m-g set has a heavy flywheel to maintain excitation voltage in case of loss of station power during the brief interval until the auxiliary transformer is automatically connected.

Three distribution voltages are available for auxiliary power: 2400, 440, and 220 volts. Power is distributed through drawout-type high- and low-voltage switchgear.

Induction motors are used for all auxiliary drives. Such motors are simple in construction and afford the utmost in reliability, so essential where emergency steam units are not provided. Totally enclosed motors are used extensively.

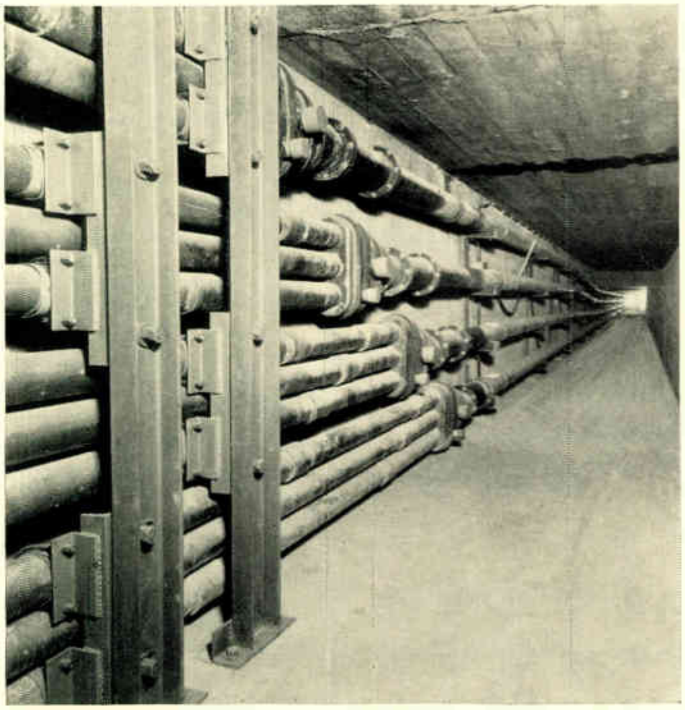
The Main Electrical Equipment

Each of the main generators for Sewaren Nos. 1, 2, and 3 is rated 111 765 kva, 95 000 kw, at 15 pounds hydrogen pressure. No. 4 generator will be rated 140 000 kva, 119 000 kw at 30 pounds. All ratings are at 85-percent power factor. The machines are of essentially the same general construction as 3600-rpm generators of the 65 000-kw class, the previous maximum capacity, except that individual parts are larger.

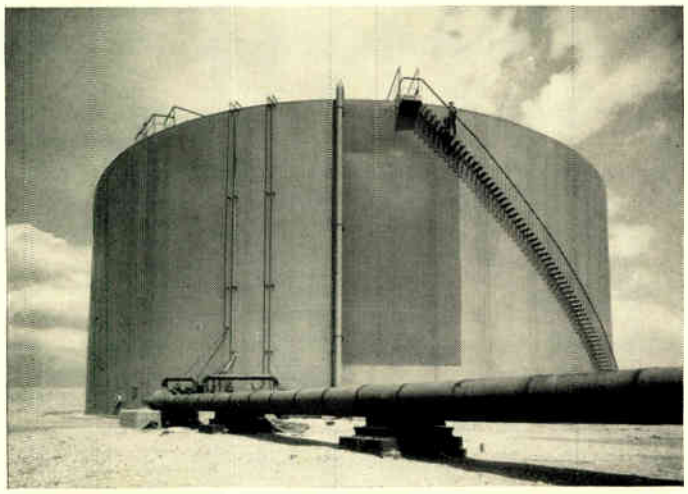
Each generator is grounded by an air-cooled transformer loaded by a resistor. With this scheme, the current resulting from a phase-to-ground fault in the machine is limited to about ten amperes.

The 13-kv leads that extend from the generator 500 feet to the transformer yard are carried in pressurized, oil-filled, Oilostatic pipes, the cables for each unit being housed in an individual underground tunnel. This arrangement enables the use of forced cooling during warm weather, which permits reduction of the copper size from twelve to six million circular mils per phase, saving in cost and facilitating handling of cables. Pipes for generators 1 and 3 are cooled by forcing air through the tunnels, and pipes for No. 2 by circulating the oil through an oil-to-water heat exchanger.

Each set of 13-kv cables emerges from its tunnel in the transformer yard and feeds into a middle-tap reactor, thus separating the outgoing power into two channels. For the first two generators, the voltage of one channel is stepped up to 26 kv, for local use, by two 51 000-kva, 3-phase, General Electric transformers. The other is stepped up to 132 kv, for transmission to other sections of the Public Service area, by an 85 000-

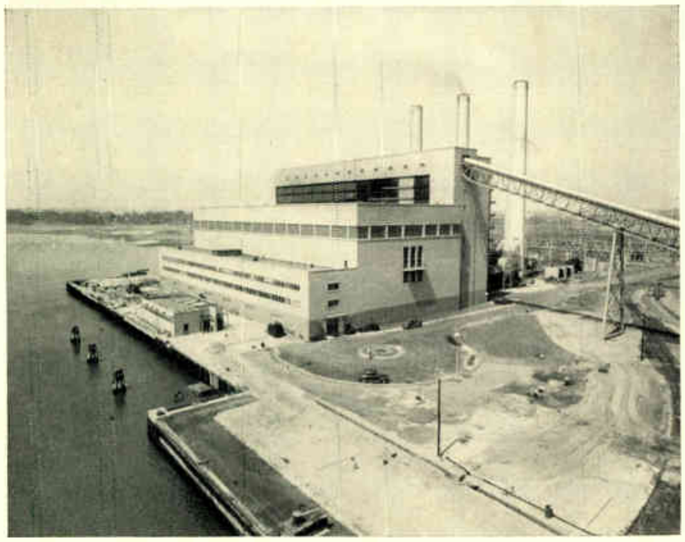


The tunnel for No. 1 generator, showing the Oilostatic pipes. It is cooled by forced ventilation during the hot weather.



This oil storage tank has a capacity of 125 000 barrels.

The main building of the Sewaren Generating Station.



kva, 3-phase, triple-rated Westinghouse transformer.

The 13-kv bus in the transformer yard is in three sizes for current capacities of 3000, 4000, and 5000 amperes. The bus consists of square aluminum tubing or welded angles, with all permanent connections welded. This construction is less expensive than the conventional outdoor overhead buswork, usually of hollow tubing, partly because of the use of inert-gas shielded-arc welding instead of the usual bolted connections. This is the first installation of its type made by welding outdoor buses of such heavy cross section.

Centralized Control

Whereas many older power stations have separate boiler-turbine and electrical control rooms, Sewaren combines the two. Also, because the auxiliaries and turbine controls are motor driven, and are hence easily adaptable to remote operation, a greater degree of supervision is afforded from the control room. As a consequence, operation is more easily coordinated and the total number of personnel is reduced. Some of the men normally placed at various locations throughout the plant to make operating adjustments are no longer required.

Sewaren will have two control rooms, one for units 1 and 2 and the other for 3 and 4. The rooms are located between the two boilers and the two turbine generators they control. The main rotating machinery is visible from the electrical bench board, which is placed along the front side of the control room. The other sides are occupied by vertical panels for control of the boilers, turbines, and auxiliaries. Windows at the rear afford a view of the two boilers. Three operators are required in the control room, one for the electrical board of both units and one for each mechanical panel.

The control rooms are air conditioned and soundproofed. The lighting is of the indirect fluorescent type, with a partly louvered, parabolic ceiling. This design is advantageous in that it diffuses the light and avoids glare on the vertical panels and irritating contrast between dark and light areas.

Another feature of Sewaren conducive to effective control with a minimum of personnel is its layout for two-level operation. This plan requires personnel on only two floor levels—the turbine and condenser floors. This is possible because the plant is dispersed horizontally, rather than built up vertically, with the auxiliary equipment as near ground level as possible. Thus, every advantage is taken of the fact that Sewaren is a new station from the ground up.

The Sewaren Building

The main power-plant building is simple, functional, and modern in appearance, with strong horizontal lines resulting from continuous rows of sash and glass block. At one end of the turbine room is a visitors' observation balcony affording a view of the turbine room, the outside coal-handling equipment, and part of the transformer yard. The turbine-room roof is supported by arched girders rather than open trusses, giving better appearance and reducing building volume.

In the turbine room, a combination of fluorescent and incandescent luminaires, following the design proposed by Westinghouse, provides a high level of lighting (22 foot-candles). The fixtures are supported under each girder.

At Sewaren, a high level of illumination is also provided throughout the station and is expected to yield dividends in improved operation, safety, and general housekeeping.

Sewaren Generating Station has paved the way to the next higher operating temperature. For taking this bold step, Public Service Electric and Gas Company is to be congratulated. This utility, long a pioneer, has done it again.

The *Single-Phase* Lifeline Motor

The single-phase Lifeline motor was created with two main purposes in mind —to make it interchangeable with the concurrently planned polyphase Lifeline motor, and to build into it the ability to meet the toughest requirements. The first has been fulfilled in manufacture, and tests on the most severe of applications indicate that the second has been accomplished as well.

J. M. STEIN, *Design Engineer*
L. J. MURPHY, *Consulting and Application Engineer*
Westinghouse Electric Corporation, Buffalo, New York

MECHANIZATION of equipment by motors, a trend accelerated during the war by the manpower shortage, has spread to light industry and to farms. Because three-phase power is often not available at such locations, the integral-horsepower, single-phase motor has been more widely applied than the three-phase motor. In industry, these motors drive small machine tools, compressors, and pumps. On the farm, they drive grain and hay elevators, silo fillers, barn cleaners, and feed grinders.

The single-phase motor is another member of the Lifeline family. It was designed to be as universally applicable as possible, thereby affording the advantages of interchangeability and standardization to both the user and manufacturer. To select the single type of motor to best fulfill most applications, a study of motor characteristics was inaugurated.

Selection of Motor Type

Four types of single-phase motors are most applicable in integral-horsepower ratings: (1) the repulsion-induction, (2) the repulsion-start, induction-run, (3) the capacitor-start, capacitor-run, and (4) the capacitor-start, induction-run. The repulsion motors require a wound armature, commutator, and brush assembly, which increase maintenance. The armature of the repulsion-induction motor has also a squirrel cage in addition to its commutated winding; this combination gives a continuous speed-torque characteristic that combines the effects of both windings. The repulsion-start, induction-run type is started as a repulsion motor but, after acceleration, is changed to an induction motor by a centrifugal mechanism that short circuits the commutator bars and, in some designs, lifts the brushes. On both types, brushes must be shifted to change torque characteristics and to reverse direction of rotation.

The capacitor motors have two stator windings in quadrature. The capacitor-run motor has both a starting and a running capacitor (one for each winding), the starting capacitor being disconnected after acceleration. The capacitor-start motor has a starting capacitor only.

In choosing the one most universally applicable type, the repulsion motors were rejected because of such undesirable components as the commutator, brushes, brush-lifting mechanism, and inevitable maintenance difficulties. Of the remaining two, the capacitor-run motor is advantageous in that its running power factor is higher and its locked-rotor and running currents lower. But the induction-run motor does not re-

The hay drier (above), run by a 5-hp, CAP motor, does a better job of drying hay than the sun. Sun drying removes some of the carotene and protein from the hay; artificial drying, by circulated air, does not. The corn-fodder cutter (right), powered by a 1-hp, CAP motor, cuts the husks, which are used for animal feed.

TABLE I—COMPARISON OF INTEGRAL-HORSEPOWER SINGLE-PHASE MOTORS

Characteristic	Type of Motor			
	Repulsion-Start Induction-Run	Repulsion-Induction	Capacitor-Start Capacitor-Run	Capacitor-Start Induction-Run
Volume	Medium	Medium	High	Low
Weight	High	High	High	Low
Rotor Construction	Wound	Wound plus cast	Cast	Cast
Locked-Rotor Current	Low	Medium	Medium	High
Locked-Rotor Torque	High	High	High	High
Pull-Out Torque	High	Medium	Medium	High
Transfer Torque	Medium	*	High	High
Locked-Rotor Power Factor	Low	Low	High	High
Running Power Factor	Low	High	High	Medium
Dual-Voltage Operation	Yes	Yes	No	Yes
Electrically Reversible	No	No	Yes	Yes
Transfer Speed	Critical	*	Not critical	Not critical
Life	Poor	Poor	Good	Excellent
Maintenance	Poor	Poor	Excellent	Excellent
Permanency	Poor	Poor	Excellent	Excellent

*Continuous characteristic

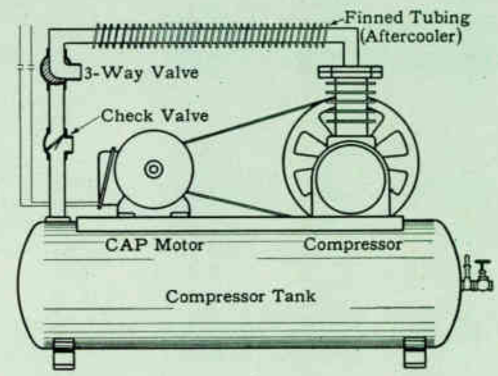


Fig. 1—Schematic diagram of a typical small compressor.

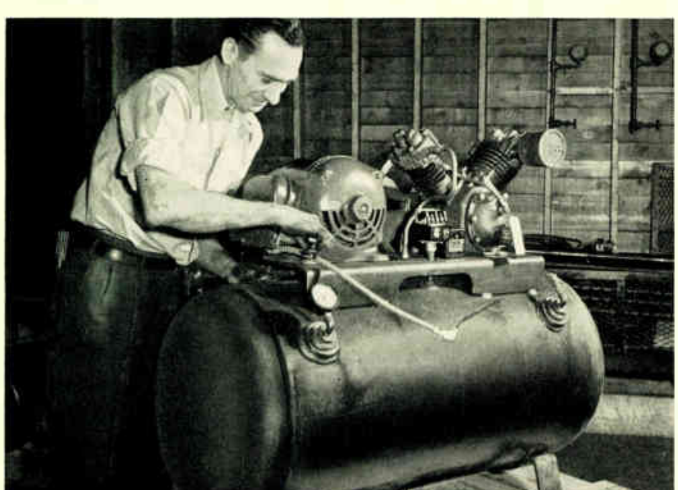
quire a large, externally mounted running capacitor and hence is simpler and needs less maintenance. The characteristics of the four motors are summarized in table I, which indicates that the most practical choice is the capacitor-start, induction-run motor. This motor is specified as the type CAP.

Mechanical Features of the Motor

The ratings of the Lifeline family were designed so that the single-phase and polyphase motors use as many common components as possible. As a result, end shields, bearings, shaft, ventilation system, and stator laminations and construction are interchangeable, which justifies the use of high-production tools and methods. Both feature frames, end shields, and foot mountings of fabricated steel, which form a more precisely made, more rigid, and more presentable motor; pre-lubricated, sealed-for-life ball bearings that require no further attention; and winding slots with rounded bottoms that eliminate sharp bending and possible cracking of cell insulation and reduce the likelihood of trouble from burrs on the punchings.

Single-phase motors in ratings of 1 to 5 hp at 1750 rpm have the identical frame size as the polyphase and can be mounted in the same space. The single-phase motor differs from the polyphase in that it has starting capacitors, a larger conduit box (which contains the capacitors), a transfer mechanism, and sometimes, inherent thermal overload protection.

A 1½-hp, 1725-rpm, CAP motor mounted on a small compressor.



Testing the Motor

To examine the suitability of the type-CAP motor for all purposes, it was tested on a small air compressor—one of the toughest industrial applications—and compared to a repulsion-start, induction-run motor, the type previously used on such machines. The results indicate several points of superiority of the capacitor motor.

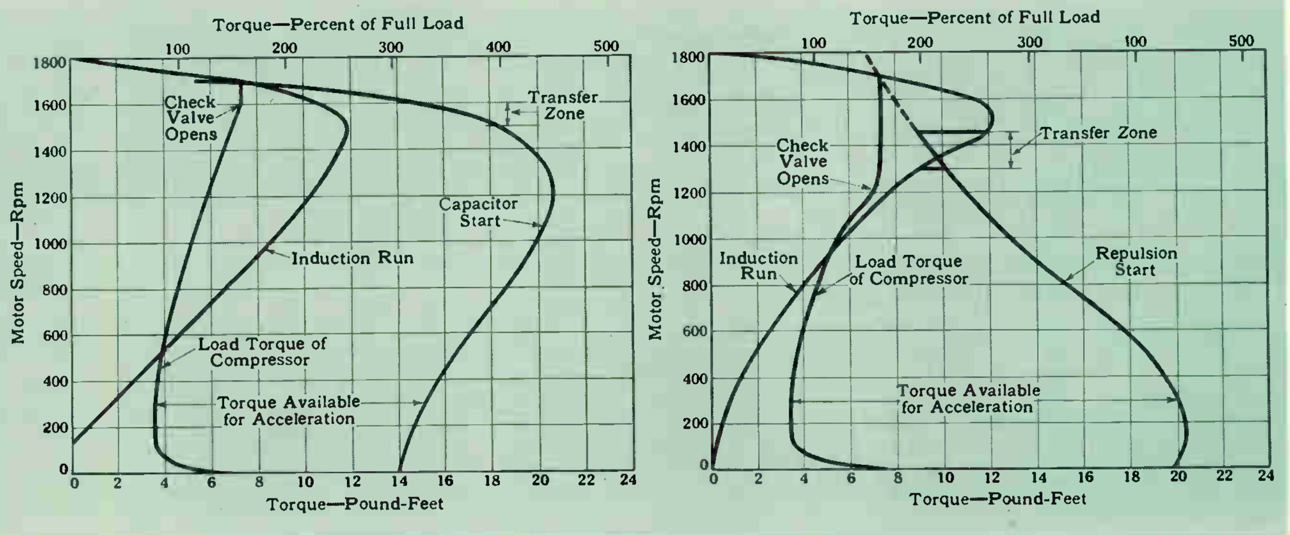
The tests were made with 1½-hp, 1725-rpm, 60-cycle, continuous-duty motors driving small air compressors typical of those used in automobile service stations and paint-spray shops. The motors have many severe requirements. First, most compressor builders, in accordance with the generally established practice of the trade, utilize the full overload capacity of the motor. Consequently, the smaller motors, rated 1 to 3 hp, must be able to carry 25-percent overload for several hours without overheating. Such operation is permissible because heavy loads are often followed by light loads.

The motor may be required to operate continuously for hours at a time, if, for example, a quantity of spray guns are in use; or, if fewer guns are operating, the motor may have to start frequently, as the tank air is periodically exhausted. Consequently, the motor must be able to start often—perhaps every five minutes—without distress. Although the capacitor motor can fulfill this condition, the repulsion motor, when called upon for such severe service, ultimately shows a burnt commutator and worn brushes. Commutator motors are generally undesirable for repetitive starting.

Repetitive overload and starting play havoc with line voltage, which may cause difficulty if the motor is located too far from the transformer, or if the wiring is inadequate. With torque varying as the square of the voltage, the motor must possess enough reserve to start the load under the worst conditions expected.

Compressor motors must be able to start in cold weather. Many times these compressors are installed in garages where the temperatures early in the morning are frequently 40 degrees F and sometimes lower. Under such conditions, the increased viscosity of the oil may double the torque required during acceleration. The running torque likewise is briefly increased, but, since it decreases after a few minutes (when the machine warms up), supplying the necessary starting torque is the first and more difficult requirement.

Figs. 2 and 3—The load-torque curves of the compressor differ for the two types of motors because of their dissimilar rates of acceleration. For example, because the CAP motor accelerates at a faster rate, the valve opens at a higher speed of rotation.



At the instant of starting, the compressor is completely unloaded (except for friction) as it is pumping against atmospheric pressure in the aftercooler, Fig. 1. However, as the motor accelerates, the compressor builds up the pressure in the aftercooler, increasing the motor load. The volume in the aftercooler is such that its pressure is raised to tank pressure by six revolutions of the compressor, after which the check valve opens. Thus, although the motor is unloaded (except for friction) at the instant of starting, its load is increased during the first six revolutions to the full torque requirements.

It is important, therefore, that the motor accelerate to at least the speed at which the transfer switch operates before the compressor has made six revolutions. (Otherwise, the reduced voltage resulting from the high current drawn at transfer, coupled with the rising load, may reduce the available torque below the required value and cause the motor to pull out.) This requirement is more difficult if line regulation is poor or if oil in the compressor is cold.

The type-CAP, capacitor-start motor and the repulsion-induction motor were compared in this important respect. The speed of each motor at which the compressor completed six revolutions was calculated from a study of their speed-torque curves and compressor-load curves, Figs. 2 and 3. The temperature of the oil in both cases was 33 degrees F, a condition worse than expected in an actual installation. The results indicate that the type-CAP motor accelerates to its transfer speed (about 1550 rpm average) in approximately 7½ compressor revolutions. The repulsion motor, on the other hand, requires about 12 revolutions to reach its transfer speed (about 1380 rpm average).

The sluggish acceleration of the repulsion motor is due to the rapidity with which its starting torque decreases as speed increases. The consequent reduction in accelerating torque may cause some difficulty if the oil is cold or voltage regulation poor. The condition can be corrected by increasing the volume of the aftercooler, or by using a time-delayed magnetic unloader (instead of the simple pressure-operated type); either alternative adds to the cost.

As temperature at starting increases, the number of revolutions and the accelerating time of the type-CAP motor decrease and the reserve torque at transfer increases, which facilitates the transfer to the running winding. However, the same is not true for the repulsion motor because of the shape of its speed-torque curve. Because of the rapidly decreasing starting torque, a higher oil temperature causes little change in the overall rate of acceleration.

Another point for consideration is the transfer speed. With the capacitor motor, the starting torque is always higher than running torque, even up to a speed well above the point of maximum running torque. The result is a minimizing of the current drawn immediately after transfer, and consequently reduced likelihood of motor pull-out due to voltage drop.

On the other hand, because the starting torque of the repulsion-induction motor falls off rapidly, the transfer speed must be lower, i.e., the curves cross at a slower speed. This results in a higher value of current after transfer and an appreciable drop in voltage and motor torque. If the torque requirements at the time are high, the motor speed may drop, causing the centrifugal transfer switch to operate in the reverse direction and reconnect the starting winding. The motor accelerates, the cycle repeats. This is known as "cycling."

The CAP motor's advantages for compressor drives extend to most operations. With its reduced maintenance, it is the most desirable single-phase motor for either farm or industry.

This 5-hp, CAP motor drives a hay hoist.

Radiation Detectors—

Atomic-Age Police Force

The Geiger counter could recount tales as fascinating as those of a Commander Byrd or Charles Beebe. For that matter, so could some of its cousins in the field of radiation detection. They have risen in balloons, been carried to mountain tops and into deep mines in the study of cosmic radiation. They have sleuthed in the trash heaps of hospitals for lost radium. Customarily they have associated with doctors of philosophy engaged in pure research. They were on hand at Los Alamos, Hanford, Oak Ridge. Now they are donning overalls for the more routine work found in industry, and in atomic-energy plants.

P. A. Duffy
X-ray Engineering Department,
Westinghouse Electric Corporation
Baltimore, Maryland

When atomic energy blossomed forth as a reality, a little-known group of research tools—the radiation detectors—was suddenly handed a heavy burden of responsibility. The solution of the mysteries of the nucleus paved the way for a multitude of new uses for radioactive materials and processes, the radiations from which constituted a serious physiological hazard. And apart from the protective angle, the growing use of tracer studies also demanded good detecting devices; and increased activity in the nuclear-reactor field called for more and better measuring instruments. Fortunately several excellent radiation-detection instruments were already in use, albeit on a small scale; development work on these, augmented by the recent discovery of new principles of detection, have furnished a plentiful crop of detectors.

Different principles of radiation detection are applied in different instruments. To a certain extent each of these principles, and thus the instruments that utilize them, is limited in use; but, remarkably, each will detect numerous types of radiation. This is due to the fact that, despite dissimilar characteristics, most radiations fall into two general classes, electromagnetic radiations or waves, and fast-moving atomic particles. There are, in turn, several varieties of each. The electromagnetic radiations include x-rays and gamma rays. Gamma rays are characterized by their very short wavelength, which means that they have great penetrating power. X-rays may have either longer or shorter wavelengths than gamma rays. The more important particles encountered include alpha (helium nucleus), beta (electron), proton (hydrogen nucleus) and neutrons (neutral particles).

To a detector these radiations appear much alike. For despite their fundamental difference, electromagnetic rays are emitted in bursts, called photons, whose effect on detectors is similar to that of particles. Of course, both particles and rays differ widely in intensity and quantity, but as it turns out these can largely be taken into account by detector design.

Each type of detector employs some particular effect of radiation. For example, some radiations cause phosphors to luminesce or scintillate. This is one of the oldest forms of detection, but its principle is still widely applied, as for example in the x-ray fluoroscope. Depending upon the luminescent material, this method can be used to detect many kinds of radiation, including protons and alpha particles as well as electromagnetic x-rays.

Another long-standing method of detection makes use of the ability of radiations to produce changes in photographic emulsions. This process is widely used in laboratory work, especially in tracer studies. Because of this sensitivity to radiation, film can also be used to measure the amount of x-rays or other radiation to which an individual has been exposed.

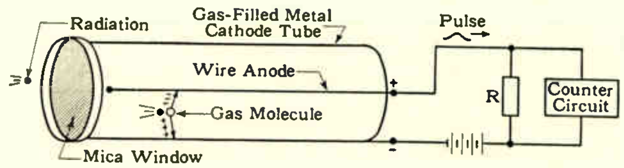
These methods, and a few others, such as the familiar gold-leaf electroscope, are largely laboratory tools, suitable for research work, but not widely used for detection purposes. Methods whose results can be transformed into electrical quantities, or whose effects can be used to activate electrical circuits are proving of the most value, especially for portable equipment. The majority of these devices make use of the fact that most radiations have the inherent ability to ionize gases.

The Geiger-Mueller Counter

The methodical, rattlesnake-like clicking of the Geiger counter has become almost a symbol of radioactivity. Its dramatic warning gives a familiar and unmistakable indication. Because of its simplicity of operation and construction, and its dependability, the Geiger counter has become the most popular of all radiation detectors.

The fundamental principle of this radiation counter—so called because it responds to individual particles and photons —was first used in a device developed by Geiger and Rutherford in 1908. Later Geiger and Mueller made significant changes in the design of the tube to give it more versatility, and the tube became known as the Geiger-Mueller counter, or as it is more popularly referred to, simply the Geiger, or G-M counter.

Figure 1



A simplified schematic drawing of a Geiger counter. Radiation in this case is entering the tube through a mica window. Inside the tube it collides with a gas molecule, causing ionization; electrons are attracted to the wire anode and positive ions to the metal cathode tube. This action causes a pulse to be registered in the external circuit at right. Current flowing through the resistance *R* causes a voltage drop, lowering the potential between anode and cathode, interrupting the arc.

In basic design the G-M tube has not changed. In the most common form it consists of a slender wire anode and a concentric cylindrical cathode, as in Fig. 1. Gamma radiation can enter the sensitive gas volume by penetrating the cathode walls. Gamma rays are extremely penetrating, and the metallic cathode has little effect in stopping them. On the other hand, particles are very easily stopped, and special thin windows are required to permit their passage into the sensitive volume. This window can be made of various materials, depending upon the type of radiation to be admitted. For instance, a thin section of mica is often used. Mica can be made thin enough to admit alpha or beta rays, yet it is mechanically sturdy enough to maintain a hermetic seal against atmospheric pressure.

A constant potential is maintained between wire anode and tubular cathode by an external circuit containing a voltage source. Batteries are often used, especially in portable instruments. The potential produces a strong electric field about the wire. Radiation that enters the chamber through the walls or the window strikes gas atoms, ionizing them. The resulting electrons are accelerated toward the wire and ionize any gas atoms in their path. This results in an avalanche of electrons and initiates a current between anode and cathode, and thus in the external circuit. An indication of the radiation incident upon the Geiger tube can be obtained with a suitable metering or pulse-counting device.

If the counter is to register each particle or photon that it intercepts, the discharge must be quenched each time it reaches its maximum value, restoring the tube to its original unexcited state. This quenching, or deionizing, can be accomplished by placing a large resistance in the external circuit between the anode and cathode. Current that flows through this resistance produces a voltage drop, lowering the anode-cathode potential sufficiently to extinguish the discharge. Although this whole process occurs in a matter of milliseconds, recovery time is still considered long. For this reason the quenching of the discharge is sometimes aided by different circuit arrangements, or by the addition of a small amount of chlorine vapor to absorb secondary radiations in the ultraviolet region and prevent multiple or continuous discharges. This shortens recovery time and permits a higher pulse rate without loss of accuracy.

The sensitivity of the Geiger tube depends upon its dimensions, and upon the gas and its pressure. For the greatest sensitivity a large gas volume is required, since the mathematical probability of a particle striking an atom depends upon the length of the path within the tube. For example, with a small volume a particle might travel all the way through the tube without striking an atom; in such a case no ionization would take place and thus no pulse would appear. The number of particles that enter the tube, of course, depends upon the cross section of the tube and window. These dimensions are thus largely determined by the sensitivity required.

Sizes of Geiger tubes usually range from that of a small pencil up to about two feet long. In portable instruments a tube about one inch in diameter and six inches long usually provides adequate sensitivity. Some typical tubes of different sensitivities are shown in Fig. 2.

With the tube, as already mentioned, an external circuit is necessary, consisting of the anode power supply, usually a battery with or without a voltage step-up system, a pulse-counting circuit, and a series resistance. The number of pulses is a function of the radiation intensity. Therefore measuring the incident intensity becomes a matter of measuring the rate at which pulses are produced. This is done in the counting circuit, and indicated on a meter, or by producing the familiar audible clicks. Other circuits can, of course, be used to translate pulses into images on an oscilloscope, or to cause a lamp to glow. Which of these indicators is used is a matter of choice, depending upon the intended use for the detector.

The anode pulse of a Geiger counter is dependent upon the dimensions of the tube, the applied voltage, the gas and its pressure, and the external resistance. The magnitude of the pulse obtained is of course constant, since these parameters are constant for a given tube. A typical tube is six inches long, has a diameter of seven eighths of an inch, contains neon or argon gas at a pressure of 10 cm of mercury, and produces pulses of about 80 volts.

The Geiger counter is suitable for detecting all common radiations—alpha, beta, and neutron particles, and gamma and x-rays. In most detection work these are the important particles, since they are the most frequently encountered.

In all gas-ionization detectors, neutrons are a special case. Inherently they have an extremely high penetrating ability,

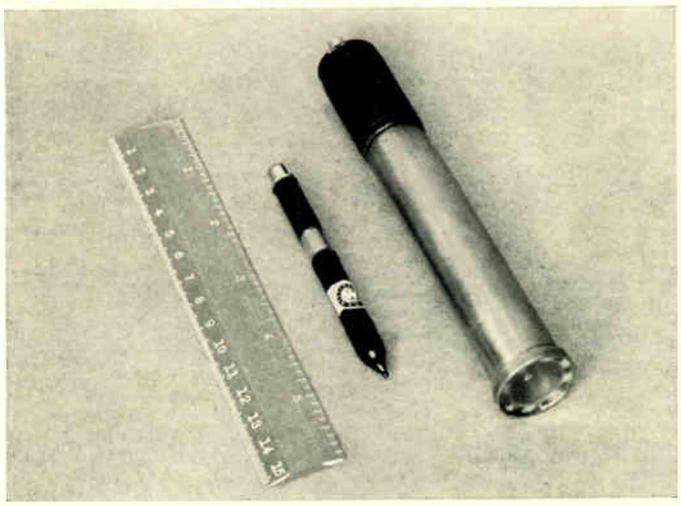


Fig. 2—Two types of Geiger tubes. At left is a low-sensitivity tube; at right one of high sensitivity.

but no ionizing ability. Thus to detect their presence an indirect method is used. One uses two tubes, one containing a boron gas, or with its sides coated with a boron compound, the other a common tube. Boron nuclei absorb neutrons, but in the process ionizing particles are emitted, so that the action of the tube can then continue as in the case as other particles. A comparison of the readings of two separate tubes, one containing boron and one without it, gives indication of the presence of neutron radiation.

Proportional Counters

The operation of the Geiger tube calls for the discharge to spread along the whole length of the tube. This, as mentioned, fixes the pulse size. Similarly, in a Geiger tube the ratio of the total ionization in the tube to the initial ionization caused by the radiation—called the gas amplification A—is very large. However since the ionization in each discharge reaches the same peak value in the Geiger tube, the gas amplification is not a fixed ratio. Regardless of the ionizing ability of the incident particle the pulse is of the same magnitude.

A tube somewhat similar to the Geiger counter—the proportional counter—allows a pulse to be registered that is pro-

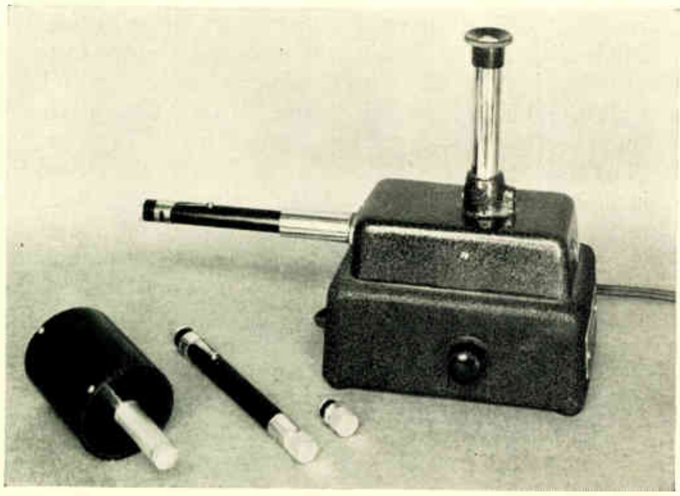


Fig. 3—Ionization chambers (left foreground), and a galvanometer indicator (center) that shows the charge remaining, which is a function of radiation exposure.

portional to the ionizing ability of the incident particle.

Assuming similar physical dimensions, this change is brought about by lowering the applied potential below that used in the Geiger tube; this reduces the field strength. Unlike the Geiger tube, in which the entire gas volume is ionized with each pulse, the amplitude of the pulse is in direct proportion to the initial incident ionization caused by a particular particle. Thus an alpha particle ionizes a greater portion of the gas and causes a large pulse, while x-rays, with their low ionizing ability, produce smaller pulses. The field strength about the anode, although it still has an accelerating effect on electrons, as in the Geiger counter, is a subordinate factor to the ionizing ability of the particle itself.

External circuits similar to those of the Geiger counter are used with the proportional counter. Usually larger electrical amplification is necessary because the gas amplification within the tube is smaller.

The proportional counter is best adapted to the detection of alpha particles, protons, and with the addition of a boron gas (as in the Geiger tube), neutrons. These are the particles with relatively high ionizing ability. Gamma and x-rays, because of their low ionizing ability are not usually detected with the proportional counter.

The choice of window materials is again dependent upon the particles to be admitted, as in the Geiger tube. For alpha particles, which despite their high ionizing ability have low penetrating power, a very thin window is used.

A typical proportional counter is ten inches long, has a cross section of one square inch, contains air at atmospheric pressure, and produces pulses of a few millivolts.

A disadvantage of gas-amplification counters is the saturation effect at high intensities. Since intensity is measured in terms of pulse rate and each pulse occupies a finite period, obviously there is a limit to the number of pulses that may occur per second. This effect gets worse as gas amplification goes up; therefore Geiger counters are limited to relatively low intensity measurements and other types of detectors are used at high intensities.

TABLE I—NUCLEAR RADIATIONS AND THEIR DETECTORS

Type of Radiation	Charge	Source	Average Energy	Comparative Range in Air	Detectors
Gamma rays	None	Natural and induced radioactive materials	50 kev to 3 mev	Thousands of times alpha	Ionization chamber, Geiger counter, scintillation counter
X-rays	None	Bombardment of a metal target by cathode or beta rays	20 kev to 100 mev	Similar to gamma rays	Ionization chamber, photographic film
Cosmic rays	Complex rays; may be composed of positive, negative and neutral particles, and gamma rays	Natural nuclear reactions throughout the universe	1 bev and higher	Most penetrating of all types of radiation	Geiger counter, Wilson cloud chamber
Alpha (helium nuclei)	Positive	Nuclear disintegration of the higher atomic number elements and their isotopes	3 to 10 mev	4 cm at 5 mev. Easily absorbed by air or any thin-walled material	Proportional counter, scintillation counter
Beta (electrons)	Negative	Natural and induced radioactive materials	50 kev to 3 mev	A few hundred times alpha	Geiger counter, proportional counter
Mesons	Positive or Negative	Associated with cosmic rays	Above 100 mev	See Cosmic rays (above)	Wilson cloud chamber
Neutrons	None	Atomic fission	About 1 mev	Slowed down by carbon, deuterium, beryllium	Boron-coated ionization chamber; proportional counter containing boron gas
		Bombardment of some elements with heavy high-energy particles	Thermal velocities to 1 mev and higher	Extremely penetrating in air	
Protons (hydrogen nuclei)	Positive	Ionization of hydrogen	Depends on accelerator	About ten times alpha rays	Any
Positrons (positive electrons)	Positive	Induced radioactive materials	50 kev to 2 mev	Similar to beta rays	Wilson cloud chamber, Geiger counter
Deuterons (deuterium nuclei)	Positive	Ionization of deuterium	Depends on accelerator	About ten times alpha rays	Any
Neutrino (theoretical)	None	Accompanies beta rays	Complementary to beta particle	Unknown	None

Ionization Chambers

The distinction between the Geiger and the proportional counters, the gas amplification, depends largely upon the field strength around the anode wire, which in turn is a function of the applied voltage. If the voltage is still further reduced below that of the proportional counter, a point is reached where the gas amplification becomes unity, and the detector becomes an ionization chamber.

Like the other two gas-ionization detectors, this instrument has an ionization chamber containing two electrodes, separated by a dielectric of air, or a suitable gas, depending upon which particles are to be detected. Radiation entering the chamber causes an initial ionization, and electrons and ions are collected by the electrodes. No secondary ionization takes place.

External circuits for the ionization chamber are similar to those of the Geiger and proportional counter. Ionization in the chamber causes a current in the external circuit that is an indication of the radiation intensity.

The chamber can also measure total accumulated radiation. To function in this manner an initial charge is stored in the gaseous dielectric, since in effect the chamber is a capacitor. As ionization occurs in the dielectric—due to radiation striking the gas atoms—the chamber gives up some of its charge. An indication of the amount of incident radiation is obtained by measuring the difference in charge.

Ionization chambers are sometimes built

with end windows like Geiger and proportional counters, but frequently the walls themselves are made of some material "transparent" to radiation, such as plastic. In either case the net effect is obviously the same.

Ionization chambers are frequently used as personnel monitoring devices. One common type, in appearance much like a fountain pen (Fig. 3), is charged, and clipped to the clothing of an individual engaged in handling radioactive materials. A later check of the charge remaining indicates the amount of radiation exposure.

For equal radiation intensities, ionization chambers have an extremely low output compared to the Geiger and proportional counters, because there is no gas amplification. In one respect this is a distinct advantage, since saturation effects are negligible up to extremely high intensities; these chambers are thus ideally suited to many applications where Geiger and proportional counters are of no value.

Scintillation Counters

In all gas-ionization detectors a current amplification of about 10^7 must be obtained between the radiation-sensitive element and the indicating device, in order that the radiation be registered. In the Geiger tube this is accomplished almost entirely in the tube itself; in the proportional counter it is gained partly in the tube and partly in the external amplifying circuit; and in the ionization chamber it is accomplished entirely in the external electronic circuits.

Other and more recent devices having an inherent high gain and stable characteristics are also useful in detector applications. Such a device is the photomultiplier tube, Fig. 4.

Radiation in the form of photons or particles is first converted to light scintillations by a suitable phosphor. This emitted light then activates the cathode of a photomultiplier tube, causing it to emit electrons. These electrons are then directed at a second cathode, and so on through several stages. Amplification is obtained because of the use of cathode materials that emit more than one electron when bombarded by a single electron. Thus the net result is a gain in the number of electrons flowing each time the stream strikes a cathode, and a greatly amplified current at the end of several stages. The chief advantage of this tube as a detector is that the amplification is accomplished entirely within the tube, as in the Geiger tube.

External circuits for the scintillation detector are similar to those used with the previously described counters.

Other Methods of Detection

The newest detector is the crystal counter, which was first demonstrated in 1945. Radiations absorbed by certain crystals release electrons, which under the influence of an external field appear as measurable currents in circuits similar to those of the Geiger counter.

The first material demonstrated was a silver-chloride crystal, which exhibits the necessary characteristics only at extremely low temperatures; this factor makes their use in portable instruments highly unlikely.

Experiments with diamonds recently have shown them to be very sensitive to gamma radiation. A diamond is clamped between two brass electrodes maintained at a potential difference of about 1000 volts. Incident radiation produces sharp pulses that can be amplified and detected on circuits similar to those of the Geiger counter. This application is as yet too new to determine what place it may assume in the field of radiation detectors.

The instruments described are primarily for detection, although they also measure the quantity and intensity of radiation. By proper design, and by the use of "screening" filters, they can also distinguish between radiations. For example, a thin sheet of aluminum will exclude alpha and beta particles but will admit gamma radiations. A plastic sheet will exclude alpha rays but will offer little filtration of beta rays. Thus a single detecting instrument can be used for alpha, beta, and gamma radiations.

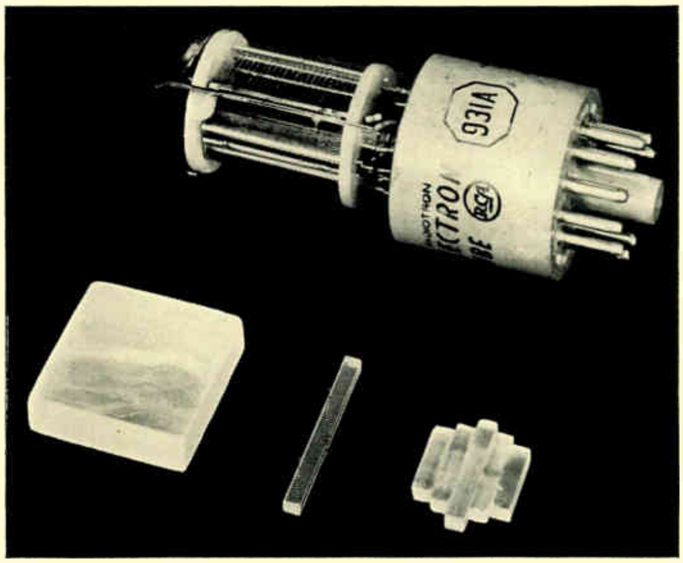


Fig. 4—A photomultiplier tube and some typical phosphors. At left a naphthalene crystal; at center a calcium-tungstate rod; at right, a calcium-tungstate mosaic.

Usually, however, a single instrument is best adapted to detection of both beta and gamma rays, or to alpha detection or neutron detection.

The various kinds of radiation and their most common detectors are shown in table I. The use of these detectors for radiations other than those listed is in most cases not practical. Although the principle of most detectors is applicable to all types of radiations, each is most suited to certain specific applications.

Radiation instruments must be built to very close tolerances and with meticulous care, for much depends upon their prompt and accurate warning. Current development work is directed toward simplification, standardization, and greater mechanical strength.

Atmosphere in House of Commons to be Cleaned Scientifically

The legislative atmosphere in Britain's House of Commons may seem cloudy at times, as it does in many government chambers, but one thing is certain; when sessions start in the reconstructed building in 1950, the air will be clear. The Precipitron, the electronic air cleaner, is being installed in the Parliament wing that was demolished during the war and is now being rebuilt.

These Precipitrons, which trap dirt electrically on metal plates, will remove 85 to 90 percent of the airborne dust and dirt entering the chamber. Their effectiveness extends even to tobacco smoke, the particles of which are as small as four millionths of an inch in diameter. The House of Commons will not be a "smoke-filled room."

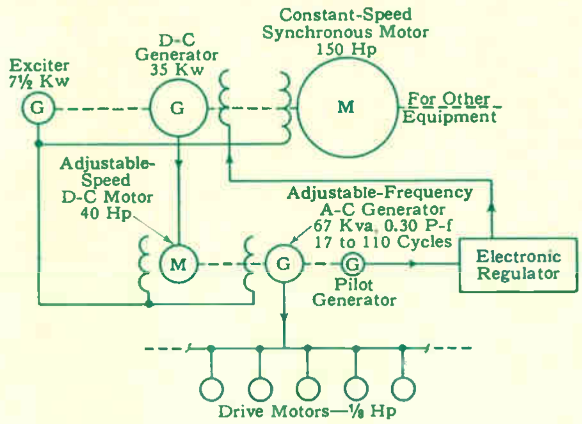
This electronic air cleaner, which is being built in England under a Westinghouse license, will certainly be effective in "clearing the air" from a scientific standpoint; engineers refuse to predict its effect on legislative atmosphere.

What's NEW!

Speed a la . . . . Constant

To say that an industrial machine requires driving equipment of adjustable—but constant—speed may seem contradictory. But actually such is often the case. The speed must be adjustable—but once set, it must be maintained as constant as possible. This is particularly true in the manufacture of synthetic textile fibers, where even a slight variation in speed can impair the quality of the product.

A new type of regulating drive provides such an adjustable, constant characteristic, maintaining the speed with an accuracy of plus or minus one-tenth percent regardless of changes in temperature, load, supply voltage, or other conditions. The drive is applicable to a variety of processes that require accurate regulation of speed over a long period of time.

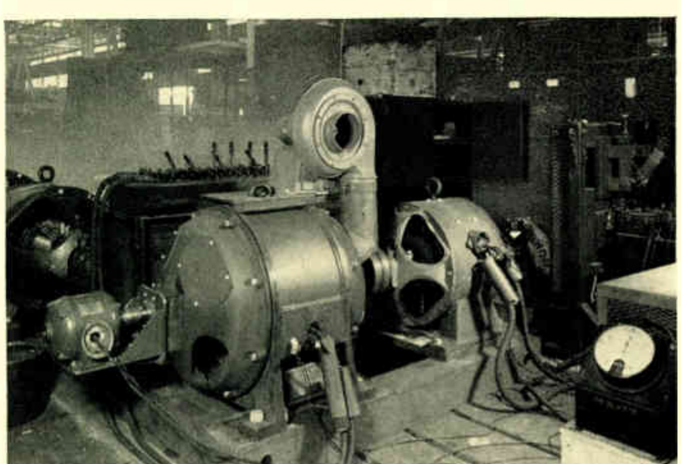


In one case, the drive is used to regulate simultaneously more than a hundred small motors over a speed range of six to one. The motors are of the three-phase, synchronous-reluctance type, rated one-tenth hp. Their speeds are adjusted by changing the input frequencies. Power for all the motors is supplied by a single adjustable-frequency system consisting of an adjustable-speed d-c to a-c m-g set, in turn supplied by a constant-speed, adjustable-voltage, a-c to d-c m-g set. The speed of the motors is, of course, determined by the speed (and output frequency) of the a-c generator.

The d-c to a-c m-g set drives an a-c tachometer generator whose output is sent to a regulator. This regulator consists essentially of an adjustable-frequency bridge, an error-detecting circuit, an amplifier, and a grid-controlled thyratron rectifier, which furnishes excitation to the d-c generator. The bridge is balanced for the desired pilot-generator frequency, which is proportional to the desired speed of the driving motors. If the speed of the a-c generator varies, changing the speed of the motors, the pilot frequency, of course, changes. This alters the output of the rectifier, and hence the excitation of the d-c generator, to correct the speed and frequency of the a-c generator and the speed of the motors.

By adjusting the frequency bridge, the speed of the motors is preselected over a range of six to one, 510 to 3300 rpm (at 17 to 110 cycles). Once set, the speed is maintained within plus or minus one-tenth percent. The system retains its accuracy regardless of changes in load, temperature, or a-c supply voltage or frequency. The high degree of accuracy is due to the use of precision capacitors and resistors in the bridge circuits, and shielding to prevent pickup of stray signals, and the high gain of the amplifier. Frequency regulation is advantageous because the system is inherently independent of changes in voltage of the pilot generator. Furthermore, this generator is of the inductor type and does not employ a commutator, brushes, or slip rings, which may introduce errors in other types of regulating systems. The drive is applicable to a variety of industrial processes requiring extremely accurate maintenance of speed over a long period of time.

The a-c tachometer generator mounted on the d-c to a-c set.



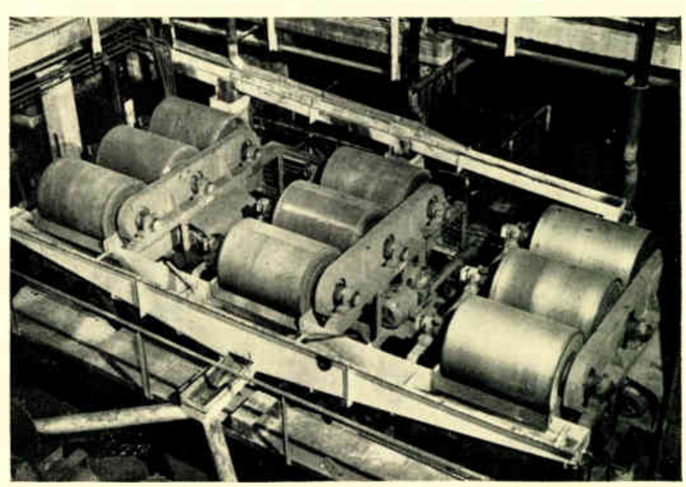
Beneficiation of Iron Ore

The cream of the iron-ore deposits in the United States—that which is merely scooped from open pits and sent directly to the blast furnace—is fast running out. At the current rate of production, it will last perhaps a decade, certainly no more than two, even by optimistic estimates.

However, the exhaustion of these rich deposits, which contain about 60-percent iron, will not terminate the steel age. More vast, although poorer, deposits (25- to 40-percent iron) provide a supply sufficient for possibly a thousand years at the present rate of annual consumption.

Conversion of lower grade ore into satisfactory material for the making of steel requires concentration of the ore to increase the iron content before it is shipped to the blast furnace. This

An installation of the new Jeffrey magnetic ore separators.



concentration decreases the cost of transportation and reduces the quantity of coke and limestone required in the blast furnace.

The greatly increasing demand for steel and the growing use of lower grade ore have called for new concentrating equipments. Two have recently been developed. The first, an improved magnetic separator, is in operation. The second, a new-type demagnetizer, will be placed in service shortly.

A large portion of the iron ore available in the United States is hematite (Fe_2O_3), which is non-magnetic—an unfortunate whim of nature, because concentration is more easily accomplished magnetically. To concentrate hematite-bearing ore magnetically, it must first be roasted to convert the hematite to magnetite (Fe_3O_4), which, as its name indicates, is magnetic. The magnetic-bearing ore, mixed with water, is sent to the new magnetic separator, which consists of a rotating drum enclosing stationary magnet coils in the lower portion. The drum rotates in the ore-water slurry and simultaneously magnetizes and separates the magnetite from non-ferrous matter. This new design of separator produces a more effective magnetic field than previous types and hence recovers a great percentage of the magnetite. The separator was developed jointly by Jeffrey Manufacturing Company and Westinghouse.

After magnetic separation, the magnetite must be demagnetized before it is fed to the classifier, which separates the finely ground material from the coarse. If the magnetite is not first demagnetized, the fine material will flocculate and will not be classified properly. The usual form of demagnetizer consists of a series of coils, energized with alternating current, that produce a progressively weaker magnetic field. As the magnetic particles pass through the field they are demagnetized.

However, this type of demagnetizer cannot completely demagnetize artificial magnetite, which is more retentive than the natural variety. The new demagnetizer differs radically in design and in the magnetic path through which the ore passes. It demagnetizes more completely both natural and artificial hematite as well as ferrosilicon, which is used in other methods of concentration. The demagnetizer is being tested by the Erie Mining Company at its experimental plant.

After demagnetization and classification, the concentrate is further processed by sintering, briquetting, or other means of agglomeration. It is then ready for the blast furnace.

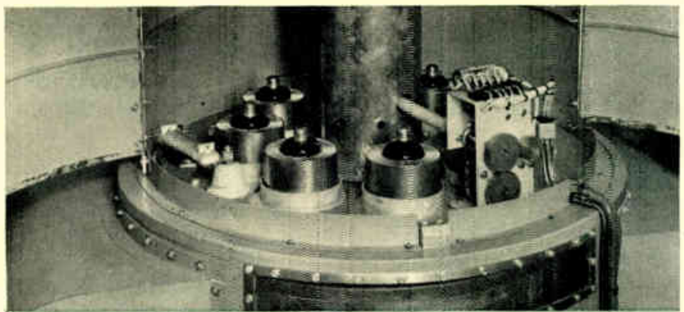
Symmetrical Amplifiers for FM or TV Broadcasting

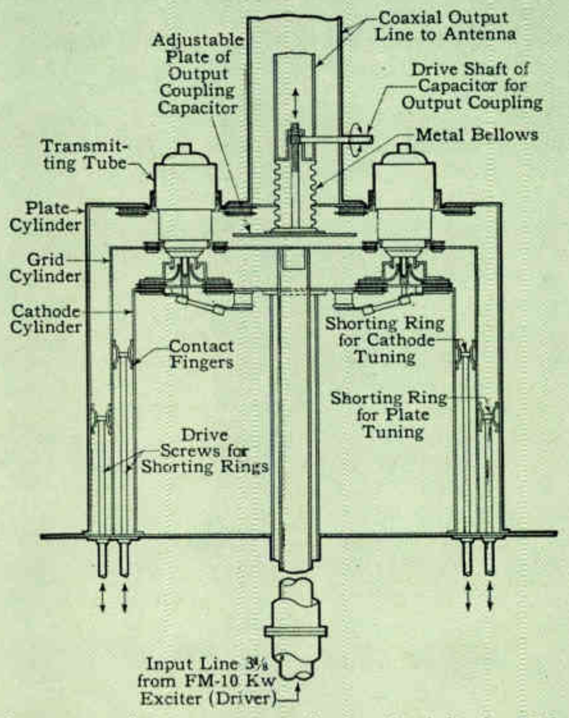
The ability to broadcast more FM-radio or television power and at a higher efficiency is the feature of a new type of power amplifier, the Symmetron. This amplifier employs a symmetrical circuit radically different from previous designs and uses low-cost, light-weight, conventional tubes.

Utilizing Symmetron techniques, amplifiers can be designed with output ratings, which vary with application and frequency, up to: for FM, 75 kw in the 88- to 108-megacycle band; for the presently assigned black-and-white TV channels, 25 kw in the 54- to 88-megacycle band and 10 kw in the 174- to 216-megacycle band; and for the unassigned TV section, 1 to 2 kw in the 500- to 1000-megacycle band. These power levels are 50 to 500 percent higher than the maximum now available from conventional amplifiers (for example, the present most powerful TV transmitter is rated 5 kw), and with new tubes designed especially for Symmetrons, still higher power outputs are possible.

The outputs of conventional power amplifiers are limited to relatively low power levels at high frequencies. Such amplifiers, for the FM band, commonly employ tubes in a push-pull tank circuit or fewer expensive, high-power tubes in individual tank circuits, the outputs being paralleled. Such tank circuits are usually characterized by insufficient electrical clearances, a lack of symmetry (causing unbalanced tube loading), and inadequate space for input and output coupling and tuning components, which introduce difficulties that increase with and limit the operating frequency.

With the Symmetron technique, on the other hand, a large





The concentric arrangement of tubes (top) in the 50-kw FM Symmetron power amplifier (bottom). The schematic diagram indicates the simplicity and symmetry of the design.

number of small tubes (eight in the final amplifier of the 50-kw FM transmitter) are operated in parallel. The tank is a symmetrical figure of revolution (within which the tubes are arranged about the common axis) and the plates, grids, and cathodes are interconnected by hollow metal cylinders, coaxially arranged and closely spaced. This design has several principal advantages: each tube "sees" essentially the same electrical and mechanical configuration for all operating frequencies, thus affording (even as to input and output coupling) the electrical and mechanical symmetry essential to insure balanced operation and uniform tube loading; the tank-circuit elements are of low impedance, because of the close spacing; the circuit is shielded; and the tuning means is simplified. The tank construction and the number of tubes depends on the application, but all Symmetron amplifiers are characterized by extreme symmetry and parallel operation of multiple electronic tubes.

Only three controls are required for tuning the FM-50 amplifier—for the cathode, plate, and output circuits. (Conventional amplifiers require as many as nine controls.) Cathode and plate tuning is accomplished by two movable rings between the plate and grid tank cylinders and between grid and cathode tank cylinders. Attached around the periphery of the rings are contact fingers that short circuit part of the tanks. Adjustable output coupling is provided by a movable-plate, air capacitor coupling the output line between the grid and plate planes of the tank. All controls are motor driven.

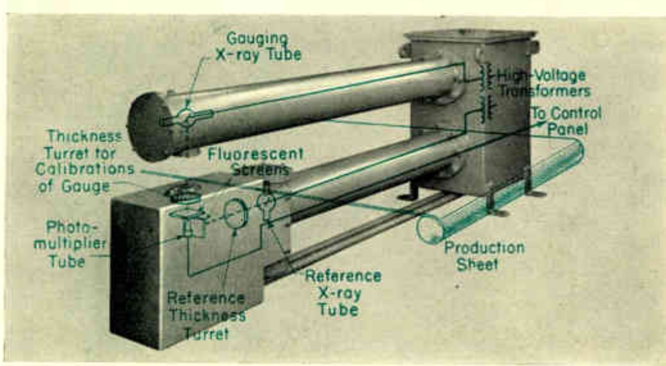
The Symmetron technique has other important advantages: the plate tank may be at d-c ground potential and hence not dangerous to personnel; r-f voltages are confined to the interior of the tank, due to the basic characteristics of cavity or coaxial transmission-line tanks, and consequently the exterior is free of dangerous r-f potentials, and stray r-f radiation is minimized; because of the parallel connection the power can be obtained from a high-current, relatively low-voltage supply, another safety feature; a Symmetron amplifier, even when operating at 75-kw output, can be cooled by a single motor-driven blower; and, finally, high amplification is obtained from a single stage, simplifying the overall equipment.

The Gauge with the X-ray Eyes

LIKE Superman, the x-ray thickness gauge* has x-ray eyes. But what's more, the gauge, by looking through an object, can measure its thickness accurately—a feat not yet accredited to Superman. The gauge, which is used to measure the thickness of moving sheet materials (such as sheet steel on processing lines, for example) has recently been redesigned to improve its flexibility and ease of operation.

Thickness is measured by comparing (using a photomultiplier tube) the intensity of x-rays passing through a standard (from the reference tube) with the intensity passing through the production sheet (from the gauging tube). The accuracy of measurement is of course limited by the accuracy of the standard. Formerly, the standard consisted of a small measured sheet inserted in front of the reference x-ray tube. With the new gauge, a standard of any thickness between 0.0050 inch (approximately 39 gauge, U. S.

Schematic diagram and physical arrangement of the gauge.

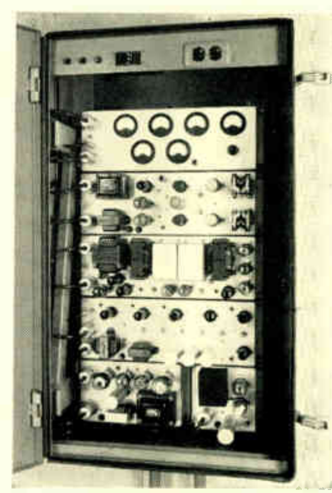


All the operator's controls are mounted on one cabinet.

Standard) and 0.1199 inch (approximately 11 gauge) can be selected in steps of 0.0001 inch. Illuminated dials are adjusted, which rotates a motor-driven turret to set the desired thickness; this eliminates manual changing of standards. The accuracy of the standard—and therefore of the gauge—is one percent, which is more than enough for most production purposes.

To insure maximum accuracy, the output intensities of the gauging and of the reference x-ray tubes are equalized before a production run. For this purpose, a second, identical turret is mounted between the x-ray gauging tube and the photomultiplier tube. The indicating instrument is adjusted to zero (by changing the gauging intensity) when both tubes are looking through identical thicknesses of metal. The gauge is then calibrated to give the desired full-scale error deflection, for example, to give full-scale deflection when the error is 0.001 inch. The gauge is now ready for a production run, in which any deviation from standard is accurately and immediately indicated.

Once the x-ray gauging generator is adjusted, the intensity of its beam remains constant, which permits continuous operation of the gauge over long periods of time without intermediate recalibration. The reading is not affected by changes in the speed at which the sheet passes the gauge.



The relay-and-tube panel of the x-ray thickness gauge.

The control can be connected to adjust automatically the mill screw-downs to correct errors in thickness or to operate automatically reject flaps to segregate sheets of steel whose thickness is beyond tolerance. The thickness gauge is easy for mill personnel to operate without special training.

Other beneficial changes have been made in the thickness gauge. The gauging x-ray tube has been mounted at the ends of a long arm that can reach a distance of 60 inches from the rear end of the sheet. The gauge can be mounted on a car and moved back and forth to scan the entire width. The arms are of heavy construction that is not damaged if the sheet buckles or breaks.

The x-ray thickness gauge is also suitable for continuous measurement, without contact, of other sheet materials such as nonferrous metals, clad or coated metals, and similar products.

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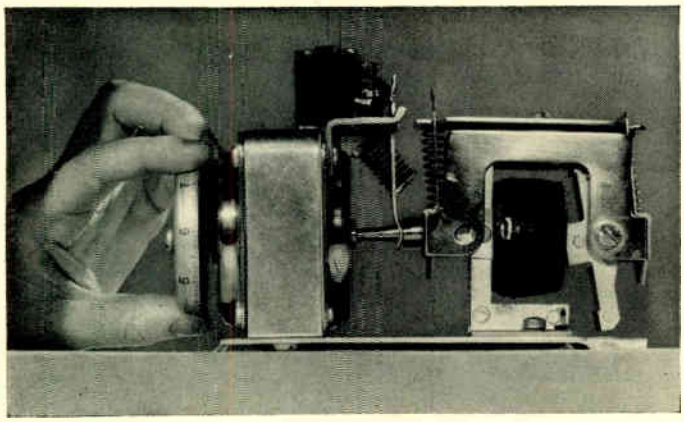
*The principles involved and an experimental model were described in the article "Measuring Thickness without Contact," by Walter N. Lundahl, *Westinghouse* ENGINEER, March 1948, p. 42.



The time delay is controlled by rotating the large dial at left.

Parceling Out Time

Good timing is a highly desirable characteristic in many fields. It is important to the athlete, for instance, and probably serves to distinguish the average player from the great in football, basketball, or baseball. It is no less important in hundreds of electrical timing operations throughout many industries. The prime difference lies in the fact that the athlete's timing is a matter of inner judgment, while the timing in electrical circuits is automatic, much more precise, and needs no factor of judgment. A new timing relay is an excellent example.

The time delay on this new a-c timing relay is adjustable from ½ second to 4 minutes. A large dial on the top of the relay controls the time setting and is readily accessible and visible from any angle. The dial directly controls the orifice of an air valve; the rate of flow of air through this orifice, into a sealed air chamber, determines the time delay of the relay. The diaphragm material of this air chamber was developed especially for this use, since no available material was entirely satisfactory. The flexing of this diaphragm, when the relay is energized, causes the air chamber to expel air, after which the adjusted orifice controls the flow of air back into the sealed chamber. This diaphragm material is substantially impervious to oil, water, and most acids and alkali. It has extremely high temperature stability, and its flexural mechanical life is very long. Tests have indicated that even at 80 degrees C its aging life will be 150 years. (An athlete is considered unusual if his timing is good after 10 or 15 years.)

The relay is normally supplied with a snap-action switch that may close or open an electrical circuit at the completion of the timing cycle. When the operating magnet is energized the contacts operate; when the magnet is de-energized the timing sequence occurs before the switch operates to replace the contacts.

All bearings in this relay are knife edges, held in place with compression coil springs. This feature eliminates one of the most common causes of faulty operation of relays—dirt on bearing surfaces—since all pin bearings for moving parts are eliminated.

There is provision on this new relay for mounting two additional switches, each having contacts that are opened and closed in a normal fashion. These can be used with auxiliary circuits, and are actuated by the magnet, but have no time delay.

This timing relay can be adjusted to operate either when the coil is energized or when it is de-energized. The change-over is very simply accomplished by removing two magnet mounting screws and reversing the position of the magnet.

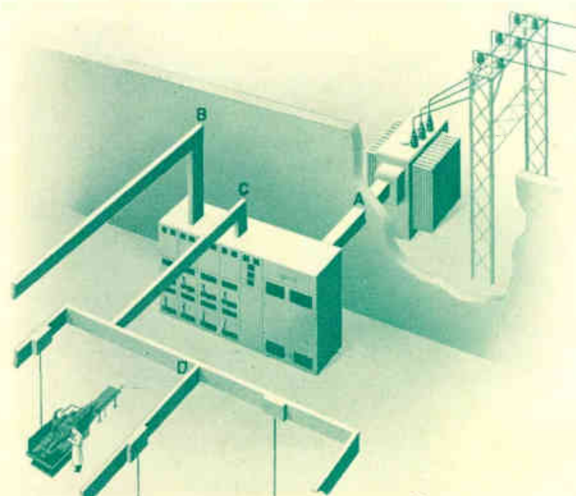
That this relay provides the utmost in timing reliability was shown by recent tests. The test was stopped at the end of ten million operations with no apparent prospect of early failure.

Bus Duct for All Purposes

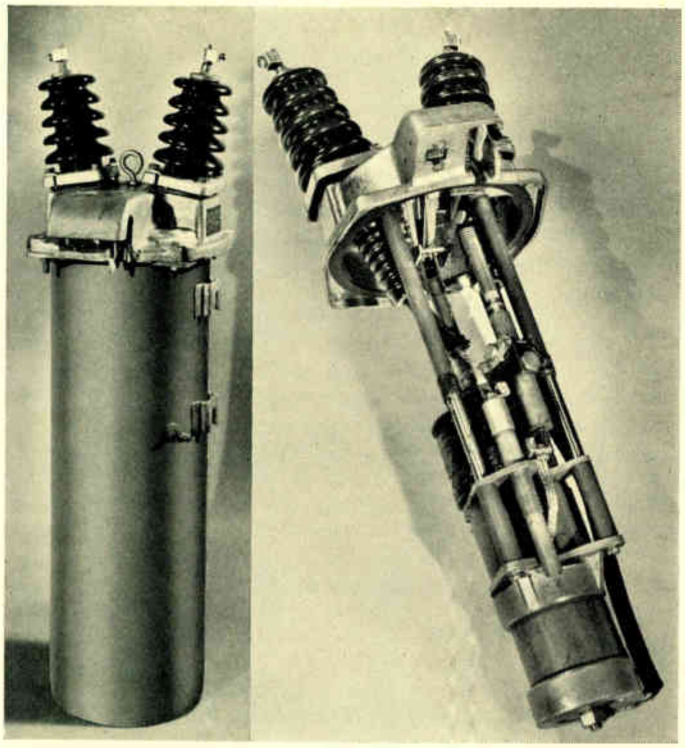
In addition to providing to industrial and commercial buildings all the features of ordinary electrical wiring systems, bus duct is flexible, interchangeable, and salvageable. It is particularly advantageous when plant-expansion programs necessitate additions or rearrangement of machinery. The duct is composed of copper bars separated by insulators, the entire assembly being encased in bonderized steel. To wire a plant, the duct is simply attached to the ceiling or building columns, transformer and service connections are made; the system is then ready for operation.

In addition to previous types of bus duct, the standard feeder (*C*) and the plug-in (*D*) varieties, two new types are now available—the weatherproof (*A*), for outdoor service, and the low-impedance (*B*), to minimize voltage drop on long feeder runs—expanding the flexibility of the system. Weatherproof duct is used, for example, to bring in power from an outdoor transformer. It is similar to standard, indoor-type feeder duct except for moisture-resisting Neoprene gaskets that run the entire length of the duct and a weatherproof, galvannealed-steel enclosure. (Galvannealed steel is similar to galvanized except that it can be more easily welded.) Also sections of duct are joined by corrosion-resisting, silicon-bronze screws. Ratings are from 400 to 4000 amperes at 600 volts, single or three phase, or direct current.

Low-impedance duct is used, for example, to connect between secondary switchgear and a load center some distance away. The three-phase duct has six conductors with the phases interlaced on ¾-inch centers, whereas the standard duct has only three conductors. With low-impedance duct, the magnetic field is partially neutralized by close spacing of the bars and by arranging adjacent bars to be of opposite polarity. This neutralization of the magnetic field greatly reduces the voltage drop. Because of the close spacing, the busbars are insulated with varnished-cambric tape, except at the joint. Covers of the duct are perforated to permit the dissipation of heat. Standard design can withstand short-circuit currents up to 75 000 amperes, but duct can be built to withstand 100 000 amperes or more, if desired. Ratings are from 600 to 3000 amperes at 600 volts, single phase, three phase, or direct current.



This installation (below) consists of both low-impedance duct (perforated) and plug-in duct. The low-impedance duct distributes power to spot welders and test equipment, which draw heavy transient currents that would otherwise interfere with the power and lighting services.



The single-pole, 100-ampere recloser, outside and inside.

Three Strikes—Then Out!

THE rural-line recloser plays a modified form of baseball with faults on a distribution line. The recloser has three chances to clear the fault and restore service (i.e., three openings followed by three reclosings). If the fault is not cleared on these three tries, the recloser opens once more and "locks out," indicating the fault is permanent and isolating that portion of the line. The recloser is used extensively on radial distribution networks in both rural and suburban areas.

A new 15-kv recloser with ratings of 25 to 100 amperes continuously and 2000 to 4000 amperes interrupting capacity, plays the fault-baseball game in either of two ways—(1) with three time-delayed openings, each followed by a time-delayed closing and then a final time-delayed opening and lockout, or (2) identical to the above, except with the initial opening made instantaneously. The selection of operating characteristics can be made in the field in approximately half a minute.

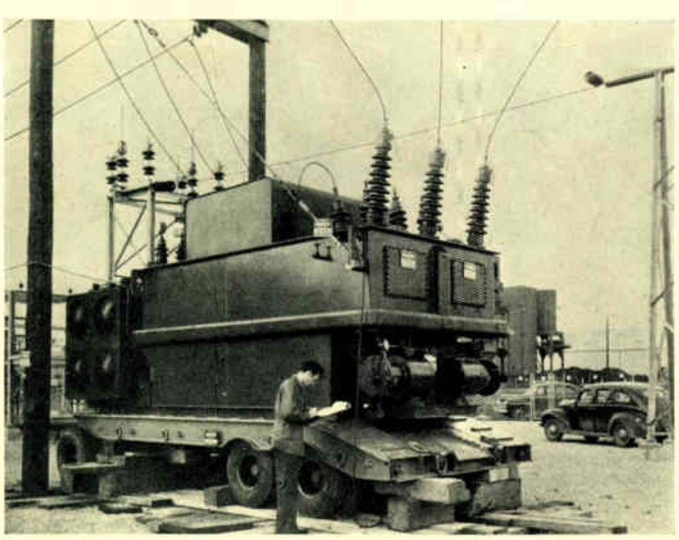
The first opening clears about 80 percent of all rural-line faults. Instantaneous operation on the first opening is desirable when sectionalizing fuses are used in series with the recloser because it prevents blowing of the fuse. Time delay is desirable when reclosers are backed up by other reclosers. The inverse-time-current characteristic of the first operation permits coordination with fuses or with other reclosers of any manufacture.

The recloser is built with either 1 or 3 poles, weighing 110 and 450 pounds respectively, for 1- or 3-phase circuits. The 3-pole unit is arranged so that only the faulted line is disconnected on the first three openings, but all three phases are locked out on the last opening. The 100-ampere recloser retains all of the desirable features of the smaller 50-ampere recloser, including a built-in lightning protector for the operating coil.

The solenoid-operated, oil-immersed recloser has a unique scheme to prevent premature arcing at the contacts when a fault occurs. The brass operating rod has a steel insert located above the magnetic center of the solenoid when the recloser is operating with normal current. When a fault occurs, the heavy line current through the solenoid coil pulls the insert down, increasing the contact pressure and thereby preventing arcing. When the circuit-opening, magnetic armature starts to move, it shields the steel insert, eliminating the contact-closing force.

When the contacts start to open, a self-energized arc interruptor, which makes the arc extinguish itself, comes into play. The mechanical linkage moved by the armature opens the contacts a short distance. The arc thus created decomposes the oil, forming a high-pressure gas pocket that forces the contacts to open fully. This scheme reduces the energy required of the solenoid coil and speeds arc interruption. After the contacts are fully separated, valves open, permitting the gases to escape and new oil to enter the interruptor chamber, readying the interruptor for another sequence of operation.

The 20 000-kva, trailer-mounted, mobile transformer.



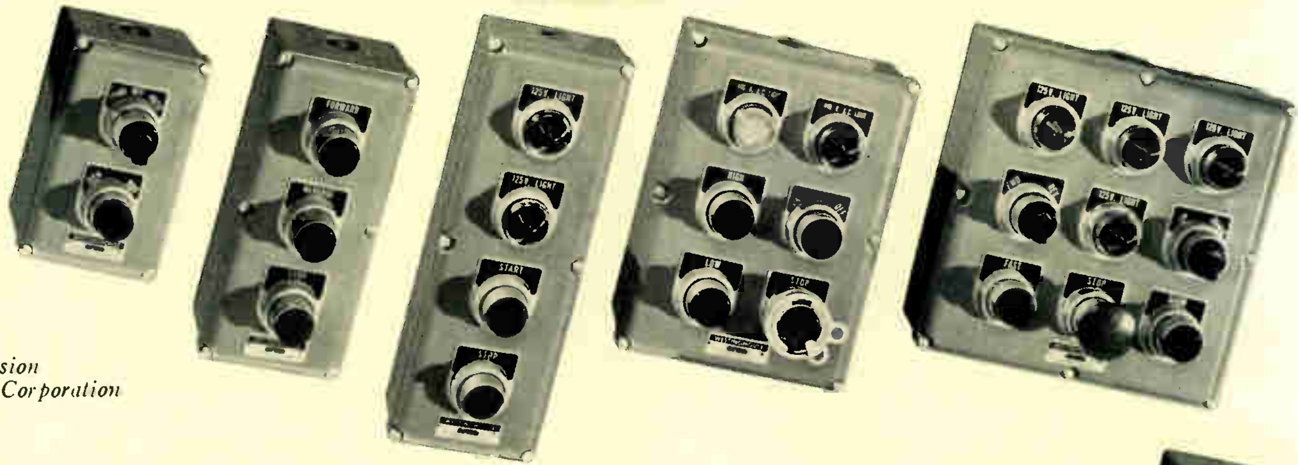
Johnny-on-the-Spot Transformer

A 20 000-KVA mobile power transformer is proving to be a Johnny-on-the-spot to the Louisville Gas & Electric Company. This unit, the largest transformer ever mounted on a movable chassis, is being used during breakdowns and for maintenance of equipment without power shutdown.

Mobile transformers have been built for some years, but none above a 10 000-kva capacity, which is insufficient to satisfy the needs of the Louisville utility. Larger ones had not been built because of the difficulty of finding trailers strong enough to support them. Confronted with this problem, engineers of the Louisville utility had an idea: The army had developed trailers large enough to support the heaviest tanks; if these trailers could handle a 60-ton tank, why not a 60-ton transformer? Several of these trailers were available and an inquiry to Westinghouse revealed that a 20 000-kva transformer of the voltage class required could be built without exceeding trailer dimensions or allowable overhead clearances.

With the aid of sketches of the trailer, Westinghouse built a 20 000-kva, 3-winding, 3-phase, 60-cycle transformer, with forced-oil, forced-air cooling. Each phase of the primary winding, which has four 2½-percent full-capacity taps, consists of two parts that can be connected in series or parallel for 69 or 36.2 kv. The main secondary winding, which has two 2½-percent full-capacity taps, is rated 20 000 kva at 14 kv. The tertiary winding, for service on lines of lower voltage, is rated 7000 kva. Internal connections in each phase give phase voltages of 2400 volts (parallel) or 7200 volts (series). External connections of the six tertiary bushings give three-phase voltages of 2400 or 7200 volts (delta), or 4160 or 12 470 (star). The tap changers are operated and all internal connections are made by means of external handwheels.

Had the transformer been of simple, two-winding design, its rating could have been over 25 000 kva. The weight (50½ tons) and overall dimensions of the mobile transformer are about one-third less than a standard unit of the same construction and rating, which brings it well within the trailer's capacity.



L. W. DYER
Engineering Manager
Standard Control Division
Westinghouse Electric Corporation
Beaver, Pennsylvania

New *Controls* for Industry

Just as the motor is the muscle of a machine, the control is its nerve center—and both are equally essential. The basic controls for industry, because they are required to do innumerable tasks, take many forms. Several types have recently been redesigned and notably improved.

THE electric motor is beyond a doubt the simplest and most used means of obtaining a rotating motion. But the motor is not in itself self-sufficient. It requires several control devices to insure that it runs properly and safely. These controls are comprised of various combinations of a disconnect means, a starter of either the manual or magnetic type, and a push-button station. Some of these equipments have recently undergone beneficial changes that augment their adaptability to the ever-changing requirements of industry.

Disconnect Means—The disconnect means, a circuit breaker or enclosed switch, isolates the motor or distribution circuit for repair and maintenance. It usually includes branch-circuit protection against overloaded circuits and line short circuits, as required by the National Electrical Code. The use of De-ion circuit breakers, rather than fused or unfused knife switches, for motor and distribution circuits continues to grow. These breakers, Westinghouse type AB, are provided either alone in an enclosure, without an enclosure for mounting as part of a large control panel, or enclosed in combination with a motor starter. They are built in ratings up to 600 amperes, 600 volts a-c, 250 volts d-c, and in either 2 or 3 poles.

The external operating mechanism for these circuit breakers has been simplified so that it is now supplied completely assembled on one plate. Where the breaker is to be incorporated on a large machine-tool control panel, for example, this plate is merely riveted to the panel door. The location of this plate on the door need not be accurately spotted, but may vary as much as one eighth of an inch in either direction. Special mounting jigs are not required. The breaker in such cases is perfectly standard. The operating handle is of pistol-grip design and is die-cast from a high-strength aluminum alloy. The operating mechanism is equipped for locking, by padlock, in the "off" position, and for mechanical interlocking with other components of a control panel. Two sizes of mechanisms are used, one for 50- and 100-ampere frames and the other for 225- and 600-ampere frames.

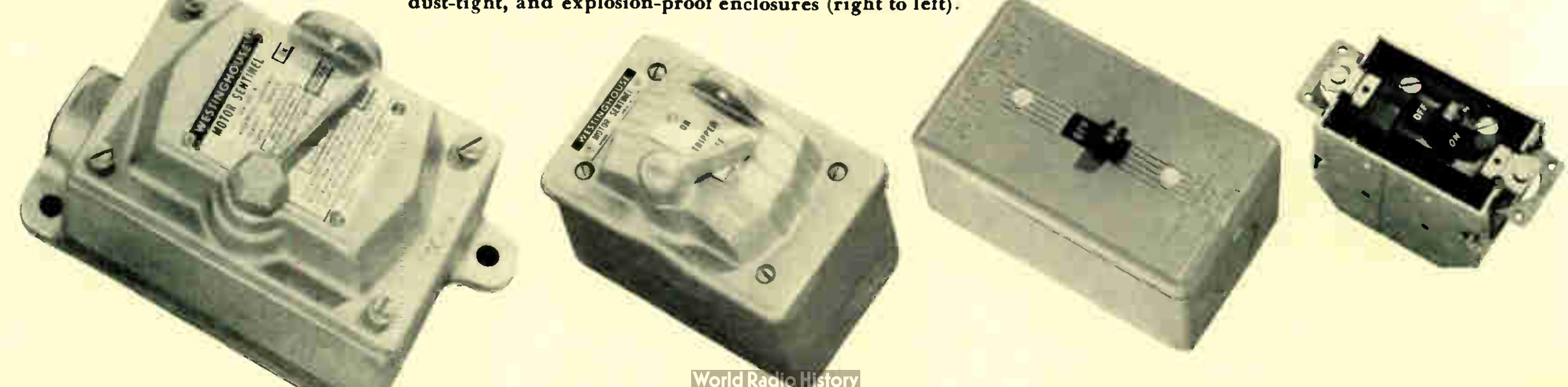
These breakers employ a trip mechanism, operated both thermally and magnetically. The thermal element consists of an indirect heater and a bimetal. When heated by a sustained overload, the bimetal, which has an inverse-time characteristic, gradually deflects until it trips the breaker. The electromagnetic element trips the breaker instantly when the current exceeds a predetermined setting. Previously this setting was fixed, but now it is adjustable on heavy-duty breakers of 100- and 225-ampere frame sizes. The range is approximately three to ten times the current rating of the breaker. For example, a breaker rated 100 amperes can be adjusted to trip instantaneously on any overload or short-circuit current between approximately 300 and 1000 amperes.

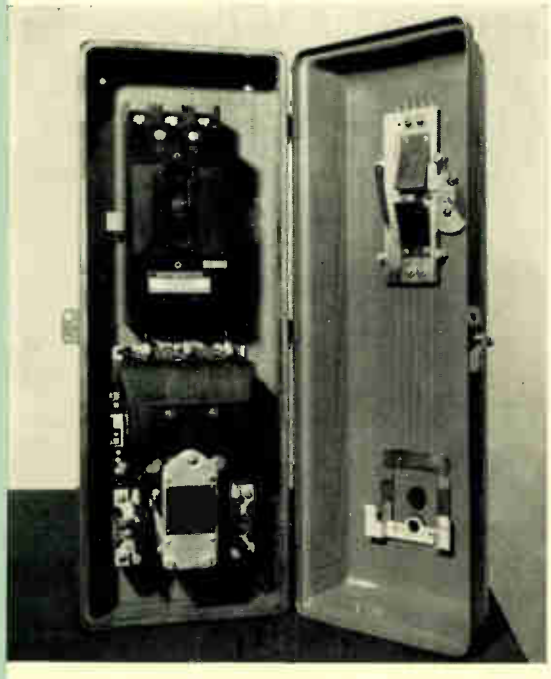
The adjustable-magnetic trip element, which can be used alone where only short-circuit protection is desired, adds greatly to the flexibility of these breakers. The combination of thermal and the adjustable-magnetic trip elements is particularly advantageous in motor-starting service to open the circuit on currents in excess of locked-rotor, and in distribution service where an accurate magnetic trip setting is required.

Direct-current breakers of 225- and 600-ampere frames can be furnished with a new reverse-current attachment that opens the circuit on a reversal as small as five percent. This attachment is now built within the breaker enclosures.

The enclosures for safety switches, also used as disconnect means, have been redesigned. The entire family of switches, rated from 30 to 200 amperes at 600 volts a-c and 250 volts d-c, now fit into 15 sizes of enclosures instead of 87, as pre-

The Motor Sentinel, open, and in standard, water- and dust-tight, and explosion-proof enclosures (right to left).





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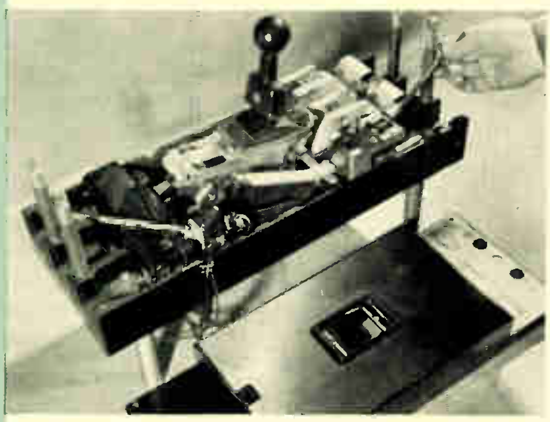

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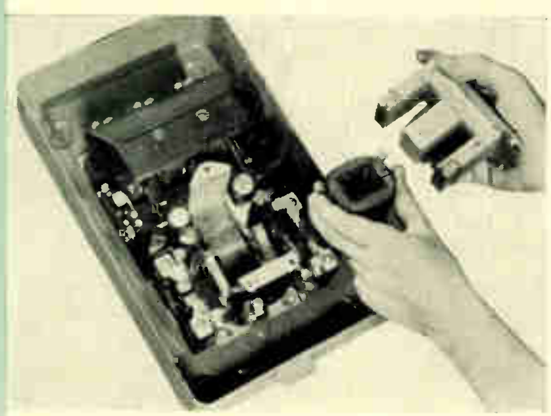


(3)

(4)

A combination Life-Linestarter (1), with a 100-amp-frame circuit breaker, the new operating mechanism, and a size-2 Linestarter. A 600-amp-frame breaker (2), with a reverse-current trip attachment within the breaker housing. The coil of this Life-Linestarter (3) can be replaced simply by loosening five screws, three for mounting and two for electrical connections. The Life-Linestarter, with a built-in pushbutton (4), presents a neat appearance.

viously. The switches feature diamond-point break jaws that isolate the arcing points from the current-carrying copper, one-piece break and hinge jaws that reduce the number of connections made during assembly and hence the resistance loss inherent in such connections, and construction that permits all copper sections to be removed from the front, thereby facilitating maintenance.

Starters—The simplest motor starter is the Motor Sentinel, which is rated up to 1 hp at 110 or 220 volts, single phase. This starter is of the manual type and contains a thermal overload trip. The new form is of more compact construction and features heaters that can be replaced simply by removing the cover of the enclosure; the mechanism, similar to that employed in small circuit breakers for domestic use, need not be removed. The starter can be mounted in a die-cast alloy housing furnished for the purpose, in a standard 2½-inch-deep wall box with a standard flush switch toggle plate, or in cast-iron water- and dust-tight or explosion-proof enclosures. The Motor Sentinel is especially adapted for control of small motors, as on oil burners, stokers, and small machine tools.

Larger motors are usually controlled by a magnetic starter. A new family of starters, identified as Life-Linestarters to correspond with Lifeline motors, is now in production in NEMA sizes 0 through 2 (25 hp maximum at 600 volts, 2 and 3 phase). It adheres to the standard NEMA mounting dimensions and wiring sequence.

The new starters follow a coordinated design, with units of similar construction in all sizes. Coils are easily replaced from the front by loosening only three screws and two electrical connections. High-strength insulating materials are used throughout, in arc boxes, bases, crossbars, etc.; porcelain, which breaks readily, is not used at all. One electrical interlock is furnished as standard and three more can easily be added in the field, increasing adaptability of the starters for special purposes. These interlocks can be changed from normally open to normally closed and vice versa. Solderless connectors are used in all sizes for all power-circuit connections and for some control-circuit connections.

The overload relays of the new Life-Linestarter family are of simpler construction, but utilize the same heaters as on previous types. The relays have a lever whose position can be adjusted for three standard types of operation—automatic reset, manual reset, or non-stop.

Life-Linecontactors are furnished alone, without an overload relay for motor protection. They have the same features and are furnished in assemblies of two to five poles.

Life-Linestarters and Life-Linecontactors will be available in all standard NEMA enclosures or for open mounting. All sheet-steel enclosures (general-purpose, semi-dust-tight, and dust-tight) are bonderized before painting. This insures adhesion of the paint to the metal and prevents the spread of rust. Cast-iron enclosures (water- and dust-tight, and explosion-proof) have an aluminum finish.

Pushbutton Stations—A new family of Oil-Tite pushbutton stations, embodying the Oil-Tite pushbuttons introduced early this year, is now available. Pushbuttons can be arranged with front or rear-connected terminals and can be mounted on either the cover or body of the die-cast, corrosion-resisting alloy enclosure. These stations are particularly applicable to the machine-tool industry, where the spray from oil coolants tends to cause deterioration of the wiring and functioning of the control pushbuttons.

These design changes—in disconnect means, starters, and pushbutton stations—while not revolutionary, contribute materially to the simplicity and flexibility of motor controls.

Personality Profiles

Chronologically, *L. J. Murphy* is past the mid-century mark in years, but in general appearance he is a decade younger. The Murphy Fountain of Youth lies unhidden in his gregariousness and convivial outlook, which also fit him well for his work as a district application engineer.

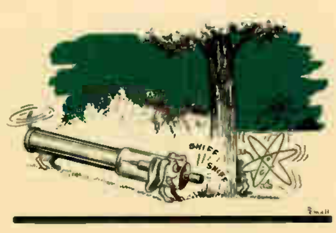
Murphy started with Westinghouse in 1919, after graduating from Carnegie Tech with a B.S. in E.E., followed by a brief stint in the then infant Air Corps. His three decades with the Company are split up almost equally between the East Pittsburgh works, the New York District Office, and the Buffalo District Office. At East Pittsburgh, he was in the General Engineering Department, handling the headquarters end of applying electrical equipment to industry. During this period, he helped develop the automatic rotary and adjustable-voltage oil-well drilling equipment now extensively used. Murphy's second and third decades have been spent in the field, applying electrical equipment in the various industries in New York State.

Murphy's likable personality makes him a much-sought-after public speaker by both technical and nontechnical groups. Also, he is chairman of his Rotary Club-sponsored Amherst Symphony Orchestra. And when he can find the time and enough bright sunlight, he preserves noteworthy occasions on color film with his 35-mm camera.

• • •

Menuhin, Man-of-War, Musial, and mesons typify *P. A. Duffy's* principal interests. An amateur (he says) violinist, he also closely follows the triumphs of Citation at the racetrack and the baseball fortunes of the Boston Braves. But of primary concern is his interest in radiation detectors, especially Geiger counters.

Duffy's career with Westinghouse began



in 1942, shortly after his graduation from Rhode Island State College with a B.S. in Electrical Engineering. After finishing the student course he was assigned to the Radio Division. Here he helped design radar-pulse and other specialty transformers. In 1945 he moved over to the X-ray Division to aid in designing and developing x-ray control and timer circuits. His first brush with radiation detectors came soon afterward in connection with the development of x-ray gauges. Since 1947 he has been engaged in a comprehensive instrument development program, which is now an important activity with Westinghouse and other companies.

• • •

Airlines add another phrase to the old saying "what goes up must come down," and that is, "safely and in the right place." *William C. Norvell's* career has been all wrapped up in helping to make this saying of flying true regardless of weather conditions. The problem of making bad weather landings safer and simpler has been foremost in his mind almost since his graduation from Trinity College in 1933. Norvell entered the student training course at Westinghouse in 1935 and has been closely allied with airport lighting ever since. After working in both the engineering and sales departments of the airport lighting section, he became Supervisor of the Airport Lighting Application Department in 1939. In 1944 he became Supervisor of Aviation and Marine Lighting Sales.

Two years later Norvell joined the Civil Aeronautics Administration in Washington as Chief of the Specification Section of the Airport Lighting Division. While with the CAA, Norvell wrote the present specifications for airport lighting being installed under the Federal Aid Airport Program, and was also in charge of all the approvals of airport lighting and control equipment. In 1948 Norvell returned to Westinghouse as Manager of Aviation and Marine Lighting Sales, the position he now holds.

• • •

The author of the article on substation transformers—*E. A. Thompson*—knows his subject from the test-floor up. When he came to Westinghouse in 1937 he was assigned to test the newly developed CSP Power Transformer and kindred transformers. Three years later he became a design engineer in the Instrument and Regulator Section, being promoted to Supervising Engineer in 1948. Thompson comes from Kansas (B.S. in E.E., University of Kansas, 1937) where lakes and game-fish rivers are not too plentiful. One is at a loss to explain his enthusiasm (and skill) with the fishing rod.

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This is the fourth occasion on which *I. R. Smith* has discussed various aspects of dry-type rectifiers in these pages. Since 1927 he has been associated intimately with, first, the development of the copper-oxide rectifier and, more recently, with improvements to selenium rectifiers. Originally Smith came to Westinghouse in 1921

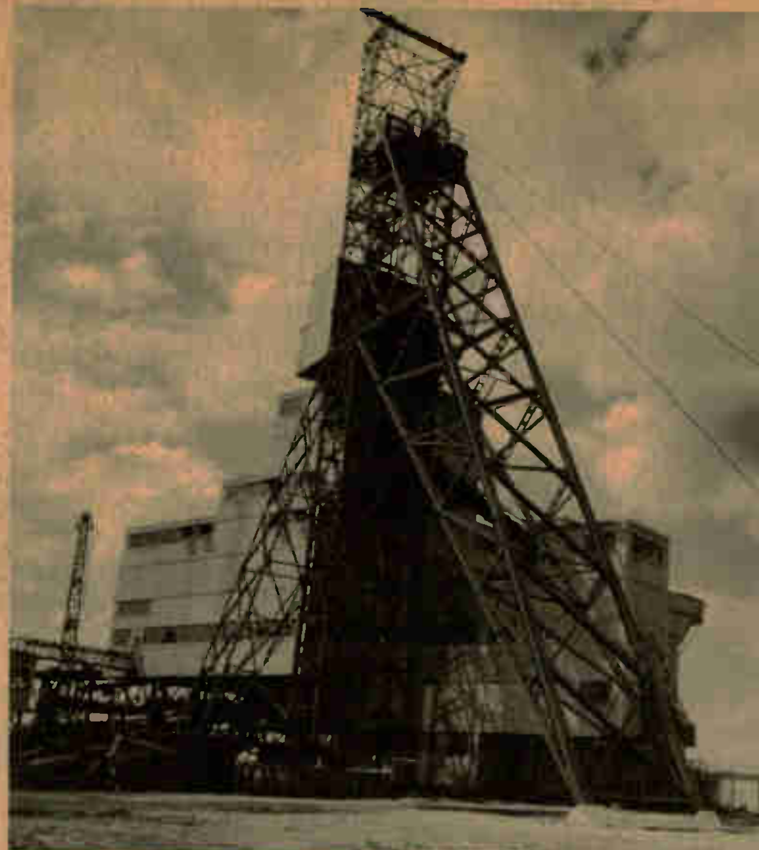
as a young electrical graduate from Worcester Polytechnic Institute. He worked on Autovalve lightning arresters before entering his present field of rectifiers.

• • •

J. M. Stein was a technician at the Research Laboratories when he took a test for and won a Westinghouse War Memorial Scholarship. Those who knew Stein were not surprised, for he had been studying higher mathematics since the sixth grade, when he first ventured to peek inside the covers of a textbook belonging to his older brother. In his leisure time, Stein still studies those subjects most engineers shun—higher mathematics and fundamental physics.

Stein majored in physics at Carnegie Tech and in 1940 joined the Motor Division, now at Buffalo, starting in the test section of the engineering department. While still "on test," he distinguished himself by writing an erudite paper on the theory of unexcited synchronous motors. Forthwith, he progressed to design, which culminated a lead role in the development of the single-phase Lifeline motor. Last spring, Stein joined the Westinghouse Atomic Energy Division, in which his mathematical background and inclinations should carry him far.

Despite his scholarly tendencies, Stein is not one to lose contact with the world. He is something of an archer and would dearly love to hunt wild game with bow and arrow. Also interested in geology, he occasionally returns to nature by roving around the countryside, pausing now and then to examine some unusual rock formation. An advocate of the outdoor life, Stein spent a summer between high school semesters on a hitchhiking tour of Ohio. But this was only a warm-up, for his graduation gift to himself was a via-thumb tour of the West.



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