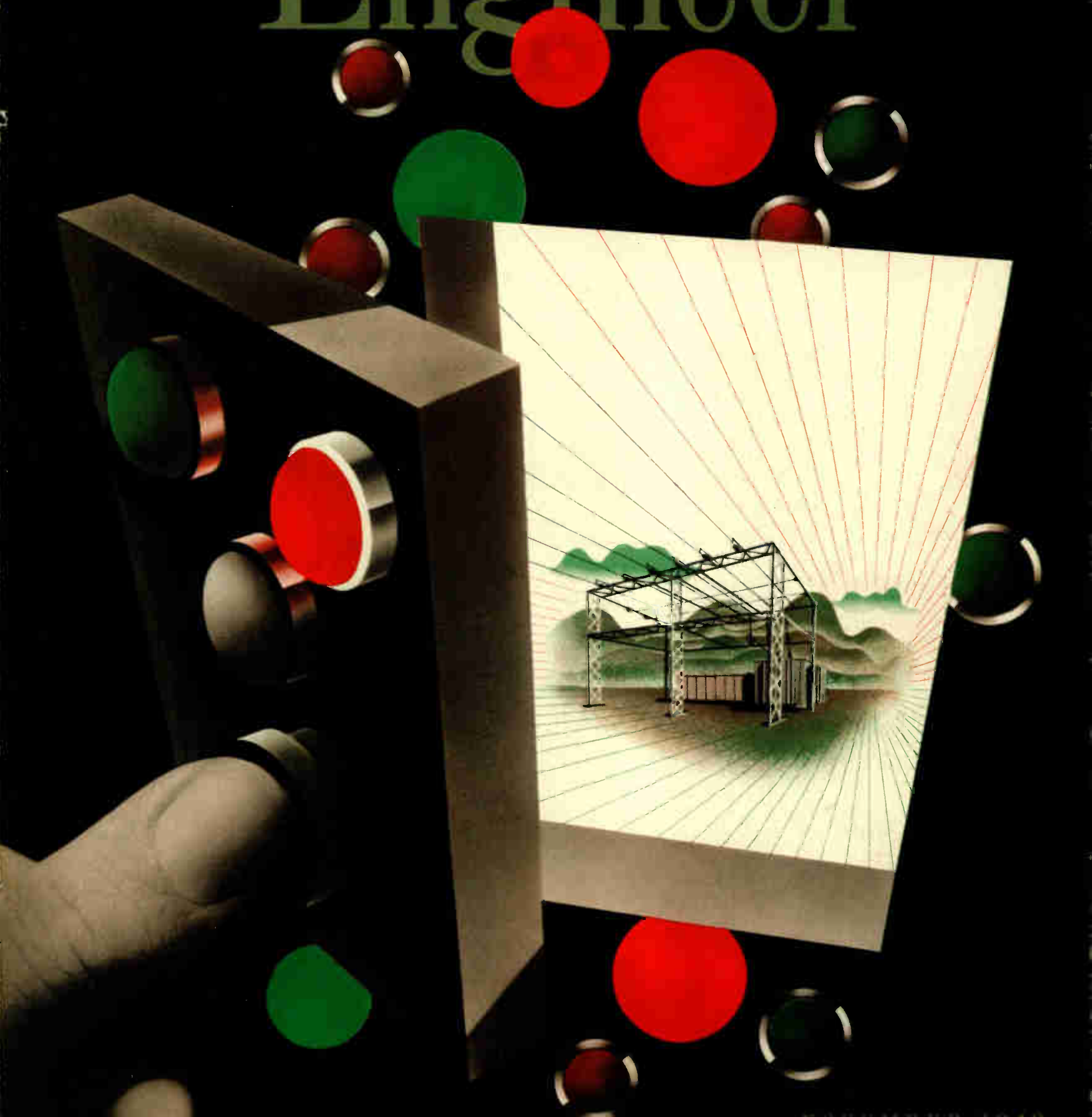
WESTINGHOUSE

Engineer



NOVEMBER 1949

INGENUITY—an engineering trademark

Engineering is characterized by ingenuity. Even a casual glance at the achievements of engineers within the past few decades is enough to show that most developments were not based on any startling new physical or chemical principles. In fact some of the more successful achievements were not even new ideas, merely adaptations of available ones. More often than not it was the application of an old principle in some new way, with a new "twist," or of a principle oft-used in one field to a totally different field. Engineering ingenuity takes many forms—adapting old ideas to new developments, or new ideas to old; changing old equipment to meet new and different demands, and so on. Ingenuity, both with and without originality, solves most engineering problems.

• • •

Not many years ago engineers were toiling with the problem of how to roll flat, uniformly thick strips of metal. Now the problem is to give a sheet of aluminum a gradual taper from end to end as it passes through a rolling mill. This came about when airplane manufacturers expressed a desire for aluminum wing sections that were relatively thick next to the fuselage and tapered off to a thin dimension at the wing tip. The major problem in rolling such a strip, of course, is to adjust the pressure of the rolls gradually and uniformly as the sheet passes through. Engineers plan to solve this problem by synchronizing the speed of the screw-down motor with that of the mill motor; the thin end of the aluminum sheet will be rolled first, and as the sheet passes through the mill the screw-down will back off uniformly to give the desired taper. Aluminum sheets, 0.6 inch thick, 20 inches wide and 20 feet long, will be given a maximum taper of 0.03 inch per foot. Drive will be accomplished in the experimental mill by a 50-hp mill motor and a 7½-hp screw-down motor, plus one speed-matching Rototrol.

• • •

The flywheel principle, one of the first to satisfy man's need for ways to "store" energy, is still finding clever and unusual application. For example, a motor-generator set recently built for a leading coal company utilizes this age-old principle to allow more reliable service for a coal-mine man hoist. The m-g set, which consists of a 125-kw d-c generator, a 7½-kw exciter, and a 200-hp wound-rotor motor, has attached to its shaft a five-ton flywheel that will store 18 400 hp-seconds of energy. The flywheel is so designed that in case of a-c power failure, the d-c power can be maintained long enough for the hoist to complete its trip. According to engineering calculations, this flywheel will store enough energy at full speed to allow approximately one and a half round trips of the hoist. This means that if a-c power failed immediately when a full cage load of men was started to the surface from the bottom of the shaft, the energy stored in the flywheel would be sufficient to bring the hoist to the top, lower the empty cage, and bring up another load before the flywheel dropped to half speed. The exciter on the flywheel set is controlled by a voltage regulator designed to maintain full voltage at all speeds between 1200 and 600 rpm.

• • •

As an indication that the same flywheel principle applied to the coal-mine hoist has many other applications, consider its use as a "landing strip" by Air Force engineers. In trying to learn what happens to airplane tires when a plane lands, these engineers decided that the logical way to do this would be to simulate a landing, but with a moving landing strip instead of a moving plane. A huge flywheel, driven by a 150-hp motor, will replace the runway. When an airplane tire is pushed against the flywheel it will get the same initial shock that it would experience in a real-life landing. Applying the brakes will be accomplished by slowing down the flywheel—the tire gets the same wear. And by varying the speed of the motor, engineers can compensate for such things as wind resistance and rolling friction. This ingenious solution to what could be a major testing problem will enable the Air Force to test the reaction of tires at speeds up to at least 250 mph.

• • •

As electrical equipment grows larger, both in size and rating, the problem of temporary "stand-ins" for use during emergencies or maintenance periods grows in equal proportion. Such is true of the transformers in the substations of the Bonneville Power Administration. The situation here will be solved by the construction of a huge mobile transformer, the largest ever built. This will be an 83 333-kva, single-phase transformer, mounted permanently on a railroad car for transportation to any of the substations. When used as an autotransformer, it will step down 220 kv to 110 kv; an isolated secondary winding will provide the full kva rating at 57 kv. To keep within headroom requirements, the transformer will lie on its side, a feat made possible by the form-fit tank and shell-form core. By keeping the long dimension of the transformer parallel to the axis of the car, bushings can be kept in place when the transformer is moved from one substation to another. The portable unit will be about 25 feet long and will weigh 135 tons.

• • •

None of these developments marks the introduction of a new scientific principle. All are based, to varying degrees, on previously used theories or methods. Yet all exhibit an unusual amount of ingenuity. That, in one sense, is the role of the engineer in industry. And, as long as they continue to display such a marked ability to find unique solutions to new problems, the parade of technical developments will never cease its steady progress.

WESTINGHOUSE Engineer

VOLUME NINE

NOVEMBER, 1949

NUMBER SIX

On the Side

The idea of a supervisory control cover caught on with Dick Marsh, our artist, the minute he saw the flashing red and green lights on the escutcheon, and heard us describe the magic way in which supervisory control directs the operation of distant machines. Thus enthused, he turned out our cover, which portrays with imagination the theme of supervisory control.

• • •

Demands for more power are being met by power utilities. Recently ordered by the Duquesne Light Company for their new Elrama Power Station were two huge 95 000-kw turbine generators. These generators will furnish enough power to supply the electrical needs of a city the size of Atlanta. These two, plus the two previously ordered 81 000-kw generators, will boost Duquesne Light's total capacity to nearly one million kw.

• • •

Until recently 3.5-million kva was considered the top rating for circuit breakers. However, this limit has now been more than doubled by the completion of the first of six 10-million-kva breakers for Grand Coulee Dam. These huge 230-kv oil circuit breakers are over 20 feet high and 34 feet long.

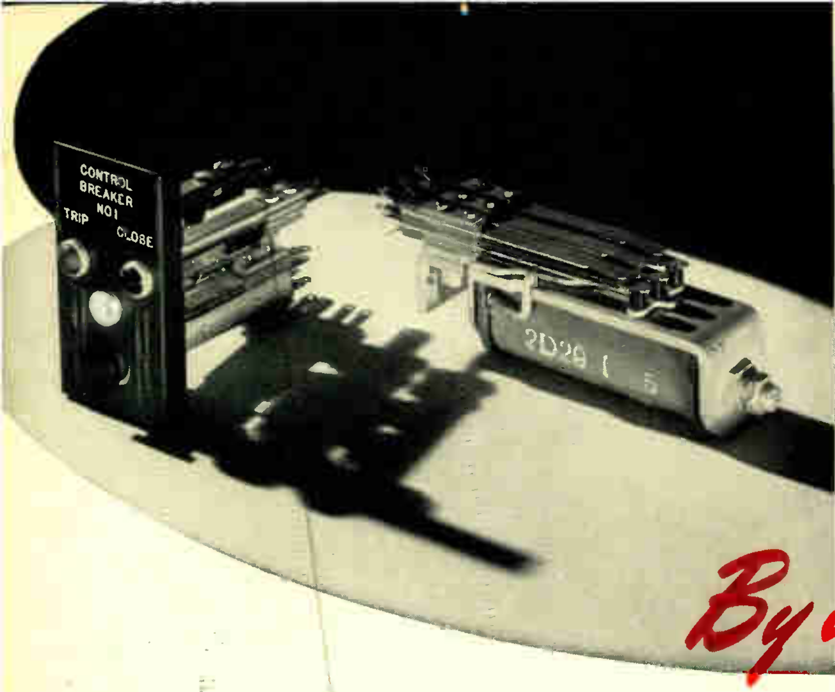
The rated interrupting time is an extremely fast three cycles, or one-twentieth of a second, including the tripping function, the separation of the contacts, and extinction of the arc. The breaker also has the added unusual ability to interrupt the full 10-million kva twice, if necessary, within an interval of only 20 cycles, or one-third second.

The contents of the *Westinghouse* Engineer are analyzed and indexed in the Industrial Arts Index.

In This Issue

The *Westinghouse* Engineer is issued six times a year by the Westinghouse Electric Corporation. Dates of publication are January, March, May, July, September, and November. The annual subscription price in the United States and its possessions is $2.00; in Canada, $2.50; and in other countries, $2.25. Price of a single copy is 35c. Address all communications to the *Westinghouse* Engineer, 306 Fourth Ave., P.O. Box 1017, Pittsburgh (30), Pennsylvania.

THE WESTINGHOUSE ENGINEER IS PRINTED IN THE UNITED STATES BY THE LAKESIDE PRESS, CHICAGO, ILLINOIS



The smooth functioning of a modern, complex power system or the scattered apparatus units of a large industrial company would be impossible without centralized control. A system that makes this masterminding possible is known as supervisory control. Well established as to principles and equipment forms after a quarter of a century of service, applications of it are occurring at an increasing rate, particularly in industry.

By a Flick of the Finger

W. A. DERR, *Switchboard Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania*

By supervisory control, any of many distantly located pieces of apparatus can be operated and their condition automatically registered—literally by the flick of a finger. Any kind of apparatus that can be controlled electrically is subject to supervisory control; for example, a circuit breaker can be opened or closed, or the amount of power being delivered at a certain point can be indicated. The controlling and indicating intelligence is transmitted over a small number of common connecting channels.

Supervisory control, the name applied in 1921 to the first commercial remote-control system, is now an accepted term. This first installation, which is still in operation, embodied all the basic principles and the forms and types of mechanisms used today. It employed telephone-type relays to create signals that were transmitted over four telephone wires connecting the dispatching and remote stations. It employed the idea of automatic check signals to prevent error either by man or equipment. However, progressive development later resulted (in 1929) in the modern design, called Visicode, which provides a complete supervisory-control system that operates over a channel of only two telephone wires. Although the name Visicode has been retained and the same fundamental principles used, the present-day system incorporates many improvements and added features; for example, Visicode can now operate over carrier or microwave channels as well as over conventional telephone-type circuits.

Many hundreds of Visicode systems are today in operation in the electric-power and other industries. They range from installations for control of but a few pieces of equipment to those for controlling several hundred units of apparatus. Visicode systems have been applied for distances of a few hundred feet as well as for distances of several hundred miles. Actually, the number of apparatus units and the distance are unlimited.

Operation of Visicode

For remote control of any equipment, one must have or create a direct connection between a control button at the dispatching station and the equipment at the receiving location. Actually, the simplest scheme would be to have a permanent connection, such as a pair of telephone wires, for each function. But for fifty functions, this arrangement would necessitate fifty pairs of wires, which would be expensive to the point of impracticality if any considerable distance were involved between dispatching and receiving stations. Visicode, then, is essentially a system for making any one of these fifty connections over a single set of wires. Simply by pressing a button, relays at each end are energized to select the desired unit. Of course, only one unit can be controlled at a time over a single channel.

Visicode equipment communicates orders from a dispatcher to a remote station, with the remote station in turn performing these orders and verifying their execution. The four essential functions—the selection by the operator of the desired unit, the automatic check signals providing proof of

In the Visicode system each remote apparatus controlled is represented on the dispatcher's board by its own escutcheon containing three lamps and a pushbutton (shown at the top of the page). The relays (beside the escutcheon) are of the type developed originally for telephone service. Below, a group of master keys that are operated to perform functions as indicated. Two control keys at the right are only effective after a selection key has been operated.

correct selection, the operation of that equipment, and the automatic indication of a change in its condition—are accomplished by codes of d-c pulses transmitted at the rate of approximately 15 per second. The pulses are all of the same length and type and are counted by sets of relays. The selection made and the control operation performed are dependent on the number of pulses transmitted and received. No dependence is placed on variation in length or spacing of the current pulses.

Each remote unit subject to supervisory control is represented on the dispatcher's control board by a small escutcheon plate. This escutcheon is equipped with a single pushbutton or selection key, and three lamps: red, green, and white. The key is used to select the desired remote unit; the red and green lamps indicate the position of the remote unit; and the white lamp indicates when selection has been made.

To select a unit at a controlled station, the selection key associated with that particular unit is pressed. Thereupon the selection code assigned to that unit is transmitted from the controlling station to the controlled station. The controlled station, on receiving this selection code, returns to the transmitter a check code that is a duplicate of the selection code. The lighting of the white selection lamp indicates that the selection has been correctly made.

This operation, called check-back, is the basic feature that provides for reliable operation. It offers a visual check that the desired remote unit has been correctly selected for operation before it is actually operated. If outside interference should cause any changes in the codes of selection and check pulses, the check-back prevents further operation until the equipment is reset.

With selection properly completed the circuits are ready for a control operation. Two control keys, common for all units, are employed. These keys are operated to perform the desired "trip" and "close," "raise" and "lower," or whatever action is required of the particular unit. The control key for the desired function is momentarily depressed after selection is completed. This results in a control code being transmitted from the controlling station over the established channel to the selected unit at the controlled station, causing it to change position. The change in position of the controlled unit results in transmission of a supervision code back to the controlling station, changing the lamp indication on the escutcheon for that unit. The supervisory-control equipment then automatically resets to release the selected unit, and is ready for any further use by the dispatcher.

When a controlled device changes position automatically, such as the tripping of a circuit breaker due to the operation of a protective relay, the controlled station immediately sends its assigned selection code (if the channel is clear; if not, the station waits until it is) and the controlling station returns the check code. After receiving the proper check code, the controlled station sends a supervision code to change the lamp indication for that particular unit. The alarm bell also rings to call the operator's attention to the fact that an equipment change has occurred. A glance at the array of escutcheons quickly tells him which unit is involved because the associated red or green lamp is flashing on and off. Thus if a breaker trips, the associated green lamp flashes at the controlling station. If a breaker equipped with an automatic recloser trips, and is automatically reclosed, the associated red lamp flashes. The alarm bell can be stopped by operation of the "alarm release" key without stopping the flashing of the lamp. After the operator notes and records the operation, the lamp is caused to burn steady by operation of the "reset" key.

The Beginnings of Supervisory Control

Editor's Note: Quoted below are extracts from a letter by Mr. R. J. Wensley, which present the interesting circumstances surrounding the early days of supervisory control. Mr. Wensley is recognized as the originator of supervisory-control systems and took the lead role in making the first application—on the system of the Cleveland Railway Company—while a member of the Westinghouse Switchboard Engineering Department. Mr. Wensley has been associated with many engineering developments, but probably he is most widely known as having contrived the famous mechanical man, "Televox," seen by millions at several World's Fairs and other exhibits, and ancestor of the current robot, "Elektro." Mr. Wensley is now associated with the Commonwealth and Southern Corporation at Jackson, Michigan. He writes as follows:

"Automatic control for substations was in an active state of development in 1920 and, as part of the promotional program, I gave a paper on 'Automatic Substations for Heavy City Service' at the Fort Pitt Hotel before the AIEE on March 12, 1920. The paper developed some active discussion during which a question was raised as to the ability of automatic control to solve the problems of a large Edison network.*

"The automatic equipment we had developed would not solve all the operating problems of a big system. The inspiration for an answer came (to me) while waiting my turn to close the discussion. I described a control system using selective systems as developed by the telephone industry. So far as I know this is the first published mention of the use of such equipment for remote selective control of power apparatus and, as far as I was concerned, it was the first time that such a system was considered as a possibility.

"We had a contract with the Cleveland Railway Company for a large installation of automatic substations. In the audience at the meeting was Mr. Lawrence D. Bale of Cleveland. After the meeting he asked me why we had not told him of the new development. Since he was a friend of mine, I admitted that the idea had just occurred to me. He insisted that it was a good idea and that his company wanted to install equipment for such functions.

"Just prior to this date the New York Edison Company had installed a selective system for transmitting lamp indications from one of the power plants to the load dispatcher, using a synchronous selector developed by the Western Electric Company for Multiplex telegraphy. No control functions were used, the device operating in one direction only.

"The North Electric Company seemed to have the right equipment and were willing to help us develop apparatus for this new use. As a result, the first installation of complete selective indication and control including selective telemetering was installed.

"The equipment was at first termed 'Remote Supervisory Control' but later was shortened to its present name of 'Supervisory Control.' I do not remember the history of the name. It seemed a natural, and probably came from the term 'Supervision' generally used in the telephone art to denote a signal indicating correct operation and 'Control,' the use of which is obvious.

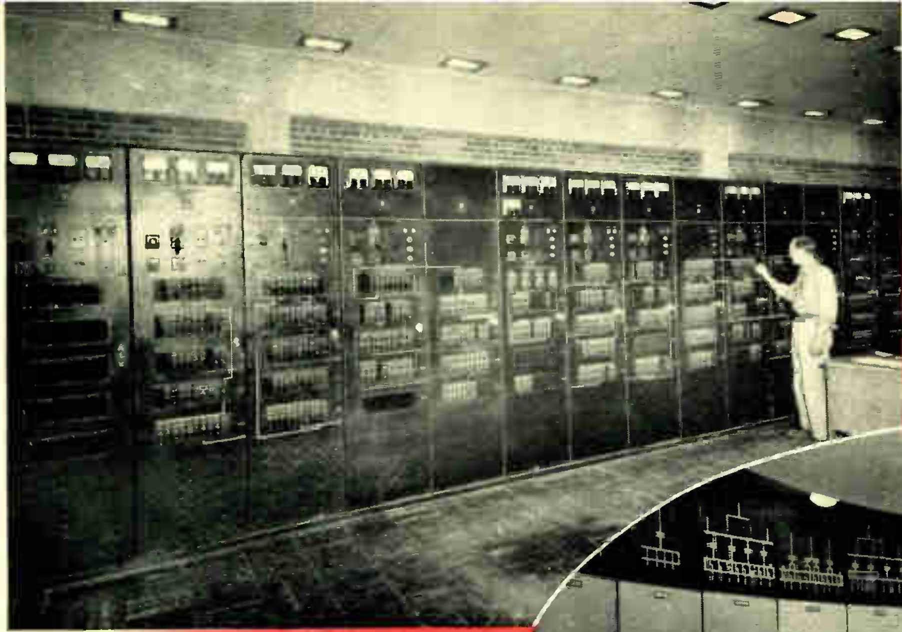
"From this beginning the idea spread rapidly and many installations were made within the next two or three years.

"What was considered to be a serious problem at Cleveland was sparking at the brushes of the converters. The converter design was better than we thought and our fears proved groundless. Before we found that the expected sparking failed to occur, we investigated the possibility of a device to 'see' the commutator with a scanner. A new man in Research was assigned to help us, and he proved to be very resourceful and full of ideas on scanning photocells and related subjects.

"We abandoned the attempt to 'see' the commutator and developed a simple 'electric eye' to signal if there was excessive sparking. I often speculate as to what effect our investigation had on the progress of television, because the research man was Vladimir Zworykin!

"Our first requirement was accuracy and dependability. We proceeded on the basis that the supervisory control must not make mistakes. If the selective equipment of the dial telephone fails, an apology settles the matter, but a wrong oil circuit breaker operation can be very serious. The Cleveland equipment employed an automanual check-back, which insured that the dispatcher could verify his selection before the actual operation was completed. Some form of check-back, either partially manual or wholly automatic, has been incorporated in all equipments manufactured by Westinghouse since that time."

*This question appears on page 696, Volume 39, Part 1, of the Transactions of the AIEE for 1920.



The eight substations of the Chicago subway system are controlled from a downtown office. →

The control for eleven substations distributing power in the Geneva Steel Corporation at Provo, Utah is brought together at this point.

This dispatcher of a large midwestern power company has before him the supervisory control for twelve large substations.

Operating Channels

The interconnecting means for transmitting intelligence between two or more locations for any communication service constitutes a channel. This can be a pair of telephone wires, a power-line carrier channel, or a microwave link. Visicode terminal equipment is essentially the same regardless of the type of channel employed. Thus, the choosing of a channel means for operation of Visicode is governed primarily by an economic study and comparison of the possible channel means themselves.

Visicode requires only a single element at the controlling and controlled stations that must be operated over the interconnecting channel, since its operation is based on a single type of signal for all supervisory functions.

Telephone-Line Wires

By far the majority of all existing installations of supervisory control operate over telephone-line wires. These can be open-construction telephone lines or wires in telephone cables, either leased from telephone companies or privately owned. The voltages and currents involved do not exceed limitations imposed by the telephone companies for operation over leased wires. The Visicode operates over a single pair of conductors, d-c pulses being employed. The use of d-c pulses minimizes interference with other services and places no practical limitation on the distance between the dispatcher and the controlled unit. A Visicode system has been in operation since 1938 for the control of substations along an electrified railroad spaced at wide intervals over a distance of 125 miles using no. 16 gauge cable wires.

Power-Line Carrier Channels

The use of power-line carrier channels for the operation of supervisory control has become more and more prevalent since the first such installation was made in 1935. In operating Visicode over a power-line carrier channel, the carrier transmitters are keyed to transmit the pulses. Since Visicode equipment requires only one signal-receiving element, it can be operated over the same type of carrier channel used for protective relaying. When Visicode is the only equipment operated on a carrier channel, the transmitters and receivers at all stations are operated on the same frequency and no modulation by audio-tone equipment is required.

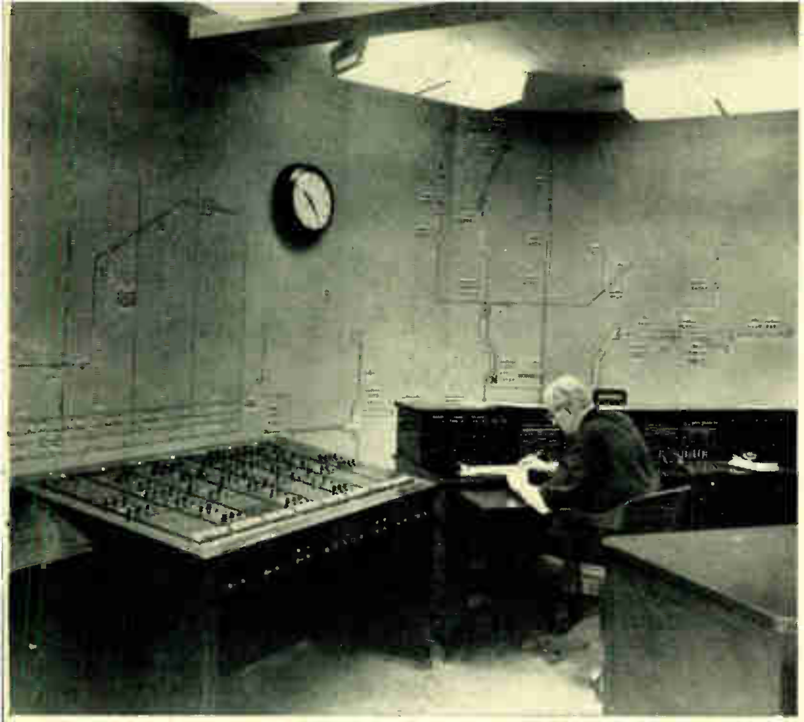
The fact that a single unmodulated carrier frequency can be used for the control of several stations is extremely important since the available carrier band is already crowded in some sections of the country.

Space-Radio Channels

The development of microwave radio equipment has provided a new channel means for operation of supervisory-control equipment. Frequency bands have been allotted by the Federal Communications Commission for remote-control installations. Visicode was successfully operated over a microwave channel between the Cos Cob and Darien Stations of the New York, New Haven and Hartford Railroad Company as early as 1943.

Telemetering

Selective telemetering, of any quantities of which local indications are obtainable, is possible with the Visicode system. When a telemetered quantity can also be controlled, the telemetered indication can be obtained simultaneously with the control. This is advantageous for the control of waterwheel gates, feeder-voltage regulators, transformer tap changers, motor-operated valves, etc. It is also possible to obtain a telemetered indication of load in conjunction with the control



of a circuit breaker feeding that load. The equipment can be arranged so that any one of the indications can be telemetered continuously, with the indication being interrupted only while selection or control pulses are being transmitted.

When Visicode operates over telephone-line wires, telemetering equipment, which operates on the principle of transmitting a d-c voltage or current proportional to the quantity telemetered, is usually employed. Pulse-type telemetering equipment can also be used over telephone-line wires.

When the supervisory control is being operated over a power-line carrier channel or a microwave radio channel, pulse-type telemetering equipment must be used. Either "rate of pulse" or "duration of pulse" telemetering can be so applied.

Construction

Visicode employs two sets of equipment, one for the controlling station and one for the controlled station. The controlling-station equipment consists of escutcheons, master control keys, telemetering receivers, and telephone-type relays. The controlled-station equipment consists of telephone-type relays and interposing relays energized by the telephone-type relays to perform, in turn, the desired control functions. If telemetering is involved, telemetering transmitters are also required at the controlled station.

The Visicode is an "all-relay" system. All the telephone-type relays used in it have the same mechanical construction. These relays require very little attention, there being no complicated mechanical parts requiring periodic inspection, oiling, adjustment, or replacement. Because a relay very rarely needs to be removed, it is possible to connect the wiring to the telephone relays by means of positive soldered connections. This eliminates any need to use plug-in type relays or relay cases with the hazard of reduced reliability due to possible poor or high-resistance contact in the plug mounting.

The telephone-type relays are grouped in cases. The number of cases required is determined by the number of functions provided. These cases have removable front and rear covers to provide complete access to the relays. Wiring is provided for as many future functions as desired so that additional functions can be performed by merely adding the necessary relays. Many different arrangements of the controlling-station equipment are possible, some of which are illustrated. Controlled-station Visicode equipment can be mounted either on open-type switchboard panels or on the swinging or stationary panels of cabinets. When outdoor metalclad substations are controlled, Visicode equipment is usually mounted on a swinging panel in one of the units. When Visicode is applied to new stations, it is usually incorporated in the design of the local control switchboard.

Summary of Uses and Operating Features

With the Visicode type of supervisory control, any number of different kinds of electrically controlled apparatus units can be remotely controlled and supervised over a single channel. Visicode can share a single-frequency power-line carrier channel with other services such as protective relaying and communication. While the control and supervision of circuit breakers is by far the most common use for this system, there are many others, outstanding among which are:

1—Circuit breakers can be synchronized by means of Visicode, either by a remotely controlled automatic synchronizer or by indications received on a special synchroscope.

2—Selective telemetered indications of current, voltage, watts, bars, water level, gate position, etc., can be obtained regardless of the type of channel employed. The same channel used for operation of Visicode can in all cases be used for the selective telemetered indications.

3—Telemetered indications of current or watts can be provided when selection is made for associated breaker control.

4—"Raise"-"Lower" control, combined with simultaneous telemetered indications, permits accurate voltage, speed and load control for generators, opening and closing of gates in hydro-stations, control of tap changers, etc.

5—Communication as well as telephone ringing can be provided over the Visicode channel.

Several features of special significance to the dispatcher are built into the system. These include the following:

1—A "check-back" causes each selection to be automatically checked before it is possible to proceed with any control operations. This provides positive protection against operating the wrong equipment.

2—The control, after selection is made, is positive. Coded operation control provides protection against the possibility of false operations of any selected apparatus units due to any external disturbing voltages that could operate the receiving relays. Trip-free or anti-pumping breaker control relays are not required for any circuit breakers controlled.

3—Continuous supervision of the line wires is provided when the equipment operates over a metallic circuit. In other words, any failure of the supervisory circuit is indicated to the operator or dispatcher.

4—If an automatic reclosing breaker is tripped by protective relays and successfully recloses, the operator at the controlling station is informed of such operation by flashing of the red lamp indication for that breaker.

Conclusion

The use of supervisory control in the central-station field has greatly increased during recent years. This is because of the reduced operating costs that result and the recognized advantages of centralized control for efficient system operation. Supervisory control has gained recognition as the most reliable and economical way to obtain centralized control.

Until less than ten years ago relatively few supervisory-control installations occurred in the industrial field. However, these applications are now increasing rapidly. Frequently they prove to be the best means of providing remote control of a variety of functions even when extremely short distances between the controlling and controlled locations are involved. The use of supervisory control in the industrial field can be expected to increase.

The fundamental principle of operation of Visicode, without guard circuits, reset and release features, telemetering circuits and the like:

A single pair of wires is used between the controlling and controlled stations. The pulse receiving relay no. 1 is normally de-energized at both the controlling and controlled stations. If the pulse transmitting relay 5 is momentarily energized at either location, both relays 1 are momentarily energized, producing a pulse. Thus the pulsing of the line may be controlled from either end, and the action of the pulse receiving relays is the same in either case. The operation would be similar for power-line carrier or microwave radio. In either of these cases, relays 1 would be connected in the plate circuit of the receivers and relays 5 would key the respective transmitters.

If, at either station, relay 4 is energized, relay 5 is also energized. This energizes both line relays 1, opening the circuit to relay 5. Relay 5 releases after a short time delay to de-energize the line relay 1, thereby establishing a circuit for relay 5. Relay 5 then energizes the line relays 1 the second time. When relay 1 is energized, relay 5 is again de-energized. This cycle of operation continues as long as relay 4 is energized.

Suppose it be desired to close circuit breaker 4, assigned to selection point 4. First, the operator pushes the selection key on escutcheon 4, short circuiting point relay *D*4 through a resistor and de-energizing it, thus energizing relay 15, which is common to all selection points when the equipment is at rest. (All of the *D* relays are normally energized.) Relay 15 energizes controlling station start relay 4, which starts the line relays 1 pulsing as previously described. Thus, pushing any selection key momentarily, automatically starts the line relays to pulse.

Unless stopped, line relays 1 would pulse indefinitely. Controlling-station counting-chain relays *A*1 to *A*16, and sequence relays 11 to 13 are normally de-energized and control the counting of the pulses to constitute definite codes. The first energization of relay 1 energizes relay *A*1. When relay 1 is de-energized the first time, relay 11 is energized in series with relay *A*1. The first pulse thus sets up relays *A*1 and 11.

Relays *A*1 and 11 energized, prepare a circuit for counting chain relay *A*2, which is completed the second time line relays 1 are energized. Relay *A*2, energized, prepares a circuit for relay 12, which is energized when line relays 1 are de-energized the second time. Relay 12 opens the circuit to relays *A*1 and 11 and these two relays release.

The length of time during which the line relays are energized has no bearing on the operation of the counting-chain relays. The sequence relays cannot be energized until the line relays are de-energized and since relays *A*1 and 11 must be energized to prepare a circuit for the second counting-chain relay *A*2, there is no possibility of setting up more than one counting-chain relay each time the line circuit is pulsed.

Relays *A*2 and 12 energized, prepare a circuit to energize counting-chain relay *A*3 and sequence relay 13 on the third pulse. Relay 13 de-energizes relays *A*2 and 12. Relays *A*1 and *A*4 are associated with sequence relay 11, so that the fourth pulse causes the setting up of relays *A*4 and 11. Thus, the counting-chain relays are consecutively operated in step with each pulse of the line relays.

The pulsing stops when line relays 1 have pulsed a definite number of times corresponding to the selection key operated. There is a *D*-point relay assigned to each selection key. Relay 15 was energized when selection key 4 was operated and point relay *D*4 shunted down. Relay 15, when once energized by a given selection key and *D* relay, opens the circuit to all other point-relay circuits and blocks all selection points other than the one first operated.

The circuit for the selection code stopping relay 6 has the *D* and *A* contacts in a series-parallel arrangement, and relay 6 upon energizing releases relay 4 to stop the pulsing. All of the *D* point relays are normally energized and only the break contact of one of them will be closed in the circuit of relay 6, depending on which *D* relay has been shunted down. In this case it is relay *D*4, and when four pulses have set up counting-chain relay *A*4, the circuit is completed to energize relay 6, which stops the pulsing by de-energizing relay 4 after line relays 1 have pulsed four times. The release of relay 4 releases the counting-chain and sequence relay.

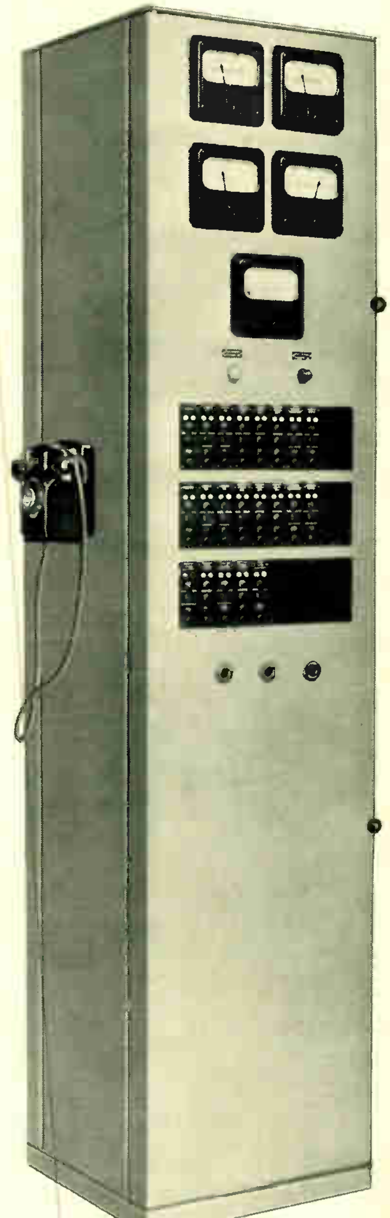
The controlled-station line and counting-chain circuits are similar to the circuits just described for the controlling station. The pulsing of controlled-station line relay 1, in parallel with controlling-station line relay 1, functions to set up controlled-station counting-chain relays *E*1, *E*2, *E*3, etc., simultaneously, with controlling-station counting-chain relays *A*1, *A*2, *A*3, etc., the termination of the counting by both sets of counting-chain relays being determined by controlling-station relay 6.

The relation of the counting-chain relays to the selection relays now enters the scheme of operation. At the controlled station, relay 2 was energized on the first pulse. Relay 2 is of the slow-to-release type, and once it is energized does not release as the pulsing continues. Relay 2 in turn energizes relay 3. When the pulsing stops, relay 2 releases and completes a circuit for an *F* selection relay. The *F* relay in turn energizes relay 8 and both are sealed in by a make contact of relay 8. Relay 8 opens the circuit of relay 3, which in turn de-energizes the counting-chain and sequence relay that was energized. The *F* relay energized is determined by the number of pulses counted.

Thus, when four pulses are completed, relay *E*4 is energized and relay *E*4, in combination with relay 2 now de-energizes, completing the circuit for selection relay *F*4.

The controlled station now sends back to the controlling station the same code of pulses it just received to energize selection relay *F*4. When selection relay *F*4 is energized, it shuts down point relay *H*4. Relay *H*4, in turn, energizes relay 15, which is common to all selection points at the controlled station. All of the *H* relays are normally energized when the equipment is at rest by the set-up circuit indicated on the diagram. Relays *H*4 and 15 function similarly to relays *D*4 and 15 at the controlling station. Controlled-station relay 15 energizes start relay 4 and initiates the line relays 1 pulsing exactly as described for the controlling station. Relay 4 also functions to keep the circuit of relay 2 open. Thus, relays 2 and 3 are kept de-energized at the station where the pulses are originated.

The check or verification code of pulses is terminated when four pulses have energized counting-chain relay *E*4, which completes a circuit to energize controlled-station relay 10, which seals in. Relay 10 opens the circuit to relay 4, thus stopping the pulsing after the line relays have pulsed four times. Relay 10, being energized, also opens the energizing circuit to the *F* selection relays and prevents further codes from the controlling station having any effect on these selection relays.



At the controlling station the four pulses from the controlled station set up selection relay *B*4 in the same manner that controlled-station selection relay *F*4 was set up when the first code of four pulses was transmitted to the controlled station. Relay *B*4 energizes relay 8 and both seal in through a contact of relay 8. Relay *B*4 also lights the selection lamp on escutcheon 4.

Summarizing at this point, pushing selection key 4 has resulted in transmitting a code of four pulses to the controlled station to energize relay *F*4. The controlled station then sent back to the controlling station a duplicate code that energizes the corresponding selection relay *B*4 at the controlling station and lights the selection lamp on escutcheon 4. The operator is thus informed that the proper selection relays are now energized at each station. The pulses are transmitted at the rate of 15 per second; hence the time required to complete a selection is extremely short.

To close circuit breaker 4, which is assigned to selection point 4, the operator pushes the "close" control pushbutton key. This energizes relay 10, which seals in. Note that until one of the *B* selection relays has been energized to energize in turn relay 8, operation of either the close or the trip key produces no effect.

Relay 10 energizes relay 4 to start the pulsing as previously described. The pulsing is terminated by the energizing of controlling-station relay 14.

which seals in and opens the circuit of relay 4. Relay 14 also opens the energizing circuit to the *B* selection relays and prevents further codes from the controlled station having any effect on these selection relays. Relay 14 is energized by a circuit, which includes make contacts of relays 10, *A*5 and *B*4 and a break contact of relay *D*4. This means that the pulsing is stopped after the fifth pulse. Five pulses are shown for "close" operations and three pulses for "trip" operations.

When the "close" control code pulsing stops, the release of relay 2 results in controlled-station relay 7 being energized. The energizing of relay 7 with counting-chain relay *E*5 energized, completes a circuit to the "close" interposing relay *CL*. The contacts of relay *CL* complete the circuits that control the closing of breaker 4, and the breaker closes.

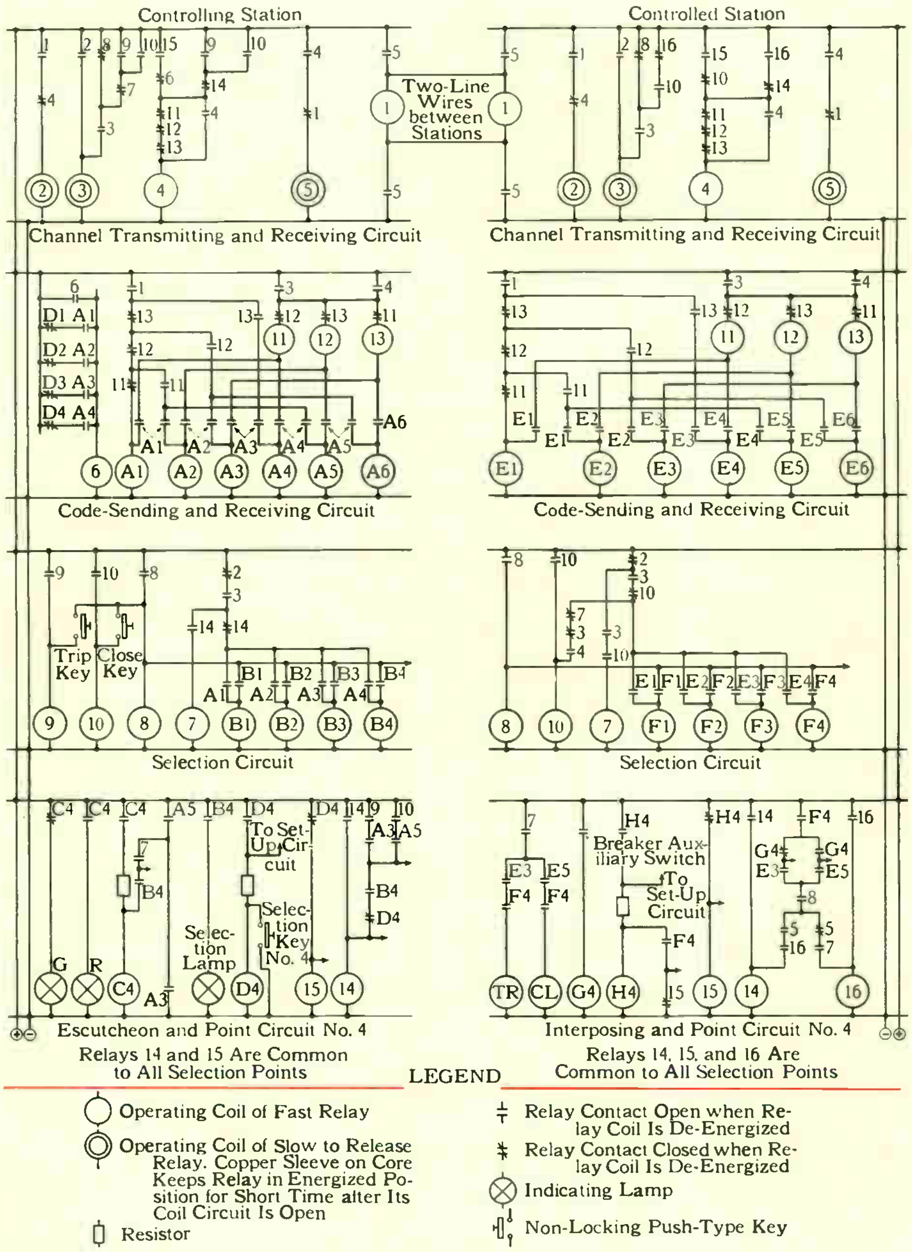
The controlled station now transmits a code of five pulses to the controlling station to change the indicating lamps for breaker 4 from green to red on escutcheon 4.

When breaker 4 closes, its auxiliary switch energizes controlled station relay *G*4. This results in relay 16 being energized to energize in turn relay 4 to start the pulsing. The pulsing continues until the end of the fifth pulse, at which time the energizing of counting-chain relay *E*5 completes a circuit to energize relay 14, which seals in and opens the circuit to relay 4 to stop the pulsing.

When the code of five pulses from the controlled station is terminated and controlling-station relay 2 releases with relay 3 still energized, a circuit is completed to relay 7. A circuit is then completed to energize point relay *C*4, which seals itself in. The energizing of relay *C*4 opens the green-lamp circuit and closes the red-lamp circuit on escutcheon 4. This completes the sequence of operation for closing breaker 4. As soon as the proper lamp indications are set up, the equipment automatically operates to reset itself to normal at the dispatching station as well as the supervisory-controlled station.

In case of an automatic breaker operation the equipment functions in a manner similar to that just described. In this case, although the circuits are not shown in detail, the controlled station originates the operation of the equipment to change the breaker-position indicating lamps to correspond to the changed position of the breaker. When an operation is thus initiated at the controlled station, the red or the green lamp on the associated escutcheon is flashed through circuits not shown. Several breakers tripping at the same time will send their signals in one after the other until all have reported.

The foregoing description applies to a system in which selection of a desired unit is made by a single series of pulses. In actual practice, such a system is only employed where 10 units or less are controlled. When more than 10 units are involved the actual point selection and point check codes are preceded by group selection and group check codes. This makes it possible to obtain control of 100 devices without transmitting a series of pulses greater than 10.



Thermal Endurance of *Silicone Motor Insulation*

The thermal endurance of electrical insulation has long been a serious limitation in the design of electrical machinery. The introduction of silicone resins and varnishes promised to overcome many of these limitations by a significant increase in permissible operating temperatures. To evaluate the place of silicone compounds in the electrical-insulation field, a comprehensive motor-test program[1] was undertaken in 1943 by the Dow Corning Corporation and Westinghouse. The specific purpose of this test program, now concluded, was to determine the thermal endurance of class-H insulated motors employing silicone varnish. Sufficient data was taken to plot a thermal-life curve over a wide temperature range; from these and other curves the results can now be interpreted. The data obtained also permits extrapolation of insulation life expectancy to lower temperatures.

In these tests a comparison was made between the behavior of class-B and class-H insulations under the same test conditions. Class-H and class-B insulations are both composed of inorganic materials such as mica, asbestos, and glass fiber; the difference lies in the resins and varnishes used as bonds and impregnants. Class-B insulation employs organic resins, whereas class-H insulation employs silicone resins. The fundamental concept followed in this test program was that appreciable decrease in the humidified insulation resistance of windings is a criterion of minimum insulation life.

Nine motors were subjected to accelerated life tests—six 10-hp induction motors with class-H insulation treated with silicone (DC 993) varnish, two class-B insulated induction motors of similar design, and one d-c motor with class-H insulation treated with DC 993 silicone varnish. The test cycle began with a period of operation at elevated temperature, followed by cooling to room temperature and exposure of the windings to 100-percent relative humidity for a 24-hour period. Subsequently, each motor was operated at load to produce high operating temperatures for an accelerated life test. The temperature of the various motors under test (as observed by the resistance method) ranged from 200 to 310 degrees C. The motors were also subjected to high humidity periodically during their operation (Fig. 1) to observe their reactions under high-moisture conditions.

Insulation-resistance measurements before and after humidification are plotted in Fig. 2 to show the effects of aging and humidification in a typical test unit. In general, similar patterns were obtained with each unit. These factors show little change in the earlier stages of aging. Then, suddenly, insulation resistance decreases and dissipation factor increases, indicating a major change in the condition of the insulation. This is the point at which moisture begins to penetrate the winding and is considered to be the minimum insulation life point. Crazing or cracking of the resin surfaces becomes noticeable coincident with the loss of moisture resistance. On these tests it was found that the cold resistance of the copper winding increased due to oxidation after thermal aging of the varnish had produced cracks or crazing in resin surfaces. Therefore, changes in the cold resistance of the winding can be used to indicate aging of the insulation. Abrupt changes in copper resistance are observed when the varnish film becomes permeable to moisture and air.

The test results in Fig. 3 are interpreted to indicate that class-H insulation, employing silicone (DC 993) varnish, follows a rule of half life for increments of 11.7 degrees C. In other words, the thermal life of silicone insulation is halved for each 11.7-degree-C increase in temperature, or doubled for each 11.7-degree-C decrease. These tests further indicated that, for a seven-year minimum life, a temperature of 220 degrees C should be permissible, insofar as the thermal aging of the insulation alone is concerned.

The conclusions reached from this comprehensive investigation are:

1—The method of testing was proved to be a satisfactory way to determine minimum thermal life expectancy of insulation in an electric motor. It is now in wide use.

2—The minimum insulation life points, determined by electrical measurements, and serious crazing of the resin often occur simultaneously.

3—Failure of class-H-insulated motor windings occurred before the bonding of the silicone resin was seriously weakened; in other words, the copper conductors failed before the insulation. Conductor failure was due to oxidation of the copper and reduction in the cross section to the point where localized heating occurred with destructive effect.

Definition of Terms

Insulation resistance is the resistance of an insulation system to current leakage through the solid insulation and over its creepage surfaces.

Cold resistance of copper windings is taken at ambient temperature conditions and corrected to 25 degrees C for purposes of comparison.

Dissipation factor is a non-dimensional measure of several electrical properties of insulation. Mathematically it is the tangent of the loss angle, or the ratio of the equivalent series resistance to the equivalent series capacitive reactance of an insulation system. It is a practical measure of moisture content of insulation.

Thermal life of insulation is the length of time an insulation can be expected to last when thermal aging is the primary factor in establishing life expectancy. Minimum thermal life is defined as the point at which insulation loses its original moisture resistance. Maximum thermal life is considered to be the point where thermal aging has produced serious embrittlement and mechanical damage to the insulation. In most insulation systems studied, the maximum life is 2.5 times (or more) the minimum life.

[1] A more detailed discussion of the results of silicone insulation tests is contained in a paper entitled "Motor Tests Evaluate Thermal Endurance of Class-H Insulation and Silicone Varnish" by Kauppi, Grant, Gibson, and Moses, presented at the recent AIEE convention at Cincinnati, Oct. 17–21.

Like many job applicants, new materials for industrial use are given "aptitude" tests to determine their qualifications for a given field. Silicone varnishes, which first applied for a job as motor insulation in 1942, have now completed the extensive tests given to determine their suitability. Results of these tests, now being evaluated, indicate that they will more than live up to their earlier promise, especially as regards their thermal aging properties.

by G. L. Moses, *Manager, Development Insulation Section, Westinghouse Electric Corporation, East Pittsburgh, Pa.*

4—Silicone insulation presents less fire hazard than other classes of insulation. Ultimate failure of class-B-insulated motors was followed by fire whereas failure of class-H-insulated motors was not.

5—The number of heating and cooling cycles affects the minimum life, as physical damage due to thermal cycling is an important factor after insulation aging occurs.

6—The minimum thermal life of class-H-insulated equipment using DC 993 silicone varnish is approximately twice that of inorganic insulating materials bonded and impregnated with the original, and now obsolete, DC 990A silicone insulating varnish.

7—The results of these tests indicate about a 100-degree-C temperature advantage for class-H insulation compared with class-B insulation. If current concepts of thermal aging are correct, the class-H insulation could be expected to operate as much as several hundred times as long as class-B equipment, where thermal aging is the primary factor in establishing insulation life.

8—Several years of continuous operation at hottest spot temperature of 220 degrees C will be required to reach the minimum thermal life of class-H-insulated equipment.

9—The thermal life of class-H silicone-insulated motors more closely follows a 12-degree-C rule for half life rather than the usually accepted 10-degree-C rule. It may follow a more optimistic rule as suggested by other experiments.[2]

10—The maximum life of class-H insulation was not determined by these tests, since the ultimate end points were the results of copper conductor failure rather than mechanical disintegration of the resin.

11—In silicone (class-H) insulated motors, insulation resistance as a function of relative humidity can be used effectively in maintenance work. If the insulation resistance is not seriously affected by humidity, the motor can be presumed to be entirely satisfactory for continued use. If the insulation resistance is dependent on the humidity, the minimum life point has been reached.

The motor test program permits engineers to evaluate the characteristics of this new design tool for specific applications. It confirms the belief that class-H insulating materials, based on silicone resins, provide an answer to the problem of thermal aging of insulation.

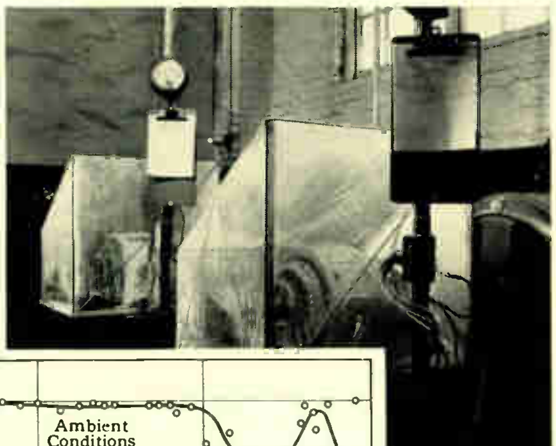
REFERENCES

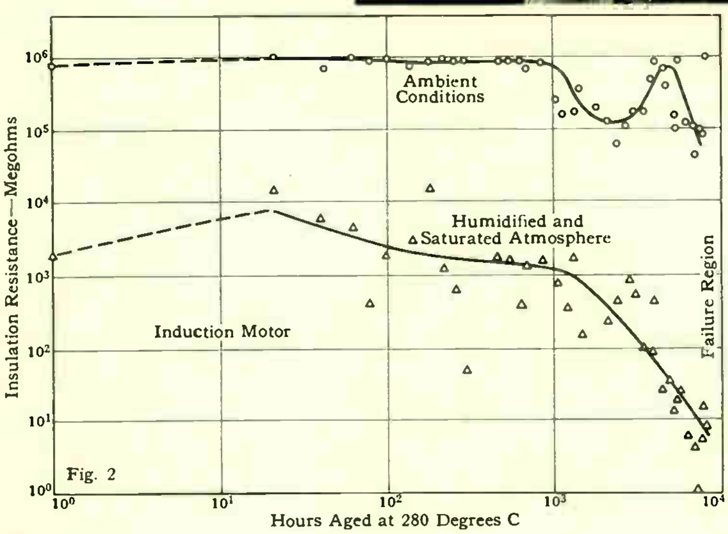
1. "Silicone Insulation Proved by Test," by Kauppi, Grant, Moses, and Horrell, *Westinghouse* ENGINEER, September, 1945.

2. "Electrical Insulation Deterioration Treated as a Chemical Rate Phenomenon," by T. W. Dakin, AIEE Technical Paper No. 48–19.

Fig. 1—These tents of Saran film are designed to keep moisture in, so that the silicone-insulated motors are surrounded by moisture-saturated air. Motors on test were subjected alternately to extreme humidification and to elevated temperatures.

Photo courtesy Dow-Corning Corp.→





← Fig. 2 Fig. 3 →

Fig. 2—Insulation resistance measurements before and after humidification, showing the effects of aging and humidification on a typical test unit.

Fig. 3—The minimum life region obtained by test compared to the life curve estimated before tests.

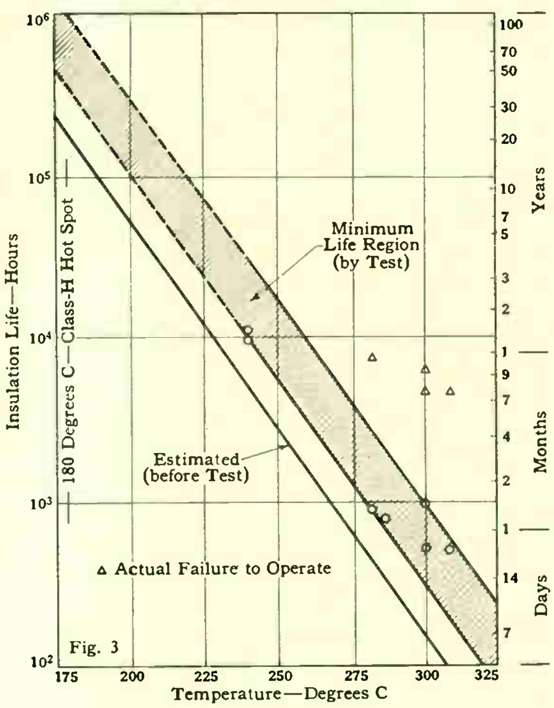


Fig. 1—A collection of sun lamps, past and present. At the top, left to right, are the S-1, S-2, S-4, and the RS lamps. Below, the newly developed 20- and 40-watt fluorescent sun lamps.

Sunlight from Electricity

The sun has all but moved indoors. Man-made "suns" have reached the stage of development where the simple flipping of a switch floods an entire area with ultraviolet radiations that closely approximate those of the sun itself. A process of evolution has now resulted in the new Westinghouse fluorescent sun lamp, whose radiations—from a mercury-arc discharge—are converted into suntanning radiation via a new phosphor.

RICHARD S. SHEETZ, *Lamp Application Engineer, Westinghouse Electric Corporation, Bloomfield, New Jersey*

WITHOUT sunlight, life would be nonexistent. Down through the centuries the light- and life-giving properties of the sun have been recognized; in fact, some civilizations, including the Persians, Egyptians, Greeks, and Romans, even considered the sun as a deity. In the past few centuries, scientists have discovered much about the sun's radiations, and in recent years have found various means of producing them under controlled conditions, thereby making them available for year-round consumption conveniently and at low cost.

Ultraviolet Light

Sunlight is a form of electromagnetic energy. Analyzed with a prism or diffraction grating, it is found to consist of many colors—red, orange, yellow, green, blue, and violet—each merging into the next. Beyond the red end of the wavelength spectrum lie the invisible infrared radiations, and beyond the violet lies another invisible group—the ultraviolet. It is these ultraviolet radiations that cause sunburning and tanning and exert the greatest physiological effects on people and animals exposed to them.

Since light is a form of electromagnetic energy, it has wave motion and its effects can be established in terms of the wavelengths that produce them. Light of about 5200 A wavelength, for example, produces a sensation of green to the human eye, whereas that of another wavelength evokes a different response. Therefore, visible and invisible light are generally measured in terms of wavelength and an extremely small unit, the Angstrom, is used. An Angstrom is equal to 1/254 000 000 of an inch.

Physiological Effects

Exposure of the skin to adequate amounts of ultraviolet energy, between 2800 and 3200 Angstroms, will result in specific reactions. The first and most apparent of these is erythema, or reddening of the skin, which develops a few hours after moderate exposure and frequently lasts for days. The relative effectiveness of the various wavelengths for evoking erythema is shown by the dotted curve in Fig. 2. When greater amounts of this energy are used than necessary to develop this response, erythema is ordinarily followed by pigmentation or tanning, which begins to develop before the erythema has completely subsided, and may persist for months. Since the degree of erythema and tanning are both dependent upon the amount of energy absorbed by the skin, and this is directly related to personal skin sensitivity, identical exposures may produce varying results on different people.

Absorption of erythemal ultraviolet energy by the skin stimulates the production of vitamin D, although this is accompanied by no visible reaction. Vitamin D is the only vitamin that can be generated in the human body and is required for normal calcium metabolism and strong, healthy bones and teeth. It has long been recognized as necessary for the prevention and cure of rickets, and now there is much to indicate that its beneficial effects on the system are considerably broader in scope.

Investigations conducted on large numbers of school children have shown that exposure to mid-ultraviolet radiations during the day caused an increase in their work capacity. Similar results have been obtained with hundreds of miners in Europe, where ultraviolet lamps were installed in "change" houses at some of the mines. These tests and other experiences elsewhere also indicate that exposure to ultraviolet radiations helps build resistance to colds and respiratory ailments.

Erythema and Tanning

Erythema is caused by the dilation of minute blood vessels in the lower levels of skin. Ultraviolet energy penetrates the skin only slightly and, therefore, does not produce the reddening directly. Instead, it is believed that these radiations activate an organic compound near the surface of the skin, probably histamine, which then migrates to the lower skin levels and causes the dilation. The time required for this migration may explain the long period that ordinarily intervenes between exposure to ultraviolet radiations and the appearance of erythema or reddening of the skin.

Tanning is believed to be a separate process from erythema but its mechanism is not very well understood. The pigment that gives a desirable tanned complexion is believed to be composed of granules of melanin formed as a result of photochemical and other reactions taking place in the skin. Many factors, such as race, sex, natural skin color, constitution, and body functions, determine the degree of pigmentation.

The wavelength of ultraviolet energy applied also plays an important role and has a decided effect upon the appearance and duration of the tan. For instance, exposure to 2537-Angstrom ultraviolet, which is mostly absorbed by the uppermost layer of skin, causes an erythema lasting only a few hours and is followed by little or no pigmentation. Mid-ultraviolet energy (2967 Angstroms) produces an erythema followed by a brownish-yellow pigmentation, which will last for several months. Longer wavelengths in the 3800-Angstrom range will develop a tan without first producing erythema. For this effect, however, about one thousand times as much long-wave ultraviolet radiation is required to obtain the same response as would be needed if 2967-Angstrom energy were used. Therefore, for all practical purposes, artificially produced long-wave ultraviolet energy is not economically feasible for ordinary tanning purposes.

Limitations of Sunlight

The sun is the most prolific source of suntanning radiations. Of course, sunshine contains tremendous quantities of energy in the other wavelength bands; some estimates state that up to 4000 horsepower of radiant energy falls on each acre of earth at sea level in Washington, D. C. Although this is a tremendous quantity of energy, it is insignificant when compared to the total amount of energy being continually radiated by the sun, for the earth receives less than one two-billionth of the radiations produced by the sun.

Of course, natural sunshine is ideal for sunbathing, but certain factors limit its use. These include the appreciable variation of the solar spectrum with the season, the time of day, atmospheric conditions, and the latitude of the observer. Since ultraviolet waves are refracted by the earth's atmosphere, little of this energy reaches the earth when the sun is low in the heavens during the long winter months, in late afternoon, or in the far northern and southern latitudes. Then, too, smoke and dust, ever present over any large city or industrial area, effectively filter out a large part of the vital radiations. Clouds and haze, while affecting them somewhat, do not reduce the sunburning radiations as much as generally believed. This fact can be readily verified by those who have been exposed on an overcast summer day with painful results.

Because of these limitations, artificial ultraviolet sources possess certain advantages over natural sunlight. These are: (1) year-round availability, (2) reliability, (3) convenience, and (4) ease of control. The degree to which these advantages vary among the different artificial sources, coupled with their initial and operating costs, determines the relative merits of the various types of sun lamps.

Artificial Ultraviolet Light Sources

Artificial ultraviolet light sources fall into three general groups: (1) carbon arc, (2) gaseous discharge, and (3) the newly developed fluorescent.

The first artificial source of ultraviolet light was the *carbon-arc lamp*. As long ago as 1897, Professor Niels Finsen, father of heliotherapy and 1904 Nobel Prize winner, effectively used such units for the cure of certain diseases.

The carbon-arc lamp develops radiations through the incandescence of its electrodes and the ionization of the gas in its arc stream. This gas is produced by the vaporization of the carbon electrodes and is ionized by thermal excitation rather than by an electrical potential, as is the case in a gaseous-discharge lamp. The units operate at extremely high temperatures and produce strong radiations, the intensity and quality of which can be varied and controlled by the proper choice of electrodes and operating current.

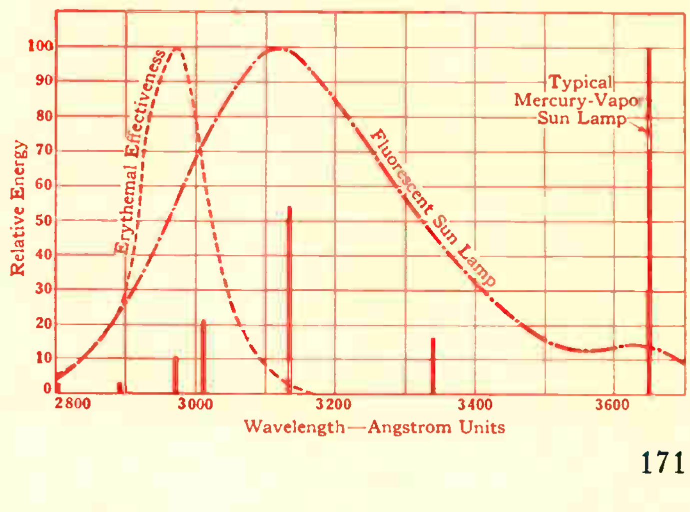
The carbon arc is a prolific source of ultraviolet radiations. However, certain mechanical difficulties make it less adaptable to sun-lamp applications, especially in the home. Adjustment of the arc length and replacement of worn-out electrodes are frequently necessary, and fumes are given off by the open arc. The high temperatures and open flames of the carbon arc also create a potential fire hazard. These factors have limited the application of the carbon-arc lamp, and it is seldom used today for sun-lamp purposes.

Gaseous-discharge lamps, such as the RS sun lamp, produce radiant energy as the result of the passage of an electric current through a combination of mercury vapor and an inert gas. When an electrical potential is applied, the gas is ionized and permits the flow of current. Electrons that comprise the current stream are accelerated to tremendous velocities; when they collide with atoms of the mercury vapor, they temporarily alter the atomic structure, displacing one of the electrons continually revolving about the nucleus. Ultraviolet energy is released when the displaced electron snaps back to its original location in the atomic structure.

The mercury-vapor sun lamp is of the gaseous-discharge type and generally consists of two electrodes sealed into an airtight glass or quartz bulb containing a small amount of mercury. Mercury was chosen because lamp design could be less complex and higher efficiency could be realized. The intensities of the various mercury lines generated by the arc discharge can be controlled by varying the mercury-vapor pressure in the lamp, and proper choice of the glass bulb provides a means of filtering out undesirable wavelengths.

Currently available are two types of mercury-vapor lamps that are considered as "sun lamps" by the public—those producing radiations down to 2537 Angstroms and those emitting practically no energy below 2800 Angstroms. The first type is constructed with a single bulb of quartz that transmits the shorter wavelengths, whereas the other is constructed of one or more bulbs made of special glass to filter

Fig. 2 Relative energy distribution curves. The dotted line shows the effectiveness of the different ultraviolet wavelengths in producing erythema. Distributions of the fluorescent and mercury-vapor sun lamps are shown by broken and solid lines respectively.



out the short-wave radiations. The American Medical Association recognizes as sun lamps only the latter type, which produce radiant energy above 2800 Angstroms, since these are suitable for home use without the supervision of a physician. The short-wave quartz lamps, on the other hand, have in the AMA's words "... spectral emission characteristics which necessitate professional supervision or control to avoid hazards of overexposure." Professional therapeutic lamps are more complex and by their nature not in as widespread use; therefore, only the more popular sun lamps that have been specifically designed for general use are reviewed here.

Original Gaseous-Discharge Sun Lamps

Although short-wave quartz mercury-vapor lamps had been used for many years by physicians for therapeutic treatments, not until 1929 was the first sun lamp developed that was safe for home use. Known as the S-1 sun lamp, it was followed two years later by a smaller companion lamp, the S-2. The lamps were of the same general construction and operation, differing with respect to size and output. The S-1 was the larger of the two and was widely used for home treatment. The S-2 was introduced to reduce the wattage and operating cost and to provide a smaller, handier unit. However, because of the appreciably longer exposure time required by the S-2, it was never widely used in home applications.

Both the S-1 and S-2 were of the gaseous-discharge type and contained a tungsten filament in parallel with the electrodes, its purpose being to preheat the lamp sufficiently for the arc to strike. As is the case with every gaseous-discharge lamp, a current-limiting device was necessary, in this case a transformer of special design. Lamps were generally used in a concentrating type of reflector.

About this time, two other gaseous-discharge sun lamps were developed. These were designated as the G-1 and G-5 and were low-current density, glow-discharge rather than arc-discharge lamps. During operation, the entire inside of the lamp was filled with a blue glow, this glow being the source of the ultraviolet radiations. These lamps were quite efficient and were intended to supplement regular lighting systems, thereby bringing vital ultraviolet radiations to those confined indoors throughout the day. However, the output of these lamps was found to be too low for most installations. For that reason they never gained wide acceptance.

During 1939 the S-4 sun lamp was introduced. This had two bulbs, an inner quartz tube to contain the arc discharge, and an outer evacuated glass bulb to protect the arc tube from changes in temperature and to filter out the undesirable shortwave radiations. The S-4 had an output about the same as the S-1 but was more efficient and consumed less wattage. It, too, required the use of an external reflector and a special external ballast, but the entire unit was smaller and less expensive.

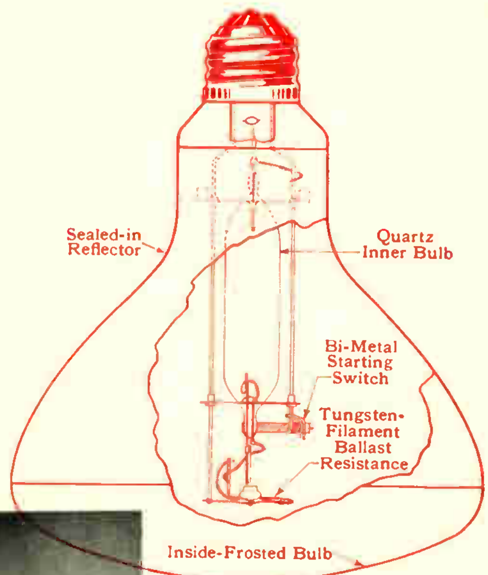


Fig. 3—A cutaway drawing of the RS sun lamp, which was the first self-contained sun lamp that could be screwed into any household socket. The vapor discharge occurs in the inner bulb.

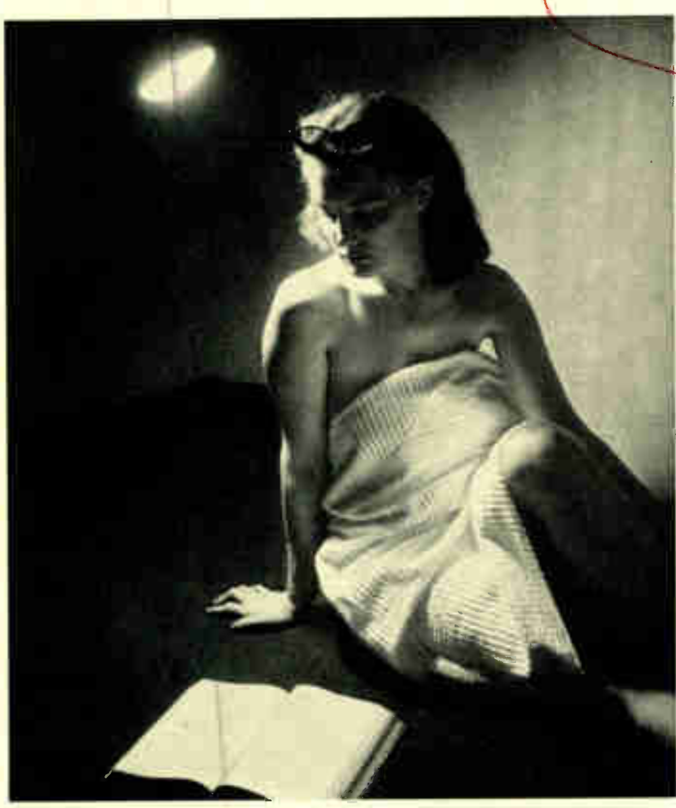


Fig. 4—The self-contained RS sun lamp is especially suited to home "sun bathing"; here its simplicity and flexibility offer prime advantages.

RS Sun Lamp

All early sun lamps had one conspicuous drawback—they required bulky external auxiliary equipment. This situation was alleviated when the RS sun lamp was developed and introduced by Westinghouse in 1941. However because of the war only a limited number of these lamps was produced before 1945.

The RS sun lamp (Fig. 3) is a self-contained, arc-discharge type of sun lamp that can be screwed into any ordinary a-c household lighting socket. It requires no separate reflector; the inside surface of the parabolic-shaped bulb is specially coated with a thin layer of aluminum, which reflects the ultraviolet radiations forward. Auxiliary current-limiting equipment is eliminated by means of the built-in tungsten filament resistance in series with the arc stream.

The complete lamp is composed of a quartz inner bulb and an outer bulb of special long-wave ultraviolet-transmitting glass. When the lamp is first turned on, current passes through the resistance filament, through the small starting filament in the arc tube, and through the special bimetal starting switch. These are all in series at this time.

Passage of current through this circuit generates a large amount of heat, which vaporizes some of the mercury in the arc tube and causes the bimetal switch to bend and open. When this occurs, full line voltage is impressed across the arc tube and is sufficient to initiate the discharge. The path of current is then through the tungsten filament and arc tube, which are in series; current is limited by filament resistance.

RS sun lamps are convenient and easy to use (Fig. 4). Their small size and lack of auxiliary equipment has made them particularly popular for general sun-lamp usage in the home.

Fluorescent Sun Lamp

Engineers have long recognized the possibilities of transforming short-wavelength ultraviolet radiations produced by mercury-arc discharges into longer suntanning wavelengths by means of a phosphor. The fluorescent sun lamp, newest in the field of artificial "suns," was made possible by the development of such a phosphor.

The lamp is identical in principle, form, details, construction and operation to the ordinary fluorescent lamp, with two important exceptions—the phosphor converts ultraviolet energy from the mercury discharge, not to visible light but to the erythemal regions, and secondly a special ultraviolet transmitting glass replaces the usual type. Fluorescent sun lamps are made in two sizes—20 and 40 watts.

A comparison of fluorescent sun lamps with other sun lamps is somewhat like comparing fluorescent and incandescent lamps, for the new sun lamp possesses all the desirable features of the regular fluorescent lamp. Fluorescent sun lamps, for example, are 20 times more efficient than the S-1, 7 times more than the S-4, and develop considerably more erythemally effective energy per watt of lamp input than any other sun lamp ever devised. They will last many times longer than other sun lamps and have a broad and diffuse radiation coverage, which is most conducive to uniform tanning. Then, too, these lamps are as cool in operation as a regular fluorescent lamp (Fig. 5) and develop a continuous type of spectrum that is concentrated in the most biologically active spectral region. All other sun lamps waste large amounts of energy in heat and light; this characteristic is inherent in their design and cannot be eliminated. In some cases this heat may be desirable, but in many others the use of energy for other than ultraviolet-producing purposes is not feasible.

The fluorescent sun lamp's special characteristics make it admirably suited for the usual sun-lamp applications, but they also make possible many desirable new applications of ultraviolet radiations that were heretofore impractical or uneconomical. Now, for example, it is possible and practicable to provide radiations that will bathe a whole room with a low intensity of beneficial ultraviolet. This form of hygienic lighting, termed "space irradiation," is designed to assure adequate production of the biological benefits of sunlight ultraviolet without the discomfort of sunburn. It is especially valuable to school children, office and factory workers, and others who, with these lamps, can obtain their share of "sunshine."

Fluorescent sun lamps can be readily used in offices to obtain a tan gradually during each normal working day. However, in this type of installation, higher ultraviolet intensities are required than in "space irradiation." Therefore, generally only one person is irradiated by a given fixture so that the exposure time can be closely controlled.

These lamps are also used in industrial applications where a cool, uniform, economical source of mid-ultraviolet radiation is desired. Many industries, such as rubber, plastics, paint, chemical, petroleum, and photographic can profitably apply the radiations of fluorescent sun lamps to solutions, gases, films and mixtures, for the creation of new products and for the improvement of chemical processes.

A typical application of their use in materials processing is found in the plastics industry, where their radiations are employed as a catalyst in the setting of certain monomer cements used in binding transparent methyl microlite laminates together. These laminates are used in forming the clear pilot-compartment molds and transparent wind screens for aircraft, and require an ultraviolet generator that produces energy in the 2950- to 3150-Angstrom band, but which develops very little heat. Heat causes an expansion of the cementing agent in such a way as to form bubbles, resulting in an imperfect, semi-transparent line where several laminates are joined together. Several other types of lamps were tried in this application, but all proved unsatisfactory.

Another type of photochemical installation is that of a large paint manufacturer, who uses the lamps to test paint samples. By combining the fluorescent sun lamp with various other lamps developing continuous spectra, this company has been able to produce a type of radiation that closely resembles certain regions of the sun's spectrum. This enables it to predict accurately the effects of sunlight on its product.

Other applications for the fluorescent sun lamp lie in the field of animal husbandry. Sun lamps have proved beneficial in the poultry industry and have been shown equally advantageous for domestic and fur-bearing animals. However, heretofore, both the initial and operating costs of sun lamps have been such that they could not be economically justified. This condition has been completely revised by the fluorescent sun lamp, and irradiation of animals is now practical.

The "sun lamp" story as to biological benefits and tanning is an old and accepted one, established through the personal experiences and judgments of millions of people. Now the fluorescent sun lamp broadens our health horizons and makes possible many hitherto impractical applications of sun lamp ultraviolet for the general promotion of health in humans and animals, as well as in numerous photochemical applications.

Fig. 5—Fluorescent sun lamps are so cool in operation that even a baby can touch them. The long tubular shape of the lamp enables it to cover a large area with radiation, thus making possible irradiation of an entire room, or uniform tanning over the body.

What's NEW!

Have a Capacitor Problem?

Power engineers with voltage or power-factor problems would do well to read a new book, "Power Capacitors," written by Ralph E. Marbury, and devoted to the use of capacitors on power circuits. Intended primarily for use by design and application engineers, rather than research and production engineers, this book provides a wealth of information on the "whys and wherefores" of capacitor application.

The first few chapters are devoted to a brief discussion of the materials and characteristics of capacitors, their ratings, design, and manufacture. Following this, Marbury really digs into the problems of applying capacitors, reviewing in detail the factors that must be taken into consideration, such as the kind and number of capacitors needed to correct either voltage or power factor (or both). The book takes up the application of shunt capacitors to both utility and industrial systems, including the fuses, switches, and connections used in these installations. The application of series capacitors is also discussed in detail. Concluding the book is a chapter on installation and maintenance to round out a complete story of power capacitors and their uses.

"Power Capacitors" is the first volume to be published in the newly established "Westinghouse-McGraw-Hill Engineering Books for Industry" series, all for college-level training.

Thermoset Varnish-Corrosion Inhibitor

Thermoset varnish was intended originally as an electrical insulation. But it has found many useful applications as physical insulation, particularly for preventing corrosion of steel exposed to salt air or water. It has been used as protective coating on power-center control cabinets, pushbutton stations, ducts, and pipes that are subject to corrosive atmospheres or chemicals. To the list—which includes a curious assortment of devices from torpedoes to automobile exhaust pipes—a new one is added: railroad spikes on electrified railways.

For years electrolytic corrosion has necessitated continuous and costly maintenance at the electrified downtown Chicago terminal of the Illinois Central Railroad. Here the rails are below the level of nearby Lake Michigan, with the result that ground moisture is very high. The steel spikes that hold the rails and the metal tie plates to the wooden tie are particularly affected. Because of the moisture in the ties, current that should normally flow through the rail back to the substation is provided an alternate path through the spikes, tie plates, ties, and ground, and back to the substation. The current through this circuit causes electrolytic action so severe that the spikes have at times disintegrated in a relatively short time. The rails, too, are sometimes affected by this action.

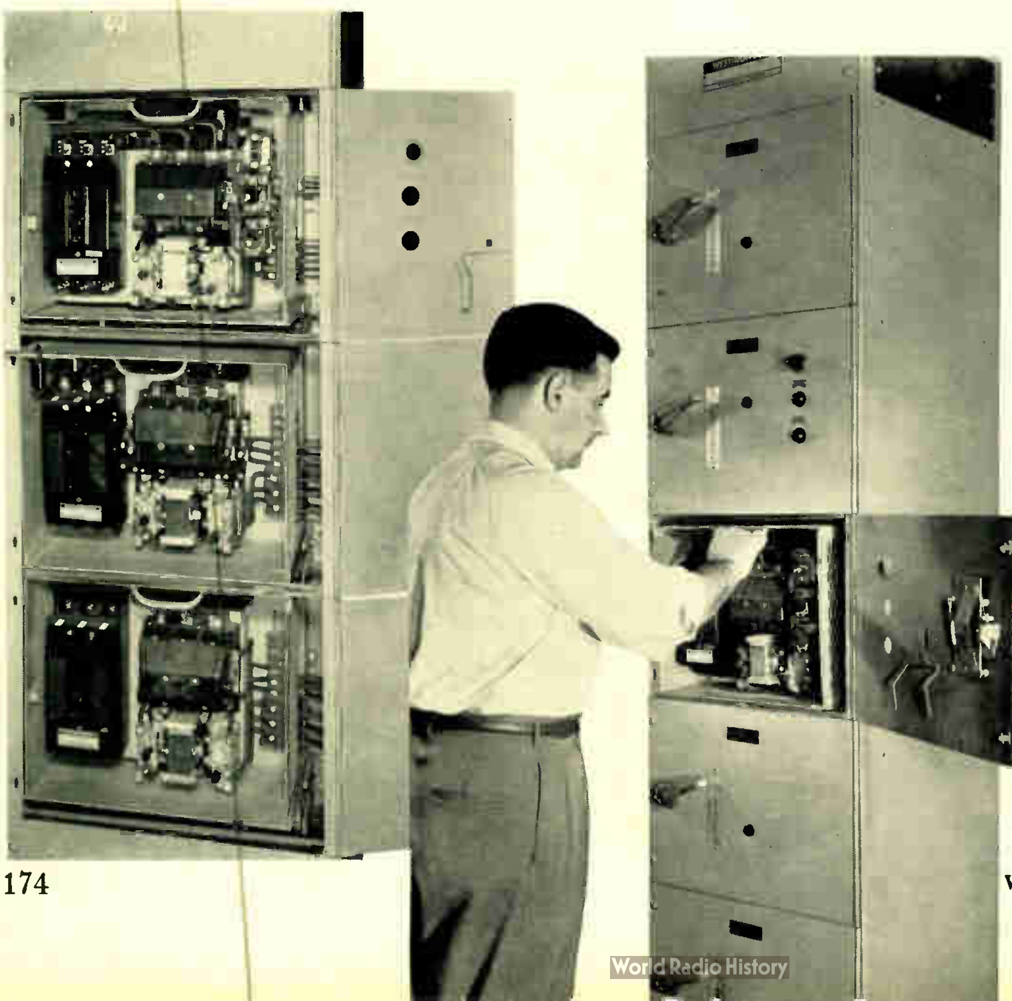
Thermoset varnish (type 7826-2), by limiting this current, has proved to be the solution. Tests established that two dips and subsequent bakes give the best result as to corrosion resistance. The varnish also increases the grip factor of the spike in the tie, so that it is not easily loosened by vibration.

New Control Centers—Simpler and Safer

Safety and accessibility are two of the most important considerations in the design of motor-control centers. Yet the two factors often seem to work against each other. Greater exposure of wiring for installation and maintenance purposes often leads to greater exposure of live parts. A newly redesigned motor-control center incorporates all the necessary safety features while actually improving accessibility.

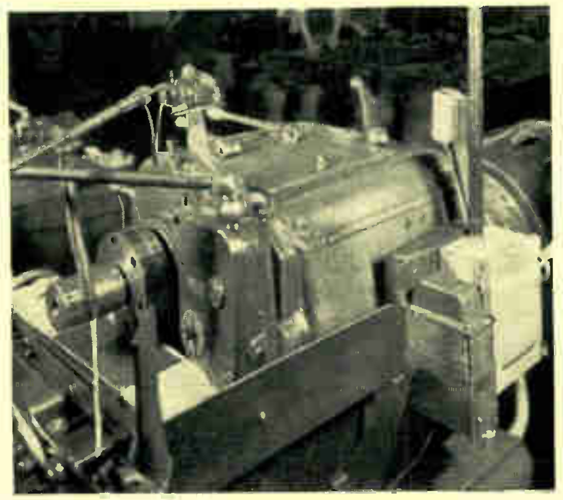
Plug-in connections to the bus provide a greater degree of safety as well as simplifying installation and removal of the starter unit. Guides for the individual starter unit assure that plug-in stabs are aligned with bus connections, eliminating any "jockeying around" to find the plug. The starter unit can also be disconnected from the bus without removing it from the structure, simply by tilting it forward in place. This enables the stab-in system to be used as a disconnect switch when desirable.

Starter units are baffled on all four sides, but, due to the design used, wiring is not complicated. The right side of the baffling slides out of the starter assembly, to facilitate work on the wiring runway, also on the right. Tests recently conducted indicate that baffling is an essential feature if faults are to be confined to the point of origin without burning

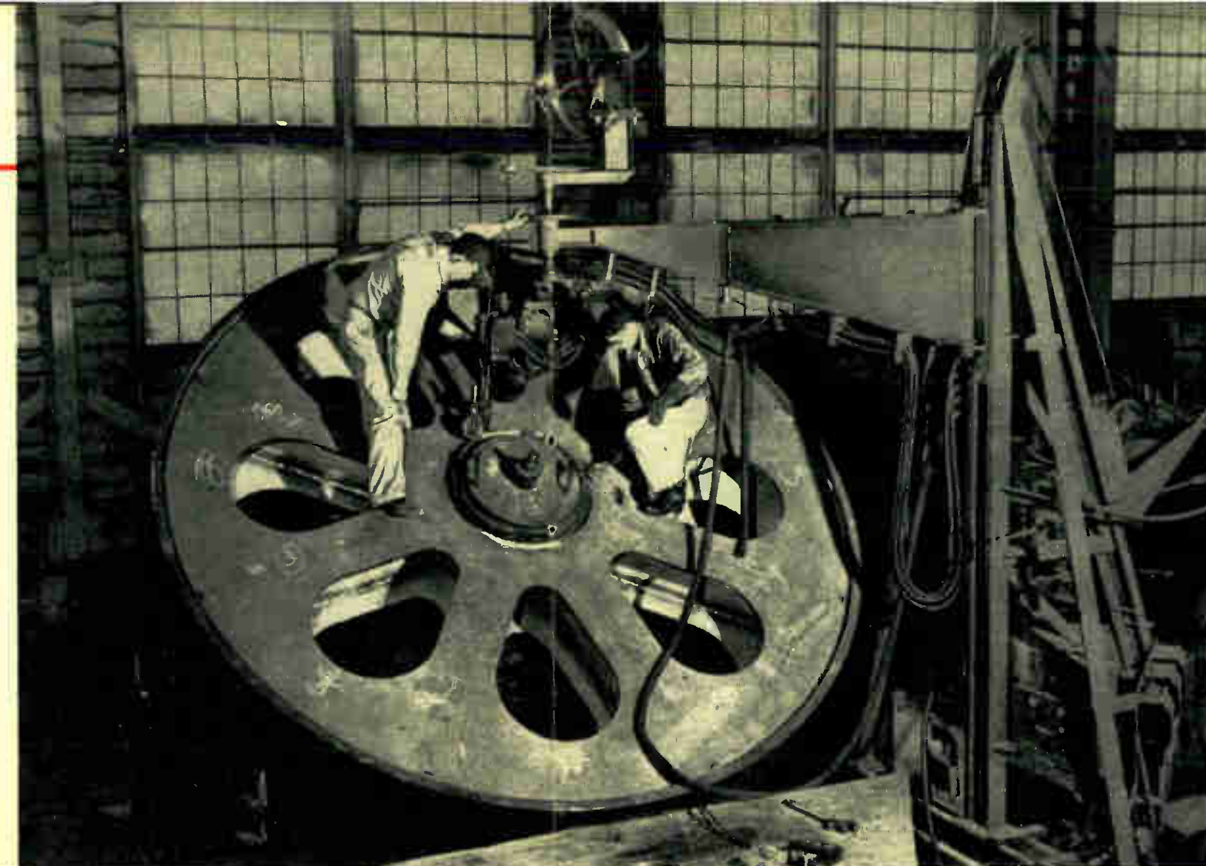


At left, with doors open, starters and wiring channel are exposed. Accessibility can be further improved by removing side plate at right of unit. At right, tilting the starter unit forward releases the stabs from contact with the bus. Unit then slides forward and out.

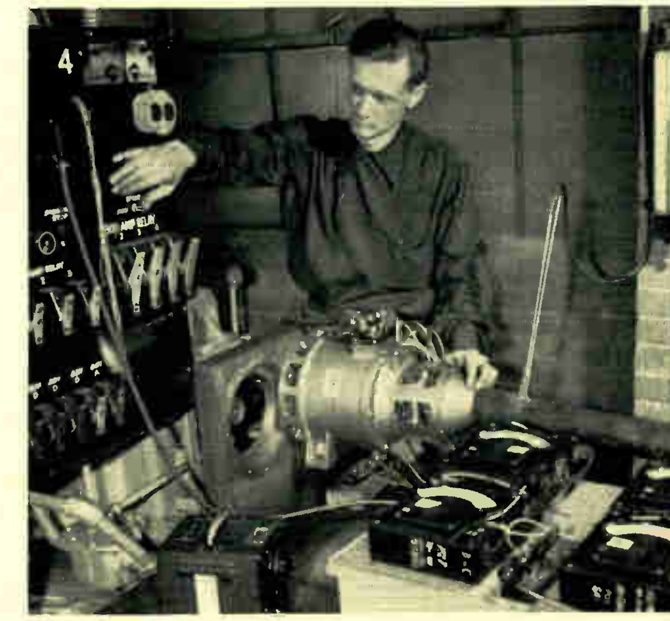
What's NEW!



THE small ¼-kva, dry-type GP transformer mounted to the left of the switch "saved" the controls of this machine when the plant distribution system was changed from 220 to 440 volts. The change in voltage, dictated by overloaded circuits, would have necessitated discarding the controls. But the 440- to 220-volt transformer enables the relays to operate on the old 220 volts and control the 440-volt power circuits. Several hundred of these type-GP transformers are being used in this plumbing-fixture factory.

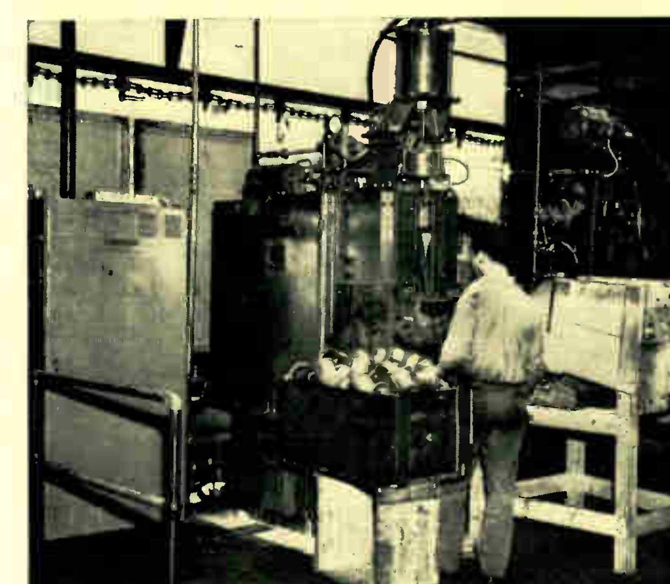


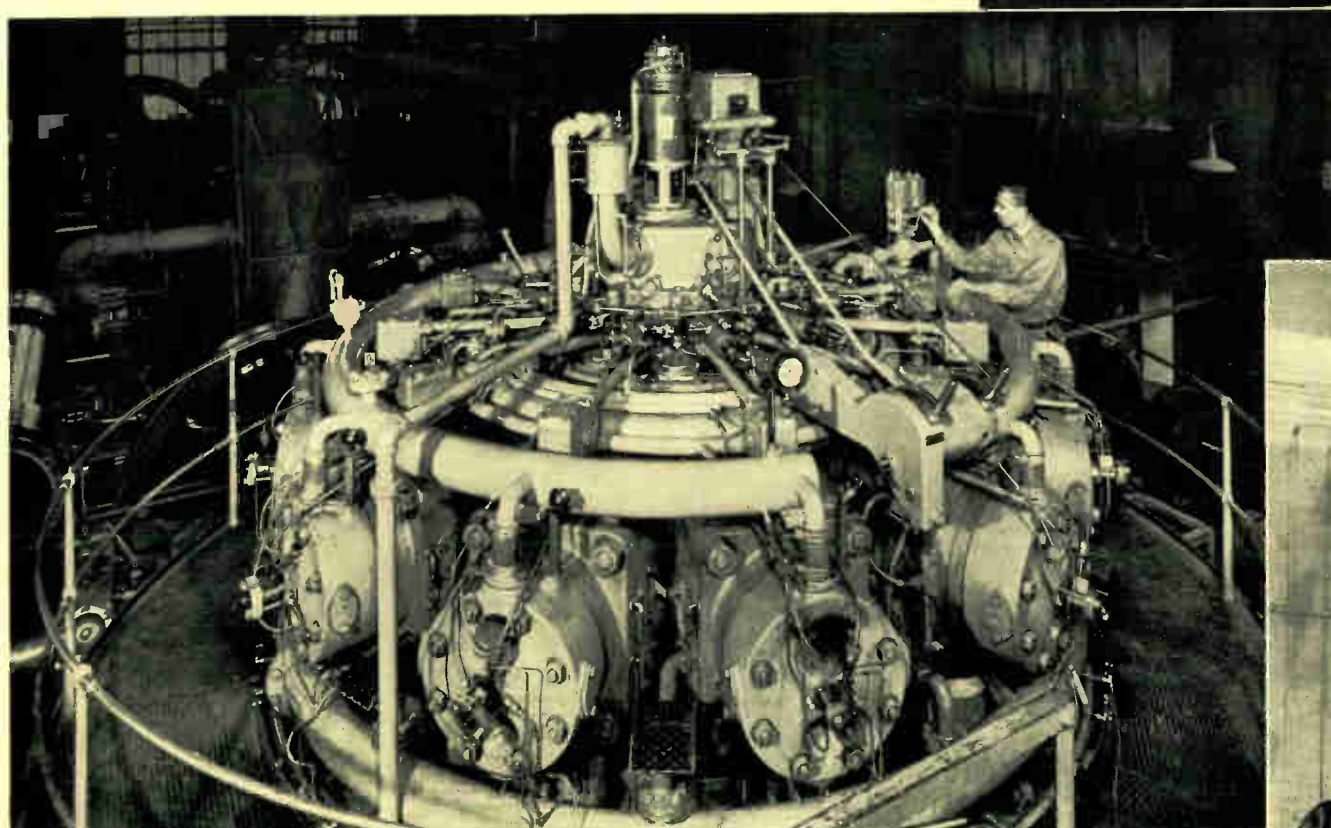
THIS giant "bull gear," being fabricated, will be one of two gears in the final stage of a marine-propulsion unit. In a later operation, 693 helical teeth will be formed in the high-carbon steel rim. When installed, the full set of gears will take the load of 7000 hp at 6000 rpm and reduce the speed to 100 rpm for the propeller shaft. Gears must be made to extremely close tolerances; any inaccuracy may cause excessive noise and vibration in the ship.



ANOTHER reminder of the growth of airborne power plants is the record-capacity, 400- to 800-cycle alternator shown here on test. It is rated 30 kva, almost three times that of the previous maximum for varying-frequency machines, and has a 5-minute overload capability of 45 kva. The alternator weighs 90 pounds (or 3 pounds per kva) as compared to 55 pounds (or 5 pounds per kva) for the 11-kva unit. Excitation of this 3-phase, 120/208-volt unit is furnished by a built-in exciter, whose output is varied inversely with engine speed to maintain constant generator voltage.

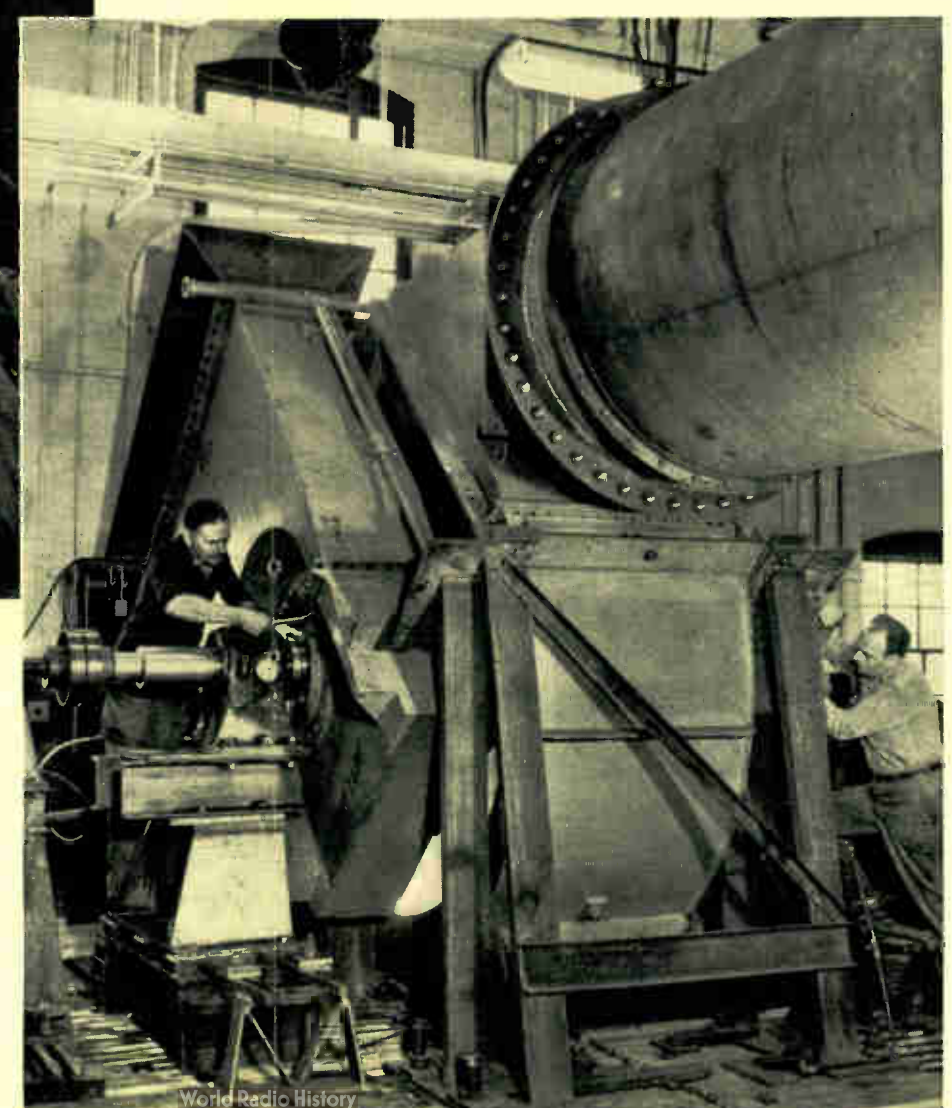
THIS Thomson projection welder, with Westinghouse three-phase, low-frequency converter, is being used by the Commercial Filters Corporation of Boston, Massachusetts, manufacturers of Fulflo filters. The welding control contains six ignitron rectifiers that convert the three-phase, 60-cycle input into a single-phase, 12-cycle output. Its principal advantages are distribution of the power requirements among three phases (thereby reducing the peak demand), and high power factor (about 80 percent). Furthermore, an improvement in the product is gained because of the slower rate of rise of the low-frequency welding current.





A VERTICAL-SHAFT radial engine that burns natural gas or oil has been combined with a vertical generator that supplies both direct and alternating current to form a unique engine generator. A total of 120 such machines are being installed by the Aluminum Company of America to provide low-cost power for aluminum production. The engines, built by Nordberg Manufacturing Company, are of the two-cycle type with eleven 14- by 16-inch cylinders arranged radially in a horizontal plane. The maximum rating at the required speed of 360 rpm is 1800 hp, but the engine can deliver this power at speeds up to 400 rpm. Westinghouse is building 40 of the generators, which have a d-c rating of 1100 kw at 645 volts and an a-c rating of 150 kw at 450 volts, 24 cycles, 3 phase. The direct current, taken from a commutator, is to be used in aluminum processing. Alternating current, taken from collector rings, is for engine auxiliaries.

THIS huge centrifugal compressor, shown undergoing performance tests, will be used to cool the atomic pile now being constructed at the Brookhaven National Laboratory. The all-steel wheel of this big blower will revolve at a tip speed of 450 miles per hour, and move thousands of cubic feet of air and gases per minute. Each of these 12-foot-high blowers is driven by a 1500-hp motor.



What's NEW!

Production Team—R-F Generator Plus Work-Handling Equipment

Fuel alone can produce only heat, but in combination with a suitable engine, it can literally move mountains. A radio-frequency generator is in much the same predicament. Alone it can produce only heat, but in combination with suitable work-handling equipment, it can boost production rates up off the chart. To reap more fully the benefits of r-f heating, a family of work-handling equipments is being formulated, the first of which is now in service.

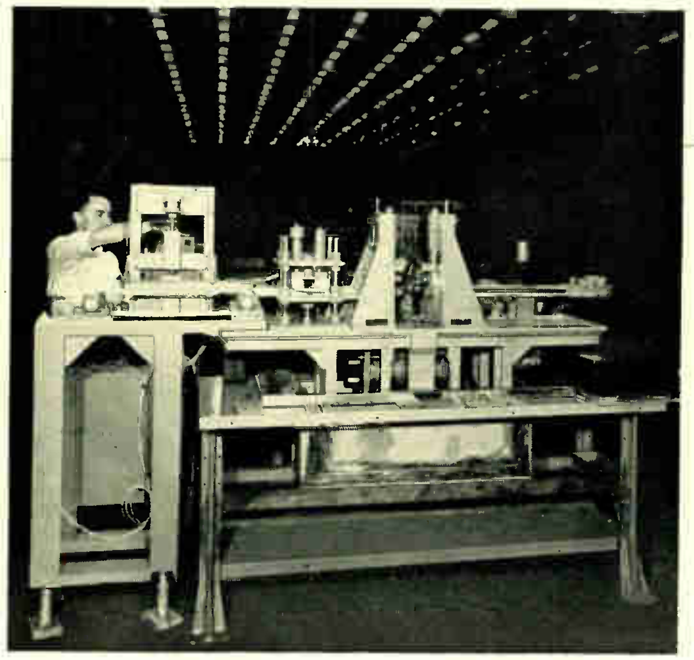
The machine is suitable for continuous high-production case hardening of cylindrical sections up to $1\frac{1}{4}$ inches in diameter and 12 inches long. It is being used by a large automobile manufacturer to harden four sizes of gear-shifter rails, a component of the automobile transmission. The rails have sections of different diameters (from $\frac{3}{8}$ to $\frac{1}{2}$ inch) and of different lengths (from $4\frac{1}{2}$ to $6\frac{1}{2}$ inches overall). The rails are selectively case hardened in certain sections to a depth of about 0.070 inch. The production rate is approximately 425 pieces per hour for the $6\frac{1}{2}$-inch rail and 600 for the $4\frac{1}{2}$-inch rail.

The rails, fed into the machine from a sloping magazine, fall on a conveyor moving at a constant, but adjustable rate. Each rail is pushed onto a stationary surface by the unit behind it and, as it approaches the r-f heating coil, is firmly and concentrically positioned by three rollers. To insure uniform depth of hardening, these rollers rotate the rail as it moves through the coil and quenching spray. The induction coil is automatically energized when the sections of the rail to be hardened pass through the coil, and automatically de-energized for the other sections. Hardened rails tumble into a discharge chute. The timing cycle is automatically reset by a limit switch, tripped by the piece just hardened as it emerges from the water spray. The operator need do nothing but keep the feed magazine supplied and carry away hardened rails. The equipment is wholly automatic in all other respects. The operator needs only "start-stop" control.

The work-handling machine, designed by M. P. Vore and W. L. Corteggiano of the Westinghouse Baltimore Works, has several other ingenious features that facilitate operation and render it foolproof. The four types of gear-shifter rails are fed by four interchangeable magazines, but each magazine will accommodate only the rail for which it is built. The selective-hardening cycle, which differs for each type of rail, is set by the operator simply by inserting a multiprong male plug, attached by chain to the magazine, into the single female socket mounted on the machine. Should the magazine be emptied, a special magazine automatically starts to feed brass dummies behind the steel rails to keep them moving until all are hardened. A centrifugal switch, actuated by the movement of rails against a friction disc, cuts off the r-f power if the flow of material stops for any reason, thus preventing improper hardening. A pressure-operated switch shuts down the machine if the flow of water stops, thereby preventing melting of the r-f coils.

For hardening rails, a 10-kw, 450-kc, r-f generator is used. Other types of work may require larger or smaller generators.

R-f heating and work-handling equipment for high-production hardening of gear-shifter rails used for automobile transmissions.



Electric Stairways Go to Sea

The success of an aircraft carrier often depends upon how fast its planes get into the air. This means that, once alerted, pilots must get to the flight deck from the "ready room" in almost nothing flat. On three 27 000-ton carriers of the Essex class, jet pilots will soon be whipped up to the flight deck at the rate of 30 per minute by electric stairways. These moving stairways, the first to be installed on a warship, will closely resemble those used in department stores, but with notable differences.

The first change stems from the fact that in order to take rough seas, ships are built with a certain amount of "give" in their structure, rather than being perfectly rigid. This means that some parts of the ship may move with respect to others, and necessitates a stairway mounting with a certain amount of flexibility. This will be accomplished on the new stairways by a sliding support at the lower end that will permit the stairways to adjust themselves to such strains. A travel of about a half inch is allowed. Step treads on the stairways will be made of extremely tough Micarta plastic instead of the conventional aluminum. To withstand shock, cast steel is being substituted for cast iron in the driving machinery; bronze is replacing aluminum in step brackets.

Stairways will be standard in width and speed—32 inches and 90 feet per minute, respectively. They will get pilots laden with 40 pounds of equipment on deck quickly and ready for action.

More Light for Night Driving

Improvements in sealed-beam headlights and sealed-reflector foglights assure better night visibility for automobile drivers and greater safety for pedestrians.

The consumption of the 6- to 8-volt sealed-beam headlight has been increased by five watts in both the country-driving and the city-driving beams, to the maximum permissible values of 45 and 35 watts, respectively. Although on the surface these increases do not seem significant, the net result is a $12\frac{1}{2}$ percent increase in light output in the country-driving beam and a $16\frac{2}{3}$ percent increase in the city-driving beam.

Sealed-reflector fog lamps for heavy-duty motor vehicles are now available in 12-volt ratings. These lamps cast a symmetrical band of light across the roadway, about 35 degrees wide and 3 degrees deep. As in all Westinghouse sealed-reflector fog lamps, a filament shield is used to prevent unreflected light above the horizontal from issuing directly from the mouth of the reflector. Such an uncontrolled light would create a veiling glare in the eyes of the driver through reflection from fog particles.

The 6- to 8-volt sealed-reflector fog lamp has also been improved. The lens design has been changed to a straight symmetrical pattern that projects a fairly even band of light across the highway similar to that produced by the 12-volt lamp. A $16\frac{2}{3}$ percent improvement in light output has also been effected in this lamp by a five-watt increase to 35 watts.

out the entire structure of the motor-control mechanism.

Individual starter units do not have doors, which makes for greater accessibility without decreasing safety. The cabinet door cannot be opened with the breaker in a closed position so that there is no danger of contacting exposed parts. This construction has several advantages. When a unit is removed the door of the cabinet can be closed over the vacant space so that the bus is not exposed. In many other constructions the door is part of the starter unit so that when a starter unit is removed the bus must be left exposed to contact.

By swinging all doors open, the entire vertical wiring runway is exposed for inspection or maintenance from the floor to the top horizontal cable trough. Thus the user's wiring from conduit to starters becomes a much simpler procedure.

The new control center retains the same overall dimensions and the same sized starter units, 14 inches or multiples of 14 inches, so that structures can be standardized. Wherever possible cam-type fasteners have been utilized instead of screws, speeding up and simplifying removal of units.

A Rectifier Welder

For those who prefer d-c welders, a new d-c arc welder operating from an a-c power system has been achieved by means of selenium rectifiers. This new welder, which has no rotating parts, is an important advancement because it combines d-c welding characteristics with the numerous advantages of a-c welding machines.

The new d-c welder capitalizes on the desirable characteristics of the selenium rectifier, which has proved its reliability in many industrial applications such as battery chargers and electroplating. Physically it consists of a streamlined metal cabinet that, for the 300-ampere version, is about two feet square and three and a half feet high, and weighs but 510 pounds. It occupies less floor space and weighs about 40 percent as much as a motor-generator welder of comparable rating. Units can be equipped with skids for stationary mounting, five-inch swivel-mounted wheels for portable requirements, or a heavy duty running gear for extreme portability over rough floors, tracks, etc. The low center of gravity of the new rectifier welder makes it as portable as a horizontal type motor-generator welder.

The operating parts of the welder consist of a three-phase transformer, which results in a balanced power load, an adjustable three-phase reactor of the moving-core type, which gives stepless current control, and six banks of selenium rectifiers, which give full three-phase power rectification. A fan driven by a fractional horsepower motor (the only rotating member) provides ventilation by drawing air through a dust filter mounted at the bottom of the welder case.

The six rectifier banks are identical in design and are mounted in a single framework. A large door in the side of the welder allows easy removal of the air filter and ready inspection of the transformer and rectifier assembly.

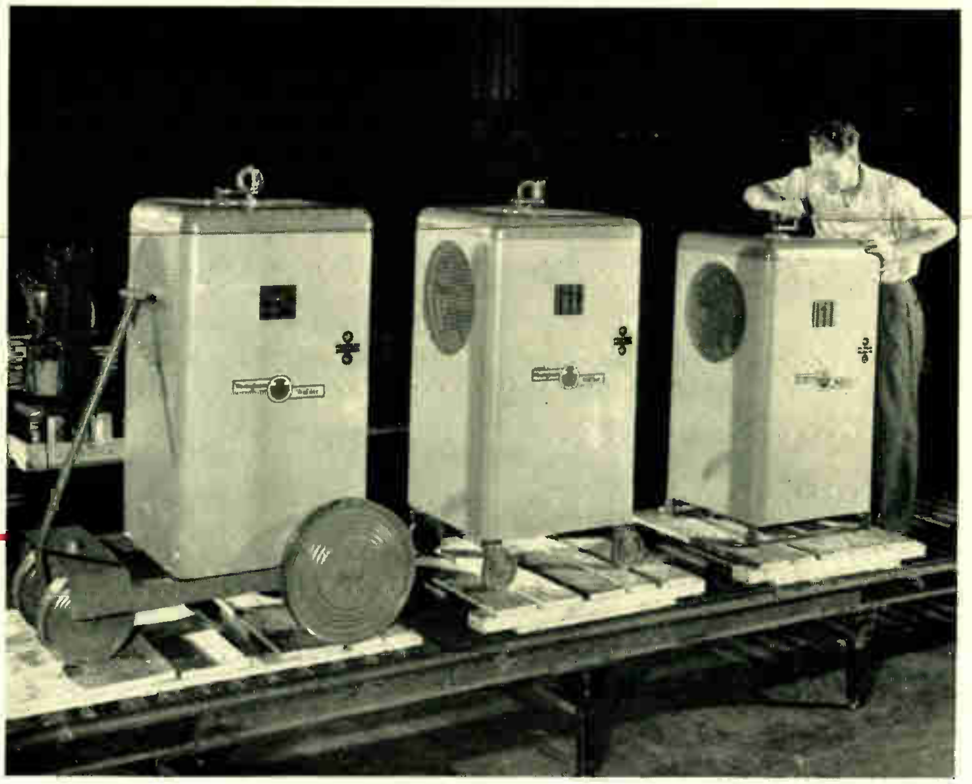
The rectifier welder has many desirable characteristics that are not obtainable in any other type of d-c welder. Its speed of response is almost instantaneous, resulting in extremely stable welding conditions over its entire current range.

The lack of rotating parts, except for the small ventilating fan, makes the welder practically noiseless and ideal for installations where large groups of machines are assembled, and where the welder is working close to his welding machine. The small ripple in the d-c output results in somewhat reduced arc blow in comparison with the unvarying direct current obtained from a rotating generator.

The no-load losses of a 300-ampere welder are only 0.5 kw as compared to 2.8 to 3.4 kw for a conventional motor-generator welder. The power factors at no load and rated load are 75 percent and 85 percent, respectively, as compared to 34 percent and 89 percent for a machine driven by an induction motor. The efficiency at full load is 66 percent as compared to 59 percent for a motor-generator welder. This efficiency increases at reduced load conditions and reaches 73 percent at 20-percent rated load while the motor-generator machine falls to 46 percent efficiency at this load condition.

The rectifier welder is built in the three conventional ratings: 200, 300, and 400 amperes.

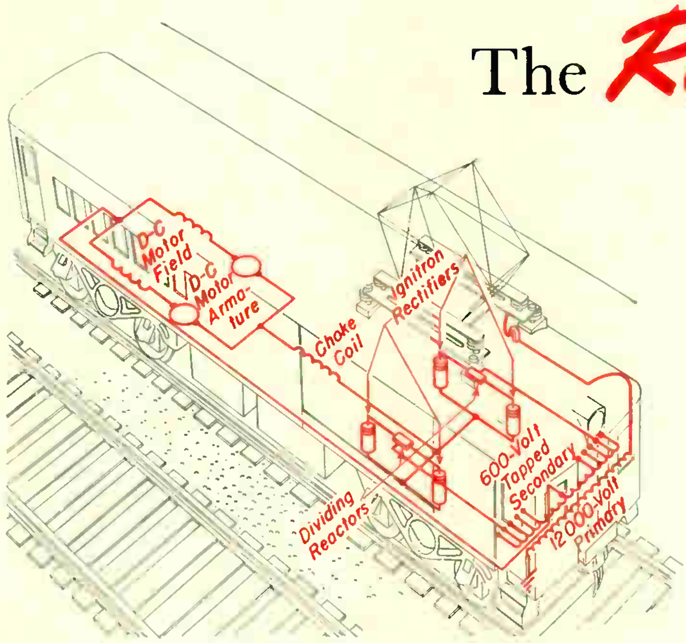
Because of the simplicity of design of this machine and its excellent welding characteristics—low no-load losses, high efficiency and power factor, small size and weight, and essential freedom from noise—these welders fill a distinct need where d-c welding is desired but only three-phase alternating current is immediately available.



At right, the three types of mounting for the rectifier welder. Left to right, the heavy-duty mounting for rough surfaces, the swivel-mounted wheels for portable requirements, and the skid-type for stationary service. Above, the skid-mounted arc welder in action.

The Rectifier Railway Car

— A-C Supplied — D-C Driven



Important engineering developments often have to wait for one or more of their component parts to mature. Such was the case with the experimental rectifier railway unit that appeared first in 1913; it had to wait for better rectifiers. But with the development of the ignitron, a unit driven by d-c motors but supplied with alternating current, via rectifiers, seemed more promising. A multiple-unit car utilizing this principle is now undergoing tests.

A simplified schematic diagram of the ignitron multiple-unit car. The sketch does not show actual location of components within the car, but only the path of current from a-c trolley to d-c motors.

The multiple-unit railway car that rolled out of an eastern electrified-railroad yard one day last July was to all intents and purposes an ordinary unit, half baggage car and half passenger section, like hundreds of others in service on electric railways. Nothing about its outward appearance distinguished it from other cars. But its crew of engineers and technicians was observing with the tense expectancy that comes only to those who have brought forth a new development and are watching it in operation for the first time. For nestled in among a vast array of test equipment were four devices that had never before operated on a railway traction unit—ignitron rectifiers. This was a car equipped with d-c motors, but with power supplied from a-c lines. Ignitrons were converting the 25-cycle alternating current from the 12 000-volt overhead trolley to direct current for the traction motors. They were standard sealed tubes, feeding power to two 225-hp d-c traction motors. The ignitron—long popular in stationary railway and industrial use—was at last displaying its talents in mobile railway service.

The use of an ignitron system has certain attractions in railway use that cannot be overlooked. It permits the use of an a-c transmission system with d-c traction units, long considered a desirable combination.

Large blocks of a-c power are far easier and cheaper to transmit than direct current. But for railway service, low-voltage d-c motors have inherent advantages over their a-c counterparts. For the same horsepower they are smaller, lighter, less complex, and have fewer commutation problems than single-phase a-c motors. A railway unit utilizing d-c motors requires less maintenance and has a higher efficiency, resulting in some saving of power. A-c motors have characteristic torque pulsations that must be minimized in railway units by the use of special flexible connections between axles and motors; in a d-c powered unit the drive can be direct, through a simple gear and pinion. Other advantages for the ignitron system also seem likely. The rectifier railway unit could conceivably operate from a 60-cycle trolley, rather than the 25-cycle common today. This, if it proves practical, could result in further standardization of wayside equipment, and possibly a reduction in equipment due to the elimination of the frequency changers now necessary.

Although the ignitron is a complete stranger to railway-car use, the idea of utilizing a rectifier in a railway unit is not a new one to Westinghouse. Back in 1913 a railway car (later used on the New Haven Railroad) was operated with a multi-

Fig. 1—On this "jiggle table" ignitrons were shaken at frequencies up to 180 cycles per minute, with an amplitude of one inch. The whole platform was shaken by means of the motor at left, appropriate gearing, and the offset cam. The rectifier, under heavy electrical load, operated normally despite the violent movement.

Written by Richard W. Dodge, Assistant Editor, based on information supplied by the engineering and commercial staffs of Westinghouse.

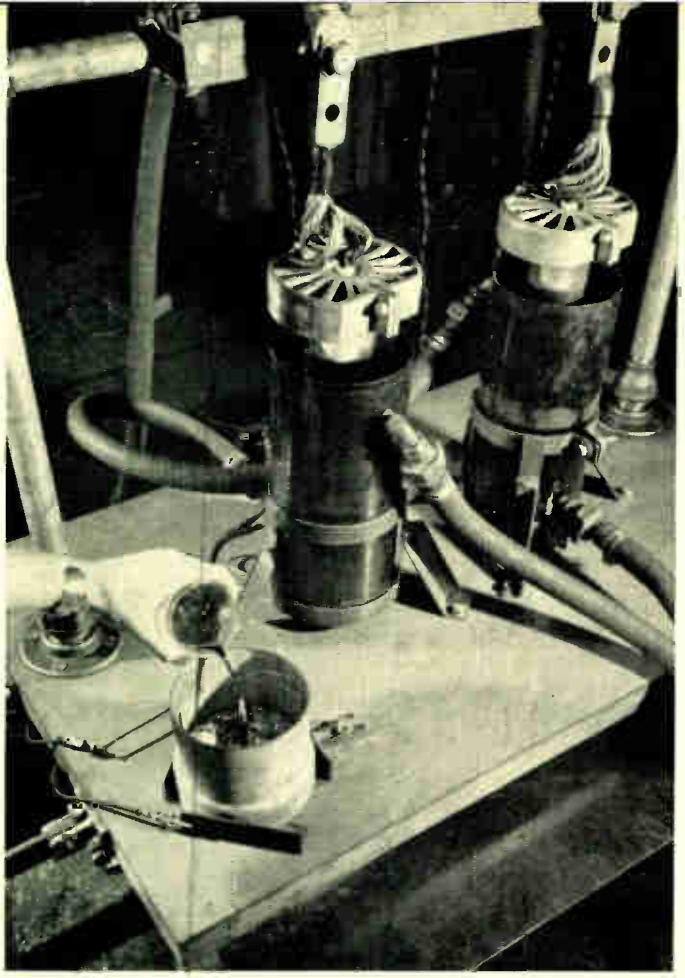


Fig. 2—A cutaway portion of part of the ignitron was left open so that engineers could actually observe the movement of the mercury. Here mercury is being placed in the cutaway tube, in preparation for tests.

anode, pumped-type, mercury-arc rectifier. This car was moderately successful; it covered a total of 22 345 miles in all kinds of service and operated satisfactorily. But it was then apparent to engineers that the time was not yet ripe for this type of traction equipment. Serious drawbacks were apparent—drawbacks that were dependent upon the state of development of the mercury-arc rectifier. Three major difficulties were encountered that ruled out the rectifier car as a serious contender at that time: arc-backs in the tube occurred all too frequently, the rectifier caused serious telephone interference, and, finally, the vacuum could be maintained over a period of only about three months at the most, necessitating frequent re-pumping. These were strictly rectifier characteristics and out of the realm of transportation engineers, so there was nothing to do but sit back and await the necessary further development of the then infant mercury-arc rectifier. The wait was not in vain. In 1930 a group of engineers, under the direction of Dr. Joseph Slepian, developed the ignitron, a vastly improved type of mercury-arc rectifier. Capable of handling relatively large amounts of power, it soon found industrial use. Then sudden expansion of the aluminum and magnesium industries during World War II and the subsequent demand for large blocks of d-c power shoved the ignitron into an even more conspicuous place. The principle of operation of this new rectifier and its success in industry once again aroused the interest of transportation engineers in a rectifier railway unit.

A d-c motored car supplied with alternating current now seemed more practical. The sealed ignitron, which came into use in 1939, eliminated previous vacuum-maintaining equipment. Several methods of overcoming telephone interference gave definite promise. Furthermore, the ignitron, by its principle of operation, lessened the probability of arc-back because, unlike previous mercury-arc rectifiers, it maintained no continuous arc but restruck an arc afresh each half cycle.

Despite the solution of these major problems, however, there remained serious doubt in the minds of many engineers as to whether the use of liquid-pool rectifiers in a moving railway car would prove practical. It seemed reasonable to assume that movement of the car would cause sloshing of the mercury in the bottom of the ignitron; since this sloshing would change the effective spacing between anode and cathode, wouldn't serious arc-backs occur? This prospect seemed so likely that most engineers dismissed the idea of a rectifier railway car completely.

But at least one transportation engineer—L. J. Hibbard of Westinghouse—was firmly convinced that this difficulty was more fancied than real. Hibbard had been in on the tests of the first rectifier car in 1913 and had taken note of the causes of arc-back in that car. Another thing that convinced him of the practicality of the ignitron for railway service was an action he had often noted on Pullman dining cars. Rarely, if ever, did coffee spill from a cup due to movement of the train. It moved around, but one movement of the train seemed to cancel out another so that the coffee never spilled over the top of the cup. But Hibbard needed more than coffee-cup proof. He decided to establish by actual test the action of the ignitron under the severest of conditions. A standard tube was bolted to a base plate and a heavy electrical load applied (Fig. 1). The plate was then mechanically oscillated with an amplitude of one inch at frequencies up to 180 cycles per minute. Nothing unusual happened. The tube worked normally, and no arc-backs occurred. Prolonged tests provided the same results. Other tests by the Navy lent proof of the ignitron's ruggedness. The base connections, slammed with sledge-hammer blows of 2000 foot pounds each, were bent completely out of shape—but only after six such blows did the tube fail. Railway service was never like this. Armed with this kind of evidence, Hibbard and his associates decided that the time was ripe for development of a full-scale experimental railway car utilizing ignitron rectifiers.

The experimental ignitron car that took the rails last summer is by no means a finished product, ready for commercial application. Rather, it is a pioneer development project, still in its early stages, but promising nevertheless. Many hours of operation in different types of service will be necessary before the practicality of a rectifier motive-power unit is definitely established. However, at this time the ignitron multiple-unit car has been in operation for several months and no serious drawbacks to its mode of operation have turned up.

Proof of the advantages of d-c powered rail units operating from a-c overhead supply will come only by thorough testing of equipment such as the ignitron multiple-unit car. Thus this car must undergo a substantial test period before final conclusions can be drawn. However, if successful, the scheme of utilizing d-c traction motors supplied with a-c power via rectifiers could have significant effects on both existing and future electrification of railways.

Editor's Note—The telephone influence of such a rectifier is being investigated on a 25-cycle system. The results, though not complete, include field-test data taken on the ignitron-equipped multiple-unit car. They indicate that practical filters can be produced that will permit the use of rectifiers as a power supply for individual traction units of an electrified railway system paralleling communication circuits in well-shielded cables. However, further study is needed to evaluate the influence of this type of rectifier system on open-wire communication circuits.

Switching of High-Voltage Lines and Cables

With the recent growths in the length and voltage of cables and lines, and in the ratings of capacitor banks, came the problem of switching heavy capacitive currents at high voltage. Opening or closing such circuits causes high surges of voltage, and sometimes a restrike, across the breaker contacts, with attendant disturbances to the system. In service, difficulty due to restriking is rarely encountered. But when it is, laboratory and field tests show it can be mitigated in several ways.

W. M. LEEDS, *Manager, Circuit Breaker Development, Westinghouse Electric Corporation, East Pittsburgh, Pa.*

THE term "circuit breaker" usually suggests "short circuits," for it is the principal function of breakers to interrupt faults as quickly as possible to minimize line disturbances. But circuit breakers have another important function—routine switching—again with a minimum of line disturbances, such as occur under certain conditions.

Switching disturbances can result when either opening or closing capacitive circuits; for instance, the charging current to a cable, a long transmission line, or a bank of capacitors. Such switching involves certain peculiarities not encountered when load current or faults are interrupted. Although breakers on low-voltage lines handle capacitive currents easily with practically no arcing, delayed restriking of the arc is often observed on high-voltage transmission lines and cables. The resulting system transients occasionally give rise to voltages several times normal, which imposes a problem in applying breakers to cable circuits.

When the problem of intermittent arcing in a power system is approached theoretically or by the use of a network calculator, the arcing and dielectric-recovery characteristics of the circuit breaker must be assumed. To examine the worst possible conditions, the most unfavorable sequence of events is assumed, timing the arc restriking so as to develop the maximum overvoltage. However, while these studies are valuable in determining the effects of variations in system constants, actual tests are necessary to ascertain the extent to which characteristics of the arc-interrupting mechanism modify the calculated surge voltages.

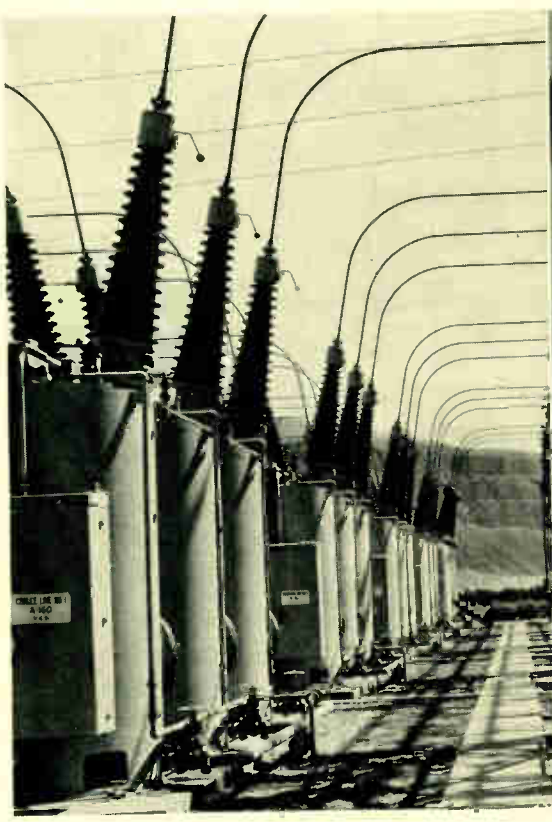


Fig. 1—Staged tests on lines of the Bonneville Power Administration have been used to study the effects of switching capacitive currents on these 230-kv, 3½-million-kva oil circuit breakers.

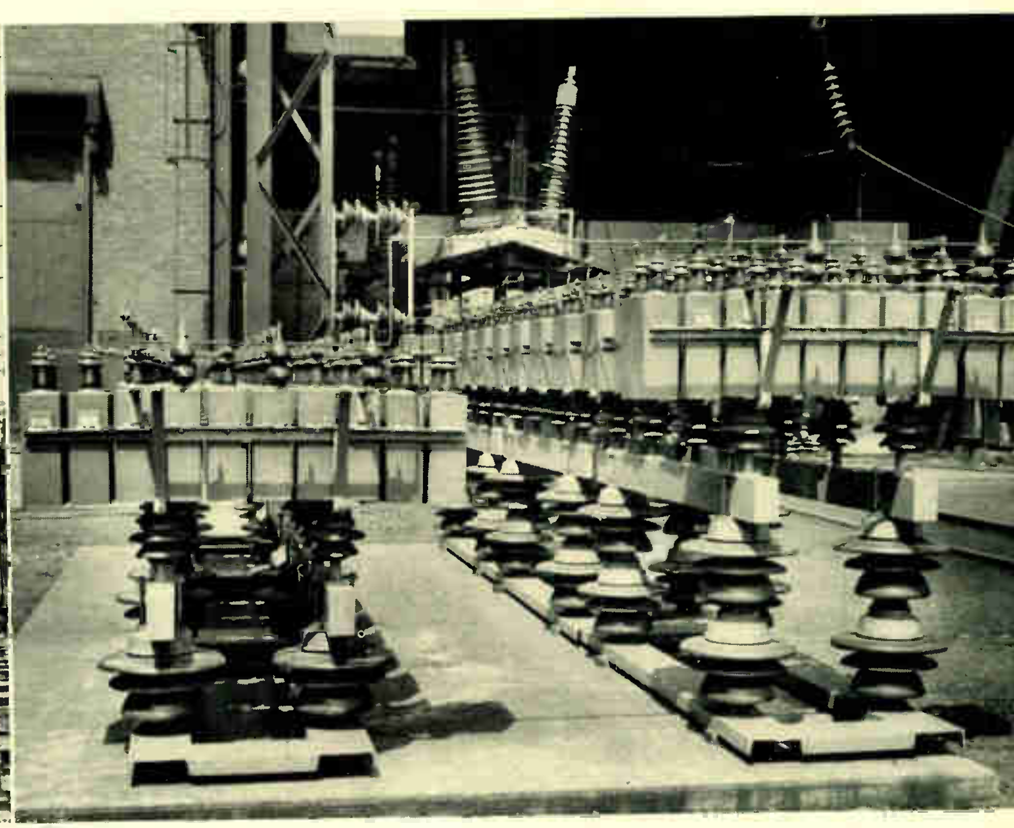


Fig. 2—One of the shunt-capacitor banks in the Westinghouse High-Power Laboratory at East Pittsburgh, where studies of the switching of high-voltage cables and transmission lines are made.

Analysis of Charging Current Interruption

The interruption of capacitive currents is illustrated by considering a capacitive load, Fig. 2, to be the approximately equivalent circuit of a cable, Fig. 3(a). The lumped capacitance C, representing the cable, is connected to a high-voltage a-c bus through a circuit breaker B. The small parallel capacitance C' represents the capacitance ahead of the breaker—the bus and the equipment connected directly to it.

Assume the current, Fig. 3(b), is interrupted as it passes through zero by the opening of the breaker. At that instant of opening, the bus voltage ahead of the breaker $e_{c'}$, Fig. 3(b), and the voltage on the cable e_c both equal the peak of the sine wave E_m. After interruption, the bus voltage $e_{c'}$ continues to vary with that of the generator, but the cable (or capacitor) voltage e_c is constant, except for a small decay due to leakage. Thus, a difference between the two voltages develops and appears across the breaker contacts, Fig. 3(c), which are still parting.

The generator voltage reverses. One-half cycle after current zero, the difference of potential across the breaker contacts (e_c minus $e_{c'}$) reaches approximately 2 E_m. If the dielectric strength between the partially opened breaker contacts is insufficient to hold this voltage, an arc re-ignition or restrike results. (The gap may break down before the voltage reaches 2 E_m, but a breakdown close to this crest is the worst possible condition.) Current surges through the breaker as the capacitor potential oscillates at a frequency determined by L, C', and C, attempting to adjust itself to the instantaneous generator voltage. During the surge, the voltage across the contacts is only the arc drop, which is almost negligible for short gaps. If the arc is extinguished after only a half cycle of surge current (the worst possible condition), the capacitor is again left fully charged, but this time to much higher voltage (perhaps 2 E_m). The bus voltage, disturbed by the transient and now trying to follow the generator voltage, oscillates at a high frequency determined by L and C' only. Following this transient, the generator voltage reverses polarity at fundamental system frequency, and the voltage across the breaker again builds up, this time to a maximum that can be as high as three to four times normal crest. If, now, a second restrike occurs at the next crest of the generator voltage, the potential across the contacts could reach 4 to 5 E_m.

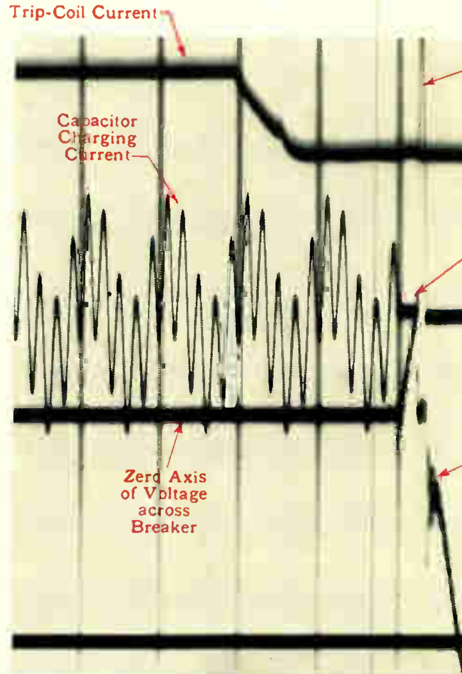


Fig. 4—Opening of a 45-ampere charging-current (having a strong fifth harmonic) during a test at 66 kv. The circuit was interrupted temporarily but the circuit breaker restruck at 1.35 E_m. After the restrike, the voltage across the breaker reached a peak of almost 3 E_m.

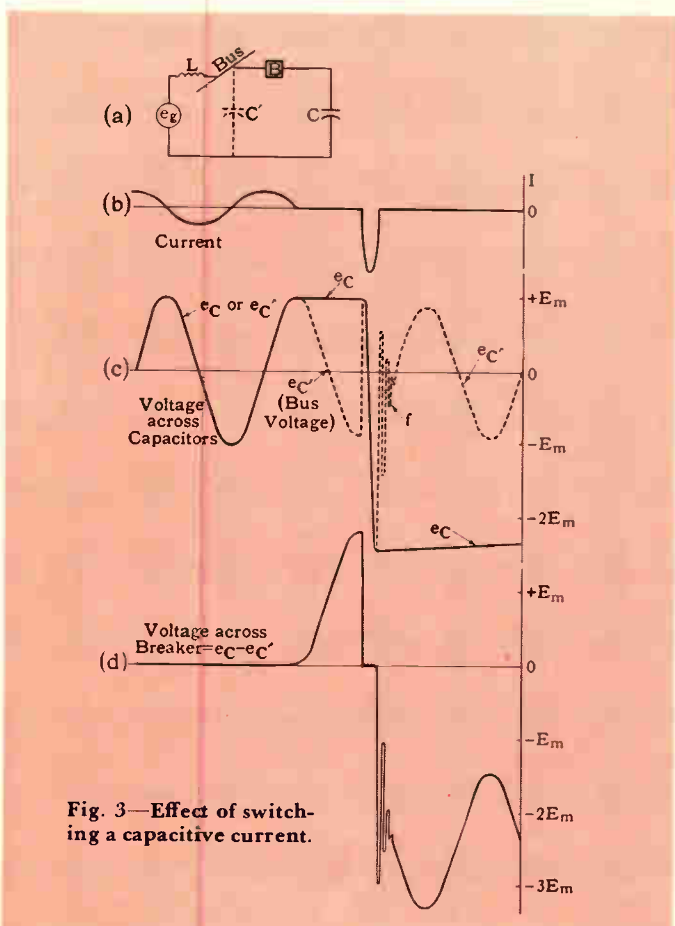


Fig. 3—Effect of switching a capacitive current.

In discussing the interruption of charging current, a delayed restrike is usually distinguished from an ordinary arc reignition by defining a restrike as "the re-establishment of the arc after the current remains at zero for one-fourth cycle or more." Since this time interval is required for the difference of potential across the breaker to build up to normal crest voltage, re-ignitions after a shorter pause do not produce overvoltage surges and are therefore harmless. A restrike, then, is a special type of re-ignition.

Restrikes ordinarily do not occur simultaneously on all three phases of a circuit breaker, principally because current zeros do not occur at the same instant. One phase may restrike while another does not.

If a long transmission line is substituted for the lumped capacitance, the interruption of charging current is similar, although there are detail differences. One is in the more abrupt change in voltage and current at the beginning and end of a restrike, due to the characteristics of traveling waves on the line. The attenuation of these waves during their travel, which reduces the amplitude of the overvoltage at the breaker when the wave returns, corresponds to damping of voltage oscillations on a cable. In general, switching surge voltages are of the same order of magnitude with either lines or cables.

Functioning of Interrupting Devices

Theoretical considerations of the simple capacitive circuit of Fig 3(a) suggest high cumulative voltages built up without limit by repeated restriking under the most unfavorable conditions. However, in actual practice, the high-frequency transients are damped by resistance and the behavior of circuit-interrupting devices does not usually produce such conditions. (In fact, one restrike often cancels the voltage built up by a previous restrike.) Consequently, in spite of theoretical possibilities of surges of 4 or 5 E_m, hundreds of laboratory and field tests on grounded-neutral systems, Figs. 4, 5, and 6, indicate that peaks of even 3 E_m are extremely unusual. Many users report no difficulty in switching long lengths of transmission lines or underground cable at 69, 115, and 138 kv in actual service with standard 8-cycle breakers.

One or two restrikes are expected when switching charging currents with circuit breakers having effective arc-interrupting devices, such as multi-flow grids, for example. High-voltage oil circuit breakers having no arc-interrupting devices (early plain-break types), or with only moderately effective interrupting devices, may experience as many as fifteen arc re-ignitions before finally clearing, but the number of restrikes usually will not exceed three or four.

The ideal circuit breaker, from the point of view of opening charging current, would build up dielectric strength so rapidly as to prevent any restrike, even when maximum voltage was developed across the minimum contact gap (by a current zero just after parting). At moderately low voltages, 2300 to 15 000, the standard oil breaker conforms very closely to this ideal, except perhaps when switching large capacitor banks rated over 10 000 kva. At higher voltages, either more contact gaps in series in the breaker or higher contact-opening speeds can be used to avoid restriking. Another method is to provide a high-velocity flow of oil suitably directed into each of a number of series gaps, so that soon after current reaches zero, the gaps are filled with oil of high dielectric strength. Some breakers have been built that provide this oil mechanically for interruption of both low charging currents and high short-circuit currents. However, such breakers are complicated because of the large number of contacts in series and the powerful mechanical effort that must be stored to produce the high-velocity oil flow in all of the breaks, which sometimes necessitates a separate mechanism for each pole.

Other types of breakers use a sudden flow of oil, produced by a small auxiliary piston, to interrupt low charging currents only; this piston is inactive during short circuits, which are interrupted by the self-generated flow of oil from a series pressure-generating arc. The auxiliary-piston arrangement requires a minimum of stored energy in the operating mechanism. However, where only two interrupting units are used per breaker pole, high-voltage gradients could be developed if a current zero occurs immediately after contact separation. To prevent restriking (after interruption) in such instances, the action of the oil-flow piston is delayed until the arc is longer, when it is more easily ruptured. Current zeros occurring previous to the oil flow cause re-ignition, but at a low voltage. After the pump has gone into action, the interrupter, aided by adequate contact separation, extinguishes the arc and withstands the twice-normal voltage occurring one-half cycle later.

Compressed-air breakers have interrupting characteristics approaching those of forced-oil-flow or impulse-type oil breakers. However, when few series breaks are used, delayed action may again be desirable to prevent attempts to clear the arc at very short contact spacings. In one commercial interrupter, the moving contact acts as a valve, practically filling an orifice until a certain separation is reached, after which the air is permitted to flow freely. Again, circuit interruption without restriking is usually accomplished at the subsequent current zero.

Use of Parallel Resistance

In spite of the favorable field experience, it is desirable to eliminate restrikes altogether or at least to limit the overvoltage surges. One means of accomplishing this objective is to use resistors installed inside the breaker and connected

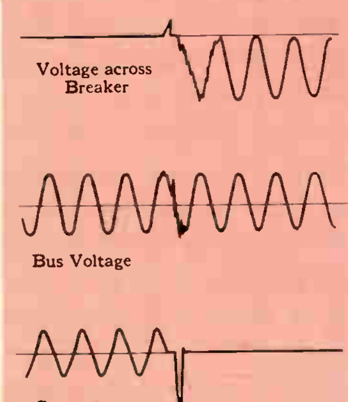


Fig. 5—Tracing of an oscillogram recorded while disconnecting 183 miles of 230-kv line. A single restrike left the line charged to a value slightly greater than E_m, as indicated by the displacement of the voltage across the interrupter.

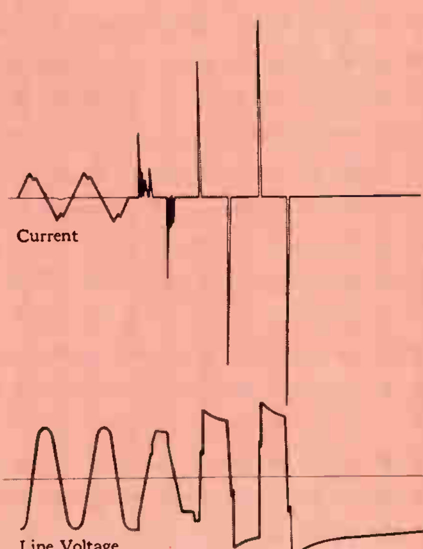


Fig. 6—In spite of six restrikes of the arc, when switching a 50-mile section of 230-kv line, the line voltage did not exceed 175-percent normal E_m, as this shows.

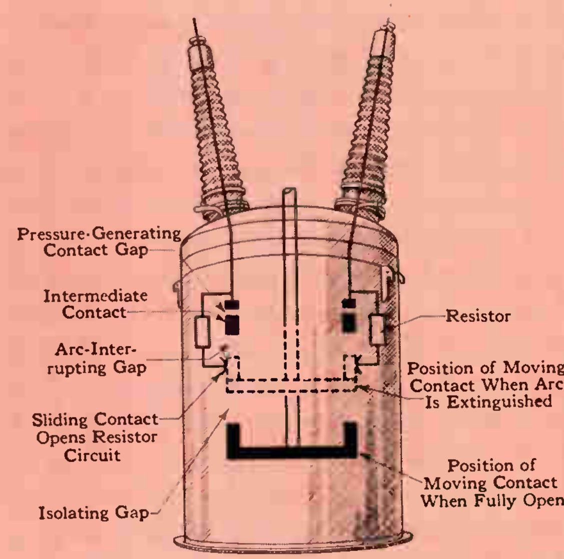


Fig. 7—The internal connections of a high-voltage oil circuit breaker showing the resistor and how it is disconnected.

across the contact gaps of the interrupting units, Fig. 7. When the contacts part, these resistors are connected in parallel with, but are short circuited by, the arc. As the contacts continue to separate and the arc is extinguished, the resistors bridge the contacts and permit the flow of a small amount of current. After the main contacts have opened fully, the resistors are disconnected by small auxiliary contacts on the breaker. Thus, the resistors are in the circuit only during part of the few cycles that the contacts are opening.

Resistance in parallel with arc-extinguishing devices is used for two purposes, for which different values of resistance are required. High resistance, Fig. 8, from several hundred thousand ohms per interrupter up to one or two megohms, is often supplied as standard equipment to insure substantially equal division of voltage among several series breaks. As a consequence, all contact gaps are utilized most effectively, minimizing the number of re-ignitions when interrupting either short-circuit or charging currents. Another purpose is to bring the top and bottom of the contact assemblies to the same potential when the breaker is in the full open position. This relieves the interrupter insulation from having to withstand high-voltage gradients over long periods of time. Because of their high resistance, these resistors absorb little power and hence their physical size is small. The interruption under oil of the residual resistor current, which is only a small fraction of an ampere at high power factor, is easily done.

If, now, a resistance of lower value, a few hundred to a few thousand ohms, Fig. 9, is used, it falls in the range recommended for reducing overvoltage surges during interruption of charging current. When the extinction of the arc inserts the resistor into the circuit, the capacitor, cable, or transmission line, instead of being isolated, is still connected to the bus, but now through series resistance. As soon as the bus voltage, which continues to alternate, differs from the potential of the charged capacitance, current flows through the resistor, reducing the magnitude of the difference.

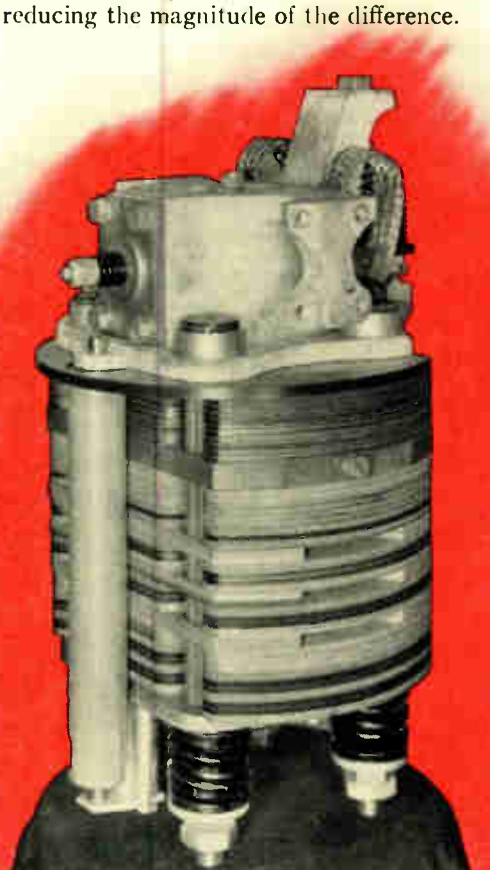


Fig. 8—Standard Multiflow, Deion grid for a 230-kv, 3½-million-kva oil breaker with a 1.7-megohm resistor to equalize the voltage between the two contact openings.

The effect on the transient voltage across the breaker contacts (i.e., across the resistor) during the first half cycle after the current zero is most important. The line or cable potential falls sufficiently so that the breaker voltage, instead of building up to twice E_m, reaches only approximately $1\frac{1}{2} E_m$. This, naturally, decreases the probability of restriking and, should a restrike occur, also lowers the overswing of line or cable voltage by 20 to 30 percent. The resistor, however, does not introduce additional damping in the voltage oscillation during a restrike, since the resistor is temporarily short circuited by the low resistance of the arc, through which practically all of the surge current passes.

The resistor is also effective when energizing a capacitive load. The reverse happens, i.e., the resistor is inserted first and then short circuited by the contacts. This sequence tends to reduce the voltage oscillation and current surge normally produced should the capacitance be connected when the bus voltage is at crest value. Another incidental advantage of the resistor is the damping effect on the recovery transient when opening short-circuit currents. This action is beneficial for less effective interrupters, which are sensitive to high-voltage recovery rates.

However, these resistors have some disadvantages. Adequate thermal capacity of the resistors, because of their low ohmic value, requires relatively large physical dimensions, which may reduce electrical clearances within the breaker. Also, the resistor current is comparable in magnitude to line-charging current. The circuit, therefore, cannot be considered interrupted until after the resistance circuit is broken, which usually requires several additional cycles. Restrikes may occur during interruption of this residual resistor current. However, the voltage surges are unlikely to be important unless the resistance is less than twice the capacitive reactance of the line.

Resistor currents of only 40 to 50 amperes are still high enough to sustain an ionized flashover path in the disconnect gaps until interrupted by the breaker. After interruption of a heavy short circuit, this arcing contaminates the oil and delays removal of the high-voltage gradient from the main gaps. On a high-speed reclosing duty cycle, the additional time for breaking this current increases (by approximately an equal amount) the minimum permissible interval before line re-energization.

Effect of Circuit Components

Certain circuit components reduce the magnitudes of switching surges. One is a grounded-neutral transformer connected to one end of a high-voltage cable. When the transformer and cable section are switched together, either on the low or high side, the grounded windings reduce the voltage difference across the breaker, thereby decreasing the probability of a restrike.

Another is a potential transformer, which discharges a line or cable in a few cycles. Although this speed is not rapid enough to prevent restriking, it reduces the energizing transients that result from immediate circuit-breaker reclosure.

Thirdly, if a substation breaker is connected to the supply through a large amount of capacitance, the switching surges developed are of low magnitude. Capacitance ahead of the breaker can be in the form of cable, either connected directly to the breaker or, if the breaker is bus connected, in parallel with the bus.

Field Tests on Cables

To obtain more information on the specific problem of switching high-voltage cables, a number of tests were made recently on the 115-kv cable circuit of a leading southern utility company. One purpose was to determine whether switching surges were of sufficient magnitude to justify installation of resistors across the breaker contacts. A standard 115-kv, Westinghouse type GM-3 oil circuit breaker, having multi-flow De-ion grid contacts and without either resistors or oil pistons, was used.

Oscillographic records of each phase were made when an isolated cable length of 6.2 miles was de-energized 11 times and energized three times. The maximum overvoltage recorded was 2.1 times normal line-to-ground crest voltage, which occurred on the only test having three restrikes. Of the 33 phase interruptions, 10 interruptions had no restrikes, 15 interruptions had one restrike, seven interruptions had two restrikes, and one interruption had three restrikes.

With two sections of cable totaling 11.1 miles connected, a maximum voltage of 1.9 E_m was recorded during five de-energizing and three energizing operations. No more than one restrike occurred, eight of the 15 phase interruptions clearing without even a single restrike.

During the one year of normal operating experience prior to these tests, the cables had been switched many times without incident. The tests verified engineers' belief that it would be unnecessary to install resistors.

Lightning Arrester Performance During Cable Switching

The electrostatic energy stored in an ungrounded high-voltage conductor during repeated switching surges can build up sufficient potential to discharge lightning arresters connected in the circuit. Cables, because of their greater capacitance and hence greater stored energy, impose a more severe duty on the arresters than do overhead lines. For example, under similar switching conditions of 69- to 138-kv systems, the charge in a cable may be equivalent to the charge in an overhead line 50 times as long; i.e., five miles of cable may store as much energy as 250 miles of overhead line.

Generally, lightning arresters do not discharge on switching surges of the magnitudes caused by modern breakers. However, if the voltage does rise sufficiently to discharge the arrester, the current is in the nature of an impulse of moderate crest current, about 1000 amperes, but for many thousands of microseconds. This long duration is due to the high time constant of the discharge circuit comprising the cable capacitance and arrester resistance. Such a discharge is more severe, and possibly damaging to the arrester than an equivalent amount of energy discharged in the form of high current of shorter duration, as is caused by lightning.

At present, precise data is not available on the length of cable that arresters can discharge repeatedly without damage. In general, Westinghouse station-type Autovalve arresters can handle switching surges high enough to discharge the arrester if the length of cable switched does not exceed nine miles on a 69-kv system or seven miles on a 115- or 138-kv system. In establishing these lengths, it is assumed that the system neutral is effectively grounded, that the cables are switched on the high-voltage side, that the conductor is isolated from ground except when connected to the supply transformer, and that the arresters are of grounded-neutral rating. Only very infrequently are arresters on overhead lines discharged by switching surges.

On certain long cable circuits, where abnormally high surge voltages could occur, it may be possible to coordinate the characteristic of a parallel rod gap with that of an arrester. The purpose of the gap is to insure that lightning surges (which have a steep wave front) discharge through the arrester, but that switching surges (which have a more gradual wave front), if of sufficient magnitude, flash the rod gap.

Fig. 9—View through the manhole of a 230-kv breaker having a special 1250-ohm voltage-damping resistor.

Conclusions

As the severity of switching duty has increased, improved circuit breakers have been developed that give better performance not only on fault interruption but also on charging-current interruption. While it is possible to construct breakers that can interrupt charging currents without restriking even at the highest voltages, such is not usually necessary.

The following are worth re-emphasizing:

1—When circuits having effectively grounded neutrals are switched with standard, modern oil breakers, surges seldom exceed 2.5 times normal line-to-ground crest voltage, despite repeated restrikes. Trouble is infrequent.

2—Lightning arresters can safely discharge those infrequent surges of unusual magnitude sometimes encountered on high-voltage lines or cables. However, special consideration is recommended when the switched cable lengths exceed nine miles at 69 kv or seven miles at 115 or 138 kv.

3—Where very long high-voltage cables are to be switched and high surges are possible, these precautions can be taken:

(a) The circuit breakers can be equipped with either forced-flow oil pistons or low-ohmic-value resistors. At present, oil pistons are provided on all Westinghouse three-cycle high-voltage breakers for more rapid interruption of low currents. Resistors of low ohmic value are not supplied as standard, but they can be provided on special applications.

(b) A power transformer with grounded neutral can be permanently connected on one end of the line or cable.

For further information, see "The Interruption of Charging Current at High Voltage," W. M. Leeds and R. C. Van Sickle, AIEE Transactions, Vol. 66, 1947.

Stories of RESEARCH

Microwaves Get "Bounced"

"RAINDROPS" up to the size of golf balls have been helping research engineers find out more about the "scattering" of microwaves by particles of various sizes. The problem first arose when the Navy discovered during the war that radar wavelengths in the 1.25-cm range were affected by rain and snowstorms. Reflections from moisture-laden clouds, and even an absence of reflections from clouds in which planes were known to be flying, presented a confusing situation. The Westinghouse Research Laboratories contracted with the Office of Naval Research to investigate the causes of this behavior, not only in this range, but also at shorter wavelengths.

Since equipment was not available for generating wavelengths much below this range with sufficient power, the two co-workers on this project, Dr. George A. Klotzbaugh and Edward J. Duckett, elected a unique approach to their problem. Instead of reducing the scale of their problem, as is common engineering practice, they blew it up to several times its normal size. Thus in place of raindrops of normal size, they used artificial drops of plastic up to an inch and a half in diameter. These spheres, a combination of carbon, finely ground copper, sodium stearate, and a plastic base of ethyl cellulose, were carefully constructed to have the same electrical characteristics as common raindrops.

The use of over-sized drops was, in effect, the same as reducing the wavelength. The microwave transmitter generated 3.2-cm waves, but if a 0.32-inch sphere with the proper electrical characteristics was used as a raindrop, the net effect was the same as if 1.0-cm wave had hit a normal-sized drop of 0.10-inch diameter.

Using this system of comparison, and "raindrops" from 0.15 to 1.4 inches in diameter, Duckett and Klotzbaugh investigated a range of wavelengths from 0.6 to 1.75 cm. With the test arrangement shown in the photograph, 3.2-cm waves from the antenna in the background were beamed at the raindrop shown in the foreground, the reflections being caught by the receiving horn, and measured by associated equipment. The horn, of course, was moved to various positions in a 360-degree circle around the raindrop. The investigation was conducted in a "penthouse" atop one of the research buildings; the wall behind the test particle was removable, so that when tests were being conducted radar waves that did not strike the raindrop could pass into space. The closest object in the transmitter beam was a sloping hillside about a quarter mile away. By using a special waveguide circuit similar to a balanced bridge detector, it was possible to separate the reflections due to raindrops from those caused by other objects.

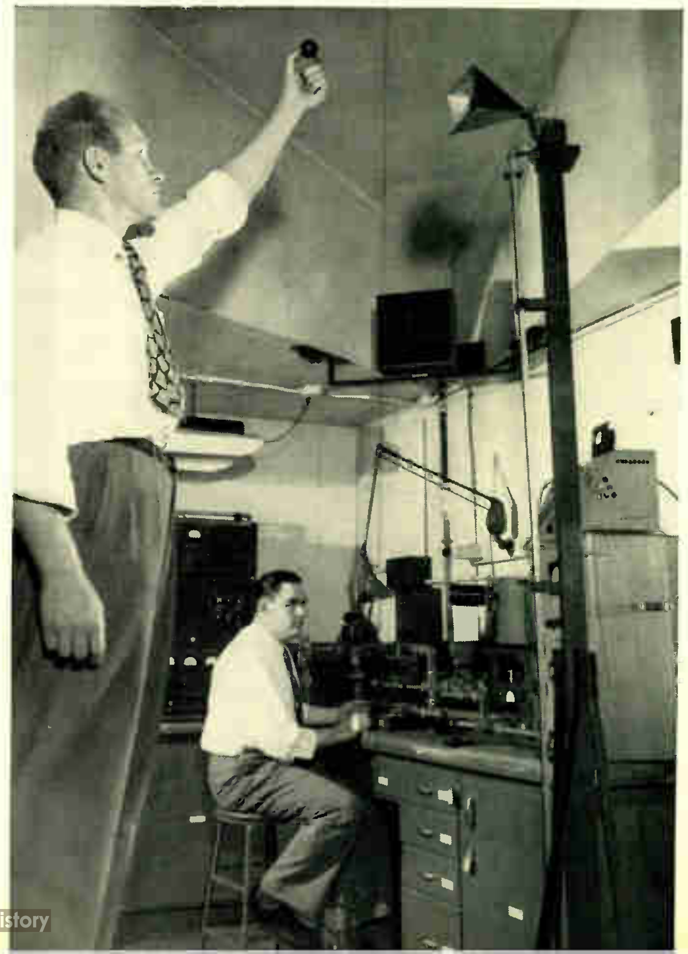
Duckett and Klotzbaugh were not working in completely unexplored territory. Maxwell's theories on electromagnetic waves in general, and Mie's work on the scattering of light provided mathematical solutions applicable to the scattering of microwaves. But heretofore almost no experimental work had confirmed these theories for radar waves in this particular wavelength region. Duckett and Klotzbaugh's experimental work agreed closely with their theoretical computations. Thus it appears that present-day theories describe the scattering of microwaves satisfactorily for the region investigated.

Confirmed in these experiments were theories that scattering of microwaves is most intense at certain wavelengths and that these wavelengths are a function of a particle diameter. In the region in which the wavelength was approximately equal to the diameter of the particle, extremely small changes in wavelength had large effects on scattering. The scattering in the region from 0.5 to 1.75 cm was extremely irregular. In general, the smaller the particle with respect to the wavelength the less scattering occurred, but in this critical region near 1.0 cm, small particles sometimes scattered more energy than larger ones, particularly in the "back" region toward the transmitting antenna. For example, the scattering from a raindrop 0.06 inch in diameter was about ten times greater than the scattering from a drop with a diameter of 0.11 inch, at an angle of 135 degrees from the path of the incident wave and at a wavelength of 0.8 cm.

The direction of scattering was unpredictable from elementary considerations. At certain frequencies almost no reflections would occur toward the antenna; at a slightly different wavelength a large part of the energy was scattered in the direction of the horn. At still other wavelengths, microwaves were scattered almost equally in all directions. This strange behavior is the result of several causes acting simultaneously; because of this, calculations for this region are extremely complex. Therefore, the experimental results provide much valuable information directly, without resorting to long and involved mathematical considerations that are otherwise necessary.

Another effect investigated was the measurement of scattering from two spheres placed side by side. Under many atmospheric conditions rain particles are far enough apart so that the scattering that takes place from all particles is represented by the linear superposition of the scattering from each drop considered separately. Also, of course, in a rainstorm, drops sometimes combine into larger drops so that the scattering changes. But under still other conditions two drops may remain in close proximity and present a totally different situation. When the spacing is very close, certain electrical interactions take place between the two drops so that the scattering is unlike that from two separate drops, or from one large one. Experimental results obtained

Here Klotzbaugh holds a "raindrop" in the approximate position that it will be during a trial run, while Duckett checks instruments. Microwaves from the antenna (top, rear) are beamed toward the particle; reflections are caught by the receiving horn, at right, and measured by equipment shown in the background.



indicate the magnitude of scattering from such combinations of drops, and also provide more information on the possible types of scattering that may be encountered in actual storms.

Most calculations prior to these experiments had measured only scattering back toward the transmitting antenna. These tests also show what happens to the energy scattered in other directions; they thus provide valuable experimental test data that confirms theoretical explanations of scattering phenomena in the 0.6- to 1.75-cm microwave region.

New Metal-to-Glass Seals

Many metals that a few short years ago were unavailable in any great quantity are now becoming more and more common. With the advent of these new metals, hundreds of new applications are being actively pursued. Two of the metals are zirconium and titanium. And among the many current experiments being conducted are those by Westinghouse at both the East Pittsburgh and the Bloomfield (Lamp) Research Laboratories in making metal-to-glass seals. Kovar has already proved eminently successful in these seals, making possible many electronic applications previously not feasible. Its war record was outstanding. But even this useful alloy does not cover all possible applications.

Basically the problem of sealing metal to glass is one of finding a metal and a glass of the same, or reasonably close, coefficient of thermal expansion over a wide temperature range. In the case of zirconium, two kinds of glass, identified as numbers 704 and 7052, were close enough to it in expansion characteristics to warrant further investigation; with titanium, one type of lead glass matches the coefficient. To date satisfactory seals for laboratory testing have been made with both of these metals. Both produce sturdy, gas-tight seals with a minimum of special precautions.

As these metals become even more common, and their cost decreases, this discovery will assume greater importance. Both titanium and zirconium offer prime advantages over some other metals now used for metal-to-glass seals. Zirconium, for example, is not readily attacked by highly reactive vapors, such as sodium, sometimes found in lamps and electronic tubes. It has a high degree of resistance to corrosion; can be easily spot welded; does not give off harmful gases at the temperature of sealing; does not require the extreme surface preparation and processing care necessary with many other types of metal-glass seals; and it is much more stable at low temperatures than some other metals used for seals to glass.

Glass-to-metal seals are but one application for some of the metals now being brought into more widespread use. Many more are in prospect and are now being investigated; they await only the necessary research and development before new application horizons appear.

Striations—Moving Clouds of Light

People who begin to see spots in front of their eyes usually take the shortest route to their family doctor. Not so H. L. Steele, research engineer at the Westinghouse Lamp Division. In fact he goes to great pains to observe bright spots of light, and fast-moving ones at that.

Steele's moving bright areas, better known as striations, occur under unusual operating conditions in some mercury discharge lamps, such as fluorescent lamps. These bright blobs of light, which move the length of the lamp, from anode to cathode, at speeds of about 2000 cm per second (about 65 feet per second), appear in lamps that are operating at much lower temperatures than are usual. Ordinary commercial 40-watt lamps running at rated current would not exhibit moving striations unless the room temperature were below freezing, or if the room temperature were normal, unless the current was reduced to one half normal. However, they would not be visible to the naked eye under these conditions. The cause of these striations is still somewhat of a mystery, and thus far only part of the answers have been found.

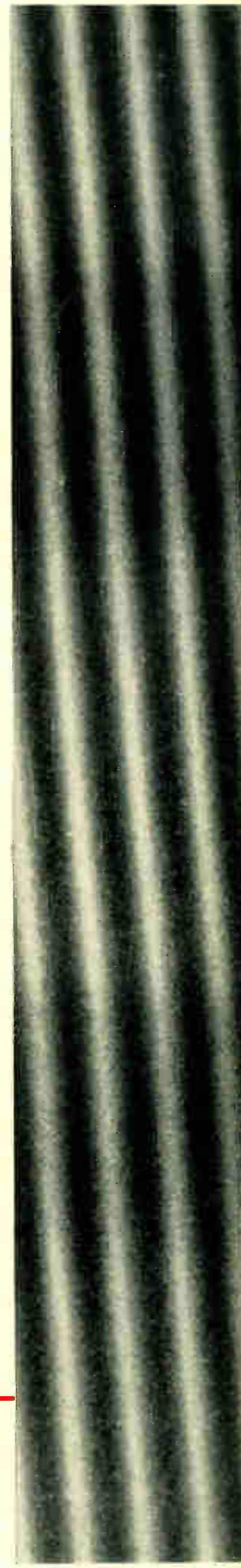
Striations are accompanied by successive potential waves moving down the length of the lamp. As these waves progress they create momentary dense regions of excited atoms and electrons. Excited atoms return to their normal state and when this happens they emit light radiations. This action, of course, is responsible for the normal creation of light by a mercury discharge; however, the extra supply of excited atoms and electrons created by the potential wave causes an extra-bright area in the lamp, brighter than surrounding areas because of this greater supply of excited atoms. Thus, although the striations appear to be moving clouds of bright light, the motion is an optical illusion. Actually the effect is the result of successive areas of the gas vapor becoming "superexcited" and then returning to their natural state as the exciting wave of potential moves on to an adjoining area of the vapor.

Using a phosphor-less lamp immersed in oil, striations have been studied under various conditions of vapor pressure and current. Of the numerous variables present in fluorescent lamps, these two seem to have the most pronounced effect on striations. As either is lowered, the cloud-like striations become more pronounced. Current and vapor pressure are also directly related. For a given lamp, a constant—the product of pressure and current—defines the point at which striations first appear in that lamp. Using a high-speed moving-film camera, Steele has obtained data for plotting curves of current versus pressure that provide these products for different types of lamps.

To the lamp, of course, lowering either the temperature or the current produces much the same effect. In either case the number of ions and electrons produced in the lamp under the lowered conditions is not sufficient to maintain the current through the lamp. At this point striations lend a hand by helping to excite and ionize the mercury vapor.

Other variables in lamp design have noticeable effects. Different combinations of gases used in the lamp change the point at which striations start. To date two gas combinations, mercury and krypton, and mercury and argon, common fluorescent lamp mixtures, have been investigated thoroughly.

Many unanswered questions remain yet to be worked out. The cause of the moving potential wave that accompanies the striations is not fully understood. Under certain conditions slow-moving striations are accompanied by fast-moving striations occurring at the same frequency. A probe inserted in the gas discharge causes an enhancement of the bright spots as they pass the probe. These factors and some others do not as yet have satisfactory explanations. H. L. Steele intends to continue to see "spots" in front of his eyes until the phenomenon of striations has a full and complete explanation.



This pattern of lines was formed by striations. High-speed moving film, whipped past the lamp at 90 degrees to the lamp axis, picks up each striation at successive points along the lamp; the result is a moving line of light for each striation. Lines slant from left to right, the direction of striation movement in the lamp.

The postwar metamorphosis of marine radar is resulting in apparatus better suited for use by operators of commercial vessels. It combines an extraordinary simplicity of operation with enough controls to give all the flexibility for fact-gathering even the expertly trained can desire. Checks on operation, new features to eliminate manipulation errors, and maintenance aids are bringing radar out of the clouds of mysterious complexity.

R. H. Foy
AND
L. J. Ulman
Industrial Electronics Engineering Department
Westinghouse Electric Corporation
Baltimore, Maryland

Radar Evolution Takes Another Step

The pattern of evolution of radar from its wartime forms to practical types for commercial marine service is becoming clearer. Out of it has emerged an improved marine radar equipment, known as the MU-1, embodying several new and important features.

Shortly after the war, when commercial radar was first produced, it was generally believed that the trend in radar equipment would be toward maximum simplicity of operation. Unlike radar-equipped military craft, most commercial ships do not have personnel whose major duty is the operation of the radar. The task of operating the apparatus is assigned to the officer on watch. Since he is not trained in radar techniques to a degree that would neglect other training, and since he is very busy at times of difficult navigation, it was believed that a set as simple as possible to operate would be most desirable.

This view has not altogether been borne out, however. As a result of a radar operational research program carried on by the Lake Carriers' Association and others during the past few years, several new trends on the part of shipping companies have become evident. More emphasis has been placed on obtaining as much navigational information as possible rather than on extreme simplicity of operation. In other words, the addition of one or two more control knobs is amply justified by the large increase in adaptability of the radar to varying conditions on the water. The size of the cathode-ray tube and the picture area have become much more important. Increased picture area, while it actually does not contain more detail, allows the tube to be viewed from a greater distance. This allows the operator, who may have other duties, more freedom of movement. A larger picture also aids an operator with less than perfect vision.

To meet the demand for large picture area, a new cathode-ray tube was developed. The cathode-ray tubes of large screen area previously used for radar were 12 inches in diameter with a curved face, having a usable diameter of 10 inches, or 10-inch diameter tubes having a usable diameter of nine inches and a nearly flat face. The new tube used in the MU-1 radar is 12½ inches in diameter and has a usable diameter of 11 inches. The radius of curvature of the face is double that of the 12-inch tubes. The combination of one fifth more picture area and comparatively flat face makes this tube definitely superior to previous 12-inch types. The flatter face of the tube is important since it reduces picture distortion and parallax when viewed from an angle, thus giving the operator more freedom of movement about the console.

In keeping with the demand for the most information obtainable, several new features have been incorporated. However, it has been recognized that the ability of ships' officers to operate radar differs widely. Therefore, the new radar has been constructed so that relatively inexperienced personnel can operate it and obtain all information necessary for collision warning and ordinary navigation. On the other hand, a skilled operator, by manipulation of the controls, is able to obtain additional useful information.

One of the problems in applying radar to lake and sea duty is to minimize the effect of unwanted reflections from the waves. The result of wave reflections is a confusion of "snow" or transient images near the center (short-range area) of the cathode-ray tube, perhaps to the extent of obscuring some small target, the detection of which is important to the navigator. Reduction of this effect is called sea suppression.

The MU-1 radar embodies two sea-suppression schemes, one of which is used on this equipment for the first time. One of these takes advantage of the fact that only nearby waves are able to provide echoes strong enough to show on the cathode-ray tube. Also, radio energy diminishes, as does any radiated energy, inversely as the square of the distance it travels, and in radar it has to traverse the distance twice (out and back). Thus the strength of any echo received at the radar diminishes as the fourth power of the distance to the reflecting object. Therefore, if the gain or amplification of the receiver in a radar set is varied as the fourth power of the distance to a given object, the amplitude of an echo from that object as presented to the cathode-ray tube remains constant. Thus objects near and far appear equally bright on the screen. Nearby waves are denied the opportunity of making particularly bright spots, and, because reflections from a moving wave are naturally less than from some solid object such as a buoy, wave echoes become comparatively faint.

In practice, the gain is greatest and becomes constant at a range beyond which the sea return is not objectionable. Also, this gain is, by proper circuits, made to decrease along a fourth-power curve for shorter ranges. The range of the maximum gain point is adjustable to suit the conditions of the sea, but no matter what range is used the gain should follow the fourth-power curve for closer objects. With this control properly set, unwanted wave echoes are suppressed to the point where they are only just visible on the scope. Once so set, the control need not be changed unless the sea condition changes and any target, buoy, small boat, etc., will stand out clearly on the scope providing only that the target is larger than the surrounding waves. When the wave size becomes larger than the target, the target will be obscured by the wave echoes regardless of the sea-suppressor control setting. This fact, incidentally, is true for any microwave radar. This control is one of two types of sea-suppression controls on the MU-1 radar and is continuously variable up to five miles.

A second phenomena is also used to reduce wave effect. Echoes from waves tend to be a long, more or less solid block of echoes, as waves are

Positive proof that the radar set is functioning and an idea of how well is given by the "light-beam" pattern superimposed on the scope by the performance indicator.

The picture at the right shows the greater detail available for medium ranges with the three-position sea-suppression control in operation. The view at left was made without sea suppression.

For close ranges (around the center spot) the use of the continuously variable sea-suppression control is extremely effective in disclosing objects that might otherwise be obscured by wave reflections. The two buoys and the ship in the right-hand view are hardly distinguishable in the left-hand view of the radar scope without using sea-suppressor control.

sufficiently close together to give a continuous return of energy to the radar receiver. Echoes from useful targets, such as buoys and ships, are of shorter length on the screen. If both types of echoes are passed through a certain type of circuit, only the first part of all echoes will appear on the cathode-ray tube. Thus, for the long block of waves, only random spots corresponding to the larger waves appear. The useful target appears as another bright spot. Therefore, a large portion of the echoes from the waves is effectively removed from the indicator. The degree of this effect can be adjusted by a control that varies the circuit. Also, because of the long persistence of the cathode-ray tube screen, the more solid, comparatively stationary objects, which occur in essentially the same position during successive rotations of the antenna, build up stronger response on the screen than do sea-echo peaks that occur in random positions. The second sea-suppression control has three positions. The first position is normal and has no effect on the sea or land masses. The second position of the control decreases the echoes from the sea and breaks up the land masses a medium amount. The third position breaks up the land echoes and decreases the sea echoes by as large a degree as practical.

To provide for the varying conditions of operation of shipboard radar, the MU-1 radar has six ranges or scales: 1, 2, 4, 8, 20, and 40 miles. The particular scale in use is indicated by an illuminated numeral that appears automatically near the lower edge of the tube face. This scale number is clearly visible to the operator even when he is studying the tube face with a viewing hood.

The combination of many ranges and a large cathode-ray tube insures the availability of an appropriate scale for practically any operating condition. The short ranges provide a clear picture of buoys, ships, dams, locks, bridges, and the shoreline for navigation in harbors and rivers, or when close to other ships in open water. The larger ranges are useful in open water for observing the positions of other ships and for navigation by reference to larger land masses when in coastal or inland waterways. Skilled operators have even been able to observe the progress of some types of storms.

The distance to any target shown on the tube is determined by the use of four range rings superimposed on the tube face, or by using a range marker that is adjustable from 200 yards to 20 miles. When the adjustable marker is moved to coincide with the target in question, distance is shown directly in miles or tenths of miles on a dial located on the front panel of the indicator console.

The heading of the ship is indicated on the cathode-ray tube by a radial line on the scope face extending out from the center, which represents the ship position. The line can be adjusted in brightness or can be eliminated, as suits the operator. When the radar is operated on relative bearing (bearings indicated relative to ship's heading), this line always appears at zero degrees. When the set is operated on true bearing, true north is always at zero degrees bearing, and the heading line or flasher appears at the true bearing of the ship.

The MU-1 radar can be equipped to receive signals from Raymark beacon provided at shore locations as navigational aids. These signals consist of a continuous transmission in the radar-frequency band. Since the radar antenna is highly directional, the signals from the beacon are received only when the antenna is pointing towards the beacon. The bearing of the beacon thus is shown as a wedge approximately two degrees wide on the cathode-ray tube. The Raymark-beacon signals aid radar navigation in the same manner that a lighthouse aids visual navigation.

When operating beyond the range of land targets, or where there are few targets, a means of determining whether the radar is operating properly is desirable. Provisions are made in the new equipment for the addition of a means to check the more important components of the set, such as the transmitter, receiver, waveguide, and antenna horn. The performance indicator consists of a broad-band echo box that receives energy from and re-radiates it through an aperture in the parabolic reflector of the antenna. Thus, it acts like a dummy target. The range to which this artificial echo extends is a measure of the overall performance of the radar set. The operation of the performance indicator is limited to a small sector to prevent its response from hiding any real targets on important bearings ahead of the ship. Thus the performance indicator gives assurance to the operator that the absence of echoes is positively due to the absence of real targets and not to malfunction of the equipment.

The indicator console is planned to facilitate maintenance. The front of the unit is a full-length hinged door, which the operator can open at any time to check the set while it is in operation. An inner control panel is located immediately behind the front door. This panel is also full length and so prevents any possible contact with operating voltages of the circuits in the console. Adjustments for the cathode-ray tube sweep circuit, receiver adjustments, calibration controls for the variable range marker, fuse indicators for fuses throughout the radar, and a multi-meter are located on the control panel. Thus, the more likely causes of trouble can be readily checked and corrected by the operating personnel without risk of contact with high voltage.

The multi-meter provides convenient metering of important circuits throughout the radar while the set is operating. It is readily removable from its normal mounting position so that it may be used for servicing the transmitter, which is often located some distance from the indicator console. The use of this meter reduces the amount of test equipment that the field service man must carry.

A removable plate on the control panel allows access to the wiring of the indicator chassis so that this unit can be serviced in its operating position. The entire inner control panel is hinged to give access to the inside of the console. Interlocks on the panel remove voltage from the set when it is opened. Major units inside the console are mounted on rails and can be easily removed.

The transmitter is housed in a weatherproof aluminum casting and so may be located on a weatherdeck. Units of the transmitter are easily removable through a gasketed door. The antenna is completely enclosed in a radome to insure continuous operation under adverse weather conditions and to prevent antenna speed variation or stalling due to wind. When required, infrared heating lamps can be added to prevent icing of the radome.

The uses for marine radar are many and varied. In addition to the obvious uses as a navigational aid and anti-collision device, it is being used by fishing fleets to locate schools of fish through the simple expedient of watching for the flocks of gulls that follow a school. Another use that has been tried experimentally is in the field of harbor advisory control service. In this case the radar is operated on the shore by the harbor authorities and is used in assisting harbor traffic movements. Extensive wartime experience, plus postwar refinements, has provided a valuable new tool for marine use. Radar will undoubtedly become as common and as widely used throughout the marine industry as the compass and the sextant are at present.

The *Industrial Gas Turbine* in Service

T. J. PUTZ, *Manager*
Gas-Turbine and Locomotive Engineering
Westinghouse Electric Corporation
South Philadelphia, Pa.

The experimental gas turbine, after extensive shop tests, is now getting a chance to prove itself in a tough application. Currently it has logged several hundred hours in pipe-line pumping service. Difficulties have been encountered, but to date these have been readily corrected. If further tests prove as successful, the gas turbine will win an important place for itself in this industrial service.

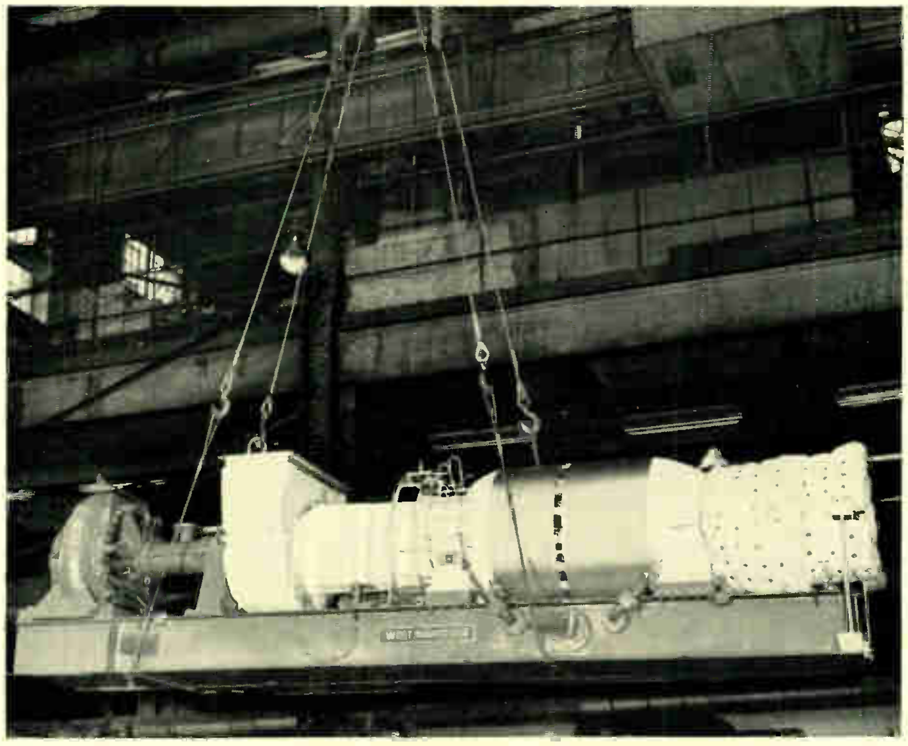


Fig. 1—The complete in-line gas-turbine unit, mounted on a single bedplate. Shown left to right: the single-stage centrifugal booster, air inlet, axial-flow compressor, combustors, turbine, and exhaust. The total unit weighs but 26 000 pounds and is 20 feet long.

SINCE last May the 2000-hp experimental gas turbine installed in a test station on a natural-gas line at Wilmar, Arkansas, has logged 900 hours in actual pumping service. While this is insufficient to prove the turbine as adequate for this service, the tests have been most encouraging. It has demonstrated that it can be put on and off the line with ease, controls well, and can operate equally well on liquid fuel or natural gas. The difficulties encountered were no more than could be expected; have been readily corrected; and have not been basic.

This test installation is on a 22-inch line of the Mississippi River Fuel Corporation connecting Monroe, Louisiana, with St. Louis. It is approximately midway between two conventional engine-drive stations at Crossett and Glendale, Arkansas. This location provides great flexibility in that it gives opportunity for the gas turbine and the centrifugal gas booster provided by Ingersoll-Rand Company to be tested throughout their entire operating ranges.

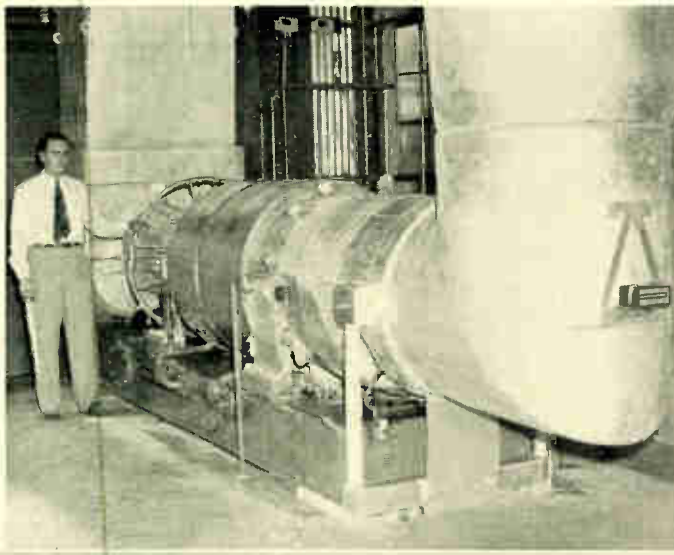
The purpose of the test is twofold. It is desired to demonstrate the suitability of this distinctly new type of drive for gas-line pumping. Secondly, each manufacturer wants to secure operating experience on his equipment in full-scale service. As for the drive, data can be obtained on the turbine, combustors, and other parts when operating at the full-load temperature of 1350 degrees F. The tests should demonstrate whether any component possesses a weakness or characteristic that would require redesign and further improvement. The tests, in short, are expected to provide data by which future gas turbines can be rated on a rational basis.

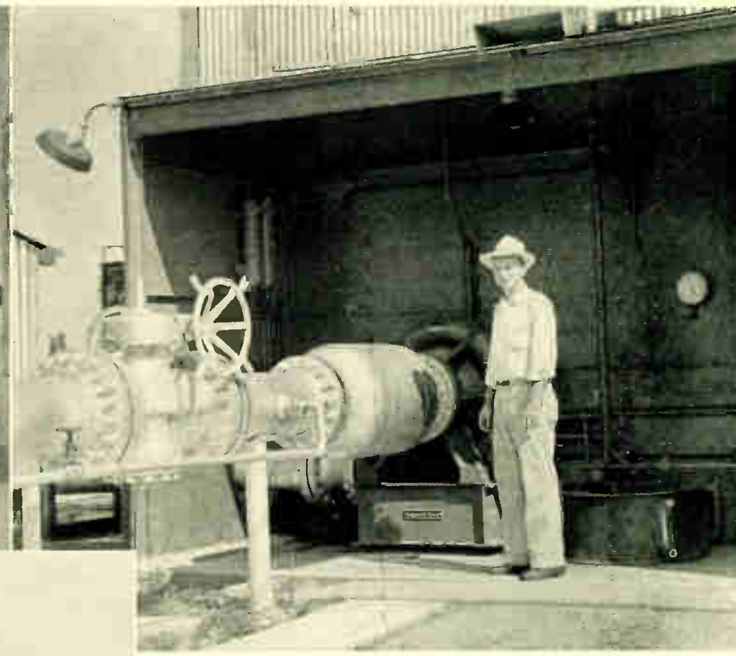
This gas turbine had already been rigorously tested at the factory.* Between August 1946 and December 1948, it underwent all manner of overall and component tests, totaling some 1500 hours of operation. This included tests that simulate a locomotive service, which is probably as severe as any that will be encountered in industrial service because the frequent starting and rapid changes in load from maximum to idling produce the worst combination of stresses resulting from heating and cooling. The results of these tests led directly to the decision to construct two identical units for a locomotive.

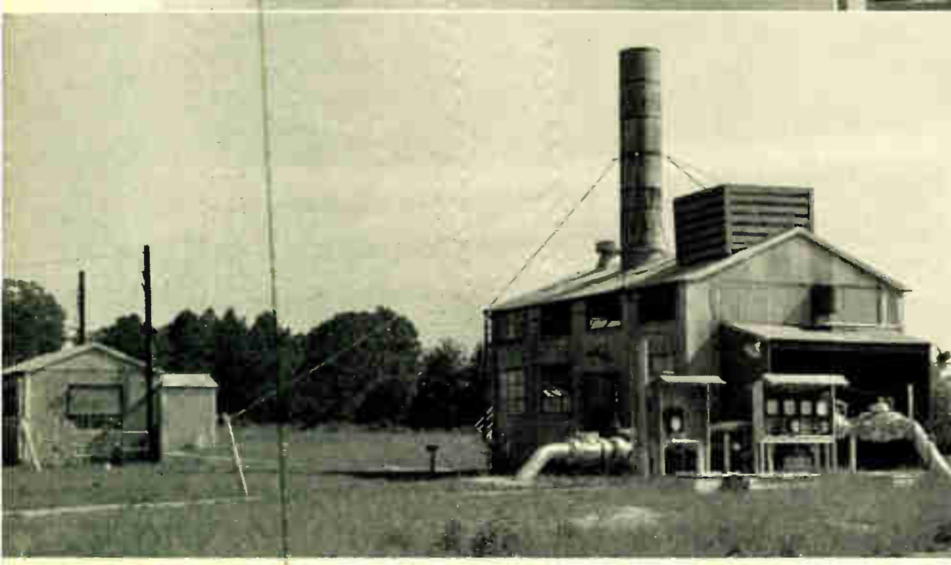
Upon completion of shop tests, the unit was altered to the extent of replacing the gear and electric generators with the new-type centrifugal gas booster and making other minor modifications. The complete in-line machine—consisting of a single-stage centrifugal booster, air inlet, axial-flow compressor, combustors, turbine, and exhaust—has a single bedplate (Fig. 1). It weighs but 26 000 pounds and is 20 feet long, by 5 feet wide and 4½ feet high. It is rated at 1850 hp at the warm inlet air conditions of 100 degrees F.

Such a drive offers promise of several advantages over present slow-speed reciprocating-engine plants customarily used at gas-line pumping stations. The space occupied and weight are small. A comparable reciprocating-engine drive compressor unit weighs about eight times as much, occupies six times as much floor area and ten times as much space—and these figures compare a well-developed piston-type drive with the first, and experimental, gas-turbine unit. This large decrease in weight and dimensions should allow significant savings in foundation and building costs, regardless of any differences in

*"2000-Hp Gas Turbine on Trial," by T. J. Putz, Westinghouse ENGINEER, March, 1948, p. 39–41







Upper Left—**The gas-turbine unit installed. The gas booster is beyond the firewall at the far end of the power unit.** ***Above*****—Close-up of incoming gas line and Ingersoll-Rand gas booster. It compresses 190 million cfm of gas daily from 337 to 400 pounds pressure. It uses successfully a new-type gas seal, in which oil under pressure higher than that of the gas is maintained in the booster casing, preventing gas leakage at the shaft.** ***Left*****—Incoming gas line and gas booster are at the right with outgoing line behind the two metering panels. The gas turbine, directly connected to the booster, is behind firewall.**

first cost, which obviously are yet indeterminate.

The gas-turbine power plant consumes almost no lubricating oil whereas any reciprocating power plant uses considerable. This direct saving is significant.

Perhaps of greatest moment in gas-pumping service is elimination completely of the cooling-water problem. In the first place the power unit requires no water. But, more important with closely spaced stations, the need for cooling water and a heat-exchanger system to cool the compressed gas before it is returned to the gas line for its journey to the next station is avoided. At present, several factors conspire to cause pumping stations to be relatively far apart. These include cost of apparatus, building requirements, operating and maintenance personnel needs, and the necessity for engine cooling water. As a result the energy delivered to the gas at each station is large, i.e., a large boost is given in pressure. Accordingly, the gas temperature is increased by 75 to 100 degrees. Unless this gas is cooled before it is discharged into the line, the capacity of the line is reduced, or the power requirements increased. This necessitates a water supply and heat-exchange system and also, in many locations, an expensive water-treating system.

Because of the potentially much lower first installed costs per station of a gas-turbine drive, the probable reduction in operating and maintenance people, and elimination of water problems, smaller but closer spaced stations could be used. The energy delivered to the gas at any one station would be reduced to the extent that the temperature rise—perhaps 20 to 30 degrees—would not require gas cooling. This would place in the turbine's favor the cost of cooling water, the freedom from water supply as a factor in station-site selection, the cost of a heat exchanger, and possibly the first cost and maintenance of a water-treating plant.

The gas turbine can burn either oil or gas. Interchangeable nozzles have been used in burning either type fuel in the same combustors. Composite nozzles can be provided that make it possible to switch instantly from one to the other in accordance with any fluctuation in the relative cost of the two, or in keeping with a sudden short-time demand for natural gas that the line carries.

Other features should weigh in the favor of the gas-turbine drive, although they remain to be proved by such tests as are now current under the auspices of the Mississippi River Fuel Corporation. The gas turbine is a rotating machine, with no reciprocating parts, and almost no metal-to-metal wearing parts. This should spell long life, infrequent overhauls, and much less operating attention. It is not outside the realm of possibility to consider that the gas-turbine drive will eventually develop into the simplicity of pushbutton starting and control—perhaps by a central operator located miles away. These and other matters will be watched at Wilmar with absorbing interest.

Personality Profiles

The research scientist and engineer have long been very much in the news and technical press, periodically breaking forth into print with notice of startling new discoveries. On the other hand, their colleague, the development engineer, rarely catches the public's eye. His is the equally important—but less glamorous—task of fully developing to a useful point the products of the researcher. Such is the work of *W. M. Leeds*.

The essential story of Leeds' extensive education (which, he says, is still continuing) can be told briefly: 1926, Haverford College, B.S.; 1930, University of Pittsburgh, M.S.; 1937, one year of study at M.I.T. as winner of the Westinghouse Lamme Scholarship; 1945, Ph.D., University of Pittsburgh. Leeds has 37 patents, all concerning circuit breakers.

In 1927, after a year in the student course and in the Meter Division, Leeds started on circuit-breaker development. He is at present manager of this development work, a position he has held for ten years. Leeds helped design the 287-kv breakers at Hoover Dam, still the largest in rating in service.

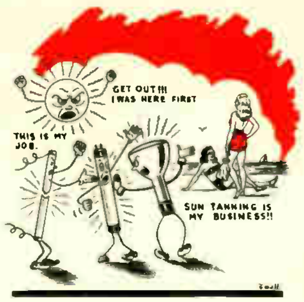
• • •

Few engineers upon graduation from college begin work immediately on the particular thing on which they are to specialize and become experts. *W. A. Derr*, however, started even before he had finished his training. His first assignment, upon coming to the student training course at Westinghouse in 1936, was to help test the supervisory-control equipment destined for the Hoover Dam to Los Angeles line. Two months later he was employed by the Switchgear Engineering Department. Thus he arrived on the supervisory-control scene in time to help with the planning of the exceptionally large control for the extension of the Pennsylvania Railroad electrification from Philadelphia to Harrisburg. Even the war couldn't divert Derr from his field. During hostilities he was involved in the planning and design of the largest Visicode system ever built—for process control in an atomic-energy plant. Since the war, in addition to making fairly conventional applications of supervisory control, he has helped adapt it to the new type of channel.

Derr is a Penn Stater twice over. He obtained his B.S. in E.E. there in 1935, and topped it with an M.S. in E.E. the following year. Since February, 1949, he has been in charge of the supervisory-control activity at Westinghouse.

• • •

Almost from the minute the fluorescent sun lamp was developed by Westinghouse, *Richard S. Sheetz* started to gravitate in its direction. For a man with his interests,



it was a "natural." On the side, Dick is an amateur magician, and the sun lamp's conversion of ultraviolet radiations of one wavelength into those in the sun-tanning region seems little short of pure magic.

Sheetz graduated from Bucknell University with a B.S. in E.E. in 1946, under a Navy training program. After his release from the Navy the same year, he entered the Westinghouse Student Course; in 1947, he was transferred to the Lamp Division as a factory engineer. Later in the year, he moved over to the Research Laboratories, and then to the Commercial Engineering Department early in 1948. Here he had his first contact with the fluorescent sun lamp, and when the opportunity presented itself to work solely on this project, he jumped at the chance, transferring to the Sterilamp-Tenderay Department that handles the sun lamp.

Sheetz is genuinely enthusiastic about his work, but his interest in magic is equally keen. He devotes much of his leisure time to frequent engagements with clubs and organizations, where he ably demonstrates how much quicker the hand is than the eye.

• • •

Most men who use apparatus or have to keep it in operating condition have definite ideas for improvement of its construction. Few ever have opportunity to execute those ideas. But *L. J. Ulman* and *R. H. Foy* were among those few. Both first "learned about radar" from the war and both in the last three plus years have been designing new radar equipment.

Ulman was able, after graduating from the University of Minnesota (B.E.E.) in 1941, to get in six months at the Philco Corporation as quality-control engineer on automobile radios before the events on December 7 brought him a new employer. Until 1945 he was with the U. S. Army Signal Corps as radar officer, an experience that took him to England and later to North Africa and Italy. Since 1945, at Westinghouse, he has worked primarily on radar design and is particularly proud of being principally responsible for the automatic focus control.

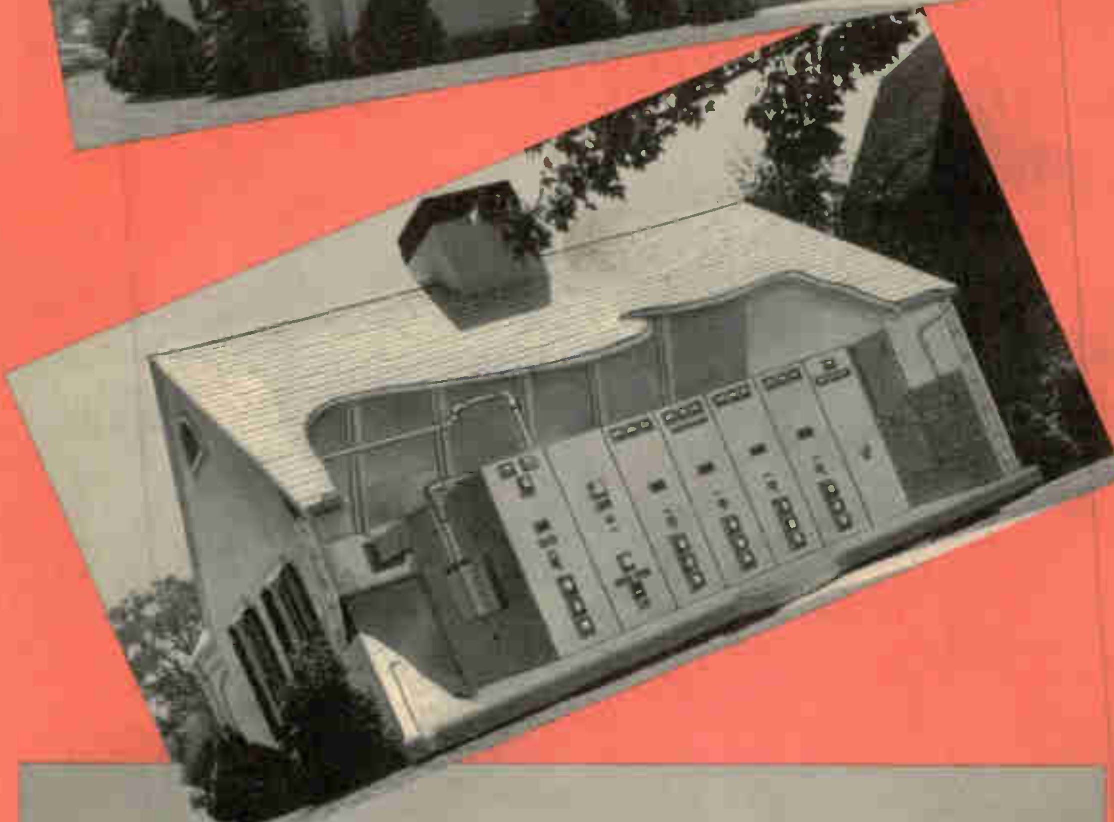
Ulman and Foy converged on radar design by similar routes but from contrary directions. Foy, a native Californian, went directly into the Signal Corps upon graduation from the University of California in 1942 (B.S. in E.E.). The first year he spent at the M.I.T. Radiation Laboratory helping develop the Army SCR-615 radar. This was followed by a year at the Signal Corps Radar Laboratory, Belmar, N.J., and two years of instructing, installing, and servicing radar, a part of this being with the 10th Air Force in Burma. Since 1946 he has been with Westinghouse, helping in the transition of radar from war to peace.

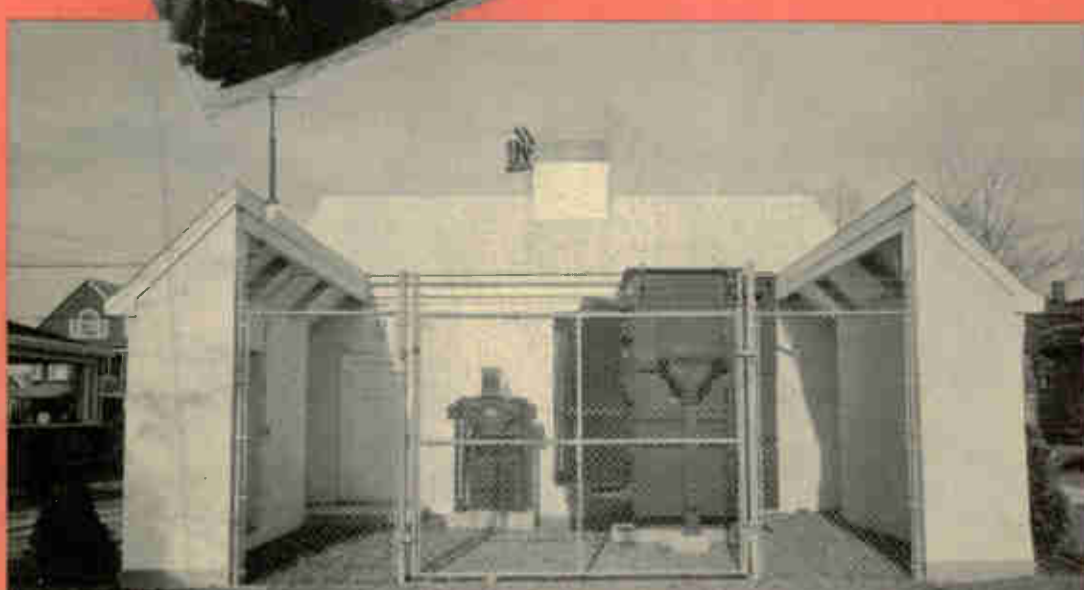
• • •

For more than twelve years *G. L. Moses* has been studying the "life" of an inanimate object. And, unusual as the subject may sound, this investigation, and subsequent development, has done much to increase the longevity of the object of his study—electrical insulation.

Moses' interest in insulation may stem from experience in his first job with Westinghouse, after his graduation from Bliss Electrical School in 1923. He joined the Railway Sales Department, and became thoroughly familiar with all the difficult conditions with which traction motors and their insulation must contend.

After leaving Railway Sales, he spent eight years in Renewal Parts Engineering and five in Railway Control Engineering, before turning to insulation problems as a full-time job. Since then Moses has made studies, and directed the work of others, on the thermal conductivity of insulation, insulation resistance, and the effect of temperature on insulation life. For the past five years Moses has headed the section responsible for these studies.





Not for Sale!

One day a lost, confused motorist stopped at the neatly kept Cape Cod bungalow (above) to ask directions. But what he saw inside the building when a serviceman, who happened to be there, opened the door, might have confused him more than ever. For the furnishings of this "house" are unusual. They consist of metalclad switchgear (center) and a 2500-kva transformer (below), forming a complete unit substation. The 13.8- to 2.4-kv transformer, which is equipped with tap-changing-under-load equipment, is located in the back of the house and is throat-connected to the switchgear in the front. The substation is located in a residential district and is "camouflaged" to prevent arousing resentment of the neighbors, who might object to the conventional substation with its outdoor circuit breakers, transformer, switchgear, and maze of steelwork. The bungalow, owned by The United Illuminating Company of Bridgeport, Connecticut, is so attractive that several ambitious house seekers have tried unsuccessfully to buy it.