BELL LABORATORIES RECORD

INDEX

VOLUME 17

from September 1938 to August 1939

BELL LABORATORIES RECORD

Bell Telephone Laboratories, Incorporated
463 West Street, New York, N. Y.

LIST OF ISSUES IN VOLUME XVII

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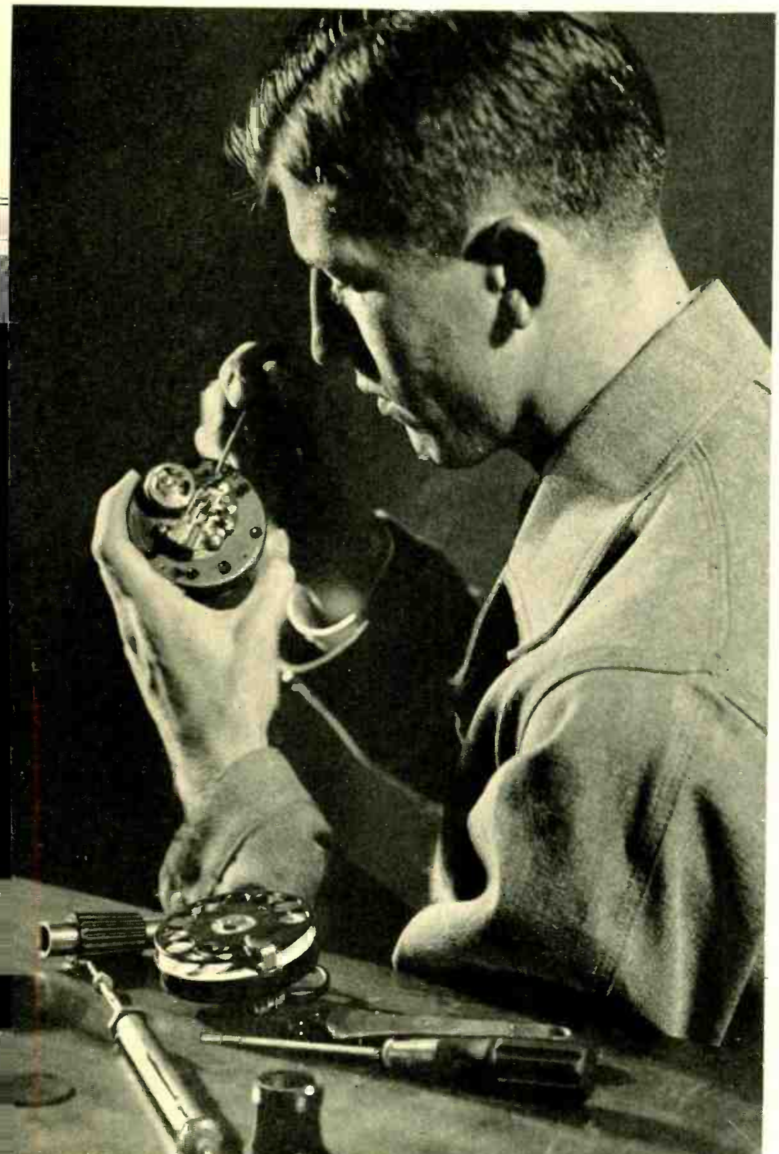

SEPTEMBER
1938

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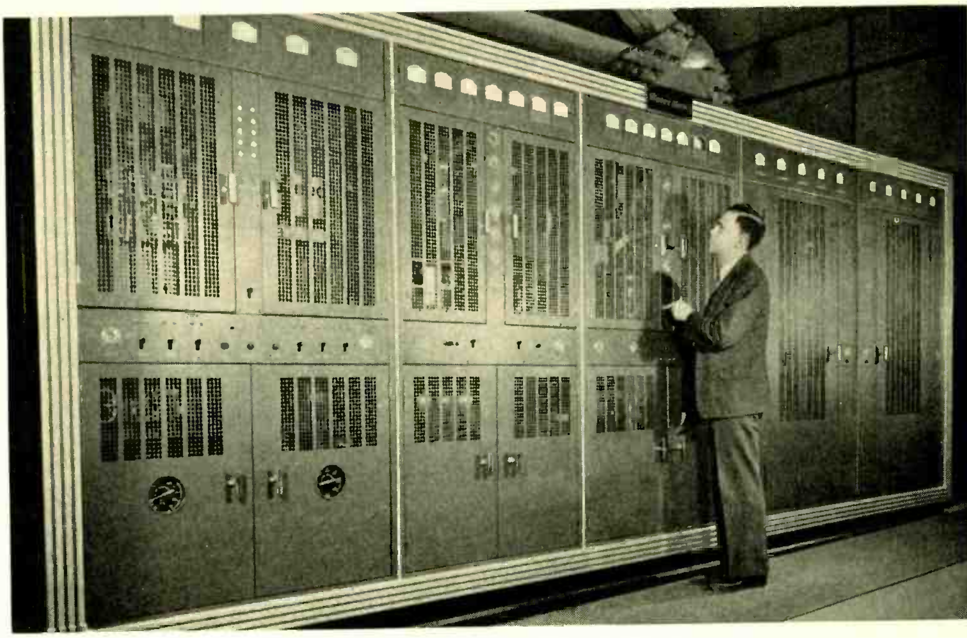
NUMBER I

Adjusting a telephone dial before it undergoes laboratory life tests



A 50-KW Broadcast Transmitter

By A. W. KISHPAUGH
Radio Development Department

A LITTLE over ten years ago the radio station call letters 3XN, of our Whippany laboratory, received world-wide notice because of transmission incidental to the testing of the first fifty-kilowatt radio-broadcasting transmitter of commercial design. The development of such a transmitter at that time was a pioneering venture involving the use of larger vacuum tubes and a higher plate voltage than had been employed before. Because of this there was a great deal of interest in the apparatus and in the tests of it. The performance of the equipment was excellent and its completion marked an important step forward in the development of radio broadcasting.

During the past year another fifty-kilowatt broadcasting transmitter has been under test at Whippany. It is the latest Western Electric transmitter of this size, and has been coded the 407A. Although the use of fifty kilowatts for broadcasting is no longer a novelty, this new equipment presents such a number of features of importance that the progress represented is comparable to that which aroused interest when the first fifty-kilowatt transmitter was being tested at Whippany in 1927. While the achievement at that time was principally in the utilization of increased power, the present advancement is in refinement of transmitter design to give improved performance, and more efficient, more reliable, and more economical operation.

An outstanding feature of the new equipment is the use of the high-efficiency amplifier circuit* invented by W. H. Doherty of the Whippany staff. By use of this circuit in the final amplifier stage, the power consumption of the transmitter has been greatly reduced, the plate losses in the power amplifier being cut from nearly one hundred to less than thirty kilowatts. Among the other features that make the transmitter outstanding in its class are the use of stabilized feedback to minimize noise and distortion, complete a-c operation to eliminate motor generators for filament current and grid bias voltages, two 100-kilowatt tubes in the final stage instead of six smaller ones, complete remote control of all power circuits, automatic regulators for plate and biasing supplies, and individual control of the filament voltages of the power amplifiers.

The equipment of the fifty-kilowatt transmitter is indicated in Figure 1. The audio- and radio-frequency circuits are included in four units arranged as a line of cabinets as shown in the photograph at the head of this article. At the left is the control unit, where is centered the operating control of the entire equipment. Here are toggle switches that operate contactors on the power-distribution panel for all circuits, and pilot lamps that indicate circuit conditions and sources of interruption. The second unit is the oscillator amplifier, which includes the oscillator and three radio-frequency amplifier stages, and the entire audio-frequency circuit. The next unit is the modulating amplifier. It includes two tubes operated in parallel with grid-bias modulation. The output of this section drives the fifty-kilowatt amplifier, which forms the final unit. In this are two 100-kilowatt tubes operated in a Doherty high-efficiency circuit. The appearance of this section, with its two doors open, is shown in Figure 2.

Besides these four major units there is the power and rectifying equipment, the component parts of which are usually installed in an enclosure behind the cabinets or on the floor below. All the power required for the transmitter is taken from a 460-volt three-phase supply, which is carried directly to the power distribution

*Record, *June*, 1936, *page* 333.

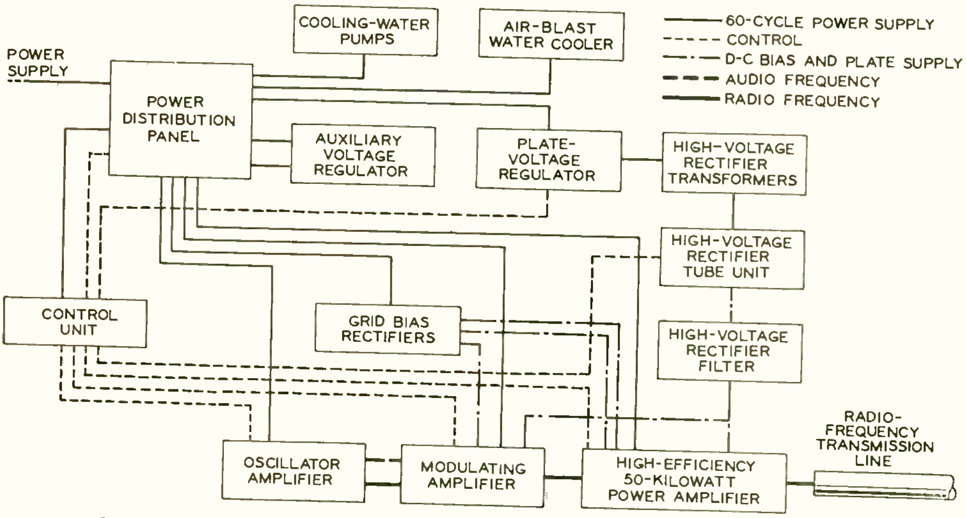


Fig. 1—Circuit plan for the 50-kw Western Electric broadcast transmitter

panel. No fuses are employed, all circuits are protected by circuit breakers and power for the various circuits is switched through contactors operated from the control unit. All the power except that for the pumps and fans of the water-cooling system is regulated to secure constant voltage. Two automatic regulators are employed. One of them supplies the high-voltage transformers for an 18,000-volt rectifier that furnishes plate potential for the power and modulating amplifiers. The other feeds a bus in the distribution panel from which circuits are taken for the oscillator-amplifier units, for filament supplies for the other amplifier units, and for three bias rectifiers for the modulating and power-amplifier stages.

It is very desirable to have the major units of a broadcasting transmitter so designed that they will serve as building blocks from which various sizes of transmitters may be assembled. This enables a broadcaster to start with a low-power transmitter and increase his output from time to time with a minimum of expense. This principle has been followed in the design of this fifty-kilowatt transmitter.

The first three units of this transmitter are essentially the same as those of the five-kilowatt transmitter that is described on page 7 and include all the features there discussed. The smaller size of the modulating amplifier of that transmitter, however, permits it to be included in the oscillator-amplifier unit, which becomes the driving unit. The five-kilowatt power amplifier occupies the third cabinet, which is the final one of the five-kilowatt transmitter. The driving unit alone of this transmitter may also serve as a complete 100-watt transmitter. Provisions are also made for increasing the output of the fifty-kilowatt transmitter to five hundred kilowatts by the addition of a five-hundred-kilowatt amplifier. In each case certain circuit and equipment changes are necessary, but by careful design the changes have been reduced to a minimum, and the flexibility provided does not impose any economic penalties on

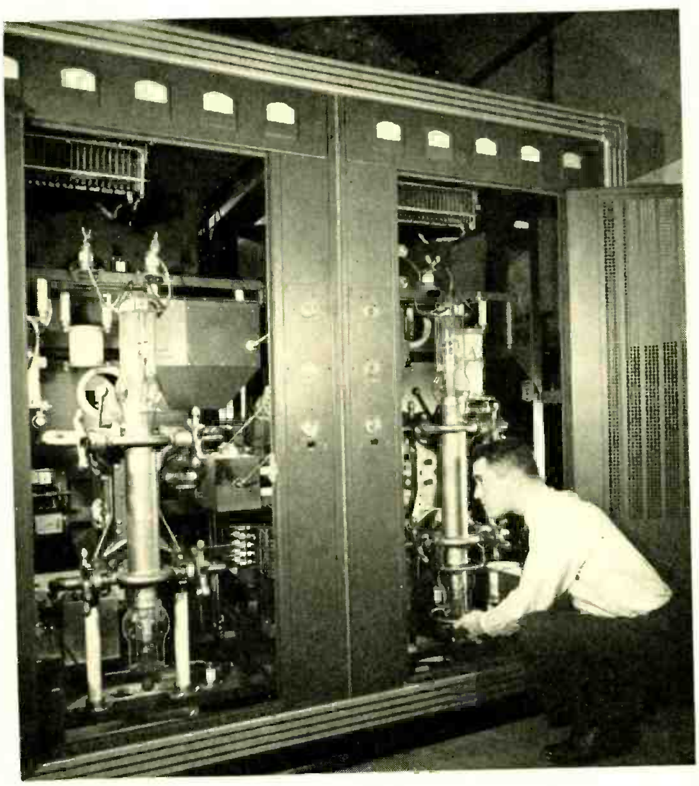


Fig. 2—The 50-kw power-amplifier stage showing the two double-ended 100-kw tubes

the purchase of any one size. Besides these arrangements for increasing the power of the transmitter, provisions have also been made for arranging the transmitter to operate at reduced power during certain hours or under emergency conditions. The minor modifications required depend for the most part on the particular conditions encountered in each installation.

Continuity of service is becoming increasingly important in the operation of broadcasting stations, and to some extent is of greater importance the larger is the station. In this new fifty-kilowatt transmitter, therefore, every effort is made to avoid shutdowns by warning signals and to reduce to a minimum the time off the air when an interruption does occur. Certain of the protective arrangements are described in connection with the five-kilowatt transmitter. One of the added features of the fifty-kilowatt transmitter is the provision of a seventh, or spare, rectifier tube in the rectifier for the power amplifier. This tube is connected to busses and may be rapidly substituted for any of the others without removing it.

Arc-backs are infrequent with modern rectifier tubes. When they do occur, they are quickly cleared in this transmitter by a very fast circuit breaker in the main feeder to the rectifier. This breaker automatically recloses once after it opens and thus makes the interruption so short as to be unnoticeable. At the same time arc-back relays give an indication of the particular tube in which the arc-back occurred. Another safeguard is the provision of three single-phase transformers for supplying this rectifier. Two of them in an open-delta connection will carry the full load, and thus any one of the three transformers may be considered as a spare.

With the same general objective, many protective circuits are included in the control unit to insure continued operation by giving warning of dangerous conditions and controlling the sequence of the operating procedures. Among these are electrical interlocks to prevent the application of power in the wrong sequence, the automatic reduction in the rectifier voltage before starting, and temperature and flow meters in the cooling water system that will give an alarm and, if necessary to avoid damage, will remove power immediately from the water-cooled tubes.

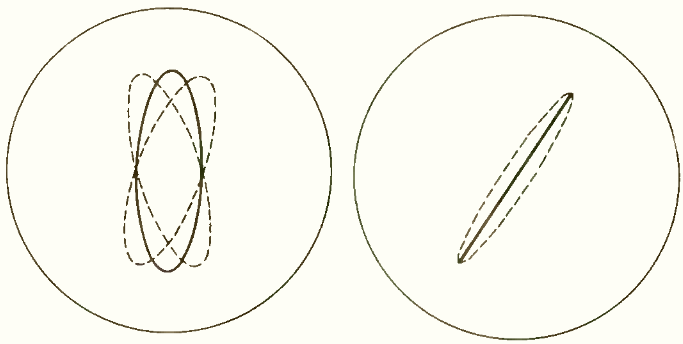


Fig. 3—Cathode-ray oscilloscope patterns obtained in adjusting Doherty amplifier. Solid curves are the patterns for correct adjustment, and dotted curves are out-of-tune patterns

Tuning for the high-efficiency Doherty amplifier is easily checked by the aid of a cathode-ray oscilloscope, which can be connected by plugs and jacks to the plates and grids of the two 100-kilowatt tubes. When correctly adjusted, the grid potentials of the two tubes are approximately ninety degrees apart, and will show a vertical ellipse on the oscilloscope as shown at the left of Figure 3. The dotted ellipses indicate improper adjustment on either side of the correct one. Between plate and grid the phase relationship is 180 degrees, and the pattern for correct adjustment is a diagonal line. When the phasing is not correct, the line widens to an ellipse as shown at the right of Figure 3.

The performance of this new fifty-kilowatt transmitter is of the high order required of modern broadcasting equipment. From the broadcaster's standpoint, the economy and ease of operation will set new standards. From the standpoint of transmission little further improvement can be visualized. Through careful circuit design and with the benefits of negative feedback, the audio-frequency characteristics approach perfection. The audio-frequency response does not vary more than one decibel between 30 and 10,000 cycles. The audio distortion at complete modulation will not exceed five per cent over the 50 to 5000-cycle range, and is very much less with average modulation. The carrier noise is negligible, being more than sixty decibels below the signal at 100 per cent modulation.

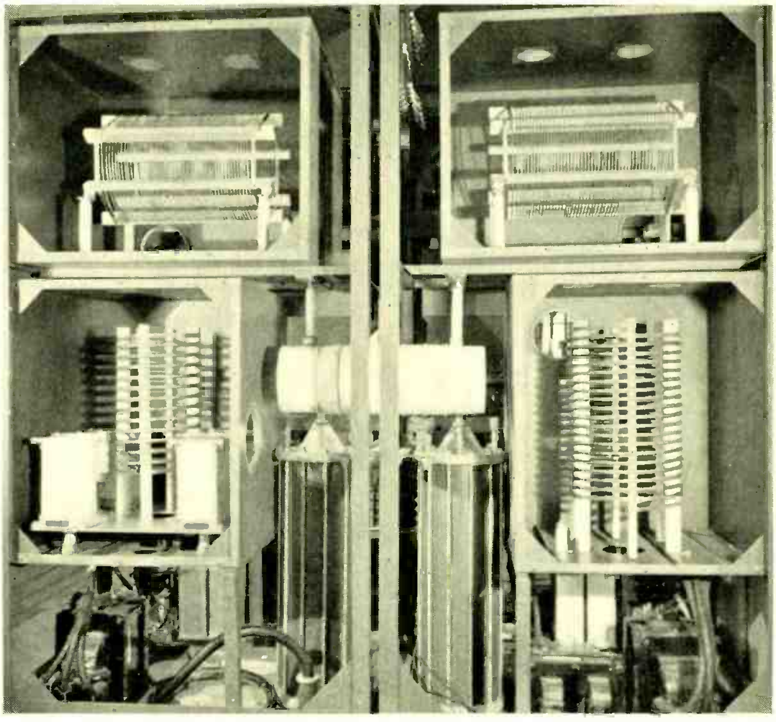
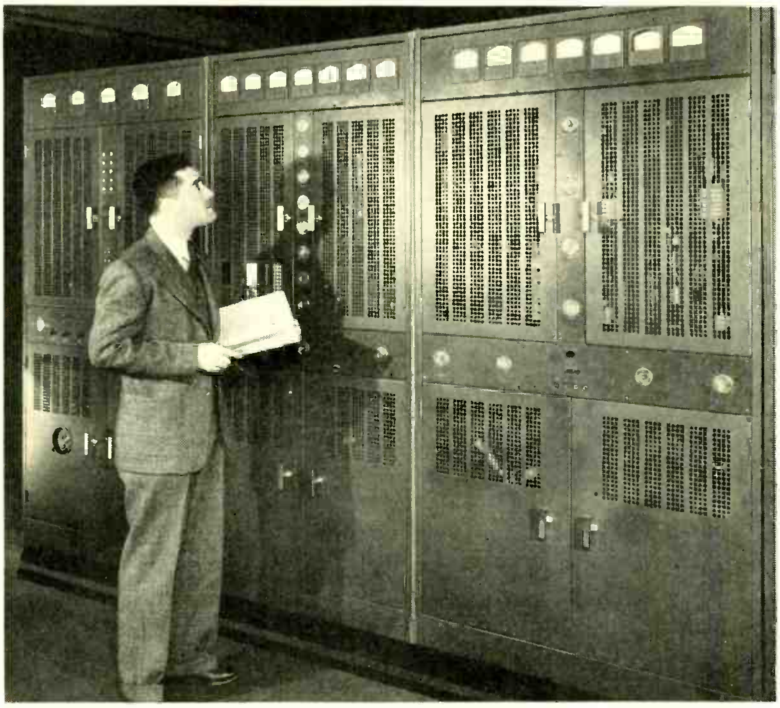


Fig. 4—Rear of 50-kw amplifier showing radio-frequency coils and gas-filled tuning condensers



Improved Design for Five-Kilowatt Broadcast Transmitter

By R. E. CORAM
Radio Development Department

THE new Western Electric five-kilowatt broadcast transmitter is the first of its size to use the Doherty high-efficiency circuit. While other five-kilowatt transmitters have operated in the neighborhood of eighteen per cent overall efficiency, thus requiring twenty-eight kilowatts input for five kilowatts output, this new transmitter operates at an efficiency of thirty-one per cent, and requires only sixteen kilowatts input. Besides this almost fifty per cent reduction in the power required, the new transmitter makes appreciably less demand on space; for the recommended arrangement an area about eleven feet square is all that is needed. The advantages of the new transmitter, known as the 405A1, are not limited to these two major improvements, however. A number of other features have been incorporated that make its operation easier and more dependable, and its characteristics are also better.

One of these features is the use of a protective circuit, already described in the RECORD,* which operates on any type of disturbance and disconnects the power until the trouble has cleared itself, which is usually only a small fraction of a second. This

*RECORD, *March*, 1938, *page* 254.

prompt removal of power avoids the serious damage that might otherwise result from heavy discharge currents, and reduces the time off the air to inappreciable intervals. An important feature of this circuit is a meter that indicates continuously the state of circuit adjustment, and in some cases gives warning of approaching trouble.

Stabilized feedback is also employed, and—as may be seen in Figure 1—is taken from the output of the transmitter through a full-wave rectifier and fed to the first audio stage, thus covering the entire transmitter. To make the feedback more effective, the transmitter circuit is grounded on one side, which permits a higher ratio of resistance to reactance than would a balanced circuit, and thus appreciably broadens the width of the frequency band over which feedback is effective.

Mounting space is provided for two 702A oscillators, both of which are kept at the operating temperature at all times, and a small switch adjacent to them permits either to be switched into the circuit at a moment's notice. With all possible variables changing in the same direction at once, the frequency deviation is much less than ten cycles. Ten cycles, although it is the guaranteed deviation for the transmitter, is only one-fifth of the fifty-cycle requirement of the Federal Communications Commission. The oscillator is provided with a fine adjustment so that the frequency can be set to agree exactly with the frequency

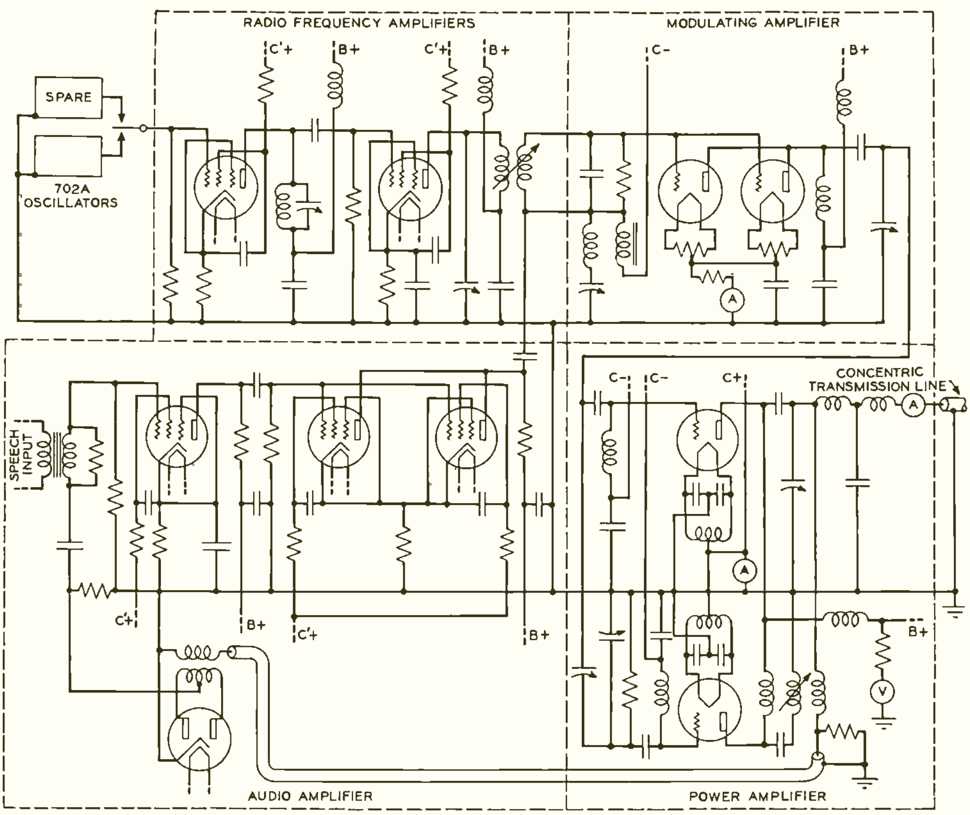


Fig. 1—Simplified schematic of the 5-kw (405A1) radio transmitter

monitor or with any other reference standard. Space is provided adjacent to the oscillator to permit the required synchronizing apparatus to be installed if the transmitter is to be made part of a synchronized system.

Following the oscillator are two stages of radio-frequency amplification, and then the modulating amplifier, which consists of two tubes in parallel. The program voltage is obtained from a two-stage amplifier which requires only six milliwatts input—zero level—for full modulation. The second stage of the audio amplifier, like the modulating amplifier, consists of two tubes in parallel. These four sections of the circuit—oscillator, radio-frequency amplifier, audio-frequency amplifier, and modulating amplifier—make up the driving unit, and are all mounted in a single cabinet as shown in Figure 2. The five-kilowatt amplifier, which the modulating amplifier drives, also consists of two tubes, arranged for Doherty high-efficiency operation. This amplifier is housed in a cabinet similar to that of the driving unit, and is shown in Figure 3.

The proper operation of this high-efficiency amplifier depends on a ninety-degree phase relationship between the plates and between the grids of the two amplifier tubes. This non-critical adjustment is made simple by the provision of an oscilloscope which can be plugged across the plate and grid of either tube, or across the two grids or the two plates. When the amplifier is properly adjusted the oscilloscope will show a diagonal line when connected across grid and plate, and an ellipse when connected across either pair of grids or plates. With the amplifier improperly tuned these lines change to ellipses, and the ellipses in turn may lie at any angle. Tuning consists only in adjusting a condenser to bring the proper orientation for each connection of the oscilloscope.

Fig. 2—The oscillator-modulator unit with front doors open. The two crystals are at the left in the upper compartment

Another convenient feature of this transmitter is its power supply. From the main circuit breaker, the power is carried through a regulator which automatically keeps the potential at 230 volts, and is then carried to the distribution cabinet. No fuses are employed. All the branch circuits pass through automatic circuit breakers, which may promptly reclose after they have tripped by an overload. The main circuit breaker is of the reclosing type, and automatically reapplies the power once after an overload. All switches are operated from the control unit shown in Figure 4 and at the left of the photograph at the head of this article. Here are installed the indicating lamps, meters, and switches that are required for operating the transmitter.

Another interesting feature of the transmitter is the use of straight porcelain pipe, glazed inside and out, as the insulating connection for the cooling water supply for the five-kilowatt amplifier tubes. Formerly these connections have been either unsightly rubber hose or a coil of ceramic tubing, which is not glazed on the inside and is difficult to clean on the outside. This piping may be seen on either side of the lower compartment of the five-kilowatt amplifier that is shown in Figure 3.

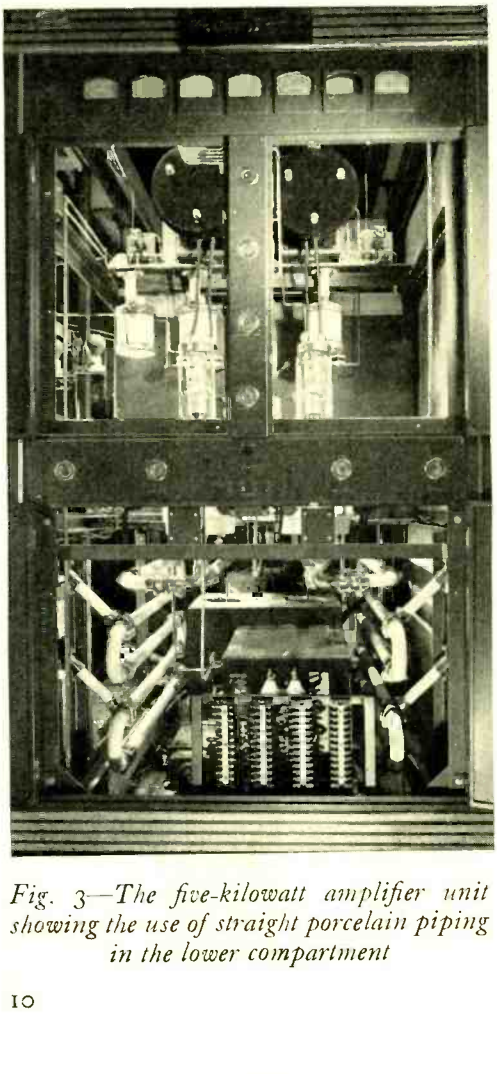


Fig. 3—The five-kilowatt amplifier unit showing the use of straight porcelain piping in the lower compartment

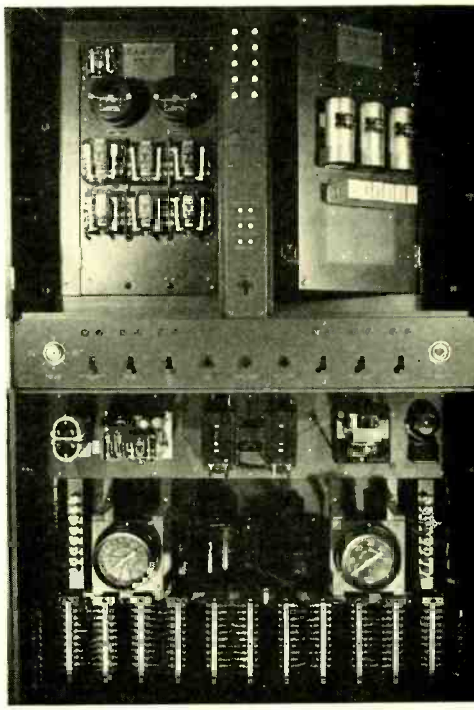


Fig. 4—The control unit with doors open

The frequency response of the 405A1 is flat to within three-quarters of a db from thirty to ten thousand cycles. At complete modulation, the distortion is under four per cent at all frequencies, and in the important middle-frequency range, it is less than 2.5 per cent. At 85 per cent modulation, the distortion is under 2.5 per cent for the entire band, and is under 1.6 per cent for the middle-frequency range. Unweighted noise is down more than sixty db from the signal.

This transmitter is a product of the development of the new fifty-kilowatt transmitter, and may be converted to fifty-kilowatt output by the addition of an amplifier and a few other changes. The output may also be readily increased to ten kilowatts if desired. Besides these possible increases in power, the transmitter is arranged for an instantaneous reduction to either 2.5 or 1 kilowatt to permit the station to operate at reduced power for certain hours of the day. These features, with the simple control and tuning arrangements, provide a highly flexible transmitter.

Improved Mouthpiece for Operators' Transmitters

A shorter mouthpiece has recently been developed for operators' transmitters, primarily for use where records have to be consulted frequently, such as at information and intercepting positions. An improvement in vision results and this in turn provides more uniform transmission since there is less need for an operator to turn away from her mouthpiece.

The curve of the horn has been reduced and the flare at the larger end increased to make an opening of approximately the same size as that of the mouthpiece in use. The transmitter housing tilts at a higher angle than at present but this does not affect its performance at angles ordinarily met in practice.

The new horn, which is molded of phenol plastic instead of rubber, has a better appearance and a more durable finish.

Electron Analysis of Stearic Acid Films

By L. H. GERMER
Physical Research

THAT a beam of electrons is scattered by a crystalline substance in definite directions has been known for some time.* In this behavior electrons act like waves, and the phenomena resemble those observed in any case of diffraction. If a photographic plate is held in the path of the scattered electrons, regular patterns like those shown in the accompanying illustrations are recorded. The locations and character of various features on the plate depend on the structure of the crystalline material and on the velocity of the electrons. In favorable cases the structure can be determined from measurements made upon the plate.

This technique has been applied to studying the structure of layers of stearic acid, a heavy fatty acid which crystallizes in soft, thin, mica-like flakes. Figures 2 and 3 were obtained by bombarding, at small glancing angles, a thin layer of this acid which had been deposited on a block of metal. The patterns consist largely of straight lines, all of which lie normal to the surface of the acid. They show that the acid layer is composed of crystals which have widely spaced planes lying parallel to the surface, and the sharpness of the lines indicates that the crystals are well formed.

Figures 4 and 5 were made by a different method. Films of stearic acid were deposited on very thin transparent foils, and electrons passed directly through them instead of being reflected at glancing angles. For comparison, the diffraction pattern of a single crystal of stearic acid is shown in Figure 6. The resemblance to Figures 4 and 5 is close enough to justify the conclusion that all three were produced by crystals of the same structure.

The stearic acid specimens were obtained by dipping the supporting block or foil repeatedly through a film of stearic acid which was floating on water. Each immersion added a layer of acid one molecule thick and another layer was added on removal. Measurements of the photographs show that the mean orientation shown in Figure 4 corresponds to a fifteen-degree inclination of one of the crystal axes to the direction of dipping, while the orientation shown in Figure 5 indicates parallelism of

*Record, *April,* 1927, *page* 257; *March,* 1936, *page* 210.

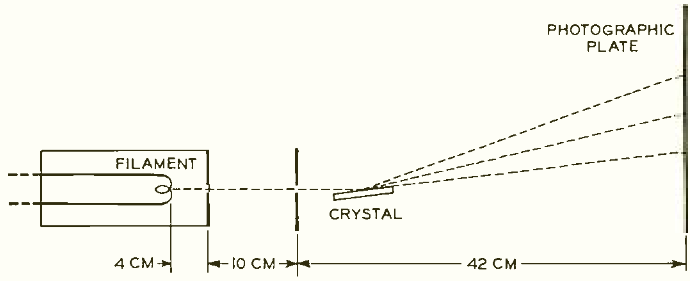


Fig. 1—Electrons from the hot cathode at the left pass through narrow slits and are reflected from the layer of stearic acid onto the photographic plate at the right

this axis and the dipping direction.

A more detailed analysis of the photographs shows that the stearic acid layers consist of monoclinic crystals in which chains of carbon atoms are parallel to the long crystallographic axis, and that the orientations of these crystals are distributed about a mean orientation which is simply related to the direction of dipping. An analysis of this kind is relatively easy, and leads one to presume that similar electron diffraction methods can be applied to determining the structures of built-up films of various compounds.

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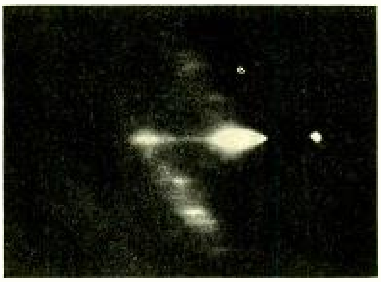

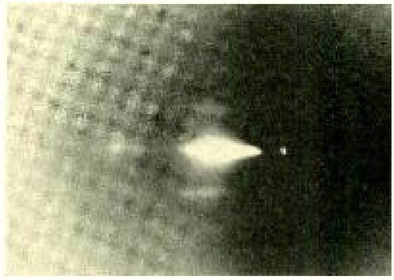

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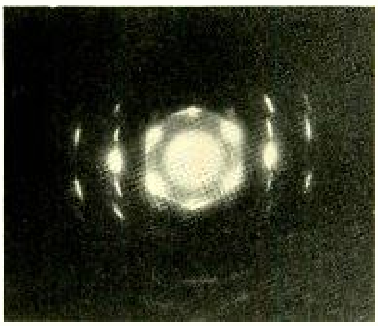

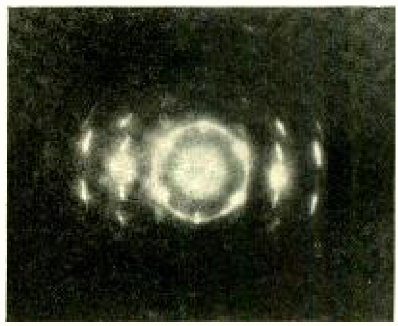

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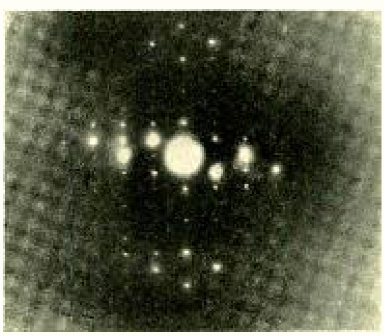

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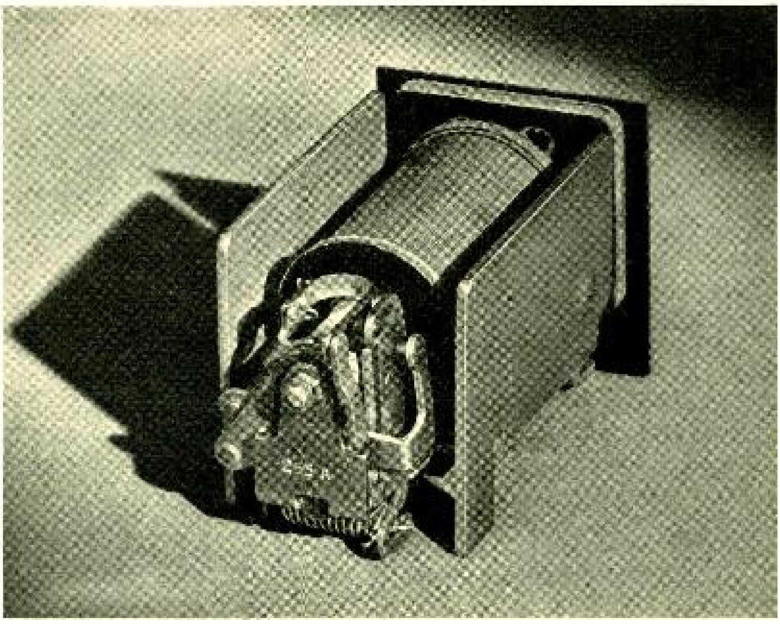
Figs. 2 and 3—Diffraction patterns obtained by scattering electrons at small glancing angles from the surfaces of built-up films of stearic acid. Figs. 4 and 5—Diffraction patterns produced by electrons which have passed normally through built-up films of stearic acid. Fig. 6—A comparison photograph obtained by passing electrons normally through a stearic acid single crystal



Charging Control for PBX Batteries

By C. S. KNOWLTON
Power Development Department

BATTERIES for the smaller private branch exchanges are generally charged on a continuous basis by a local rectifier or over cable pairs from the central office. The charging rate is adjusted periodically so that the battery will not become too badly discharged after heavy load periods or excessively overcharged after light load periods. To secure longest life and least maintenance on a battery, however, it should be kept as nearly as possible at full charge all the time, with a minimum of overcharge or discharge. With a periodic adjustment of the charging rate at fairly long intervals, this is not possible. To improve the charging of PBX batteries, therefore, a relay known as the 253 type has recently been developed which—arranged in a suitable circuit—will permit a much closer approach to the ideal conditions.

The primary function of the 253-type relay (designated CC in Figure 1) is to select either of two charging rates depending on the state of charge of the battery. One is a high charging rate, which is set by adjustment of the resistance R2, to replace the telephone load drain; the other is a "trickle charge" rate, which is set by adjustment of resistance R1 in series with R2. This latter rate is adjusted to supply the required "trickle" charge to compensate for internal losses in the battery, and also the current for operating the relay and any other fixed load, such as lamps, that may be normally connected across the line. With the relay unoperated, the resistance R1 is short-circuited by its back contact, and the battery is charged at the higher rate. When the relay operates, R1 is cut into the circuit, and the charge is reduced to the trickle charge rate.

To enable it to function properly in such a circuit, the 253 relay is designed to have a stable operate voltage, and adjustments have been provided on the relay to make it operate at the desired value. As the battery is charged, its voltage rises, and when the voltage corresponding to full charge is reached, the relay operates and removes the short-circuit across the resistance R1.

The relay is thus a voltage-sensitive device to stop the charging when the battery has reached the full-charge condition. The release voltage of the relay is not accurately controlled, however, and as a result the relay will not release as the battery voltage begins to drop. Some other arrangement must be provided to trip the relay periodically without regard to the state of charge of the battery. After the relay is tripped the battery will begin to charge at the high rate, and the relay will then again discontinue this charge automatically when the battery has been properly charged.

One method of furnishing this tripping feature, used in some of the smaller installations, is provided by the CT relay as shown in Figure 1. This

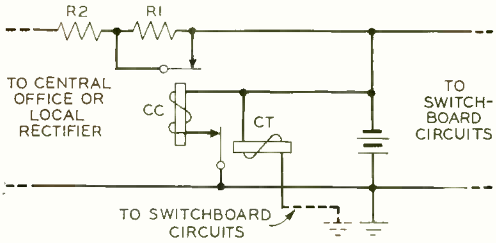


Fig. 1—Circuit used for controlling the charging of small batteries

relay operates whenever a subscriber has the receiver off the hook, and, in operating, it opens the circuit to the winding of the CC relay, thus tripping it, and allowing the higher charging current to flow, which continues until the battery is full charged and the

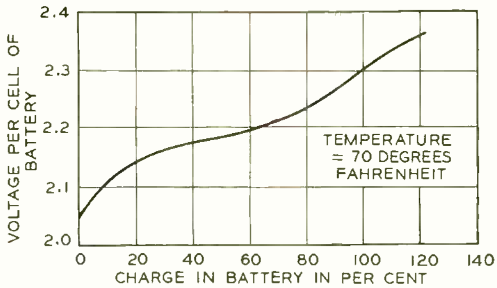


Fig. 2—Variation of battery voltage with state of charge

CT relay has released, when the CC relay operates, thus reducing the charging current to the trickle rate. Other methods of tripping the CC relay may be used, controlled by different circuit operations or by time-delay relays.

The voltage across a battery undergoing charge varies with the state of charge, with the amount of charging current, and with the temperature of the battery. The resistance R2 is adjusted so that at full charge and some specific temperature the charging current will be of the correct value to give the "operate" voltage of the CC relay. Should the temperature change, however, the battery voltage would change, with the result that the CC relay would operate at some other than the correct state of charge.

The variation in battery voltage with state of charge and temperature is shown in Figures 2 and 3 for one particular charging rate. It will be noted that for the particular charging rate illustrated the battery voltage at full charge is 2.3 volts per cell at seventy degrees Fahrenheit. This is the voltage at which the cc relay is adjusted to operate. Should the temperature change, however, the usual type of relay would operate at some other condition than full charge of the battery. If the temperature were higher than seventy degrees, the relay would operate only after the battery were overcharged, while if the temperature were less than seventy degrees, it would operate before the battery were fully charged. To offset the effect of temperature, the relay operate voltage should vary with the temperature—being lower for high temperatures, and higher for low.

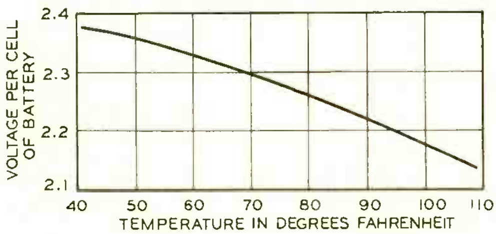
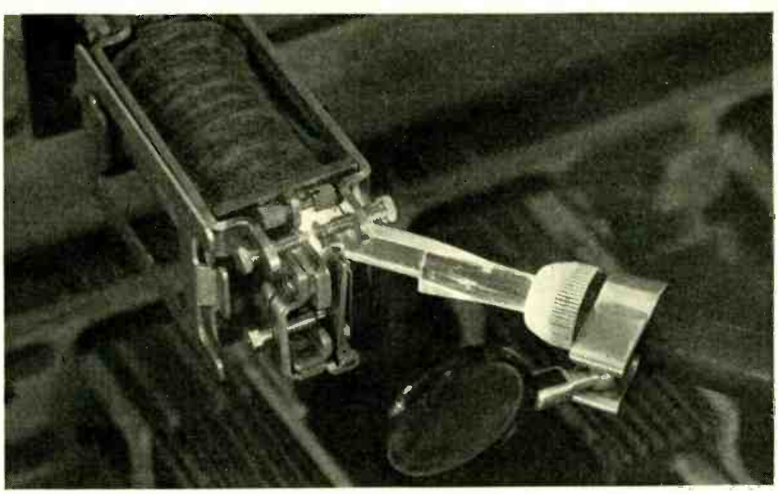


Fig. 3—Variation of battery voltages with temperature

This temperature compensation is provided in the 253-type relay by a bimetallic strip that changes the tension on the restoring spring of the relay. As the temperature rises, this bimetallic strip flexes to lessen the spring tension, so that the relay will operate at a lower voltage, and as the temperature drops the reverse action takes place. The relay is mounted near the battery so that the air conditions will affect both alike.

This new relay thus provides a simple and economical method for controlling the charging rate of small batteries supplied from a d-c source such as rectifiers or through cable from a central-office battery. By preventing excessive overcharging and undercharging, it is expected that the use of the relay will effect a marked increase in the average life of the small batteries in telephone plants.



Light from a small lamp in the handle of this relay tester is reflected from the front surface of the transparent lucite end-piece back onto the rear of the contact spring of the relay. The silhouetted spring-assembly is inspected with the magnifying glass

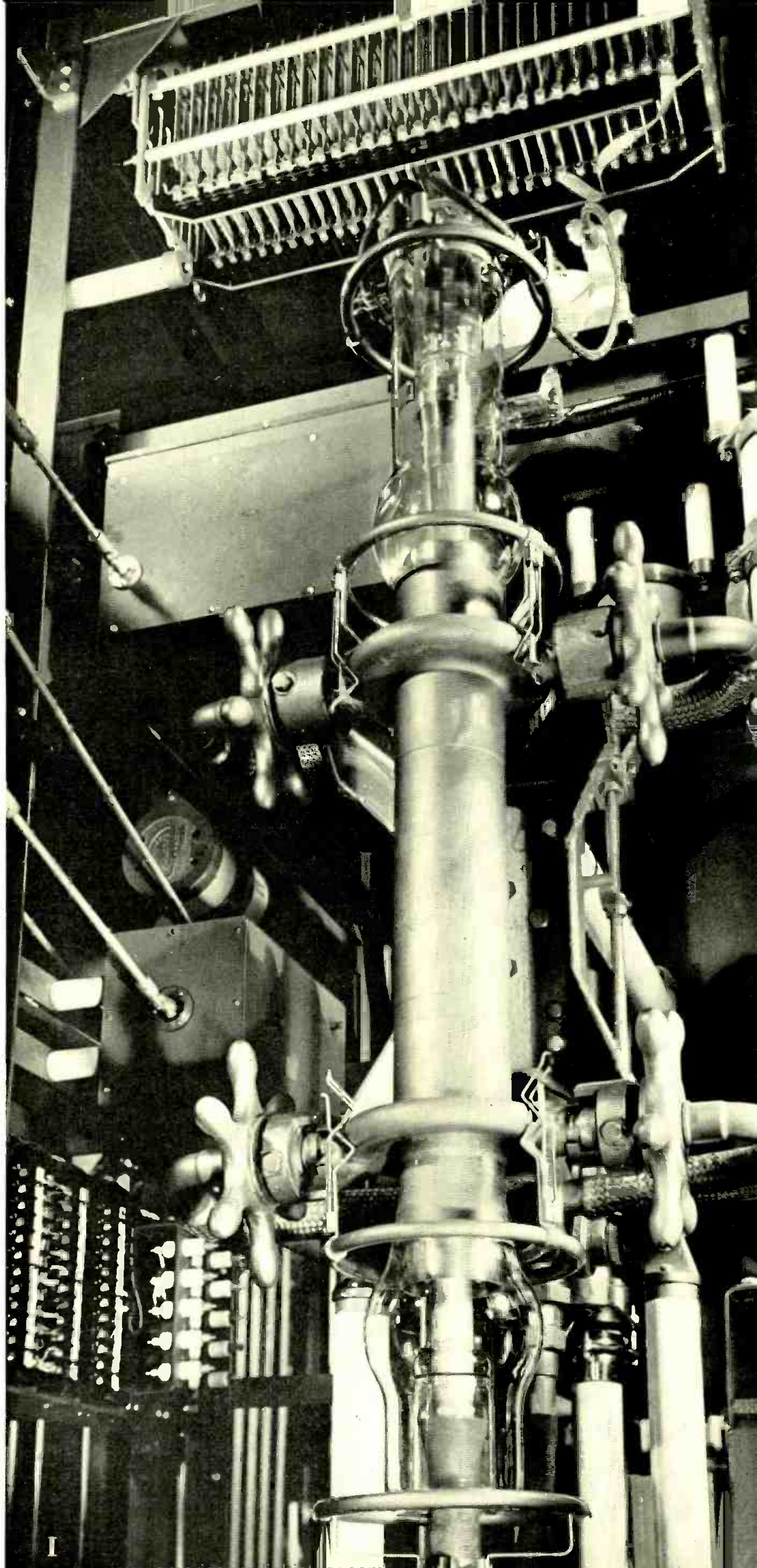
WESTERN ELECTRIC 50-KW BROADCASTING TRANSMITTER

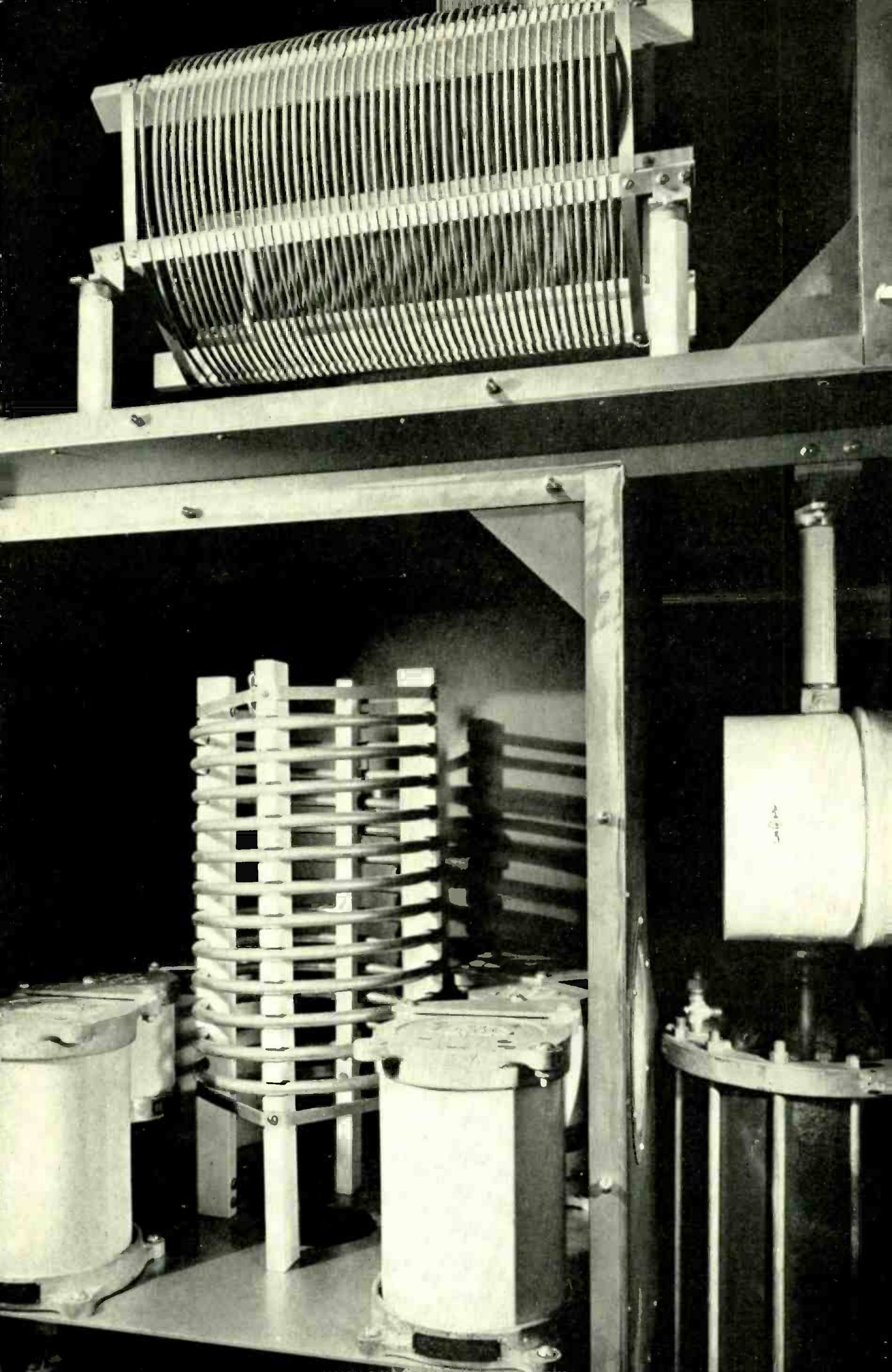
I
One of the two 100-kw tubes in the final amplifier

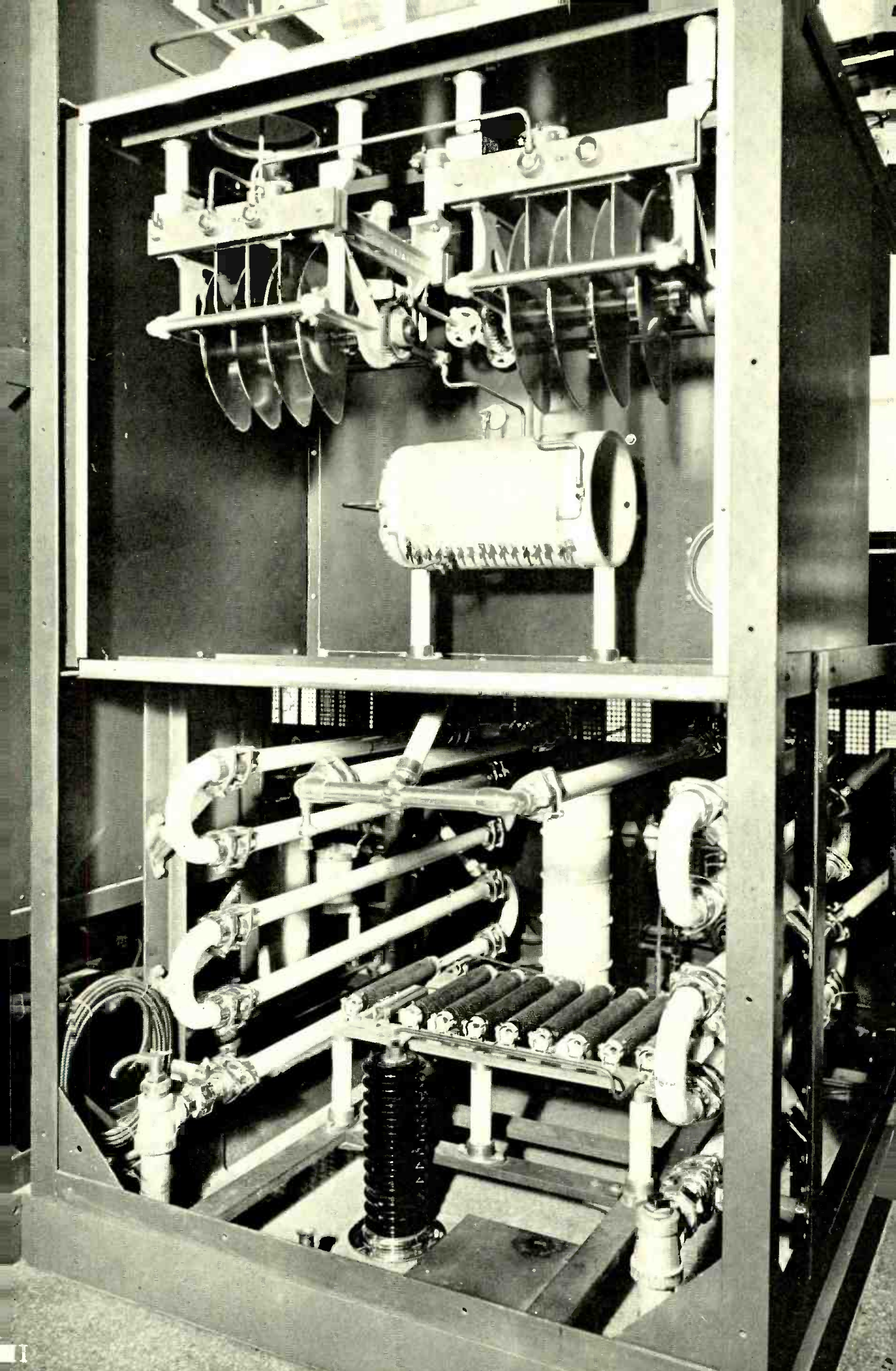
II
Coils and condensers of that stage

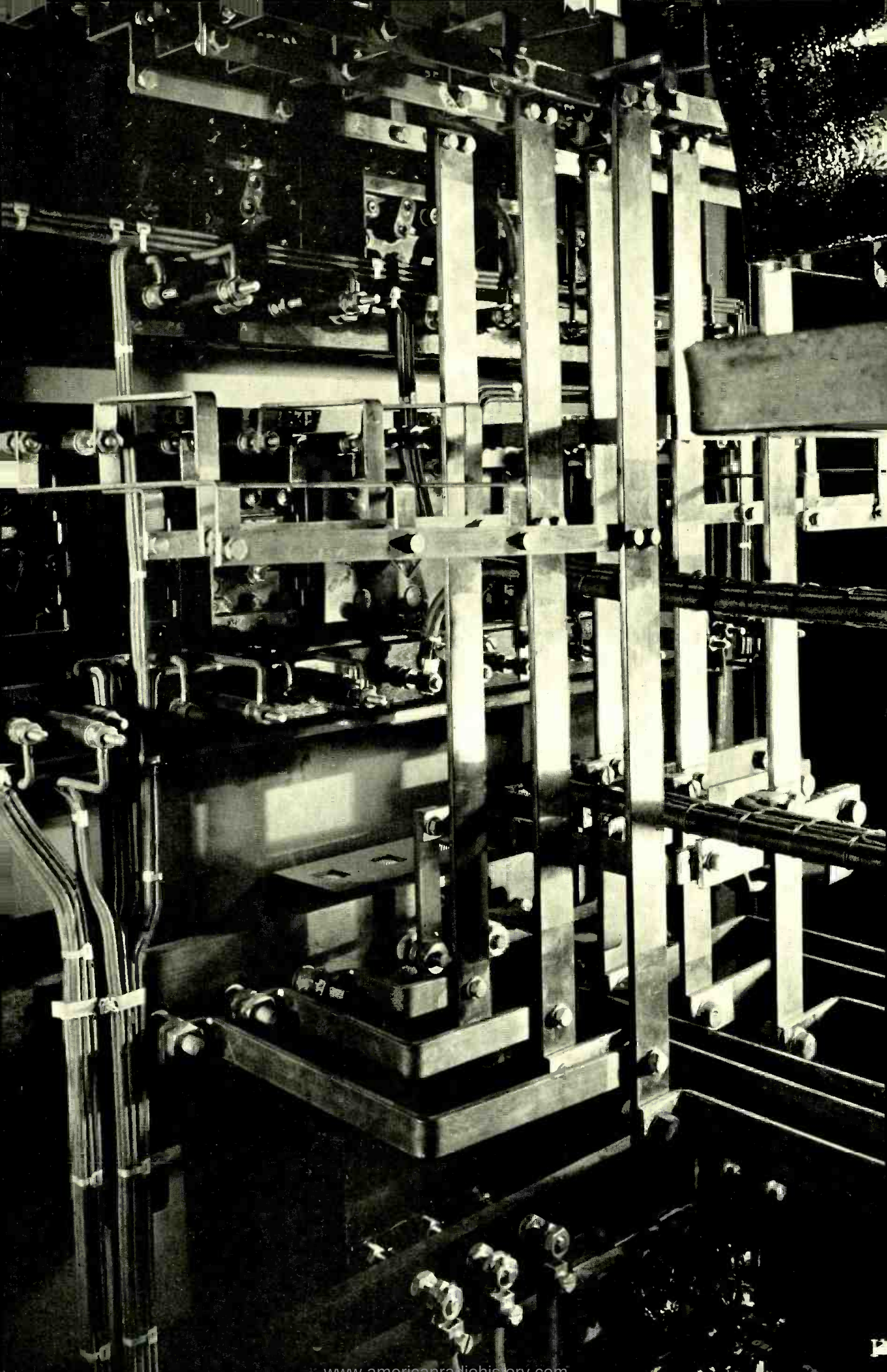
III
The preceding stage is a driving unit

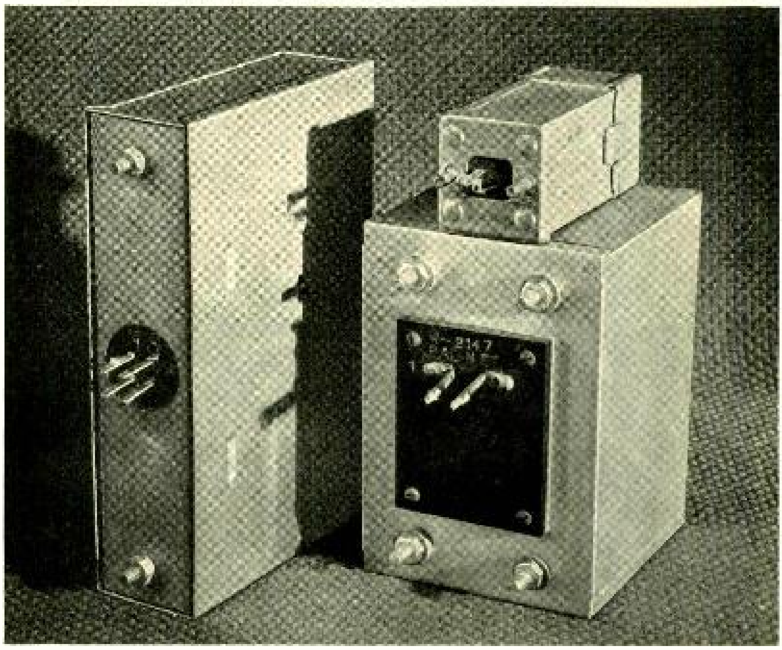
IV
Power distribution unit











Simplified Balancing Networks for Toll Cables

By H. A. ETHERIDGE
Toll Transmission Development

BALANCING networks are designed to have an impedance characteristic simulating that of a section of toll line; and the closer the similarity, the better is the balance obtained. They are employed at each repeater on two-wire toll circuits; and the repeater gain as well as the overall circuit performance is limited by the degree of balance obtainable. Recent development work has resulted in certain simplified networks whose design is such that their impedance is adjustable over a limited range. In addition a new mechanical design has been made available which is less expensive to manufacture and requires less space. It seemed desirable, therefore, to review the requirements of balancing networks to see whether the new mechanical and electrical arrangements would not permit less expensive networks to be produced.

Assuming a uniform value of resistance, inductance, and capacitance per load section, a section of cable between two repeaters will have an impedance whose reactance and resistance components would be as represented by the solid lines of Figure 1, when measured at the middle of a loading section, that is half way between loading coils. It is such an impedance-frequency characteristic that the balancing network is designed to meet. It is economical, however, to design the basic network to simulate the impedance of a cable having an end section of about 0.2 of a loading section, since under these conditions the resistance component of the impedance is practically constant with frequency. Since cable end sections are generally greater than 0.2, however, this basic network is built out by means of an adjustable unit inserted

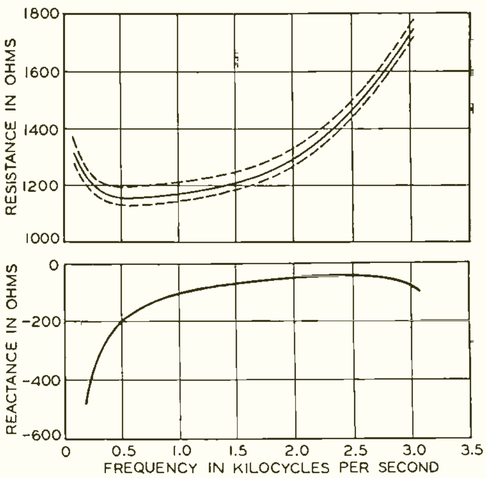


Fig. 1—Resistance and reactance components of the impedance of a section of cable measured at mid-loading section. The dotted curves show the range of variation in the resistance component due to variations in the capacitance of the cable

in the circuit so that its impedance simulates that of a cable ending in the fraction actually existing.

A schematic of a typical network that has been employed for two-wire circuits, together with its building-out unit, is shown in Figure 2. If the coils, condensers, and resistors composing the manufactured network were all exactly at their designed values, the impedance characteristic would follow almost exactly the desired characteristic curve. Since manufacturing variations can never be entirely eliminated, however, the component units of the network will rarely be exactly at their designed values, and as a result the impedance of the network will vary somewhat from the desired characteristic. The deviations from the design values permitted in manufacture are definitely specified, and the narrower the range of deviations allowed, the more expensive will be the network. In designing the new network, advantage was taken of the adjustable feature to eliminate two of the network elements, thus simplifying the network structure.

The cable itself varies from its nominal values of capacitance and resistance, and thus the impedance characteristic of any section of cable will deviate somewhat from the nominal characteristic shown by the solid lines of Figure 1. The variations encountered are chiefly in the capacitance, since the wire itself is drawn with considerable precision to its specified diameter, and any variations in resistance that exist are too small to have an appreciable effect on the characteristic. These deviations from nominal values unfortunately do not occur at random, but instead tend to be systematic, depending on several manufacturing variables that would be difficult to control to any greater extent than is now done. Since toll cables are manufactured for a particular project, there are likely to be whole repeater sections whose average load-section capacitance is systematically higher or lower than the nominal value. The effect of variations in ca-

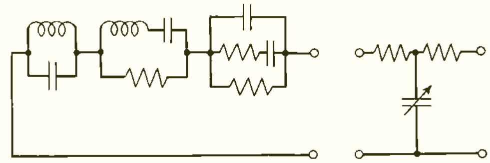


Fig. 2—Schematic of the former type balancing network, with the building-out unit, mounted separately, at the right

pac e is chiefly to raise or lower the resistance component of the impedance, especially at low frequencies; the effect on the reactance component is very minor. Permissible variations in cable capacitance would permit the resistance component of the cable to fall anywhere within the two dotted curves of Figure 1. Because of the expense of avoiding these variations in manufacture, it is more economical to design the balancing networks to absorb the effect of these variations to a considerable extent.

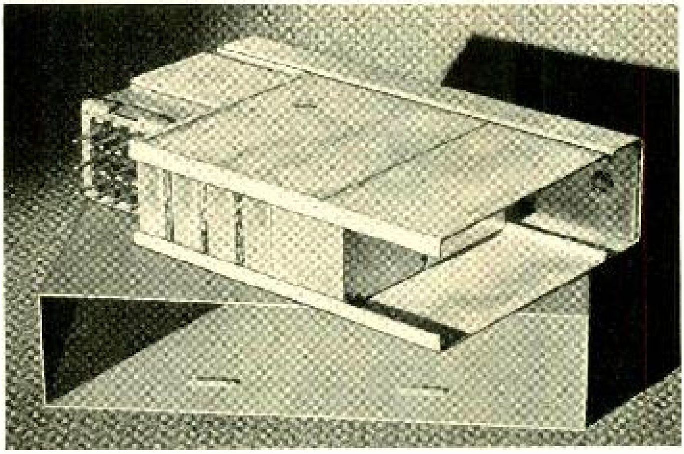


Fig. 4—The 113 *type balancing network, showing the formed-channel construction and the slip-over cover*

Because of the inevitable variation in the cable, it seemed feasible to design a network having the lowest required resistance needed to balance a cable whose capacitance was high, and to provide in addition adjustable series resistances which could be set to compensate for lower cable capacitances. The practicability of this method was demonstrated in a recent trial of new toll facilities.* On one section of the cable the load-section capacitance was found appreciably lower than normal, with the result that over a considerable portion of the useful frequency range the resistance component of its impedance was higher than the value for which the network was designed. By using an adjustable series resistance, however, the match between network and line could be considerably improved.

*Record, *April*, 1936, *page* 275.

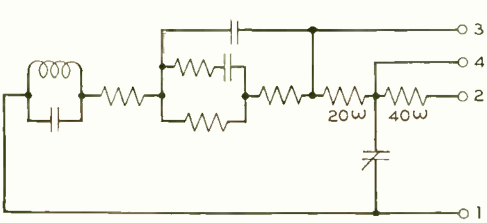


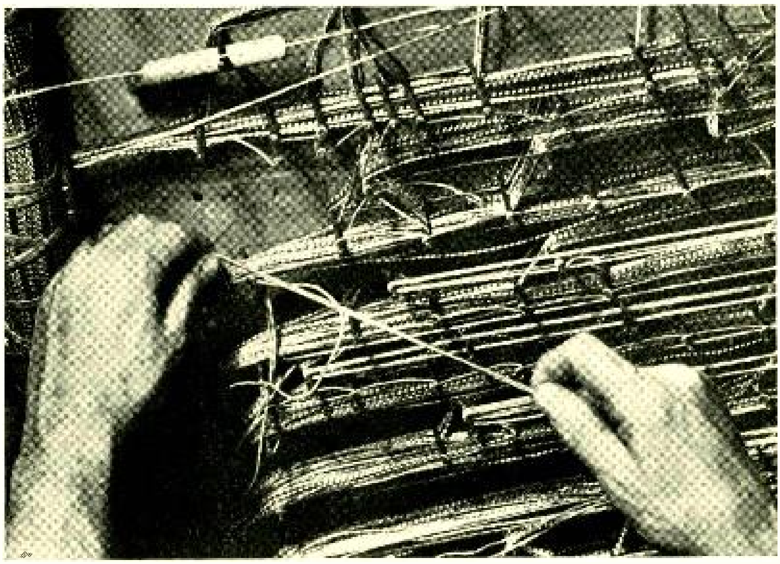
Fig. 3—Schematic for the 113 *type network showing the building-out condenser and adjustable resistances integral with network*

To make the prospects of providing an inexpensive and yet satisfactory network even more promising, the Apparatus and Equipment Development Department of the Laboratories had recently developed a new method of mounting the network elements which not only would decrease the manufacturing cost, but would decrease the space required by the networks on a relay rack as well. With the previous construction, the network elements were assembled and sealed in a rectangular box, such as shown at the right of the photograph at the head of this article, and the building-out condenser, shown resting on it, was mounted separately. The new proposal was to employ as a container for the network elements a formed channel into which standard coil, condenser, and resistance units could be slid to make up the network.

This construction is shown at the left of the photograph at the head of this article, and in more detail in Figure 4. Such a unit requires a much narrower space on the relay rack, and readily accommodates any likely combination of coils, condensers, and resistances. It was also possible to include the building-out condenser in the same structure; and that also tends toward simplification in use.

This network structure is known as the 113 type. For balancing 19-gauge H-88-50 loaded cable it is made in two forms, the 113P for side circuits, and the 113R for the phantom. The adjustable series resistance can be set to either 0, 20, 40, or 60 ohms for the P network, and to 0, 15, 30, and 45 for the R network. These ranges are adequate to compensate for any normal variations in cable capacitance. The new network, shown in schematic in Figure 3, is somewhat smaller than its predecessor, even though the building-out unit and adjustable resistances are made part of it instead of being supplied as a separate unit. The line is connected to terminals 1 and 2, and the resistance is varied by various strappings of terminals 2, 3, and 4.

Tests on these networks in actual service have shown that by making suitable adjustment of the resistors, balances can be obtained that meet the requirements for the types of circuits with which they will be used. As a result the same principles have been employed in the design of new networks for B-135-N loading systems using 22-gauge BSA cable. This cable is designed primarily for exchange area use, where the allowable variations in capacitance are greater than in the usual toll cable. The adjustable features of these new networks are particularly desirable, therefore, to adapt such circuits to toll use.



A Radio Telephone Set for Small Vessels

By B. O. BROWNE
Radio Development Department

THE fifty-watt marine radio telephone apparatus recently described in the RECORD* provides a simple and effective means for vessels within a few hundred miles of the coast to communicate with shore stations, and through them to be able to talk to any Bell System subscriber. Although these sets are compact and simple to operate, they are larger and more expensive than is warranted for use in many small vessels such as harbor tugs, pilot vessels, and small yachts, which would seldom be more than fifty miles from a port equipped with a radio shore station. To provide essentially the same type of telephone service for these smaller craft, a fifteen-watt set operating over the frequency range from 2.0 to 2.8 megacycles has recently been developed, and is known as the 226A radio telephone equipment.

In this equipment desirable economy in space is secured by assembling the transmitter and receiver on a common chassis. This chassis, together with a common power supply unit, is mounted in a metal cabinet about fifteen by fourteen by eight-and-a-half inches. Attached to the side of the cabinet is a standard handset mounting for a handset, although the handset and handset mounting may be removed from the cabinet and placed in some other location. A loudspeaker is also mounted in the front of the cabinet, and may be used for monitoring incoming calls. It is expected, however, that in many cases selective calling will be desired,

*June, 1938, page 358.

which may be obtained through the use of a selector set* which is an accessory item.

Both the transmitter and receiver are crystal controlled, and four quartz plate holders are provided so that communication may be held on any of four frequencies. These plate holders are of the double type, each holding two crystals. Frequencies are assigned in pairs, one for transmitting and one for receiving, and the transmitting and receiving crystals for an assignment are mounted in the same holder. A four-position switch on the front of the cabinet permits ready selection of the frequency combination desired.

The radio transmitter employs only four tubes: an oscillator, a power amplifier, and two tubes in a push-pull circuit forming an audio amplifier. The handset is connected to the latter through a transformer, and the audio stage modulates the plate and screen voltages of the power amplifier through another transformer. Coupling between the power amplifier and the antenna is effected through a condenser and an inductance. The latter is of the roller-coil type and gives continuous adjustment for both plate impedance and antenna tuning. This coil is adjusted when the set is installed to tune the antenna with which it is associated, and no further adjustment is required. Different taps on it are selected by the same switch that selects the desired crystal.

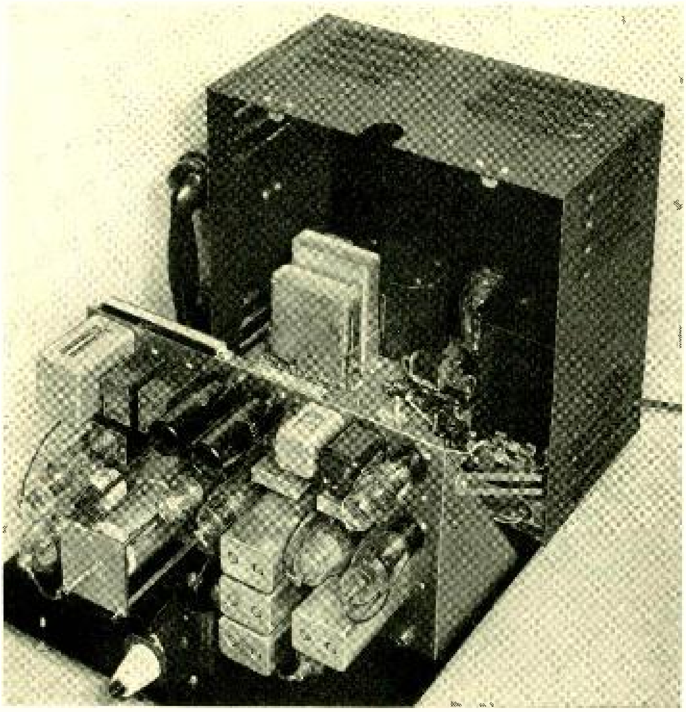


Fig. 1—The construction of the cabinet makes all apparatus readily accessible

The radio receiver is of the superheterodyne type with one radio-frequency stage, a modulator, a crystal-controlled beating oscillator, one intermediate-frequency stage, a combination detector and first audio stage, and a power amplifier stage. A single dial on the front of the cabinet controls the receiver tuning. It is set when the crystal switch is changed, and requires no further adjustment.

As the power supply facilities on the various types of vessels using this equipment differ widely, it was decided to design the power unit for 115-volt, 60-cycle supply, and use a standard motor-alternator to provide the required voltage and frequency.

*Record, *April*, 1936, *page* 255.

The unit includes a transformer that supplies a low voltage for the filament circuit and a high voltage for a single rectifier tube, which furnishes plate potential for both the transmitter and receiver. Filament current is supplied to both transmitter and receiver all the time that the power switch is "on," but the high voltage is switched from one to the other through relays operated by the press-to-talk switch on the handle of the handset.

In designing this equipment, every effort has been made to make all parts readily accessible in spite of the compactness of the assembly. The chassis on which the power unit is mounted slides into the bottom of the cabinet and is fastened to it by screws through the bottom. The front of the cabinet is hinged to the chassis of the power unit, and may be tipped out as shown in the accompanying illustrations. By removing the screws that hold the power unit to the bottom of the cabinet, the complete equipment —transmitter, receiver, and power unit—may be removed from the cabinet for inspection or maintenance.

Operation of the set is very simple. After it is connected to the antenna, the roller-type tuning coil in the transmitter output circuit is adjusted by a screwdriver inserted through the top of the cabinet to produce a minimum reading of the plate meter mounted on the front panel. This adjustment is not touched again unless the antenna is changed. The set is put in operation by the power switch, which connects power to the primary side of the transformer in the power unit. When this switch is "on," nothing else need be done but lift the handset and talk, except possibly some slight adjustment of volume.

Under normal conditions the power switch will be on, and the speaker switch will be set for loudspeaker monitoring. When a call comes in, this latter switch is thrown to the handset position, and conversation is carried on as with any other telephone set except that the switch in the handle of the handset must be pressed when talking. This switch transfers both the power and the antenna from the receiver to the transmitter, and when it is released, both are returned to the receiver. The relays that make these transfers are with the power unit in the lower part of the cabinet.

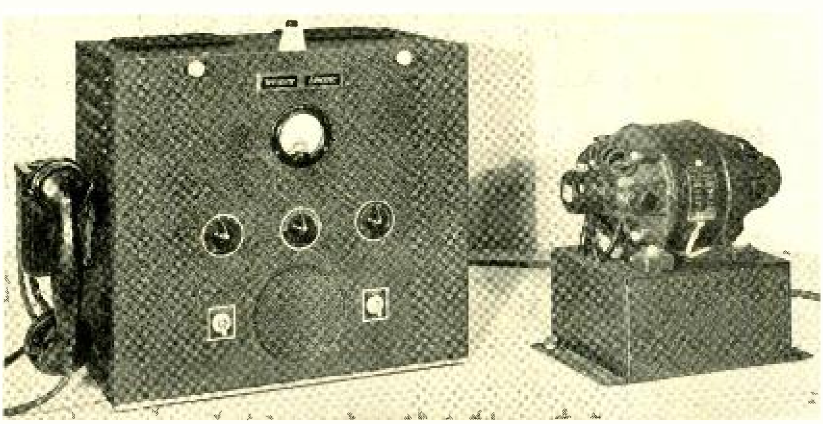
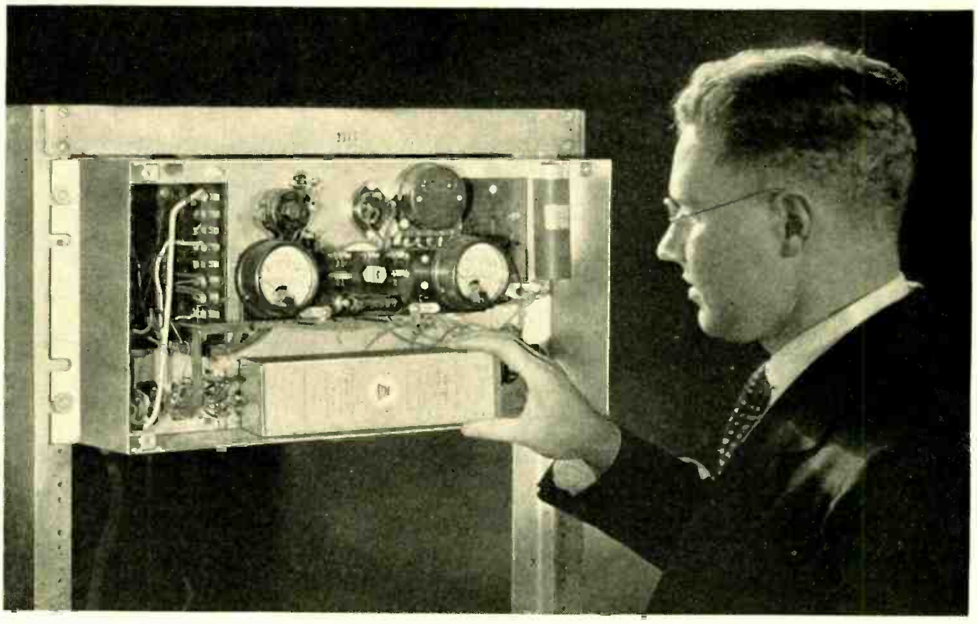


Fig. 2—The 226A radio telephone equipment with motor-alternator for connection to the ship's power supply



Regulated Tube Rectifiers Using Magnitude Control

By D. E. TRUCKSESS
Power Development

IN an ordinary three-element vacuum tube the grid has continuous control of the space current, but in the thyratron, which is also a three-element tube, the grid controls only the start of the space current. One or more gases are present, and their ionization maintains the space current until the plate potential becomes zero. Once stopped, the space current cannot reëstablish itself until the plate potential becomes strong enough to draw electrons past the grid in spite of the latter's opposition. Thus an adjustment of the grid potential will determine whether the tube becomes conducting early or late in the cycle, and so will control the rectified current which reaches the load.

Rectifiers with grid-controlled tubes have been used for some time in the telephone plant to charge storage batteries and as sources of small power. These rectifiers have been hand regulated by the operating staff, a procedure which involves extra maintenance cost and does not give the desired constancy of output. Recently self-regulating rectifiers which require very little attention have been developed by adding to the circuit means for controlling automatically the bias of the rectifying tube. The method has been named "magnitude control" because it depends on varying the magnitude of the voltage applied to the grid of the tube.

A simple half-wave rectifier circuit, which incorporates a thyratron tube and uses the magnitude method of self-regulation, is shown in Figure 1. The transformer T1 furnishes the alternating voltage, the retardation coil L and condenser C form the filter, and the load is a storage battery and a resistance. The control circuit consists of a potentiometer connected across the load to furnish a negative potential with respect to the cathode, and a grid battery connected to oppose the voltage drop of the potentiometer so that the net voltage applied to the grid is slightly negative. The resistor R limits the grid current. When the load is applied to the rectifier the output voltage decreases and this change, reaching the grid through the regulating circuit, permits the tube to fire earlier in the cycle. This causes current to flow longer and increases the output voltage sufficiently to return it to the regulated value. When the load is very light with a circuit of this type, the condenser C maintains the voltage constant enough to keep the tube biased out part of the time and so prevents it from firing every cycle. If the voltage falls the condenser discharges and the tube fires until the condenser is recharged. This irregular operation of the tube at light loads can be noticed as a flicker in the haze of the tube, but the voltage can be maintained at the regulated value with proper circuit design.

A circuit with magnitude control arranged for full-wave operation is shown in Figure 2. It has all the advantages over half-wave rectification which are characteristic of conventional two-element tube rectifying circuits. The control circuit operates in exactly the same manner as in the half-wave rectifier. The tube which has the lowest critical voltage for a given plate voltage will fire first but the output will be very small because the impedance of the filter circuit remains high. When the output voltage is reduced sufficiently to fire the other tube, full-wave operation begins and normal control is exercised. One tube will carry slightly more load than the other, but the impedance of the filter coil tends to balance their loads.

If the alternating input voltage changes, the regulating circuit tends to compensate for the effect on the plate voltage of the tube. The grid voltage required to make the tube fire also changes at the same time and causes the output voltage to increase with the plate voltage. This effect may be nullified by connecting in the potentiometer circuit a small direct voltage obtained from a copper-oxide rectifier and a winding on the plate transformer. The ripple in this voltage is smoothed by the condenser C_1. If the alternating input voltage increases, the direct voltage supplied by the copper-oxide unit will also increase proportionately and the potential applied to the grids of the tubes, through the grid battery, will be more negative. This causes the tubes to pass current later in the cycle

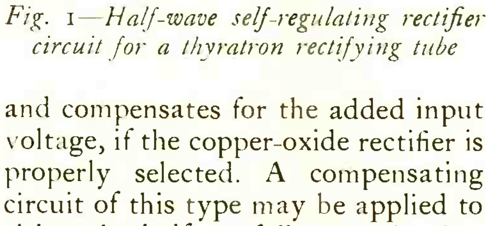


Fig. 1—Half-wave self-regulating rectifier circuit for a thyratron rectifying tube

and compensates for the added input voltage, if the copper-oxide rectifier is properly selected. A compensating circuit of this type may be applied to either the half- or full-wave circuits.

The magnitude method requires a small amount of inductance in the direct-current output for satisfactory control even when it is not needed for noise suppression. The characteristic of the tube, with a pure resistance load, is such that as the direct voltage on the grid becomes less negative the output current will go abruptly from zero to approximately one-half the maximum value, and then gradually to the maximum. With an inductive or nearly inductive load, on the contrary, the grid of the tube has smooth control from almost zero to the maximum value.

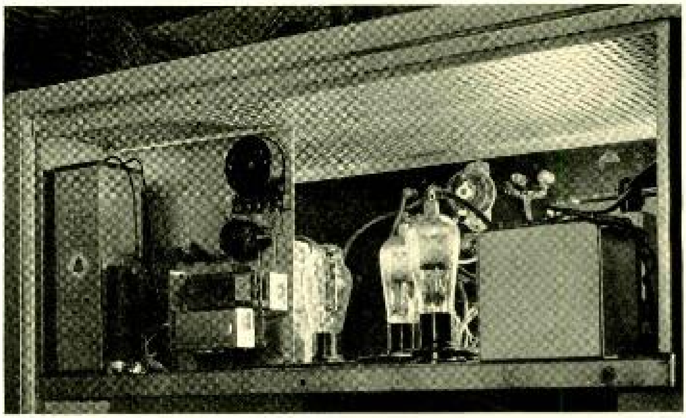


Fig. 3—A full-wave rectifier with self-regulation designed to charge storage batteries in small central offices—rear view with casing removed

The operation of these circuits on resistance loads usually requires that the output be filtered more than with battery loads; in fact, when a storage battery is used, the filter condenser can in many cases be eliminated. If conditions are such that it is not necessary to filter the output to any great extent to suppress noise, the voltage applied to the regulating potentiometer must be filtered so that the ripple on the output voltage will not feed back into the grid circuit.

In all grid-controlled rectifiers with hot-cathode tubes the filament has to reach its operating temperature before space current flows to prevent bombardment of the cathode. This may be accomplished by having the grid of the tube connected to the filament through a condenser which holds the grid negative and prevents plate current from flowing until a thermal relay operates and transfers the grid to the regulating circuit.

The headpiece shows the rectifier corresponding to Figure 1. It delivers a current of 0.6 ampere at an output voltage of 52 to 75 volts and was designed primarily for mounting directly on the telephone central office power boards to operate message registers. Although intended for a resistance load it may also be used to float a battery. Two other rectifiers of this general size and shape have been developed. One has an output of 0.6 ampere at 120 or 130 volts and was designed to furnish voltage for the coin control of public telephones. It is suitable for resistance loads or may be used to charge a storage battery. The other rectifier, which is intended for battery charging only, may be adjusted to operate at any voltage from 17 to 45 volts

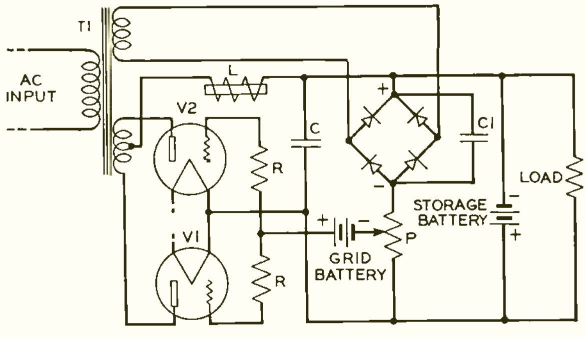


Fig. 2—Circuit for full-wave self-regulating rectifier with thyratron rectifying tubes

and delivers an output current of 0.6 ampere. Its principal use is to charge the battery employed in ringing circuits.

Figure 3 shows a rectifier corresponding to Figure 2. It was designed to float a 50-volt battery and to deliver 3 amperes. A similar rectifier, Figure 4, installed in a case of the same size and shape, delivers 10 amperes at 50 volts. These two rectifiers are used as part of the power plant for private branch exchanges and small central offices. In addition to the rectifier, this unit contains all of the power-plant equipment required for small central offices such as the charge and discharge fuses, station voltmeter and the high and low voltage alarm.

Since the magnitude of the grid voltage necessary for control is about the same for all the plate voltages used, the regulation improves at the higher output voltages. It varies from about ±3 per cent for 17 volts to ±1 per cent for 48 volts, with load changes up to three-quarters full capacity and ±5 per cent variation in alternating input voltage. The output voltage of battery-floating rectifiers is made to taper off at three-quarters load as a protection against overload when connected to nearly discharged storage batteries.

The magnitude method of control provides a relatively simple and inexpensive means of regulating the output of thyratron tube rectifiers, which are being used increasingly in central offices where small amounts of direct-current power are required.

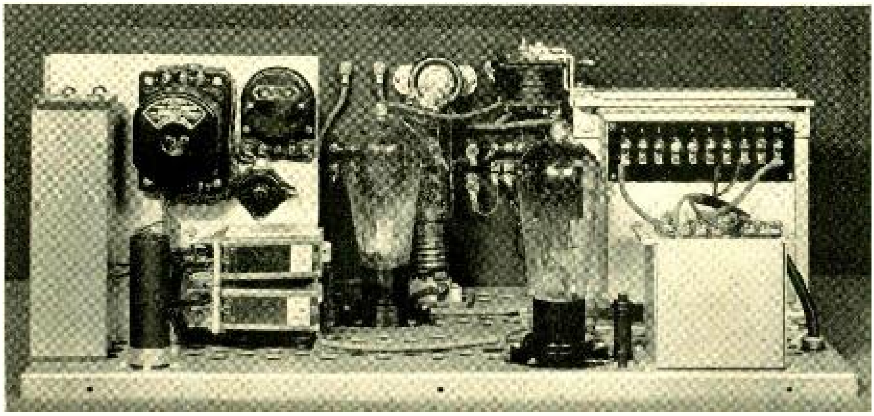


Fig. 4—A full-wave rectifier for private branch exchange or small central office use designed for charging batteries at 10 amperes

Grid-Controlled Rectification Used in Small 48-Volt Power Plant

By J. L. LAREW
Power Development

UNTIL very recently, power plants for small PBX's and central office switchboards have employed tungar rectifiers. The voltage characteristic of these rectifiers is rather steep, so that their regulation is poor, and as a result it has been necessary to provide some external means of voltage control to keep the batteries in the proper state of charge. With the recently developed regulated-tube rectifier, the utilization of external regulation becomes unnecessary, since the output voltage is maintained within very close limits for all normal variations of line voltage and load. It seemed desirable, therefore, to incorporate this improved rectifier in the power plants supplying direct current for small central offices and private branch exchanges. There were four types of such plants in use, which differed in their manner of voltage control, in the actual voltage supplied, and in other features; but a study indicated that because of the close and automatic regulation of the new rectifier, a single plant could be made to take the place of the four existing ones. The 105A power plant, rated at ten amperes and forty-eight volts, was the result.

The previous small power plants were an assembly of a number of units. The rectifier was usually mounted by itself as a separate unit; the voltage control equipment varied for the four different plants, and was mounted on a panel separate from the rectifier, and the fuses, alarms, and small miscellaneous equipment were arranged as proved convenient. Some of these power plants have already been described in the RECORD* in connection with articles on the PBX's and small central offices they were particularly designed to serve. In the new

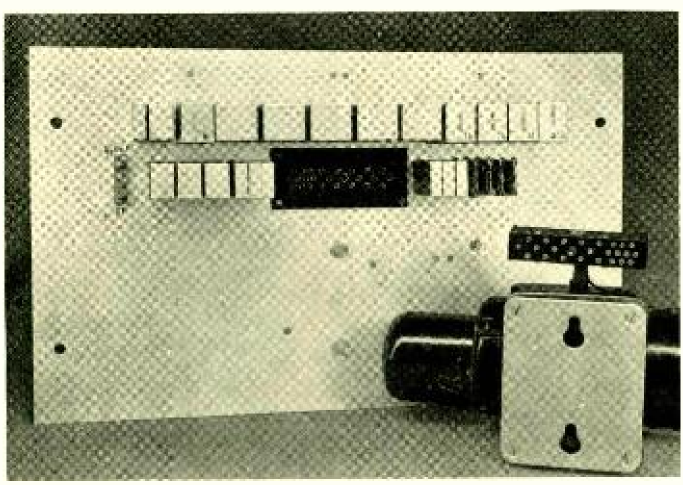


Fig. 1—Ringing machines used with the new power plant are electrically connected to their mounting panel through a plug attached to a short flexible cord

*RECORD, *Nov.*, 1926, *page* 87; *Aug.*, 1928, *page* 388; *May*, 1930, *page* 416.

power plant no external regulating equipment is required, as has already been mentioned, and all the fuses—charge, discharge, and distribution—as well as the alarms are mounted on the rectifier panel to form a single unit. The alarm arrangement, further, has been simplified so that any condition requiring the attention of a maintenance man—high or low voltage, fuse or rectifier failure, or ringing machine failure—will be indicated by a single alarm. An inspection of the meters and fuses on the front of the rectifier panel will then at once indicate the source of the trouble.

Besides the rectifying equipment, a power plant usually incorporates a ringing machine, except for very small installations where ringing is obtained over conductor pairs from the central office. The 105A power plant provides for the use of any one of several possible ringing machine arrangements. Figure 1 shows one such machine arrangement with the connections to the machine made through a plug and jack so that it may quickly be replaced in the event of trouble. The mounting of the ringing machine employs a jack, in which a plug, connected to the machine through a short flexible cord as shown in Figure 1, can be readily inserted. Heretofore the plug has been rigidly attached to the ringing machine, and very accurate mounting has been necessary to secure proper contact. The ringing-machine panel includes the starting relays and other accessory equipment, so as to be completely self-contained.

The new power plant, shown in Figure 2, is housed in a floor-supported cabinet 6 feet 10 inches high, thirty-three inches wide, and seventeen inches deep, and is equipped with shelves for mounting the various units of equipment. The regulated rectifier

Fig. 2—The 105A power plant provides a compact unit for the smaller central offices and private branch exchanges

itself is mounted at the top, and the shelf immediately beneath it is for the ringing equipment. The two lower shelves are for the batteries. Doors for enclosing the equipment below the rectifier may be obtained for both the front and back of the cabinet in cases where these are desired.

At any output up to three-quarters load, the new rectifier will maintain a constant "floating" voltage across the battery with ± 5 per cent changes in line voltage. With changes in load up to three-quarters load, the "floating" voltage is held constant to within ±1 per cent. Beyond three-quarters load the voltage will drop slightly, reaching about two volts per cell at the rated capacity of the rectifier. Beyond full load the voltage drops further, which has the advantage of preventing an overload on the rectifier at low battery voltages. These characteristics not only insure longer life for the batteries, but broaden the field of application of the new power plant by making it suitable for offices with heavy peak loads of short duration. Besides these advantages arising from the use of the grid-controlled rectifier, the 105A power plant is smaller and less expensive than the previous plants, and its compact arrangement and suitability for any of the smaller installations marks a distinct advance in power-plant design.

Contributors to this Issue

H. A. Etheridge left Princeton to serve in the U. S. Army in 1917, but returned on receiving his discharge, and received the B.S. degree in 1919. For a short period he was in business for himself, but in 1921 he joined the Southern Bell Telephone and Telegraph Company. His work there was with the Transmission Department, until 1923, when he transferred to the Department of Development and Research of the American Telephone and Telegraph Company where he was concerned chiefly with transmission problems arising from the use of repeaters on long telephone circuits. Since 1934, when the D. and R. was consolidated with the Laboratories, Mr. Etheridge has continued this work in the Toll Transmission Development Department.

After studying mechanical engineering at the Massachusetts Institute of Technology, R. E. Coram joined the Plant Department of the New England Telephone Company where he took part in the early demonstrations of the transcontinental circuit. In 1919, he came to the Systems Development Department of the Laboratories at West Street where he immediately became associated with the development of the Type-C carrier-telephone system, and took part in the first commercial installation of this equipment. In 1924 he was responsible for the design and development of the low-power

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equipment for the long-wave transmitter at Rugby, England, and Rocky Point, Long Island, and of the receiver at Houlton, Maine. In 1926 he transferred to what is now the Commercial Products Development Department, where he has since been in charge of a group developing radio broadcasting transmitters.

A. W. KISHPAUGH graduated from the University of North Dakota in 1912. After two years each with the General Electric Company and the Utah Power & Light Company, he joined the Engineering Department of the Western Electric Company where, in the research group, he was concerned with radio receiving problems and with the development of radio equipment for the Army and Navy, particularly for use on aircraft. Later he was engaged in the development of apparatus and systems for the commercial applications of radio telephony and in the development of broadcasting equipment. At present he is in charge of a group in the Commercial Products Development Department engaged in the design of commercial broadcasting equipment.

D. E. TRUCKSESS received the degree of B.S. from Pennsylvania State College in 1926 and joined the Laboratories the same year. His work, with the Systems Development Department, has related primarily to the development of power apparatus. Recently he has spent much of his time on regulated rectifiers of which the one described in this issue of the RECORD is representative.

C. S. KNOWLTON spent three years at the General Electric Engineering School and at the same time studied electrical engineering at Lowell Institute. He graduated in 1926, and then spent a year with the Boston and Maine Railroad as inspector of automatic train control equipment. The next year he joined the Technical Staff of the Laboratories, and engaged in power development work in the Systems Development Department. With the same group, he has more recently been occupied in developing copper-oxide rectifiers and relay-controlled apparatus for voltage regulation of telephone power plants.

J. L. LAREW received a B.Sc. degree in mechanical engineering from Rutgers University in 1917, and during the following five years he held positions with several engineering and construction companies, gaining a varied engineering experience. In 1922 he joined the Laboratories and was assigned to the power division of the Systems Development Department. For the past twelve years he has supervised a group engaged in the development of power plants for the toll system. Among these have been those for telephone and telegraph repeaters, transatlantic radio, picture transmission and the more recent coaxial and Types J and K carrier systems.

AFTER NINE YEARS with the Crocker-Wheeler Company, B. O. Browne joined the Apparatus Drafting Department of these Laboratories in 1919. He transferred to the radio development group in 1924 where he has since been engaged in the mechanical design of aircraft receivers and ground station receivers and transmitters. He has also been engaged in ship-to-shore projects such as the 224A and 226A radio telephone equipments.

L. H. GERMER was graduated from Cornell University in 1917 and came to the Laboratories directly, but in August of that year he joined the United States Army where he served until the spring of 1919 in this country and abroad. On returning to the Laboratories in 1919 he became interested in research work in thermionics and electron physics. Dr. Germer has spent the last several years applying electron diffraction methods to the study of surface films and surface chemistry. He received the A.M. and Ph.D. degrees from Columbia University in 1922 and 1927, respectively.

B. O. Browne

L. H. Germer