BELL LABORATORIES RECORD

SUBSCRIBERS' KEY EQUIPMENT
W. F. MALONE
W. M. BEAUMONT

CROSSTALK MEASUREMENTS
R. S. ALFORD

HIGH-FREQUENCY POWER SUPPLY
E. G. SHOWER

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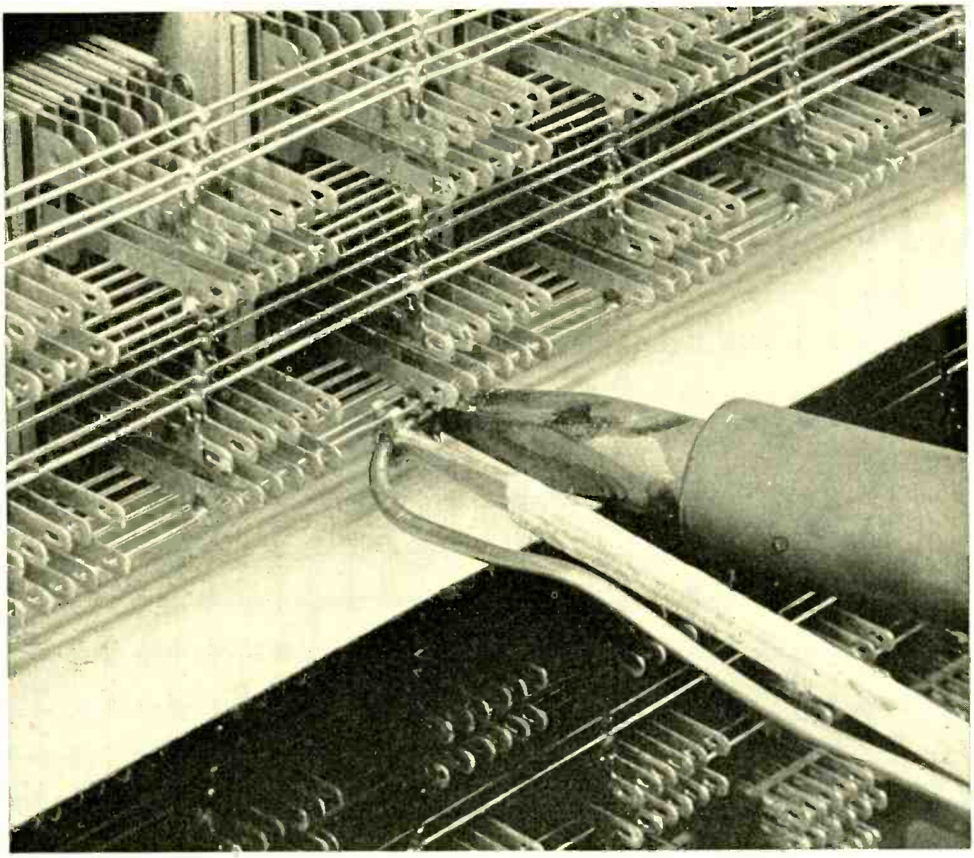


Soldering a strap wire on a crossbar switch

AUGUST, 1937

VOLUME FIFTEEN—NUMBER TWELVE

101-Type Key Equipments

I—By W. F. MALONE, II—By W. M. BEAUMONT
Systems Development

I. Equipment Features

The extension telephone and the PBX both provide increased communication facilities for the subscriber, but there are many situations where the simple extension is not adequate and where the PBX is either too elaborate or unsuited to the particular requirements. To meet these intermediate demands, there has grown up in recent years a wide assortment of subscriber facilities known as "wiring plans." Their increasing diversity has lately led to a coördination of their design, and since most of them require keys to perform certain operations, the name "key equipments" is applied to the latest types.

Although, in general, the key equipments are designed for serving smaller numbers of lines and trunks than the PBX, this is not always the case, since the larger key equipments frequently accommodate more trunks than the smaller PBX's. The distinction is chiefly one of function, and it is quite common to find one or more of the key equipments used on PBX extensions. The fundamental purposes of the PBX are: first, to economize on trunks by giving a large number of extensions access, through the PBX board, to a comparatively small number of trunks; and second, to allow intercommunication between all the local extensions. With the key equipments, intercommunication, although sometimes provided, is generally more incidental, and the ratio of central office trunks to local extensions is ordinarily higher. The primary purpose of the key equipments is usually to allow any of a number of stations to answer or originate calls on any of a number of trunks, but the more specific uses will appear from the following description of a number of the leading equipments.

In the 15A and 23A key equipments, the keys are usually in the form of push buttons in the base of the telephone handset. These two systems are alike except that the 15A provides for only one central office trunk, and the 23A, for two. They have already been described in some detail in the RECORD.* Talking and signalling between local stations are carried on over a single intercommunicating channel, and a call may be held at one station while the telephone instrument is used for communicating with another station over this intercommunicating line. All or only part of the local stations may be given access to the outside lines. These two systems are employed chiefly by large estates, where the local extensions may be installed in the various living rooms, the butler's quarters, the garage, or in any of a number of places that local conditions dictate. With either the 15A or 23A, as many as eleven extensions may be employed.

The 107 and 108 key equipments are essentially the same as the 15A and 23A except that they provide for only five extensions and one central office trunk. The distinction between the 107 and 108 is that the latter permits intercommunication, while the former does not. The keys for these two equipments, instead of being in the

*RECORD, *April*, 1933, *p.* 244.

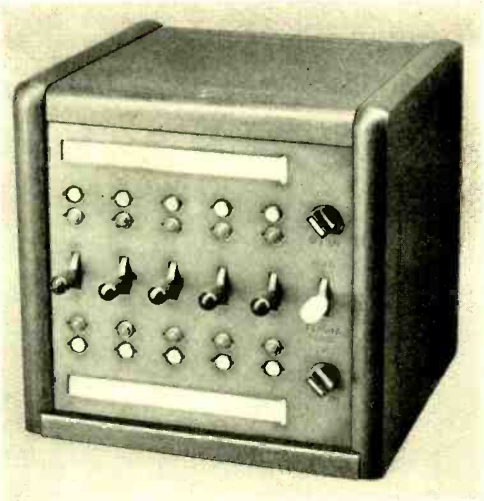


Fig. 2—*The keys and lamps are arranged in ten-line units, and each unit has a common holding key*

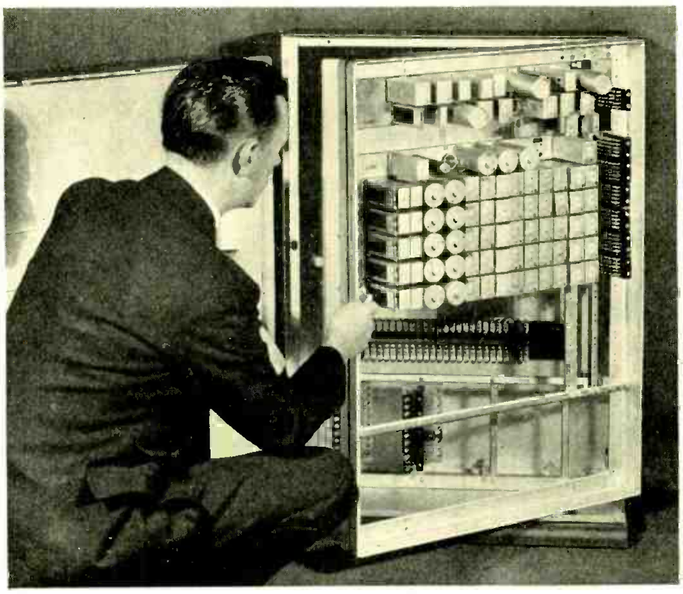


Fig. 1—*Relay cabinet used with the* 101-*type key equipments*

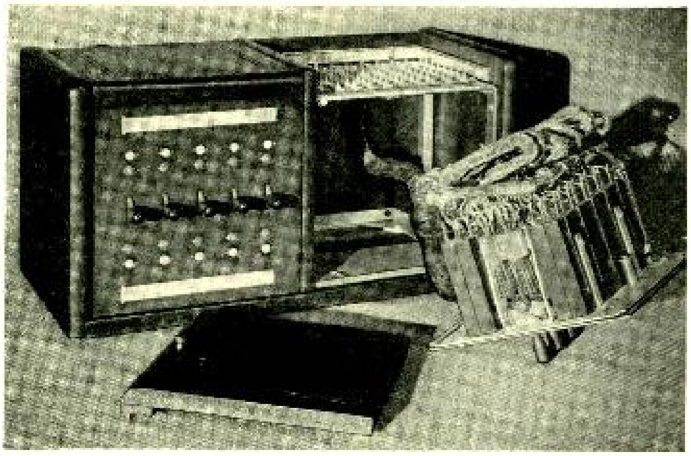


Fig. 3—The key and lamp equipment is all mounted on a metal face plate, which may be mounted in a wood box or set flush in the top of a desk or table

base of the handset as with the 15A and 23A, are assembled in a small metal box that can be mounted on the side of a desk or in any other convenient place, and standard telephone sets are used with them.

The relay equipment for all four of these smaller systems is mounted and wired as complete units on nineteen-inch plates which, in turn, are assembled on a hinged gate inside a metal cabinet. The cover of the cabinet may be readily removed and the gate opened to give access to the wiring. Suitable mounting arrangements permit the cabinet to be fastened on the wall or to the floor as may be most convenient. Battery for operating the relays and signalling current for the lamps are usually obtained over cable pairs from a nearby central office. When larger amounts of current are needed, or when the distance to the central office is greater, a local storage battery may be used, which may be charged either by a local rectifier or over cable pairs from generating equipment located in the central office.

The 100 key equipment, which has also been described in the RECORD*, permits several central office, PBX, or private telephone lines to be made available to a telephone user with but one telephone set. These same telephone lines can also be made available to as many as eleven other telephone sets on the same premises by the use of multiple key boxes. Any person before whom the lines appear may either originate or answer calls. The 100 key equipments are generally used in such places as brokers' offices, small taxicab headquarters, or telegraph offices. They may also be employed as small order-receiving turrets.

New key equipment, similar to the 100 type but of considerably greater capacity, has recently been developed and called the 101A and 101B. With these new equipments as many as forty lines can be made to appear before one attendant, and the lines may be multipled to as many as twelve attendants. As with the other systems, the equipment includes a key box and a relay cabinet. The latter is similar to those used with the other systems, but because of the larger number of lines that may be used is provided in three sizes—the largest of which is shown in Figure 1. All of the cabinets have a hinged gate on which 1¾-inch mounting plates are fastened; the smallest size accommodates up to four plates, the medium size up to eleven plates, and the largest size up to eighteen plates. The smaller cabinet is designed for wall or floor mounting, and

*RECORD, *July*, 1930, *p.* 527.

the two larger ones, although they may be mounted on a wall, will usually be located on the floor.

The key equipment is provided in ten-line units as shown in Figure 2. There is one holding key per unit and five line keys, each of the latter controlling the connection to two lines depending on whether it is moved up or down. Line lamps are mounted immediately above and below the keys. All this apparatus is mounted on a metal face plate and wired to a terminal panel with a flexible cable as a complete unit. This construction makes it simple to set the face plate flush with the top of a desk or table when desirable, and in this form the system is known as the 101B key equipment, the 101A designation being reserved when the box-mounted key units are employed. An "old brass" finished moulding, which matches the face plate, is used to frame it in its flush mounting.

Depending on the conditions of use, there may be from one to four of these key units used at any one position, and to provide greater compactness when several are to be used together, combination mountings have been provided. In one, two ten-line units are mounted in a cabinet back to back so that they will be accessible to two people sitting on opposite sides of a table. Another arrangement is two units side-by-side as shown in Figure 3, where one of the units has been removed to show the construction. This double unit is just like two single ones except that the two end panels are replaced by a separator through which the two cabinets are bolted together to give the appearance of a continuous cabinet. When mounted flush in the top of a desk two frameworks are available, one for two key units and the other for four. When not fully equipped, blank face plates the size of the key units are used to fill up the remainder of the cut-out. A metal cover is fastened to the underside of the framework under the desk to protect the units against dust and mechanical injury.

Among other uses the 101-type key equipment lends itself well to providing secretarial service, where a girl in an outer office may answer any of several lines. An installation of this

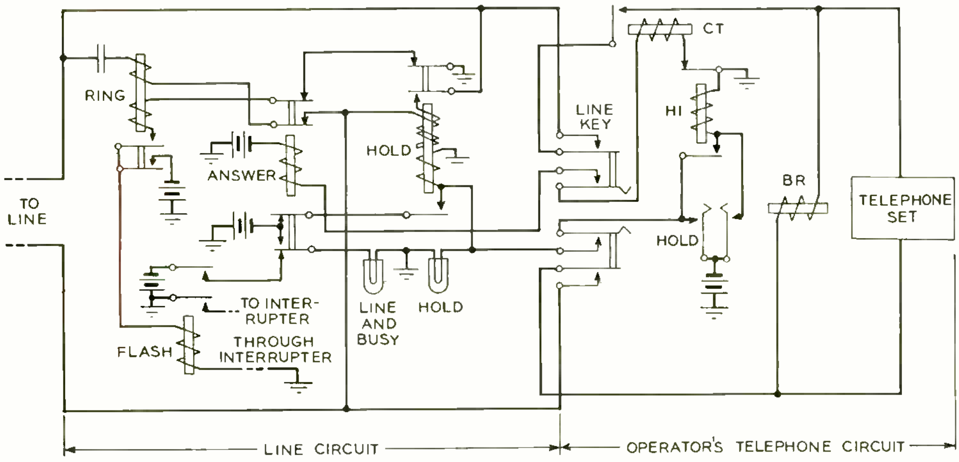


Fig. 4—Simplified schematic showing the wiring of one of the line circuits and the attendant's telephone circuit

secretarial type is suggested by the photograph at the head of this article.

II. Circuits

In developing the 101-type key equipments certain specific classes of service were particularly in mind, but the circuits were arranged to be flexible enough to meet any demand that was likely to be placed on equipment of this type and size. Probably the widest use for the new equipments will be for order-receiving service in smaller business houses, for information bureaus such as are used by railroads, for brokerage houses, and for steamship lines to provide for booking passages. They are also very well suited to secretarial service. With a number of doctors occupying the same suite or building, one of the new key equipments would enable a single attendant to answer any of a number of lines when the doctors were out; and when they were in, the key equipment would not interfere with their personal use of their phones. The equipment provides for a maximum of forty lines in units of ten each, and the lines may be multipled to appear at as many as twelve of the key equipments. The attendant may use a hand set or an operator's head receiver and breast transmitter, and the circuits may be arranged for either manual or dial service. The lines may be regular central office lines or they may run to a PBX board or to another key equipment.

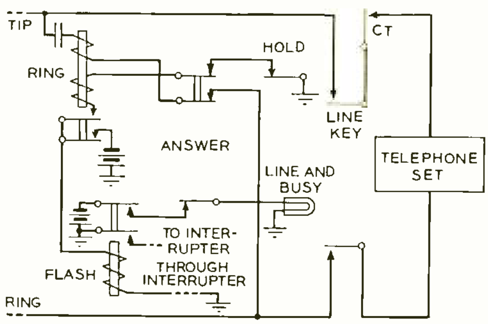


Fig. 5—Circuit connections immediately after a line has been rung

Each of the lines is provided with a line lamp and a hold lamp. On incoming calls the line lamp flashes and when a line is busy, it lights steadily. The hold lamp lights when the attendant is holding a line while she is getting information wanted or is talking over one of the other lines. Connection between a line and the attendant's telephone set is made by a line key, each of which serves two lines—the key being thrown up for one line and down for the other. A single holding key serves for a unit of ten lines, or for several units if more than one is used at a single position. It is operated only momentarily, and afterwards the line key may be returned to the normal position so the attendant may talk over another line.

A simplified schematic showing the wiring of the attendant's circuit and of one of the line circuits is given in Figure 4. In a ten-line unit there will be ten line circuits like that at the left of the diagram but only the one

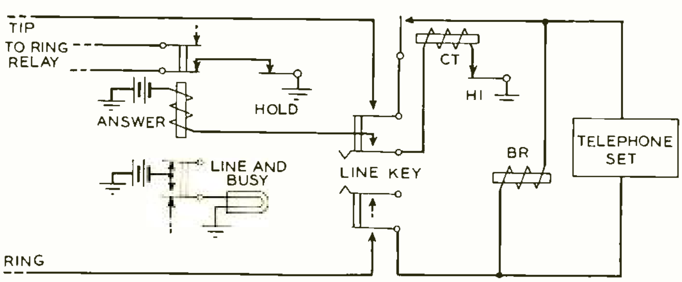


Fig. 6—Circuit connections after a line key has been operated

attendant's circuit, and if more than one of the ten-line units are used at the same location, a single attendant's circuit will serve them all. Through contacts not shown in the diagram, the attendant's circuit is wired in series through contacts on each line key that are closed when the keys are not operated. This prevents the local telephone set from being connected to more than one line at a time. When more than one key is operated, the telephone set will be connected to the line with an operated key that is nearest the right-hand side of the unit.

In each line circuit there are four major relays, one of which is common to four circuits. The ringing relay acts on incoming ringing current, holds itself operated through one of its contacts, and operates the common flashing relay through a relay interrupter not shown on the diagram. The operation of the flashing relay connects battery to the lamp, and the interrupter operates and releases the flashing relay about twice a second to give the flashing lamp signal that indicates an incoming call. Figure 5 shows that portion of the circuit in use at this time. Only the flashing and ringing relays are shown, but contacts of other relays that are in the circuit are indicated.

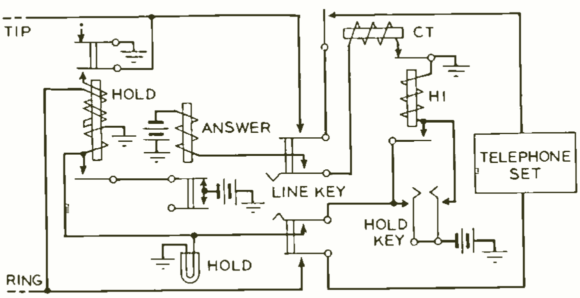


Fig. 7—Circuit connections while "hold" key is held operated

When the attendant throws a line key to answer the call, the four wires of the attendant's telephone circuit are connected to the corresponding wires of the line circuit, and the an-

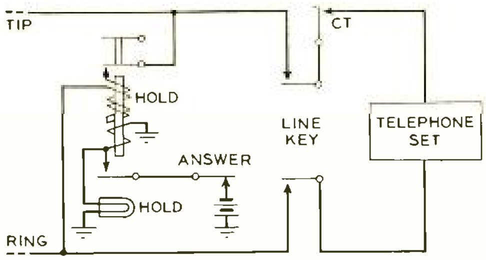


Fig. 8—Circuit connections after hold and line keys have been restored to normal

swering and CT relays are operated in series. The operation of the answering relay releases the ringing relay, and its release in turn releases the flashing relay. Battery is connected to the line lamp through a contact on the answering relay, and the lamp lights steadily to indicate that the line is busy. The operation of CT completes the connection to the attendant's telephone circuit and connects the impedance BR across the line to provide a supervisory signal at the central office showing that the call has been answered. The portion of the circuit in use at this time is shown in Figure 6.

The attendant may now talk over the line, and at the completion of the call, the restoration of the line key to normal will release the answering and CT relays, and put the circuit in a condition for another call—with the operating winding of the ringing relay connected across the line through a condenser and a back contact of the answering relay. If, before terminating the call, information must be obtained by calling over another line, the attendant operates the hold key, which holds the calling line and releases the telephone set for other use. The hold key is operated only momentarily, and after it is restored the line key is also restored to normal to leave the attendant's telephone set free for use on another circuit.

Holding is done by two relays and the hold key. The main holding relay is in the line circuit, but the holding key and an auxiliary holding relay are in the attendant's telephone circuit. The circuit connections during the time that the hold key is held operated is shown in Figure 7. The auxiliary holding relay, HI, is operated directly by the hold key, and the main holding relay, H, is operated by the hold key through a contact on the line key. The operation of HI releases relay CT and the answering relay, which is in series with it, and the release of the answering relay allows H to hold itself operated through one of its contacts and a back contact of the answering relay. The operation of H connects a holding resistance, wound non-inductively on its own core, across the line to hold it. The release of the answering relay extinguishes the line lamp, but the hold lamp is lighted through a contact on the H relay.

The hold key is now released, but HI is held operated through one of its contacts and through a contact on the line key, a contact on the H relay, and a back contact on the answering relay. It is necessary to hold HI operated at this point since if it were released, the CT and answering relays would be again brought in through the line key, which is still operated. The line key, however, is now restored to normal, which releases HI and frees the attendant's telephone circuit for other use. The circuit will now be as shown in Figure 8; the line is held by the holding resistance, and the attendant's circuit is free.

The attendant now proceeds to call over another line or do whatever else is necessary to get the information needed. When ready to talk over the original calling line, the attendant merely operates the line key pertaining to that line. This operates the CT and answering relays, and the holding relay is released by the operation of the answering relay. The circuit is now again as shown in Figure 6, and talking proceeds. At the completion of the call, the restoration of the line key will release the CT and answering relays, and the line will be ready for another call.

When the key equipment is used for secretarial service, the bell at the subscriber's station will ring at the same time that the line lamp flashes at the key equipment. The line may be answered at either place, and the circuit, which is somewhat different from that described above, is arranged so that in either case the line lamp will change from flashing to steady, which is a signal to the attendant that the call has been answered. If desired, the circuit can be made to cut off the attendant when the main station answers.

Crosstalk Measurements

By R. S. ALFORD
Noise and Crosstalk Prevention

THE measurement of crosstalk between communication circuits is almost as old as the circuits themselves, for whenever two or more such circuits are brought into close proximity, the inductive interaction results in some transfer of energy from one circuit to the other. This transfer of energy may or may not be of importance depending upon its magnitude and upon the type of service involved. Under some conditions the interaction may be sufficiently large to affect the service over the particular circuits. It is desirable, therefore, for the study and correction of such conditions that a suitable method of measurement be available.

Originally, two circuits suspected of crosstalk were tested by a person listening on one circuit while another person talked on the second circuit. The listener then decided whether the crosstalk condition was good or bad. The conclusion drawn from this test depended to a great extent upon the judgment of the listener.

Later, the errors of judgment were reduced somewhat by the use of a graded set of six criteria for loudness of crosstalk, ranging from "crosstalk completely inaudible" to "crosstalk so loud as to admit of intelligible conversation." The result for a particular test, however, still depended largely upon the listener's hearing, upon the loudness and quality of the talker's voice, and upon the amount of room noise at the listening subset. As a result, a need was felt for a testing method incorporating some standard of comparison.

The first method employing a physical standard of crosstalk is shown schematically in Figure 1. With continuous talking into the transmitter of the subset, the observer listened to the crosstalk when the switch was in position "A," and to direct transmission when the switch was in position "B." The loss of the direct transmission path was fixed by the shunt resistance across the receiver, the value of resistance having been chosen experimentally to represent the maximum crosstalk tolerable. By comparing the crosstalk to this "standard of transmission" it could readily be determined whether the crosstalk of the line under test was above or below this "standard."

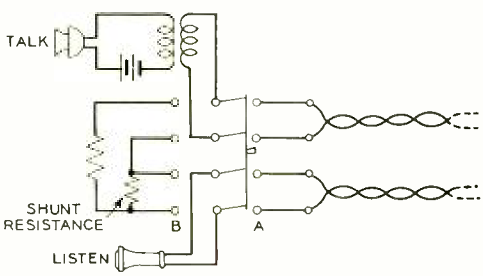


Fig. 1—With the first crosstalk meter one listened first to the crosstalk in the circuit and then to a direct circuit of fixed loss

The next step was to replace the fixed resistance shunt across the receiver with a variable slide-wire resistance which permitted an actual measurement of the crosstalk rather than a comparison with a single value. The slide-wire was calibrated to read crosstalk as millionths of the direct transmission.

The first complete crosstalk meter manufactured as a standard product was designed in 1904 and came into general use about 1911. The circuit of this meter together with that of the associated apparatus required is shown in Figure 2. The method of measuring with the meter is essentially the same as that of the present day aural measurement of crosstalk coupling. By means of the four-pole, double-throw switch, speech currents from the talking subset were transmitted to the receiver alternately through the crosstalk path and the crosstalk meter, which was a simple variable attenuator. The loss of the meter was adjusted until the speech sounds in the receiver were of equal volume for the two positions of the switch. The dial of the meter then indicated directly the magnitude of the crosstalk.

In making tests with this crosstalk meter the usual procedure as outlined in the instructions was as follows: "One experimenter talks into the set marked 'TALK'; usually counting in an even and fairly loud tone as follows: 'one, two, three, four, five; one, two, three, four, five,' etc. The observer at the listening set throws the switch back and forth in time with the successive series of counts."

When a large number of tests were to be made, the talking experimenter was sometimes replaced by a "howling" telephone. The receiver of the talking set was placed against the transmitter in such a way that the set howled continuously. The tone generated in this manner was then used as the testing source.

In 1921, there was made available an improved type of crosstalk meter designated the 50A, which is practically the same as the current model designated 50B. The outstanding improvement incorporated in this meter is a noise compensation feature. Previous to this time, the listener heard the circuit noise as well as the crosstalk when he listened on the line, but he heard only the talking when listening on the meter. Under these

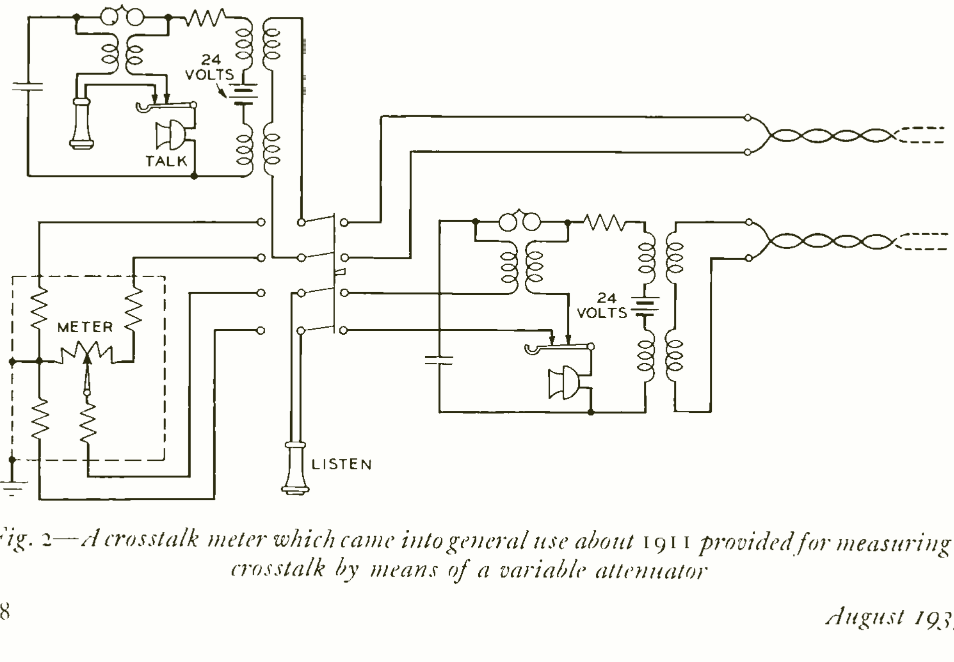


Fig. 2—A crosstalk meter which came into general use about 1911 provided for measuring crosstalk by means of a variable attenuator

conditions it was frequently difficult for the ear to appreciate the true relative intensities of the two sounds being compared.

As shown in Figure 3, compensation for the effects of noise is provided in the 50B crosstalk set by a special network arranged in the form of a Wheatstone bridge. The two carefully balanced windings of a retardation coil form two arms of the bridge. These windings are poled so as to be non-inductive, and thus of low impedance, when connected in parallel, as for currents from the transformer "T_2," and to present a high impedance when connected in series, as to currents from the crosstalk meter. Each of the two remaining arms of the bridge is made up of a condenser, a resistance, and a receiver connected in series. Since the retardation coil acts as a very high impedance across the arms containing the receivers, it diverts practically none of the energy passing from the crosstalk meter to the receivers. Also, since the bridge circuit is balanced, the crosstalk meter and the disturbed circuit have practically no effect upon each other; that is, neither absorbs any appreciable amount of energy from the other. This permits the disturbed circuit to remain connected to the receivers while the source of disturbing current is switched to the crosstalk meter, thereby allowing the noise from the disturbed circuit to be heard in both positions of the double-throw switch.

The meter unit of the 50B crosstalk set consists of three fixed resistances and a variable slide-wire resistance connected as shown in the diagram. The dial of the slide wire indicates crosstalk coupling in both crosstalk units and decibels. A curve showing the relationship between crosstalk units and db down is given in Figure 4.

Although speech can be used as a source of testing power for the 50B crosstalk set, it is much more convenient to use a purely electrical source. The magnitude of crosstalk coupling does not ordinarily vary uniformly with frequency and thus a measurement with a single-frequency source of power, such as the howling telephone, does not give a true indication of speech crosstalk. Measurements with a complex tone covering a band of frequencies give much more representative results.

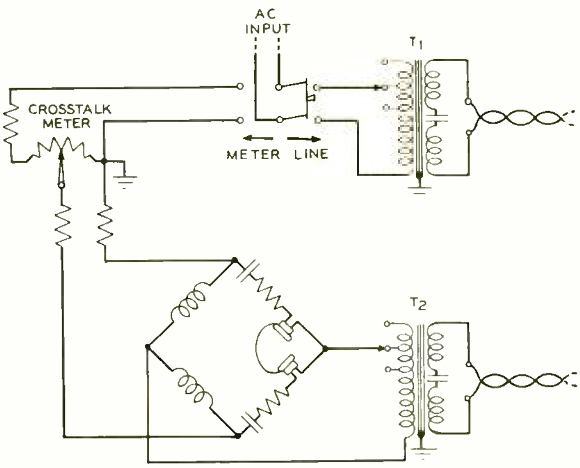


Fig. 3—Simplified schematic of the 50B crosstalk set

Studies to develop a practical power source for crosstalk testing culminated in the design of the 14A oscillator. This oscillator is of the so-called warbler type, the frequency of its output sweeping back and forth over the range from 830 to 1230 cycles per second, approximately seven times per second.

Even with standard types of testing apparatus, ear measurements of crosstalk coupling are slow, tedious, and sometimes of doubtful accuracy. To remedy these faults, a visual method of measuring crosstalk coupling was developed about ten years ago. This method is suitable for most field measurements. It is faster and easier than the ear balance method, and obviates the inaccuracies in that method arising from differences in frequency-response characteristics of

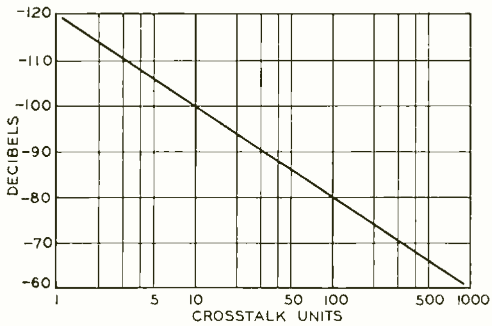


Fig. 4—Relationship between crosstalk units and db down of the crosstalk coupling

various observers' ears, and the differences in observers' judgments. Existing equipment designed for other purposes has been found suitable for the visual meter method so that it has not been necessary to design special apparatus for this purpose. The preferred arrangement employs a 2A noise measuring set* as a measuring unit, and a 14A oscillator as a sending unit, although the 2A noise measuring set can be replaced by any visual meter apparatus suitable for the measurement of message circuit noise providing it has sufficient gain.

In making a measurement of crosstalk-coupling the disturbing circuit is energized by a warbler oscillator, and a measurement of the weighted energy level is made on the disturbed circuit. The difference between this measurement and that of the oscillator output gives the crosstalk coupling in db.

Since the readings of the transmission measuring set are obtained from a visual indicating meter, they are much less susceptible than aural measurements to the effects of distortion caused by transmission through the crosstalk path, whose loss usually decreases with frequency. This permits the voice to be more closely simulated by the use of a wider band of frequencies. The most satisfactory frequency band that can be obtained from the 14A oscillator has been determined by experiment as that between 670 and 1650 cycles.

Crosstalk coupling measurements are made on practically all types of circuits in both cables and open wire lines, and also on various parts of apparatus associated with the circuits. The two purposes for which they are used most are the checking of new work at the time of installation and the location and clearing of specific trouble conditions. Until the last few years, measurements of crosstalk coupling were also included as part of the routine testing of toll circuits, but as a criteria of performance they are being largely supplanted by measurements of crosstalk volume.

Crosstalk volume is the weighted energy level of speech crosstalk occurring in practice. The measurement of crosstalk volume is the latest development, and is used in maintenance testing as a more simple and rapid method of checking the crosstalk performance of toll circuits than the measurement of crosstalk coupling.

For a coupling measurement, two circuits must be taken from service at a time. Also, to completely test a group of circuits, a measurement must be made on each combination of two circuits. This requires considerable time and labor, especially in the case of large circuit groups. For crosstalk

*Record, *April*, 1937, *p.* 252.

volume measurements the high impedance input of the 2A noise measuring set is used. This permits measurements to be made without taking the circuit under test out of service, since with high input impedance the bridging loss is low, and transmission is not seriously affected if the circuit becomes busy during the test.

Because crosstalk volume measurements do not interfere with the normal commercial traffic, they can be made during peak traffic periods. At such times the measured effects are more typical of those experienced by subscribers than during periods of light traffic. Since crosstalk volume varies in magnitude with time, a single measurement will not, in general, indicate whether crosstalk requirements have been met. Several measurements, preferably distributed over a considerable period of time, are necessary.

If the volume of crosstalk is found so great that secrecy is likely to be endangered, crosstalk coupling tests may be made to determine the magnitude and location of the crosstalk coupling. Thus, a crosstalk volume measurement is used as a sort of qualitative test to determine if crosstalk trouble exists, while a crosstalk coupling measurement is a quantitative test of the magnitude of the trouble.

Any device capable of measuring message circuit noises properly is satisfactory for the measurement of crosstalk volume provided its input impedance is sufficiently high not to introduce excessive loss when bridged across a 600-ohm circuit.

For convenience, crosstalk volume tests are made in conjunction with noise tests. One measurement is made on each circuit, and the result is recorded as crosstalk, babble (simultaneous crosstalk from a number of circuits), or circuit noise depending on which particular type of disturbance predominates. Routine measurements of crosstalk volume and noise are usually made periodically on a sampling basis, the percentage of circuits tested each time depending upon the size of the office and the results obtained from previous measurements.

A Diverter-Pole Generator for Battery Charging

By R. D. de KAY
Equipment Development

FOR the continuous floating of batteries, a constant d-c supply voltage is desirable. With a constant-voltage supply, the drop in the battery voltage, when current is taken out of the battery, is just about enough to make the charging rate increase in proper proportion to restore the charge to the battery. In this way, the battery is always in a fully charged condition. A shunt-wound generator, because of its drooping voltage characteristic, is thus not suitable by itself for floating a battery—some voltage control, either manual or automatic, is essential. A compound-wound generator could be made to have the required flat characteristics, but it is not safe to use because should the a-c power fail, the battery would run the generator as a motor if the reverse current circuit breaker did not operate, and the reversed current in the series winding would reduce the field flux sufficiently to cause dangerous speeds. In the Bell System, shunt generators with automatic voltage regulators are commonly used, but it would be desirable to obtain a generator that in itself provides a constant voltage, and that would not "run away" on a reversal of current.

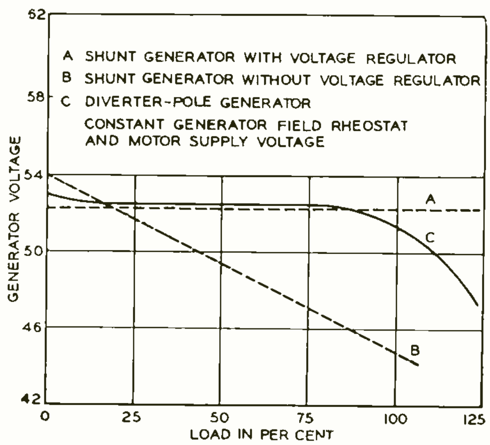


Fig. 1—Voltage characteristics of shunt generator with and without a regulator, and of the diverter pole generator

The diverter-pole generator provides these characteristics and it has recently been adopted by the Bell System in a form suitable for charging and floating batteries at the smaller central offices. The largest standard rating is 200 amperes at fifty volts. These new charging sets are in general appearance much like the former ones. The motors, in fact, may be identical and the generator armature is essentially the same; the difference between them is in the magnetic circuit and in the field windings.

The voltage characteristic of this new generator, compared with that of a shunt generator with and without a regulator, is shown in Figure 1. Contrasting with the rapidly drooping characteristic of the shunt generator, the diverter-pole generator maintains its voltage essentially constant up to about full load, and then allows it to decrease. This decrease in voltage above full loads prevents the motor carrying heavy overloads, and also helps to equalize the load between generators when two or more are operating in parallel. In this respect it is better than the regulated shunt motor, which tends to maintain a constant voltage regardless of the load.

These characteristics are obtained by the use of a series field winding; but instead of being placed on the same poles as the shunt windings, as with ordinary compound generators, the series windings are placed on separate poles midway between the main poles. These are called diverter poles, and between each main pole and the diverter pole adjacent to it in the direction contrary to the rotation of the armature is a magnetic bridge. Under no-load conditions, indicated in Figure 2, there is no current in the winding on the diverter pole, and part of the flux from the main pole, instead of crossing the air gap, is diverted across the bridge, through the diverter pole, and back to the main pole. The bridge and diverter pole thus act as a shunt to the main-pole flux, and decrease the flux in the main gap and thus the voltage generated in the armature. The amount of flux that can pass through the shunting path, however, is limited by holes in the bridge so that it becomes saturated at the desired flux.

With normal direction of current flow, the action of the winding on the diverter pole opposes the flux leaking over from the main pole, and thus forces more of the main pole flux across the air gap, and increases the generated voltage. The condition at full load is indicated by Figure 3, which shows practically no flux in the diverter pole. Having, at full load, forced all the main-pole flux across the air gap, the diverter cannot further increase the main air gap flux, so that the voltage drops at further increases in load.

Should the power to the driving motor fail, the generator will run as a motor supplied by the battery. The current in the series winding will reverse, and the effect of the diverter pole, instead of forcing the main-pole flux across the air gap, is to tend to shunt more of the main flux, and thus to decrease the air gap flux and increase the motor speed. As already pointed out, however, the bridge, because of the holes through it, is

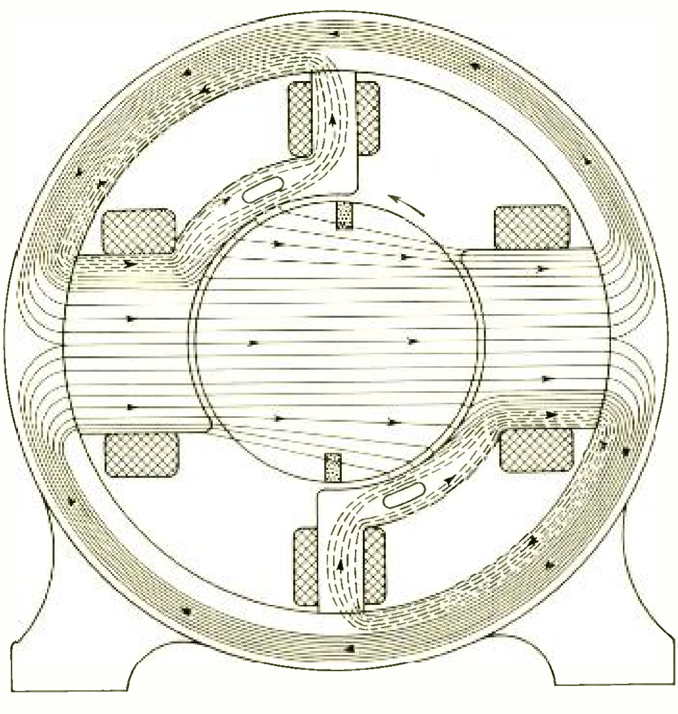


Fig. 2—Cross-section of the diverter-pole generator showing flux distribution under the no-load condition

quickly saturated, preventing the diversion of any large amount of flux, and thus the reversed current has very little effect. As a result of this condition the speed does not rise above safe values.

The self-regulating action of the diverter pole generator insures that the generator will perform its charging function under all conditions without overloading, and such a charging set may be used in an unattended office with full assurance that the set will not "run away" should the reverse current relay fail to operate on a failure of the alternating-current supply. Even after a prolonged power failure, when the battery voltage has been appreciably lowered by the office drain, the generator—on restoration of the power—will automatically charge the battery without serious overload because of the drooping characteristic of the voltage above full load. As the battery becomes charged, the charging current will decrease until normal "floating" values are reached. Moreover, the position of the diverter poles enables them to act as interpoles to improve the commutation, so that satisfactory operation is secured at all loads.

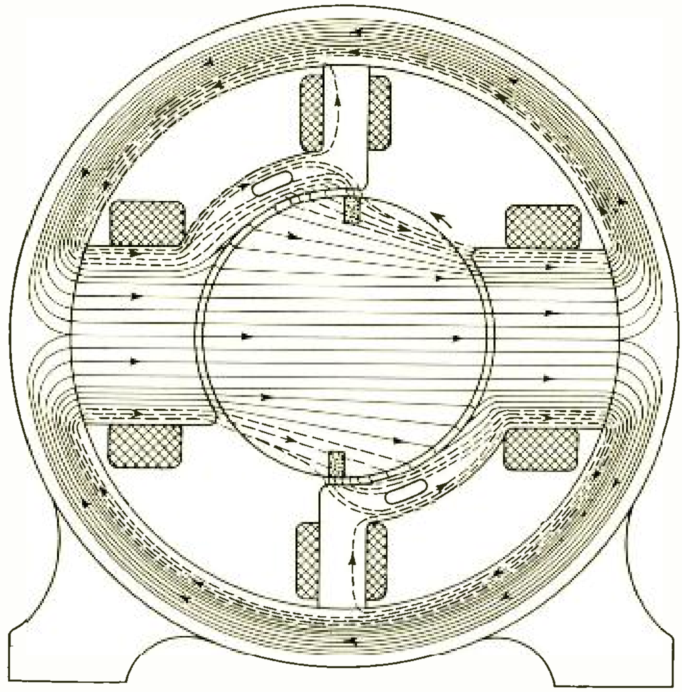
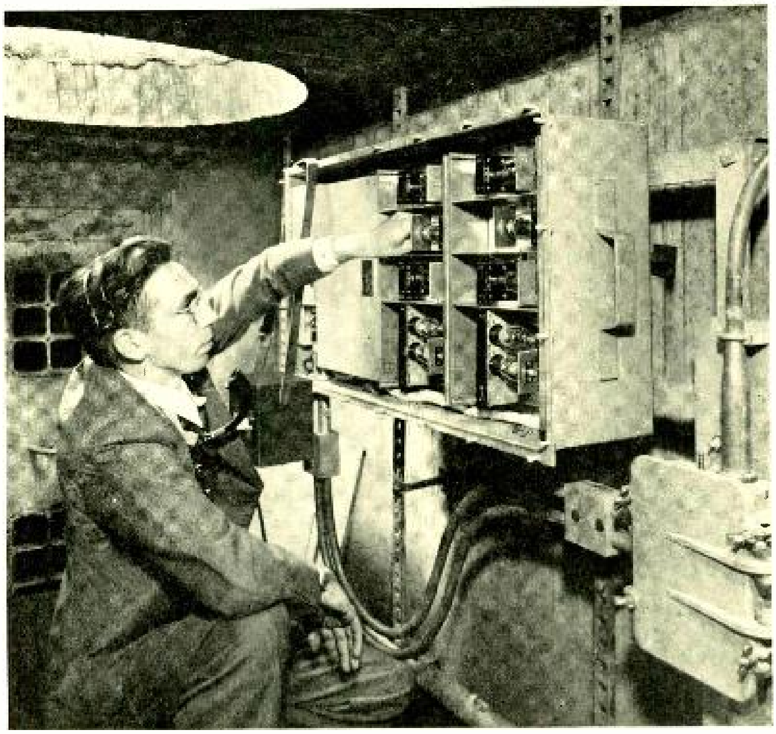


Fig. 3—When the generator is operating at full load, practically all the main-pole flux crosses the air gap



Repeaters for the Coaxial System

By K. C. BLACK
Transmission Development Department

IN the development of communication systems for transmission on many channels over a single pair of conductors, lines good for high frequencies are, of course, of prime importance. Having provided such a line, the problem next in importance is to provide amplification for all the channels in a single repeater, since the additional apparatus necessary to separate the channels, amplify them while separate, and recombine them would be very complicated and expensive. With the experimental coaxial system between New York and Philadelphia, which provides 240 telephone circuits and has an upper frequency of 1024 kc, the undertaking involves many difficulties and complexities.

The attenuation of the coaxial line at its top frequency is far greater than that encountered by previous systems at their highest frequencies, and, in addition, the difference in loss between the highest and lowest frequencies is also much greater than in conventional types of lines. This means that considerably more overall gain must be provided at the higher frequencies than in other systems, and that a much greater change in gain with frequency, or equalization, is also required. As an example, 100 miles of ordinary toll cable circuit (19 gauge H-44-25) has an attenuation at voice

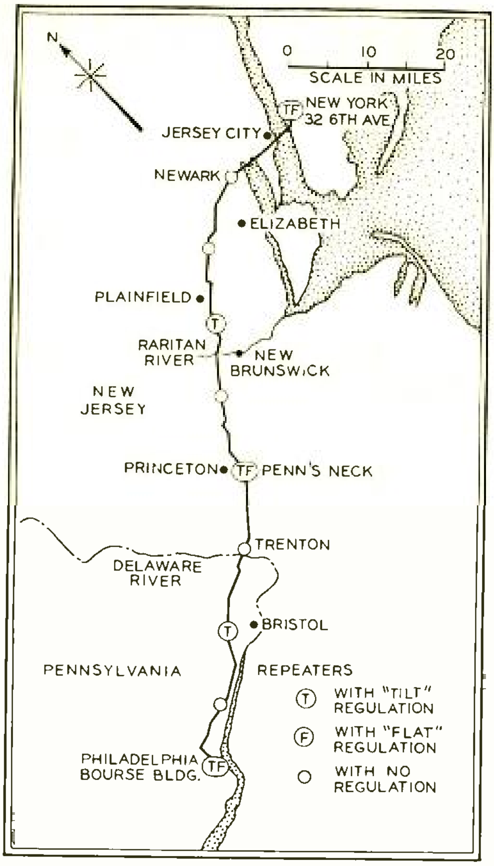


Fig. 1—Route map of the experimental coaxial line showing repeater locations

frequencies of about 50 db while the same length of coaxial cable has an attenuation of 600 db at its upper frequency. Present voice-frequency practice spaces repeaters about 50 miles apart so that some 25 db of gain is required at each point. The enormously greater attenuation to be overcome in the coaxial system has made it necessary to space the repeaters about 10 miles apart for the experimental installation between New York and Philadelphia, and to provide a gain of 60 db at each one. This difference has required a radical change in the design of the repeaters. Previous repeaters have been installed in attended repeater stations, where their performance could readily be checked at all times, and where tube changes or other adjustments could be made in a very short time. To provide attended repeater stations every ten miles, however, would be a serious economic handicap. The repeaters had to be designed for unattended operation, therefore, and built so that they could be placed in manholes or hung on poles as occasion warranted.

Another difficulty in the design of repeaters for the coaxial system is the large amount of additional, and variable, gain required to compensate for changes in temperature. On a 100-mile line, for example, some 80 db more gain is required at the top frequency at 110 degrees Fahrenheit than at −10 degrees Fahrenheit, and the desired change in gain with temperature is different for each frequency. Besides the changes in gain with frequency that must be provided, there are also other changes that are not

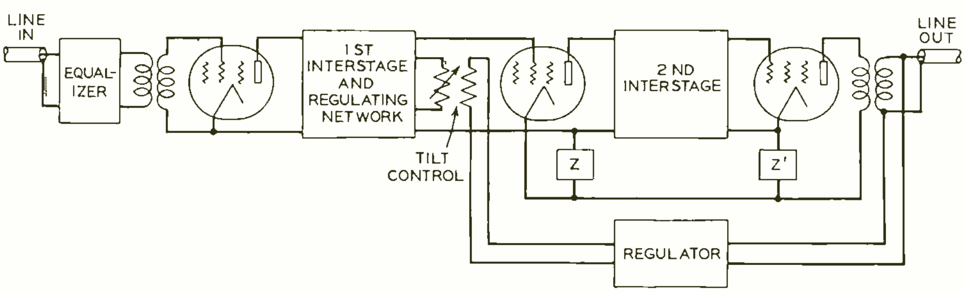


Fig. 2—Simplified schematic of the 1000^{-1} *amplifier*

Fig. 3—The 1000^{-1} amplifier employed on the original experimental coaxial line

of transmission will tend to bring its output level to the proper value so that the overall gain will remain constant.

The pilot signal for controlling the flat regulation is at 60 kc, and thus has an attenuation about the same as the lowest frequency of the communication band, and that for controlling the tilt or twist regulation is at 1024 kc, and thus has an attenuation about the same as the highest frequency of the communication band. Too low a level at 60 kc causes the regulator to increase the gain of the repeater at all frequencies, and too low a level at 1024 kc causes it to increase the gain according to the attenuation slope, with the result that the greatest increase occurs at the highest frequency.

Both of these types of regulation are not necessarily required at each repeater. For an aerial line, twist regulation would be required at every repeater, but for an underground line, such as that between Philadelphia and New York, every second or third re-

dependent on frequency. These may be caused by variations in the voltage of the repeater power supply, by aging of the tubes, or by other factors.

Two types of regulators are provided in the coaxial repeaters: one to give "tilt" or "twist" regulation to compensate for losses that vary with frequency, and one to give "flat" regulation to compensate for the losses that do not vary with frequency. For each type of regulation a pilot signal is transmitted over the coaxial conductor, and a deviation from normal level of this signal at the output of a repeater causes the regulators of that repeater to insert or remove gain as may be required. The advantage of this method is that the output of each repeater is held at some pre-established value, within the precision of the regulator, so that an error in the setting of a regulator does not lead to a cumulative error. If one repeater fails to regulate, the next repeater in the direction

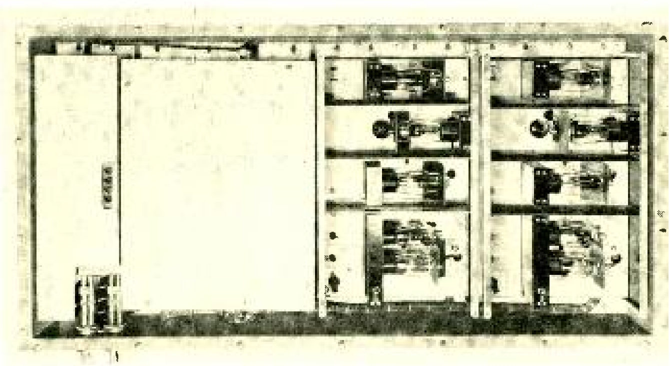


Fig. 4—The complete repeater for the coaxial system

peater is sufficient. In either case about every fifth repeater is frequent enough for flat regulation. In the experimental installation, the flat regulators are installed only at the attended repeater stations at New York, Princeton, and Philadelphia, while twist regulators are provided at these stations and at two intermediate points as indicated in Figure 1.

Current for operating the repeaters is supplied at sixty cycles over the coaxial conductor itself by a method which will be described in a subsequent article. The primary sources of current are at New York, Newark, Princeton, and Philadelphia. Newark and Philadelphia each feed one adjacent repeater, while Princeton feeds two on each side. New York supplies only its own terminal repeater. Equipment is provided for filtering out this power current at each repeater, and supplying it to the amplifier in the proper forms.

The amplifier as originally designed for the experimental circuit is shown in schematic form in Figure 2, and in the photograph of Figure 3. The three tubes at the left in Figure 3 are the three amplifier stages shown in the schematic, while the tubes at the right form part of the regulator circuit. Most of the tubes used are specially designed pentodes. Negative feedback is used around the last two stages of each amplifier to meet the severe requirements placed on distortion. Since the repeaters are designed for unattended operation, all adjustments have been reduced to a minimum. At the non-regulating repeaters, of which there are five in the experimental installation, only one adjustment is required in the field for each direction of transmission, and at the regulating repeaters, only two. It is expected that the only routine maintenance will be the occasional replacement of tubes.

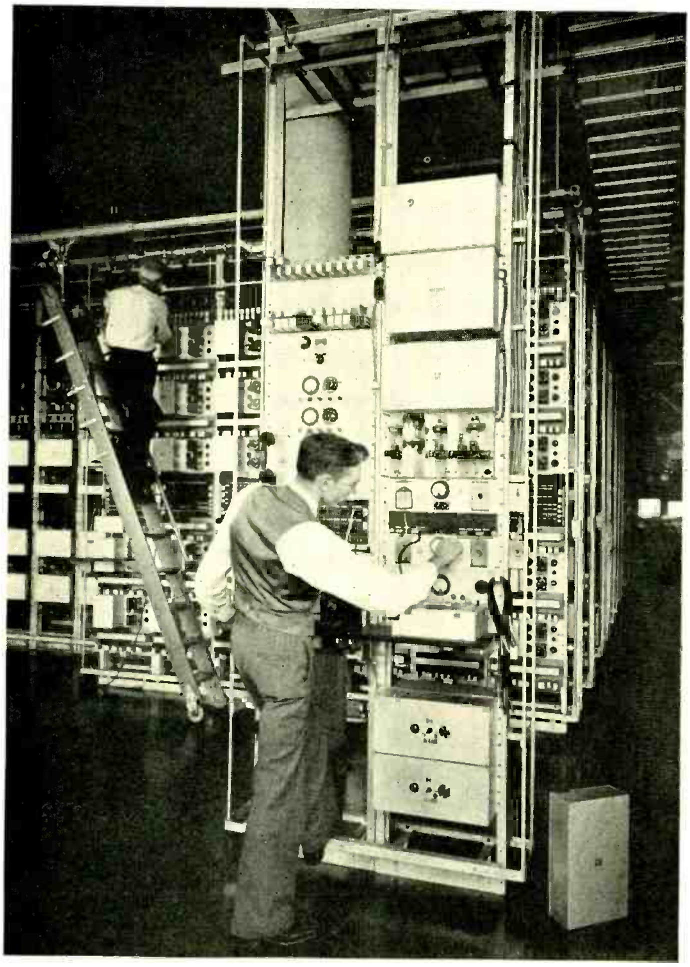


Fig. 5—The coaxial bays at the Princeton repeater station

Two of these amplifiers, either of the regulating or non-regulating type, are mounted with a power separation filter panel and a power pack to form a complete repeater. These four units are then installed in a steel box with a water-tight cover as shown in Figure 4, where the power filter is at the left, then the power pack, and then the two amplifiers, one for each direction of transmission. The complete unit weighs about 300 pounds. One of the repeaters installed in a manhole is shown in the photograph at the head of this article, while one of the "above ground" installations was shown on page 274 of the May RECORD. The coaxial equipment at Princeton is shown in Figure 5; in this photograph the cover is removed from one of the amplifiers.

Fig. 6—Lowering a repeater into manhole E, some ten miles south of Trenton

In preliminary tests on the experimental circuit the repeaters have proved very satisfactory from the point of view of transmission. The transmission on the overall system is the same at all frequencies within about ±½ db for average temperatures. Additional transmission variations due to imperfect compensation for temperature appear to result in overall variations of about ±1 db. Talking tests have been made over the circuit and the quality of transmission is not noticeably affected by the repeater equipment.

The present trial repeaters are not satisfactory from the point of view of maintenance, no provision being made to insure service during tube or repeater failures, nor has any provision been made for supplying power from standby equipment. From the point of view of modulation the present amplifier, though satisfactory on a circuit of moderate length such as that used in the New York-Philadelphia trial, would not be suitable for use in very long circuits. Furthermore, the near-end crosstalk in the present repeaters which would manifest itself as echo, although satisfactory on short lengths of line or on high velocity circuits, is dangerously near the limit imposed on long lines that may have a considerable length of lower-velocity voice-frequency cable connected at the terminals.

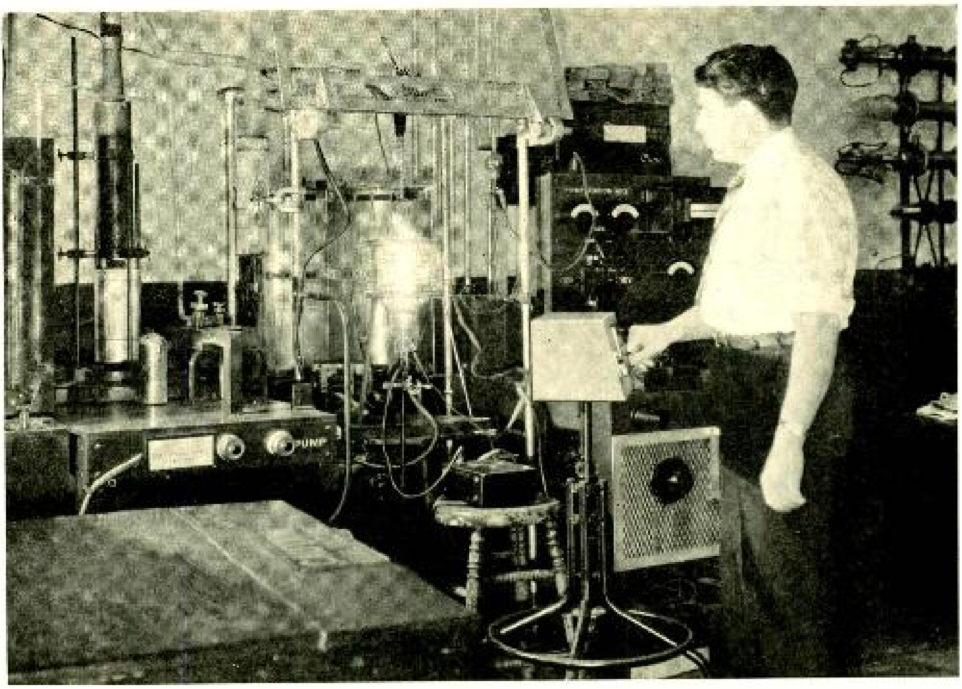
As yet the present repeaters cannot be regarded as suitable for use in the telephone plant even though some of the major technical difficulties, such as transmission and regulation, have been overcome. Considerably more development work is being carried on to correct the shortcomings which still remain. It is encouraging, however, to note that in the recent service trial of the coaxial system (reported on page 360 of the RECORD for July) that the problems which were experienced at that time, although they were individually unpredictable, were all of the type which is normally to be expected in the first working out of a radically new system. In those tests there was experimental transmission also of telegraph and telephoto signals, and the system proved that it could handle more than one type of facility at the same time—which is a very desirable characteristic from the standpoint of flexibility.

THE MAKING OF INDUSTRIAL PHYSICISTS

The human material for the construction of an industrial scientist may be qualitatively described with considerable ease; but to write for it an engineering specification with inspection techniques and with prescribed tolerances is at present impossible. Unless, however, we would credit evolution with having changed human nature within the times of recorded history we will agree that, despite his specialized training, modern scientific point of view and wealth of precise instruments, the industrial scientist of today is the man of yesterday and of yesteryear and so on back into prehistoric days. What did this type of human being do in the past? Was he king or priest? captain or explorer? medicine man or scribe? trader or pirate? None of these. He was thinker and craftsman. His was the type that invented the wedge, the inclined plane, the lever and the screw. He surveyed and built the Pyramids; designed and constructed triremes, roads and aqueducts; shaped the tools of his day; and led the way from stone to bronze to steel.

His urge was the instinct of workmanship, a pleasure in the act of creation or construction which is its own reward. Neither driven by acquisitive instinct nor maddened by lust for power or fame, his satisfaction was his work; he sought little reward; and died unknown. More practical than the philosophers; spending little of his time in teaching or writing; and no follower of the Muses, he burned with a quiet steady flame of the same divine fire that suffused the great teachers and poets of his time. The captains and the kings depart; but what he wrought is the hidden basis of our material grandeur.

—From a paper delivered by John Mills before the Society for Promotion of Engineering Education, July 1937.



High-Frequency Supply for Degassing

By E. G. SHOWER
Vacuum Tube Development

ALL materials which eventually go inside a vacuum tube will absorb into their mass and adsorb onto their surface a considerable amount of gas when they are at atmospheric pressure and temperature. Under the low pressures and high temperatures found in vacuum tubes during operation, the amount of these gasses which can be held bound is much less. If a tube were rapidly pumped without heating, the excess gasses would come out of the elements, slowly while the tube remained cold and rapidly as soon as it was placed in service. So many molecules thus appearing inside the envelope would be ionized by collision with electrons that the tube would not function properly and a destructive arc might strike between the elements. These facts were discovered early in the high vacuum art, and means were provided to drive off the gasses by heating the parts before and during the pumping operation.

Materials which go into a tube can be classed roughly into two groups, conductors and insulators. The insulators must be heated by conduction or radiation as for example the glass envelope, which is heated at the beginning of the evacuating process by an electric oven fitted around the outside of the tube. The insulators used inside the envelope are degassed previous to assembly, or during evacuation by conduction or radiation from parts which are adjacent to them.

The conductor class of materials

can be heated by two additional methods; namely, electron bombardment and high frequency induction. As the name of the first process implies, the part is bombarded with high velocity electrons which give up practically all their energy to the bombarded surface, thus heating it to the desired point. However, the bombardment process necessitates, first, a source of electrons sufficient to supply the required amount of energy, and second, a geometrical arrangement whereby the electrons will travel in essentially straight lines and still be made to strike the surface of the material to be heated. In general, the second condition cannot be fulfilled for all of the internal parts of a vacuum tube. In some cases the filament could not safely emit a sufficiently large electron current to develop the required temperature. In other cases the part to be heated is isolated either electrically or mechanically in such a way as to preclude heating either by conduction, radiation or bombardment. In such cases, high frequency inductive heating is used. Essentially this process is accomplished by surrounding the tube with an inductance coil through which high frequency current is passed. The resultant eddy currents in the metallic parts of the tube, which act as the secondary of an oscillator transformer, raise the temperature of those parts to a degree dependent upon the coupling, frequency, field strength, and resistivity of the material.

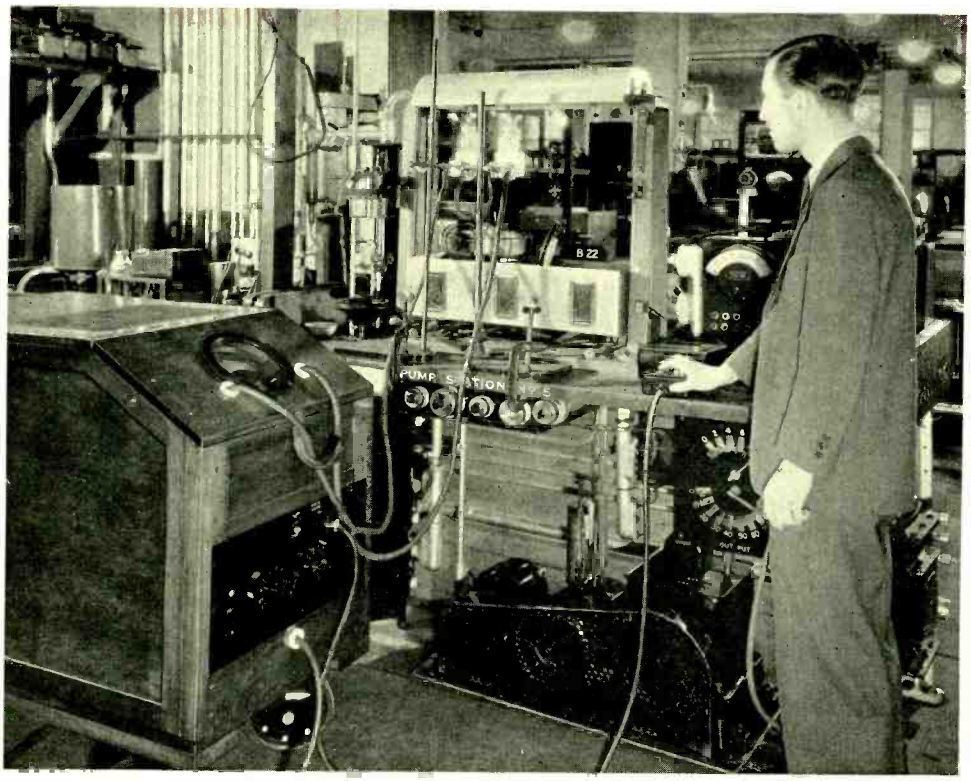


Fig. 1—A portable oscillator provides a convenient source of high-frequency heating current capable of expelling the gasses from the smaller tubes

Since the internal geometry of the tube is determined by operating requirements, it frequently happens that the metallic parts are deeply buried in the tube, with a correspondingly low coefficient of coupling with the inductor coil. Energy transfer, however, increases with the square of the frequency and hence high frequencies are invariably used.

The Poulsen arc, the spark oscillator and the high frequency alternator have been used, but the vacuum tube type of generator permits the use of higher frequencies than these other methods and in addition is considerably more flexible.

The simplest form of vacuum tube generator is a portable set shown in Figure 1, and used in pumping the smaller tubes. It is self-contained, operates on sixty cycles, 208 volts, and consists of a plate-supply rectifier, oscillator, tubes, switches, transformers and condensers. The heating coil serves as the tuning inductance of the oscillating circuit. The frequency at which this set operates depends, of course, upon the heating coil used since the oscillating condenser is fixed, but is usually in the range of 250 to 500 kc. Tap switches are provided to regulate the oscillator plate voltage, which determines the circulating current in the heating coil and hence the temperature of the parts being treated. All tubes used in this type of equipment are air-cooled.

In pumping large tubes or tubes where the contained parts are very small as compared with the glass envelope, hence involving poor coupling, the maximum available power in the portable sets is not sufficient to reach

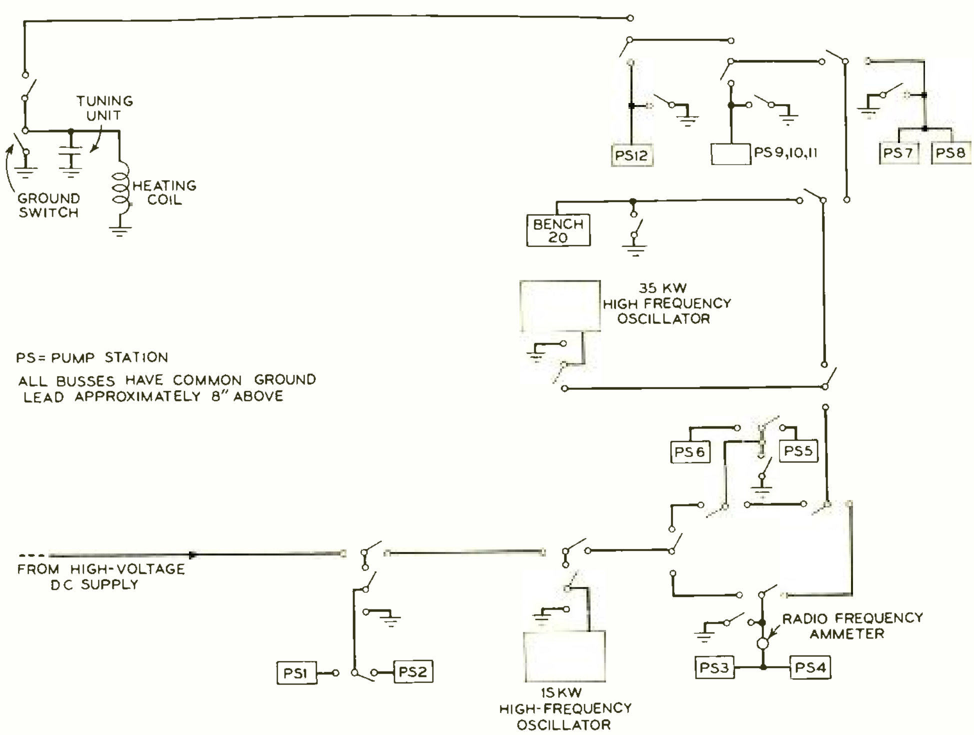


Fig. 2—Schematic of high-frequency distribution system. The arrangement of heating coil and tuning condenser is shown only with the pumping station at the upper left

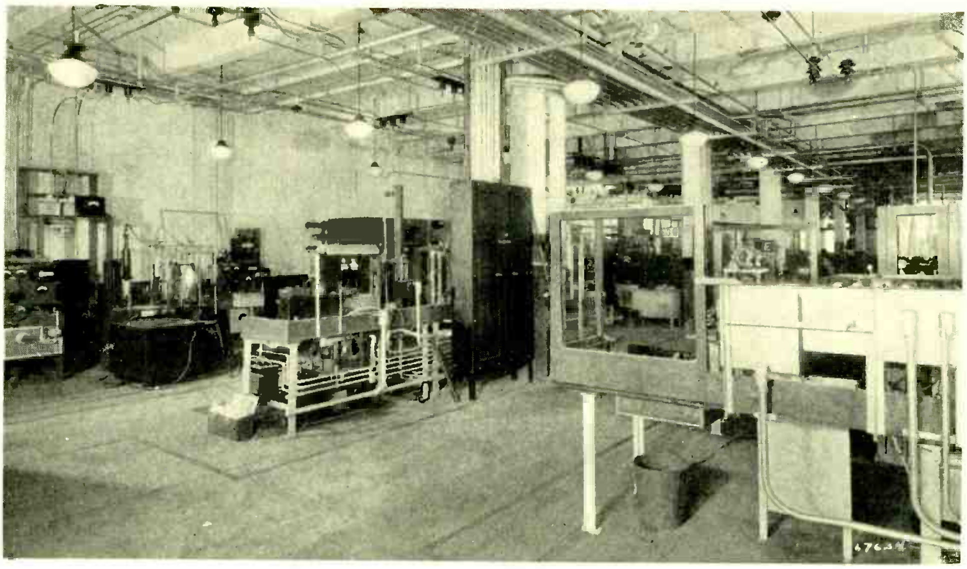


Fig. 3—A view of the vacuum tube laboratory showing a typical pumping station at the extreme left and the overhead bus structure and disconnecting switches

the required outgassing temperatures. It has therefore been necessary to design non-portable oscillators using water-cooled tubes. There are two such sets in use in the Vacuum Tube Development laboratory at the present time, one nominally rated at fifteen kilowatts output and the other at thirty-five kilowatts.

When a fixed set is used, it is, of course, necessary to transmit its power to the pump stations, of which there are about a dozen in the laboratory. Since the transmission line must be well over a hundred feet long and must transmit substantial amounts of power at frequencies in or near the broadcasting band, precautions were necessary against loss through radiation, either into space or into adjacent metal structures. Accordingly the impedance of the system was made high by tuning the coupling circuits at both ends, thus minimizing the line current while giving a large current through the heating coil. To guard against radiation when a unit is slightly detuned and a considerable current flows in the line, the return (grounded) line is run physically parallel to the high side of the transmission line and about eight inches away from it. As will be seen from Figure 3, the construction of the line follows current high-tension practice, with interlocking switches so that the two generating sets cannot be connected together or to the same pumping station. Safety grounding switches are also provided.

The fifteen-kilowatt oscillator shown in Figure 5 employs two 228A water-cooled tubes in parallel as oscillators, and two 255A mercury-vapor tubes as rectifiers for plate supply.

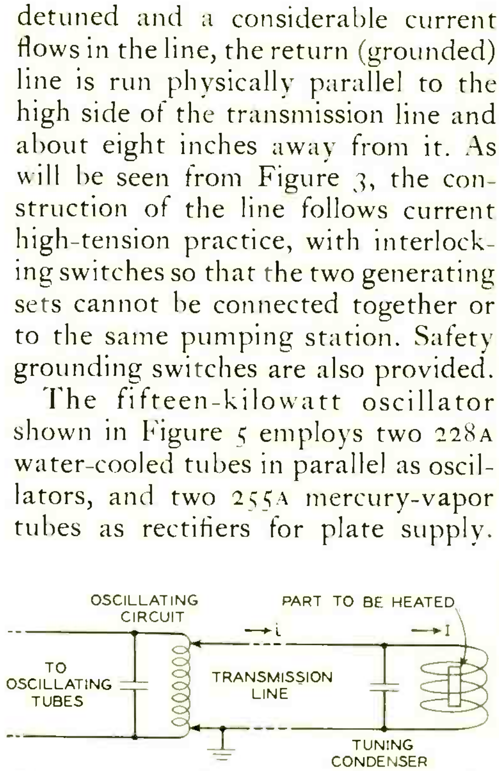


Fig. 4—By employing a condenser at the pumping station to tune the heating coil, only a small current is transmitted over the line

Regulation is accomplished by a manually operated tap switch on the front of the set. With the control at the oscillator itself, it is desirable to transmit the high frequency only to points where the operator at the oscillator can watch the heating process. For this reason the switching system of the transmission line is so arranged that the fifteen-kilowatt oscillator can be connected only to the six pumping stations in the immediate vicinity of the oscillator.

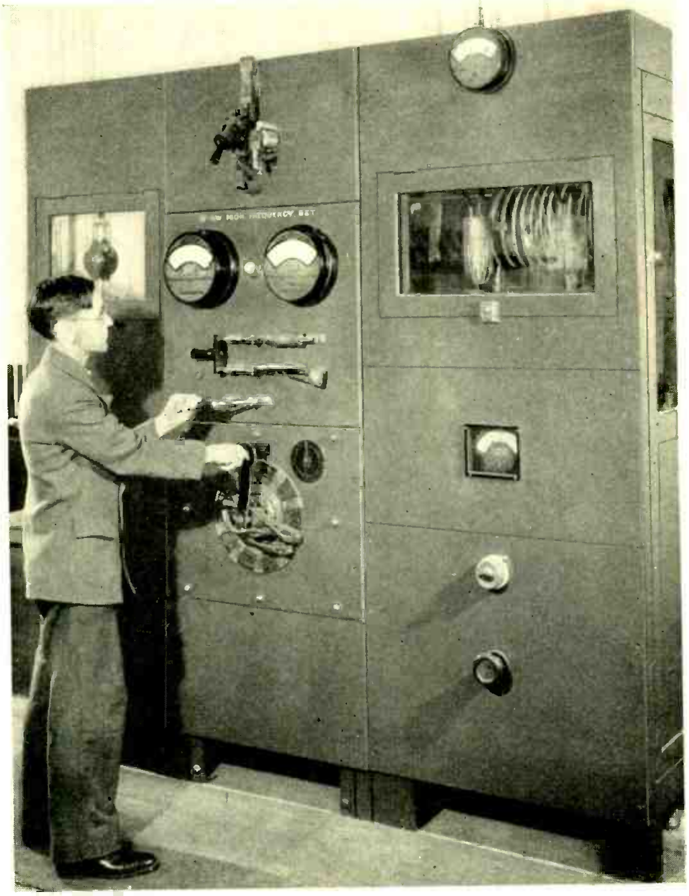


Fig. 5—The fifteen-kilowatt oscillator employs a manually operated tap switch for adjusting the output

In some cases it is not possible to obtain the desired temperatures due to lack of available power or to the fact that the coupling is poor. For these reasons a thirty-five-kilowatt set using four 228A tubes as oscillators was designed and built. This set is provided with a remote-control feature (shown on page 391) whereby it can be fully controlled from the point of use. The same transmission line is used for the high frequency as with the fifteen-kilowatt set, interlocking switches being provided for this purpose. Remote control is provided through a six-conductor cable which terminates in a convenience outlet at each point of use. The remote-control apparatus consists of an "on-off" switch, a voltmeter and a "raise-lower" switch. The "on-off" switch controls a magnetic contactor in the primary of the oscillator plate-supply transformer. The voltmeter indicates the voltage across the primary of that transformer and the "raise-lower" switch controls the three-phase motor which operates an induction regulator in the 120-volt, sixty-cycle supply line to the plate transformer. This induction regulator performs the same functions as the tap switches in the other sets, but here there are no perceptible steps.

Although the high frequency is controlled remotely it is necessary to turn on cooling water and filament supplies at the set, but this operation is only performed one or two times in a working day. In order to change the point of use the remote control apparatus is rolled to the new point and plugged into the outlet and the interlocking switches in the transmission line thrown to the proper positions. There is no necessity for going back to the set itself. The plate voltage is turned off when the remote-control unit is disconnected from the convenience outlet, even though the operator may have failed to turn off the plate voltage in the usual manner.

The thirty-five-kilowatt set has an additional feature in that it provides for three different frequencies. Adjustable bus bars and heavy terminals accessible from the front of the set (shown through lower right-hand glass panel, Figure 7) serve to connect the four oscillator condensers in parallel, series parallel or in series, giving nominal frequencies 250, 500 or 1000 kc. The higher frequencies are particularly desirable in cases where coupling conditions are poor, such as in the case of a tube with small elements and a relatively large glass envelope. The recently developed ultra-high frequency Western Electric 316A tube is an example of a tube heating problem which requires high frequencies. Since for any given material the power consumed by eddy currents is proportional to the square of the frequency, this increase in frequency, where possible, is a definite advantage.

The impedance at the terminals of the resonant circuit at the load end is relatively high as compared with the line impedance. There would be reflection losses at this junction of the transmission line with the heating coil and condenser combination and standing waves would result if the electrical length of the line approached a quarter wavelength. This difficulty could be overcome by the use of impedance-matching networks with the risk of considerably complicating the set and reducing its present flexibility. For these reasons it was not deemed advisable to generate and use frequencies above 1000 kilocycles. In some of the more remote stations in Section 1-R the length of transmission line involved makes it necessary to limit the frequency to 500 kilocycles or less.

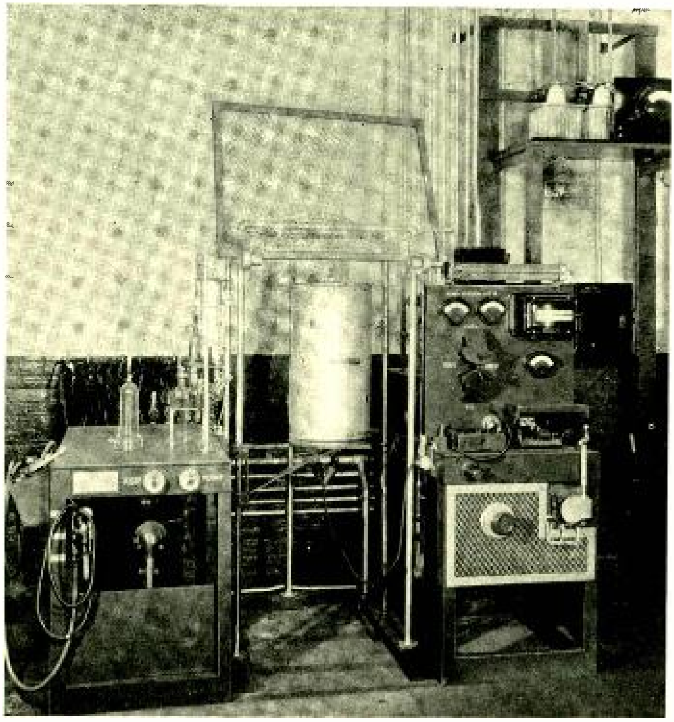


Fig. 6—One of the pumping stations, showing the arrangement of tuning condensers at the upper right

When large circulating currents are used, the design of adequate heating coils is somewhat complicated. The coils become hot due to resistance and eddy current losses within themselves, with resultant danger to the nearby glass envelope and to insulation and adjacent parts. The problem has been solved satisfactorily by the use of water-cooled coils. The coil shown in the headpiece consists of a partially flattened copper tube wound edgewise and supported by slotted micalex insulators. The flattening of the tube allows the required number of turns to be wound in the available space without danger of arc-over between turns and still permits the passage of an amount of water sufficient for adequate cooling. Rubber hose connections to the water supply and drain provide insulation for the high voltage from ground, the local water supply being pure enough to prevent high current leakage even at the high voltage used under these conditions.

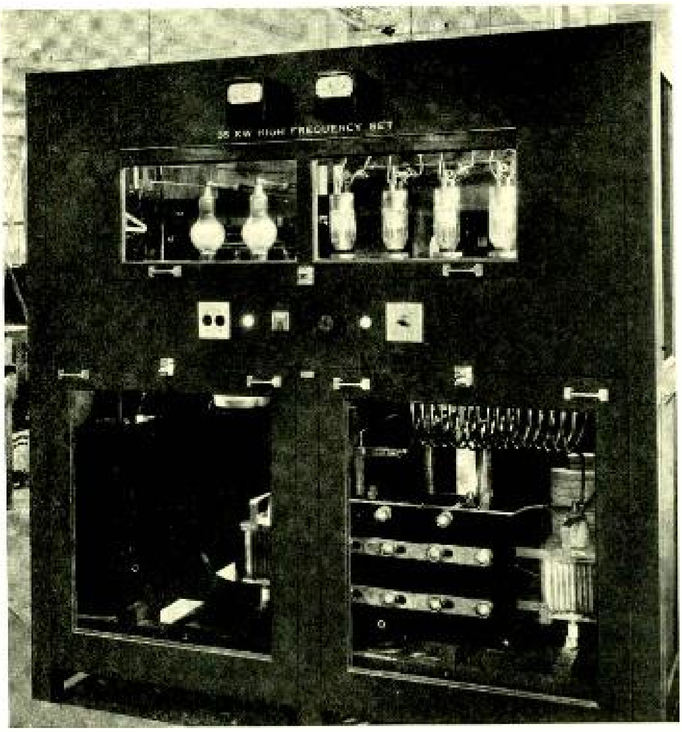


Fig. 7—The thirty-five-kilowatt oscillator is remote controlled and provides frequencies of 250, 500, *or* 1000 *kc*

Aviation Radio First Demonstrated Twenty Years Ago

On August 18, 1917, the first successful two-way communication between a ground station and an airplane was established at Langley Field, Virginia. Two days later—barely three months after the Signal Corps had asked F. B. Jewett and E. B. Craft to undertake this radio development—two airplanes in flight maintained communication with each other. In the twenty years now passed millions of miles have been flown by commercial and military planes equipped with Western Electric radio systems.

First one-way transmission had been made early in July, 1917, with a transmitter consisting of a Colpitts oscillator operating directly into an antenna and modulated by the Heising constant-current system. The receiver was a vacuum-tube detector with one stage of amplification. Power was supplied by batteries. Members of the Engineering Department of Western Electric Company, now Bell Telephone Laboratories, taking part in these tests were H. W. Nichols, R. A. Heising, L. M. Clement, J. P. Minton and C. A. Finley; later H. M. Stoller and R. W. Armstrong joined the group. Practical apparatus was at once begun, and it was successfully demonstrated between August 14 and 24. A wind-driven generator in place of batteries was tried out, and filters were developed to eliminate the commutator noise from its output.

During the next three months airplane antennas were analyzed and further communication tests were made by Mr. Heising, E. L. Nelson, A. A. Oswald and A. Haddock. By this time the experiments had conclusively demonstrated the practicability of the system and during succeeding months orders were placed by the War Department with the Western Electric Company for both ground and airplane apparatus.

E. B. Craft, Ralph Bown, Nathan Levinson and N. H. Slaughter using early Western Electric apparatus to carry on two-way conversation with an airplane

Contributors to this Issue

K. C. Black received the A.B. degree in physics from Harvard in 1924, and in the three following years received the A.M. and Ph.D. degrees. During the summer of 1926 he worked on inductive interference studies in Virginia with the D. & R. Department of A. T. and T. Co. After two years as instructor in physics and communication engineering, he then became associated with the Boonton Research Corporation—working on high-frequency measuring equipment, vacuum-tube design, and automatic volume control. In 1930 he joined these Laboratories, where he has been engaged chiefly in the design and development of repeaters that are used in the coaxial system.

K. C. Black

R. D. de Kay was graduated from the United States Naval Academy in 1918. He served in the war as engineer officer on destroyers, and after the war as commanding officer. In 1922 he left the navy and joined the power development group of the Laboratories, where he supervises rectifier and machine development.

W. M. Beaumont entered the Bell System as substation installer with the Bell Telephone Company of Pennsylvania early in 1911. After a short time he transferred to the Maintenance Department and remained in that department until 1919, when he joined the engineering department of the Western Electric Company. With the Circuit Laboratory he has participated in the development of manual central offices and private branch exchanges. At present he is en-

R. D. de Kay

W. M. Beaumont

E. G. Shower

W. F. Malone

R. S. Alford

gaged in the development of both manual and dial PBX's. He is a graduate of the night school of the Drexel Institute of Philadelphia.

E. G. Shower received the B.E. degree from Johns Hopkins Engineering School in 1925 and immediately after joined the Technical Staff of the Laboratories. With the Research Department he carried on studies in acoustics and hearing for the next nine years. In 1934 he transferred to the Vacuum Tube Development Department, where he has since been engaged in the development of water-cooled tubes for high-power radio transmission.

W. F. Malone joined the Engineering Department of the Western Electric Company in 1917, where with the Systems Drafting Department he engaged in the preparation of drawings and specifications for the new panel dial offices. In 1923 he transferred to the Equipment Development Department and for the next eight years prepared manufacturing information for models and trial installations of new equipments. During this time he was responsible for supervising the installation of the terminal equipment for the Key West-Havana submarine cable and the radio control equipment at 24 Walker Street, New York. For the past six years Mr. Malone has been engaged in developing equipment for carrier telephone circuits over cable pairs, and more recently in the design of various types of key equipments such as those which are described in this issue of the Record.

R. S. Alford was graduated from the University of Colorado in 1920 with a B.S. degree in Electrical Engineering. In July of that year he joined the Development and Research Department of the American Telephone and Telegraph Company where he worked on open-wire crosstalk problems. During the last few years his work has dealt with a number of problems connected with crosstalk and noise, including the methods of measurement of various types of interference, and the evaluation of their effects on transmission.

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