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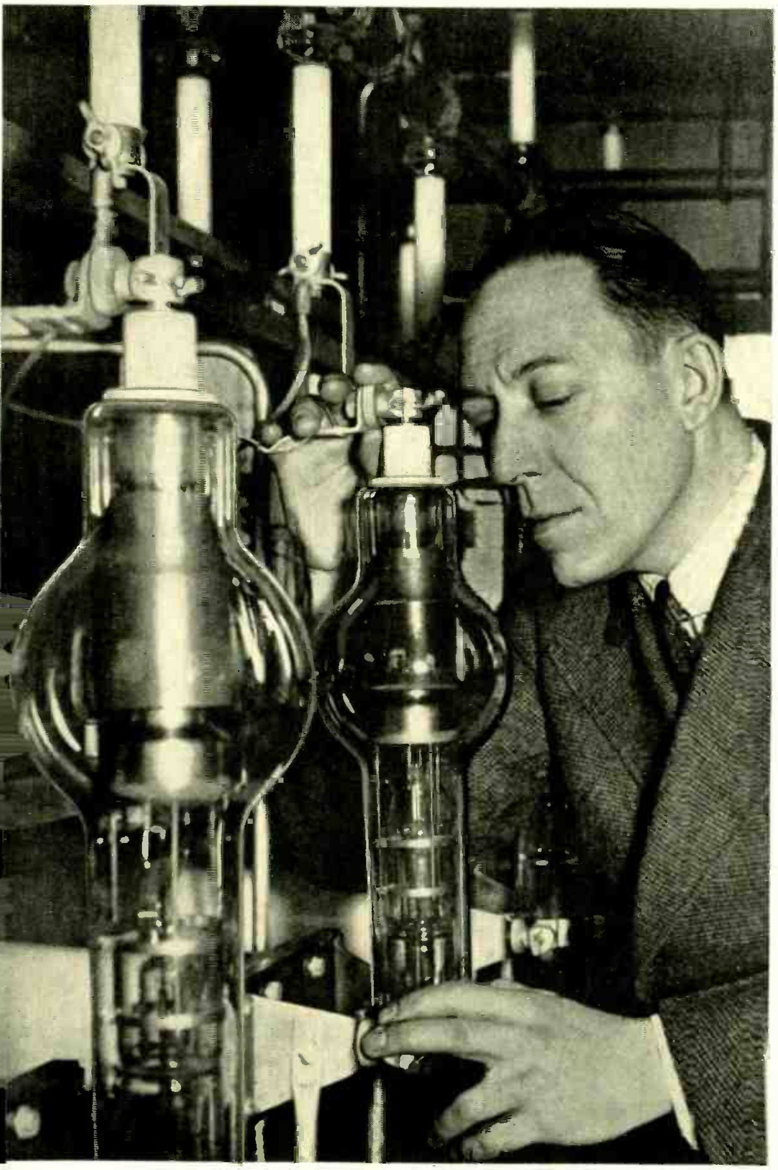

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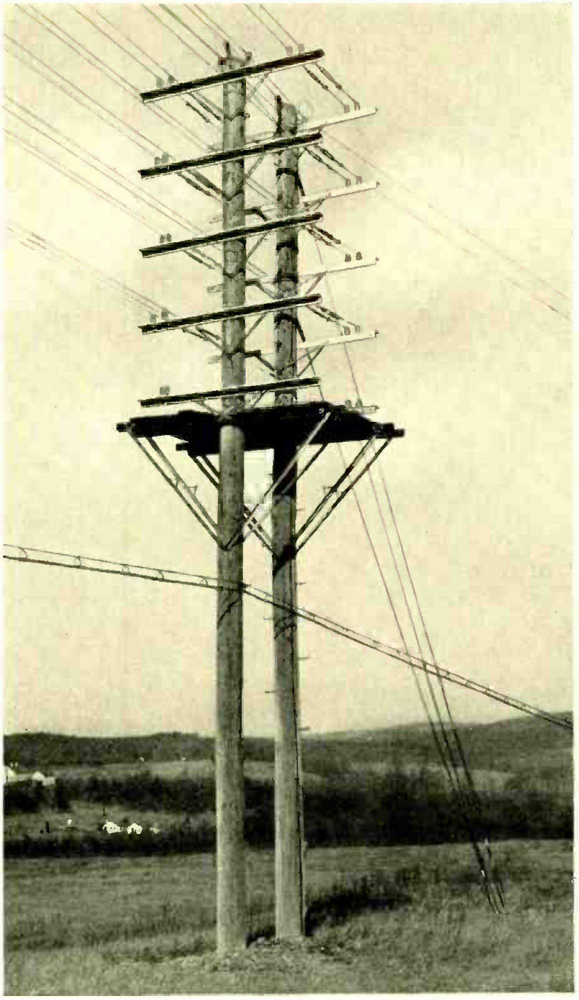
Rectifier tubes in a high-power radio transmitter for broadcasting



Spacing of Telephone Wires

By J. A. CARR

Outside Plant

On telephone poles the spacing of wires is limited by the closeness with which they can be installed without coming in contact when swung by the wind. Until recently Bell System practice has called for a separation of twelve inches but field tests, made over a period of several years, show that eight inches is enough in many situations. This couples the wires of a pair more closely and reduces the noise induced from external sources such as radio broadcasting stations, static and crosstalk between circuits. These improvements in turn make possible the transmission of higher carrier frequencies which provide for additional telephone channels.

The chance of two parallel wires contacting in the wind was studied theoretically but difficulties were encountered in allowing for wind gusts and the same limitation applies to tests of model lines in a wind tunnel. In the Laboratories studies, therefore, a full-scale test was undertaken and lines were erected on high ground at Chester, New Jersey, where they were exposed to strong northwest winds.* Two pole lines with spans from 100 to 260 feet long were erected in a direction approximately across the prevailing wind. Lateral spacings of three, four, six, eight and twelve inches between the wires of a pair were provided and the sag range was from six inches in 100-foot spans to forty inches in 260-foot spans, in conformity with Bell System practices. Apparatus was provided to record graphically the number of contacts occurring on each pair

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*During the eight years this test was under way the instantaneous wind velocities reached 60 miles per hour on several occasions each year and exceeded 70 miles per hour on at least one.

of wires and simultaneously the velocity and direction of the wind. The temperature and other weather conditions and the sag of the wires were recorded at regular intervals by an attendant.

From the data obtained an empirical equation was derived for the relationship between the instantaneous wind velocity, v, normal to the line at the time contacting begins and the fundamental factors of wire sag, *d*, spacing, s, and span length, L, namely:

$$v = 22.4 \left[\frac{L^{0.1} s^{0.3}}{d^{0.25}} \right]^{2.1} \quad (1)$$

v is in miles per hour; L in feet, and s and *d* in inches. A nomogram of this relationship which applies when both wires of a pair have the same sag is shown in Figure 2. The data were insufficient to develop a similar relation for wires of unequal sag.

With this equation or the nomogram the approximate wind velocity at which contacting begins for any lateral separation of wires within the scope of the tests can be determined. The frequency of occurrence of certain velocities in a given section of the country indicates the likelihood of wires separated by a given amount coming into contact. At Chester winds of forty miles per hour and higher occur about twice as often as those of forty-five miles per hour and higher. Thus a given wire arrangement on which contacts begin to occur at a wind velocity of forty-five miles per hour would be subject to contacting only about half as often as one on which contacts begin to occur at forty miles per hour.

The equilibrium position of a span of wire under the influence of a steady wind has been computed theoretically and a study was conducted at Chester to test this theory under the varying conditions of gusty winds. The problem was to measure the angle between the vertical plane through the supports and the plane of the suspended wire for a large number of cases over a range of actual wind velocities and to determine the agreement between these values and the angle given by the theory for the cor-

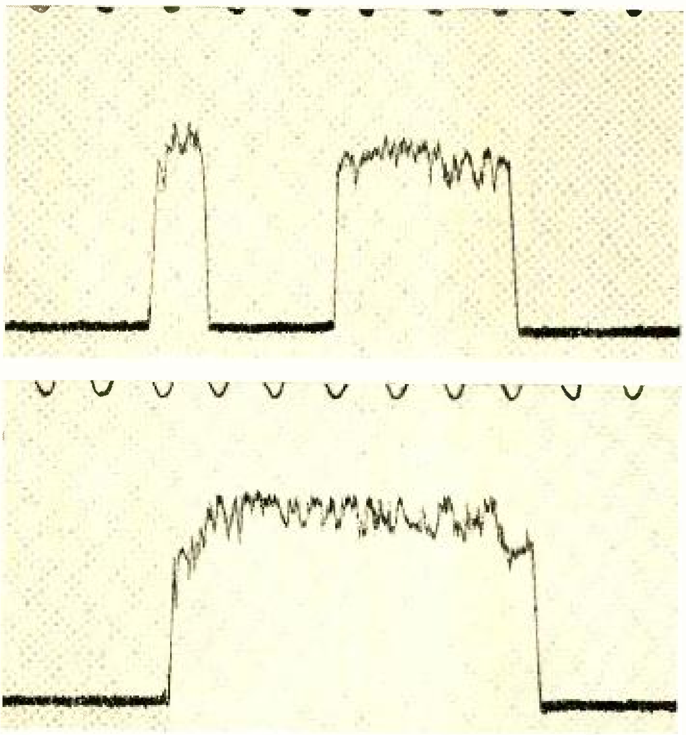

Fig. 1—*Oscillograms of contacts between swinging wires. Contacts lasted from* .004 *to* .23 *second. The contact resistance varied from* 0 *to* 50,000 *ohms*

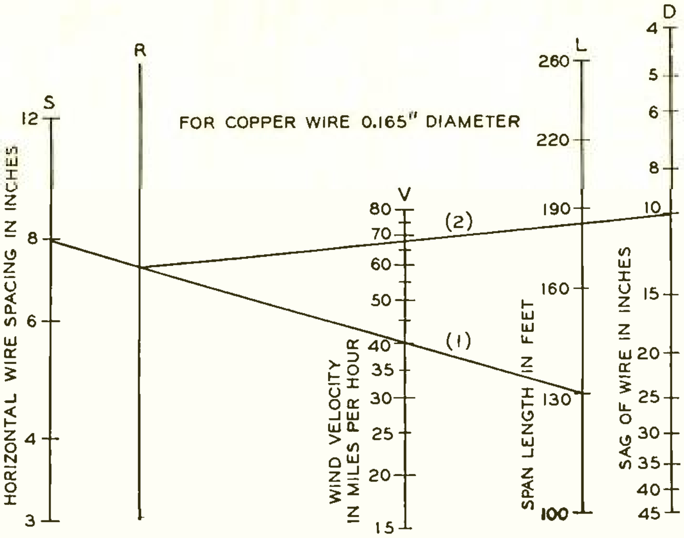

Fig. 2—The wind velocity at which the wires of a pair begin to contact is found by locating a point on (R) by drawing a line (1) through a given value of spacing (S) and span length (L). A line (2) from this point on (R) to the given sag on (D) indicates the velocity sought at its intersection with (V)

responding steady wind velocities. For this study a pair of hard-drawn copper wires 0.165 inch in diameter was used. The wires were maintained at equal sags throughout the study. The swaying of the wires was recorded continuously on a moving film in a special camera mounted rigidly under the wires at the center of the span. A means for synchronizing the wind-velocity record with the film was provided. With rare exceptions, when the wind velocity was low, the wires were continually in motion and the point photographed on each wire was represented by the wavy lines of Figure 3. From these films computations were made of the angles of deflection for a range of wind velocities. The results obtained substantiated the equilibrium position theory of suspended wire in a steady transverse wind.

Theory indicated that the relative merits of a wire arrangement could be determined approximately by deflecting one wire of a pair outward and upward and releasing it to swing towards the other wire through known

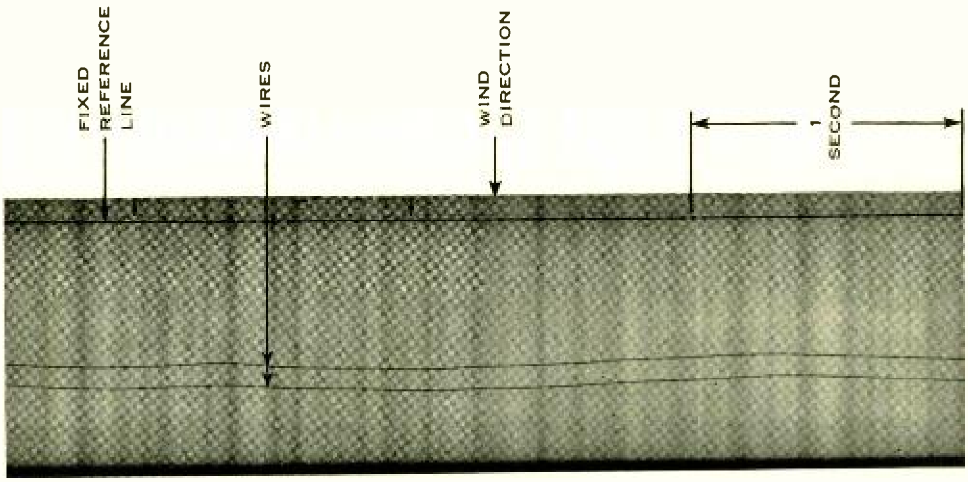

Fig. 3—A section of motion picture film showing the transverse movement of wires in wind. The swing of the wires is recorded by the wavy lines running lengthwise of the film

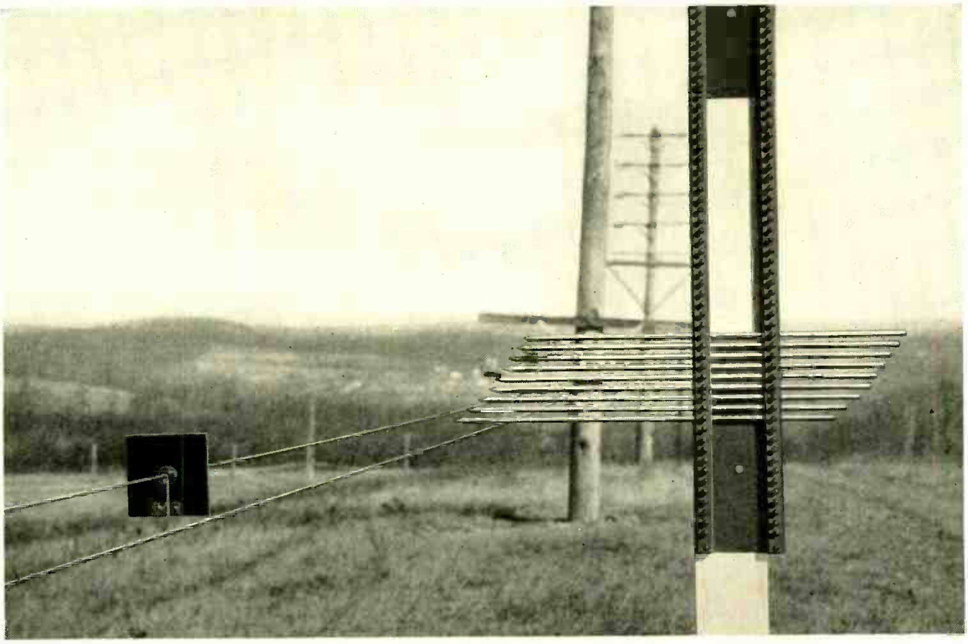

Fig. 4—Apparatus for the accelerated test. The ends of the parallel rods are reference points from which one wire of the pair is swung to simulate motion caused by the wind

angles which were increased until the two contacted. From the angular displacements the theoretical wind velocity could be determined. This procedure does not simulate accurately the contacting of wires in winds but it gives comparative data from which the best proposal can be selected for tests in winds. There was also the possibility of establishing a correlation between the velocity as indicated by the empirical equation for winds and the theoretical threshold velocity obtained from such accelerated tests. Figure 4 pictures some of the apparatus used in this test.

From the results obtained by the accelerated method the following empirical equation was developed for a pair of wires with equal sag:

$$V_m = \frac{10Y}{1 - 0.692Y} \qquad (2)$$

where $Y = L^{0.05}S^{0.2}/d^{0.2}$, V_m is the velocity obtained by the accelerated method and the other terms are the same as in the first equation. By combining the two equations the "threshold" velocity at which wires begin to contact in winds can be calculated approximately for a wire arrangement for which the contact velocity, found by the accelerated method, is known.

For wires spaced three inches or four inches apart the threshold wind velocities are of frequent occurrence. To increase the allowable velocities for such arrangements anti-contacting devices such as insulating discs and spacers were considered as shown in Figures 5 and 6. The accelerated test was used to determine the most effective size and shape for these discs. One, two and three discs were tried per span per pair of wires. When one disc was used it was placed at the approximate center of the span on the wire of the pair to the windward. Two discs

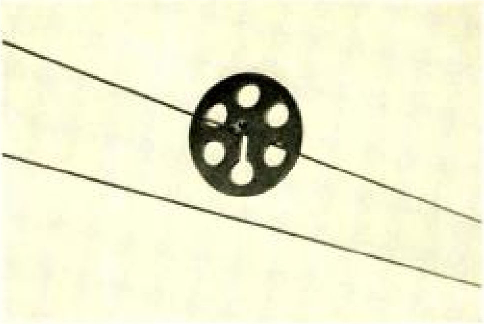

Fig. 5—With insulating discs wires will withstand wind velocities from five to twenty miles per hour greater before coming in contact than without them

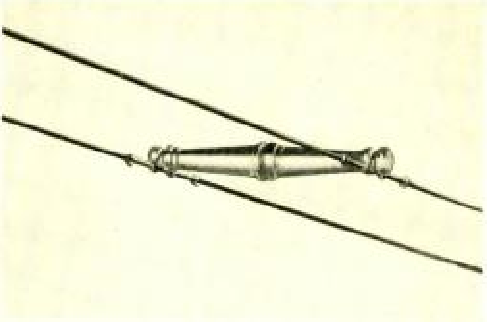

Fig. 6—Insulating spacers are somewhat more effective than discs in preventing contact between wires, particularly for spans 160 *feet or longer*

were placed on the windward wire at one-third of the distance from each support. The three-disc arrangement was like that for two discs with a third disc located at the center of the span on the other wire of the pair. The insulating spacer bridged both wires of the pair at the approximate center of the span and only one was used per span. Insulating discs increased the threshold wind velocities from five to twenty miles per hour. Three discs per span or even two were somewhat better than a single disc but the gain was relatively slight. The spacer was found to be slightly more effective than the discs.

Contact data were also obtained with ice on the wires for different spacings and at wind velocities as low as ten to fifteen miles per hour. The number of contacts increased to some extent with the thickness of the glaze and with the velocity of the wind and also with decreased wire spacing, but the movement of the wires was erratic and the data were not analyzed in detail.

These studies confirm the practicability of reducing the spacing between the wires of a pair from twelve to eight inches, or even less under some conditions. This reduces the susceptibility of the circuit to induced noise and crosstalk. In addition the closer spacing of the wires of a pair permits greater separations between adjacent pairs on the same crossarm, thereby effecting a further improvement in crosstalk. For these reasons, reduced wire spacing has played an important rôle in broadening the field of use of carrier telephone systems on open-wire lines.

Ringing Power for Large Offices

By W. S. ROSS

Power Development Department

ANY telephone system must provide some means of signaling subscribers and of indicating to both operator and subscriber a variety of conditions that may exist on the lines and circuits, such as that dialing may be begun, that a line or trunk is busy, or that the party called is being rung. Ringing is ordinarily done by an alternating current of about twenty cycles per second superimposed on a d-c potential. Other signals are given by tones of various frequencies interrupted in different manners. The capacity required for the ringing and tone generators, and the number of different tones needed, depends on the size and type of central office or PBX to be supplied. All the apparatus and equipment for supplying ringing and tones is generally grouped together, and the assembly is called a ringing power plant. A number of such plants are manufactured to meet the various needs, ranging from those of a small PBX to those of a group of central offices located in a large central-office building.

The fundamental apparatus of a ringing power plant is a ringing generator coupled to a driving motor, which may be of the a-c type for connection to the commercial power supply, or of the d-c type to be run by the central-office battery. The generator is equipped with slip rings for supplying the twenty-cycle ringing current, and with a commutator to supply 110 volts d-c for coin control. Both commutator and slip rings are connected to the same winding on the generator, and the brushes on the slip rings are connected to the primary of a ringing transformer, which is grounded at the midpoint. This is equivalent to a ground at the center of the winding of the generator, and permits the coin-control current from the positive or negative brush to be sent over one side of the line to ground. The voltage of the generator is held constant by a centrifugal-type voltage-regulator.

Attached to the generator end shield is the tone alternator,* which supplies three basic tones. Oscillographs of these tones are shown in Figure 1. It is by interrupting these tones by commutators geared to the generator shaft that the various operating tones are secured. Besides audible ringing, the major tones required are dial tone, line busy, tandem re-order, trunks busy, trunk assignment, number checking, permanent signal, and vacant tone. Not all of these, of course, are used at every installation.

Except for the very small PBX's, it is desirable to have a second source of ringing supply available in case of failure of the regular supply. Since the central-office battery is kept as a reserve supply for talking and signaling current, this battery is generally employed to drive the ringing generator on failure of the a-c supply. Several methods have been used in ringing power plants to make the

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*Record, *September*, 1932, *page* 6.

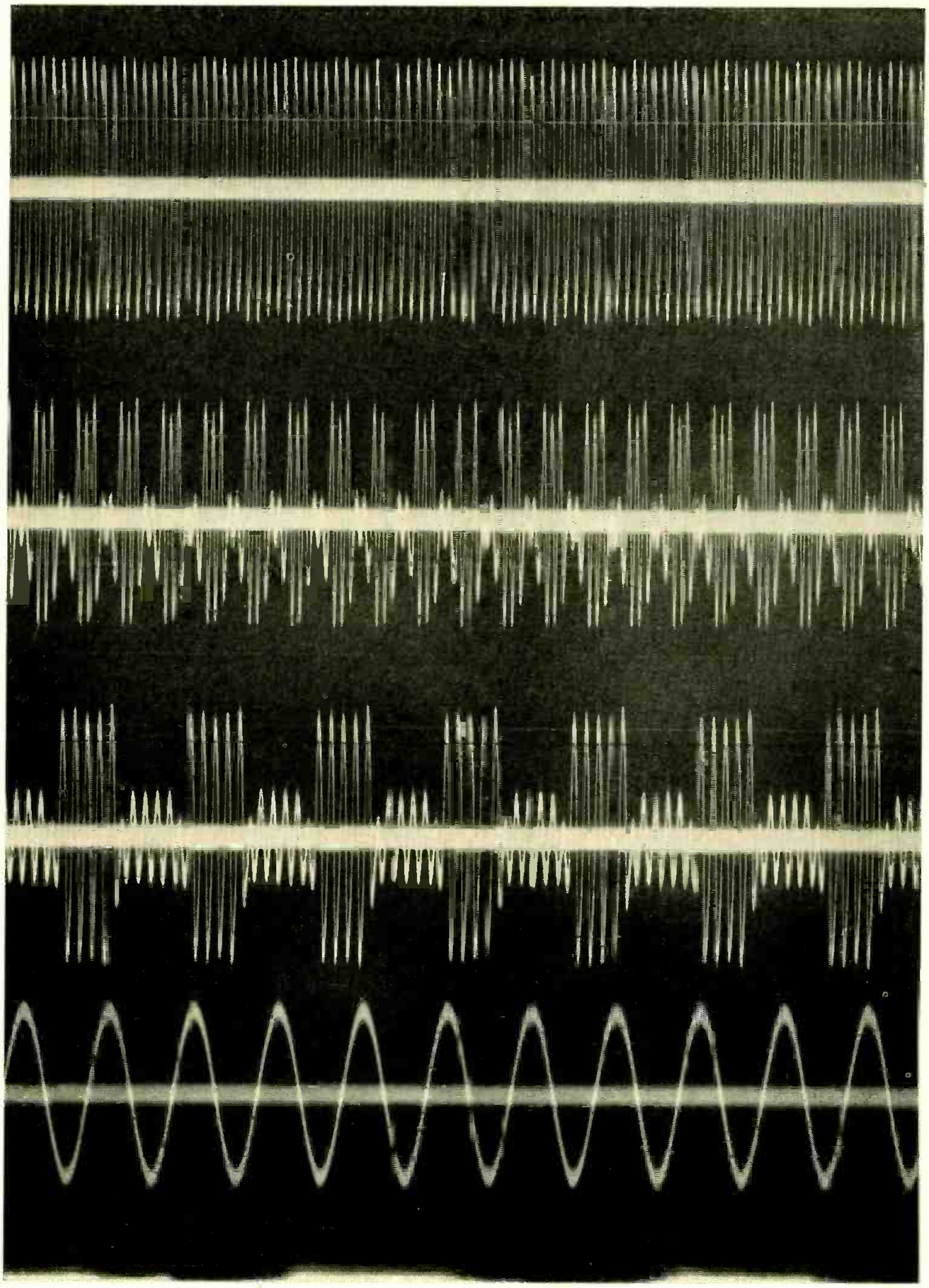

Fig. 1—Some of the various signals used in telephone operation are high-frequency tone, upper oscillograms, low-frequency tone, second from top, and "audible ringing." The lower oscillogram is a 60-cycle timing wave

emergency supply promptly available. One of the first was to have two ringing generators—one driven by an a-c motor and the other by a d-c motor. On failure of power an alarm would ring, and the d-c generator set would then be started by hand, and allowed to carry the load until the a-c service had been restored.

With this arrangement there was an appreciable time between the failure of the a-c and the time the d-c set picked up the load. To avoid this short interruption of the ringing supply, an a-c and a d-c motor were both connected to the same ringing machine. The a-c motor normally carried the load, but a back contact was provided on the a-c contactor so that when it released, on failure of the a-c voltage, the d-c motor would be connected to the battery, and would immediately assume the load. A second set was required, however, so as to provide a spare generator. This increased the cost of the ringing power plant more than seemed justifiable, so that a return was made to the former method of two sets, one with an a-c and one with a d-c motor, but circuits were provided to start the d-c set automatically on failure of the a-c power. A simple circuit was developed using a relay that connected the d-c motor to the battery when the a-c voltage dropped to about thirty or forty per cent of normal. The release of the relay would start the emergency set and transfer the ringing load to it.

Although this method proved very satisfactory for the most part, it was found that at times the a-c voltage would drop enough to cause an appreciable decrease in the ringing voltage without dropping low enough to start the spare generator. A new

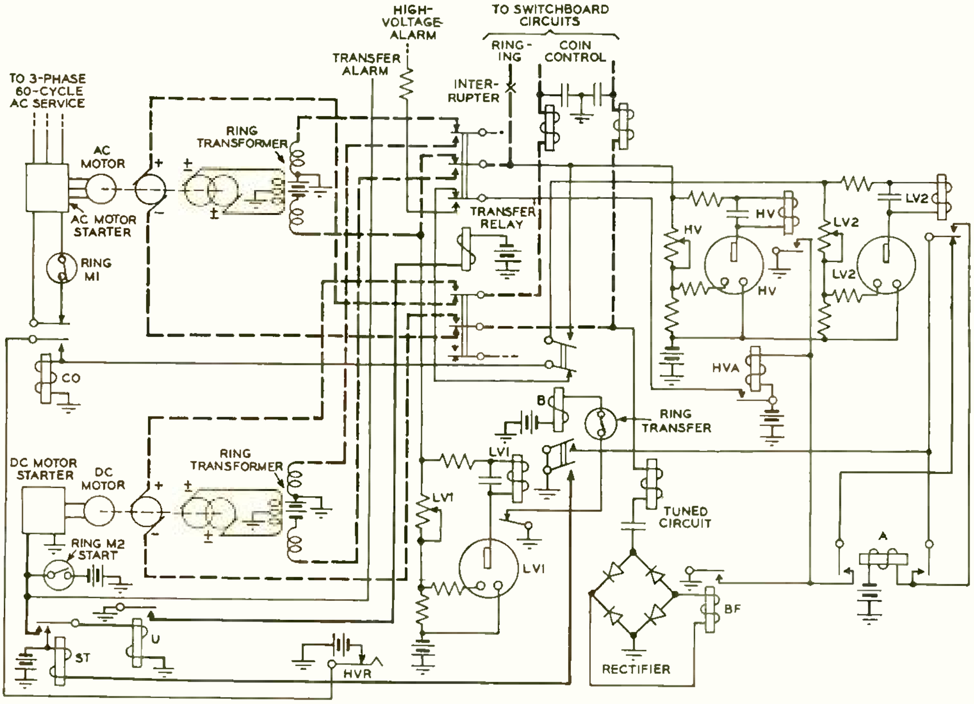

Fig. 2—Simplified schematic of transfer circuit for the 803C ringing power plant

design was therefore made for the ringing power plant for large offices that not only transferred the load on a much smaller reduction in ringing voltage, but that also provided a high-voltage alarm and a more effective brush-failure alarm. It is called the 803C ringing plant.

The transfer circuit that switches the ringing load to the spare generator in the event of low voltage, high voltage, or brush failure is shown in Figure 2. Transfer of the ringing and coin-control circuits from the regular to the spare generator or vice versa is accomplished through four interlinked control circuits, which may be called the low-voltage control (of which there are two), the high-voltage control, and the brush-failure control. The transfer relay is under the control exclusively of the first low-voltage circuit, which, in turn, is controlled by the voltage of the regular ringing generator. When this voltage drops to ninety per cent of normal, the low-voltage circuit first starts the spare generator, and then immediately transfers the load to it. The regular ringing generator is not stopped by this circuit, and whenever its voltage comes back to normal, the low-voltage circuit stops the spare generator and transfers the load to the regular generator. The operation of this circuit acts through the vacuum tube and relay marked LVI, and through the chain of relays B, ST, and U.

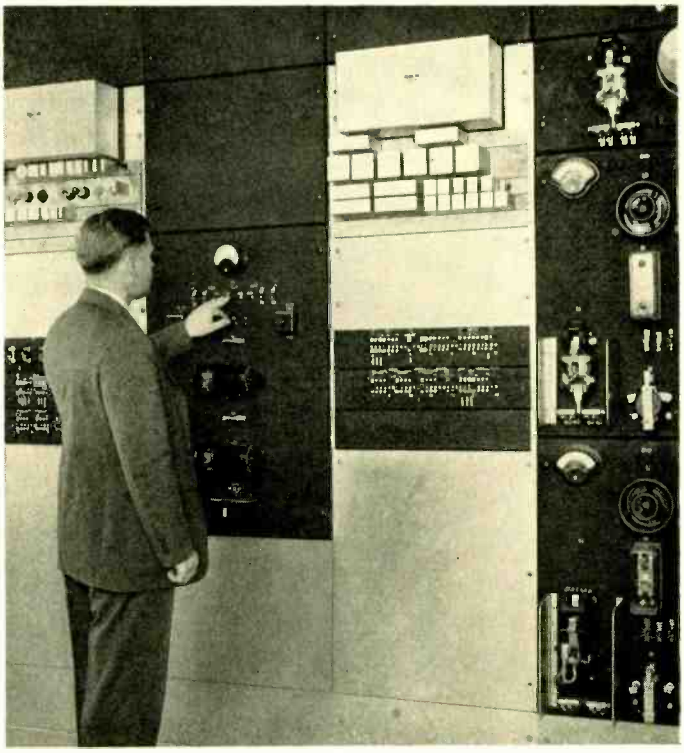

Fig. 3—The 803C ringing power plant includes two motor-generator sets and three bays of equipment

The high-voltage circuit, which is controlled by the voltage on the main ringing circuit rather than by that of either of the generators, acts through the vacuum tube and relay marked HV and through the auxiliary relay HVA. The circuit from the contact of this latter relay passes through contacts on the transfer switch, and thus performs different functions depending on whether the ringing supply is connected to the regular or spare generator. When the connection is to the regular generator, the circuit—under high-voltage conditions—operates relay CO, which trips the motor of the regular generator and holds it tripped through the key HVR until it is manually started. As the regular generator slows down, its voltage drops, the spare generator is started, and the load transferred to it through the first low-voltage control circuit. When the transfer switch is operated to the spare generator, operation of the relay HVA rings an alarm, and the necessary adjustments made.

The second low-voltage circuit consisting of the vacuum tube and relay marked LV2 is connected into the circuit only when a transfer has been made to the reserve set. This circuit functions at the same voltage as the LV1 vacuum tube, but operates the HVA relay to bring in an alarm.

The vacuum tubes used in this circuit are of the 313 or cold-cathode type. The control gap of each tube is connected across a potentiometer by means of which the voltage across the control gap may be varied. By this means the tube can be made to fire at the desired voltage. As the tube fires once each cycle a condenser is placed around each relay in order to hold it operated during that portion of the cycle when no current is flowing in the main gap of the tube.

Brush failure, meaning primarily the failure of a brush to make contact with its slip ring, really covers any condition that results in an open-circuit in either side of the ringing circuit. It might seem that such a condition would result in a low voltage, which would cause the transfer of the load through the low-voltage control circuit, but because of the grounded ringing transformer and the grounded condenser in the filter of the coin-control circuit, sufficient current may flow through the remaining brush and ground to maintain the voltage except under very heavy load conditions. It seemed desirable therefore to provide a circuit to transfer the load under brush failure conditions.

Although there is not necessarily an appreciable drop in voltage with brush failure, the forty-cycle ripple that normally appears in the coin-control circuit on the generator side of the filter is changed to a twenty-cycle ripple. This change is employed to operate the BF relay which operates the HVA relay, and the subsequent action is the same that occurs under high-voltage conditions. The change in ripple frequency operates the BF relay through a tuned circuit and a copper-oxide disc rectifier.

Besides these three major control features, an alarm is also provided which is operated whenever the spare generator is started, and manual controls are provided for stopping the regular ringing generator, for starting the spare, or for transferring the load from one to the other.

The 803C ringing power plant includes the two generator sets mounted on a sheet-metal table, and three bays of equipment, shown in Figure 3. A ringing battery, on which the twenty-cycle current is superimposed, is also included, together with the necessary rectifiers for floating the battery. The battery is mounted in the rear of the control panels, and the rectifiers are mounted on the front. This ringing power plant has been improved by a number of new features, such as the extensive use of self-alarm telephone fuses in place of the larger NEC fuses, and the employment of perforated wiring strips for vertical runs on the rear of the power board. These strips permit the wiring to be covered up over the height of the bay and yet to be brought out where desired. It eliminates the necessity for sewing, and permits changes in wiring to be made much more readily. The 803C plant represents a major revision in ringing power plants and reflects the modern trend in development in all respects.

Four-Wire Circuits in Retrospect

By L. L. BOUTON

Transmission Development Department

WHEN the first attempts were made to apply amplifiers to long-distance telephone circuits, it was found that only a small improvement in overall circuit efficiency could be gained by their use. If larger amplifier gains were applied, sustained oscillations resulted. This propensity toward singing came about largely because of lack of electrical similarity between the lines which at that time were balanced against each other on opposite sides of the repeater. Later the circuit of Figure 1 was employed in which the lines were balanced separately against their individual networks. The singing path around a single repeater of this type is indicated by the arrows. Methods were later developed for improving the regularity of the lines so that they could be more accurately balanced but it still remained that the use of more repeaters in a two-wire circuit or increases in individual repeater gains would aggravate the tendency toward singing.

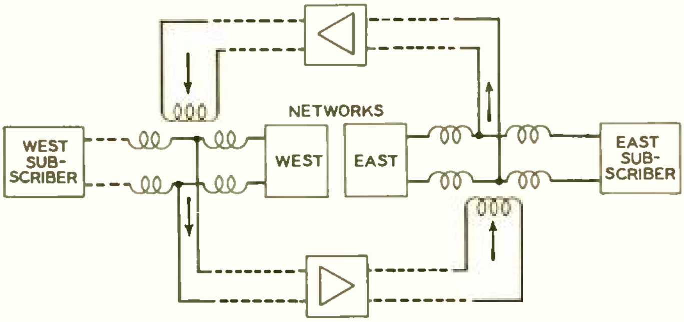

Fig. 1—Two-wire circuit showing method of balancing

Somewhat earlier, G. A. Campbell had pointed out that the parts of the two-wire repeater circuit, shown dotted in Figure 1, could be stretched out and could even include additional one-way amplifiers, as indicated in Figure 2. A two-path voice-frequency telephone circuit such as this is usually spoken of as a four-wire circuit. Of course, if the paths are made up of phantoms, a four-wire circuit actually involves eight wires, but similarly, a two-wire circuit may employ four wires. The apparent extravagance in the use of line conductors by four-wire circuits is offset by the fact that much higher repeater gains are allowable than in two-wire circuits, and accordingly smaller wires may be employed or the amplifiers may be spaced farther apart.

The first tests of long-distance four-wire circuits were made early in 1913, using large-gauge conductors in the then recently completed underground cable between New York and Washington. In the actual layout, shown by Figure 3, all the repeater equipment was located at Philadelphia, and two-wire extensions were used to connect to New York. The repeaters were of the so-called mechanical type, since vacuum tube repeaters had not yet been made available; and the length in the four-wire part of the circuit was 625 miles. These tests demonstrated the transmission advantages that had been anticipated for four-wire circuits.

In April, 1915, after preliminary lining-up tests, a four-wire cable circuit extending from Boston to Washington (450 miles) was placed in commercial service. It employed thirteen-gauge pairs principally, with single-stage vacuum-tube repeaters at New Haven and Philadelphia. The circuit gave satisfactory service but it was observed that the quality of the received transmission was somewhat impaired by the absence of the higher frequency components of speech, due to the considerable length of loaded cable involved.

An extensive series of tests of four-wire circuits up to 1500 miles in length was conducted in 1916. Different lengths were obtained by looping back and forth in the Boston-Washington cable; two-stage vacuum-tube amplifiers were used, and attenuation equalizers were employed to extend the transmitted band to higher frequencies. The use of equalization and the extension in length emphasized certain effects which previously had caused little or no concern. Due to a considerable degree of irregularity in the spacing and inductance of the loading coils the circuit efficiency, within the transmitted band, varied in an irregular manner from frequency to frequency. This was avoided in later installations by setting up stricter loading requirements. Again, the larger number of repeaters included in the circuit emphasized the effects of variations in the gains of individual repeaters and it was necessary to make arrangements so that the battery voltages could be maintained more nearly constant. During the tests, transmission was seriously interfered with by peculiar effects, sounding like the chirping of birds, which were observed to follow each spoken syllable. Oscillograms were obtained which showed that these transient oscillations had their source in the cable. It was also found that for the longer circuit a higher degree of balance at the terminals between the two-wire lines and the networks was required in order to reduce the unbalance or echo currents to tolerable proportions. In spite of all these difficulties the results were considered sufficiently encouraging to warrant intensive development work and plans for extensive commercial use.

Four-wire circuit tests using thirteen-gauge conductors in the New York-Philadelphia "B" cable were made about the middle of 1917. These tests showed that with more uniform

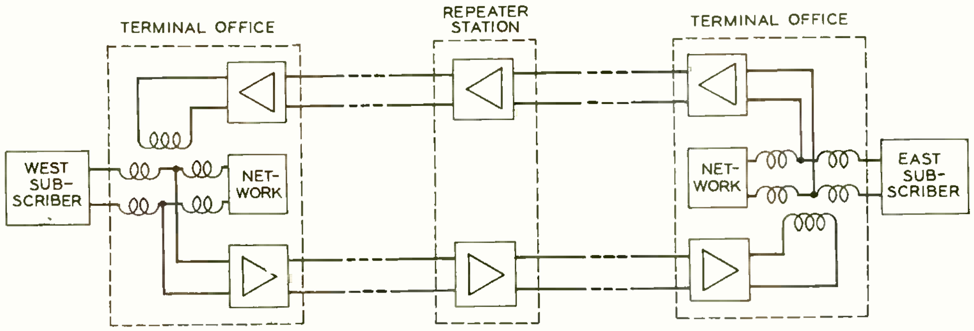

Fig. 2—Four-wire circuit for a two-path voice-frequency circuit

loading, smooth overall characteristics were readily obtainable, yet the equalizers used were very much simpler and cheaper than those employed in previous tests. Further data as to transient and echo effects were taken and a large number of syllabic tests were made which indicated materially better intelligibility as a result of the equalization. Later in 1917, tests were made on 19-gauge four-wire circuits in the Hudson River cable. Various lengths up to about 1200 miles were obtained by looping back and forth. The loading was designed to permit a wider band of frequencies to be transmitted. The new loading, called "medium-heavy high-cutoff" (and later H-172), was also advantageous in reducing echo and transient effects. The grade of transmission was considered at least as good and probably superior to that of commercial New York-Chicago circuits at their best.

Several four-wire circuits between New York and Catskill were put into commercial operation July 4, 1918. With the use of small-gauge conductors and higher gains in the repeaters in this cable, the practice of segregating conductors connected to the inputs of repeaters from those connected to the repeater outputs was initiated in order to avoid serious increases in crosstalk from one circuit to another. Also, the use of high gains required that the circuits connected to the inputs of the repeaters be practically free from noise. In setting up the four-wire circuits considerable difficulty was experienced due to noise which was found to result from high-resistance joints in the cable splices. This was eliminated by opening all the splices and soldering the "pigtail" joints. Soldering was then established as a standard practice for all small-gauge conductors in cables used for toll business. Non-linear effects, depending on the energy carried by the circuit, were also experienced. In later cables, these were reduced to tolerable proportions, mainly by improvements in the core materials and design of loading coils.

In plans for extensive commercial use of small-gauge cables it was desired to employ, to a considerable extent, aerial cable instead of underground cable which had been the usual type of construction. Aerial cable is, of course, much more affected

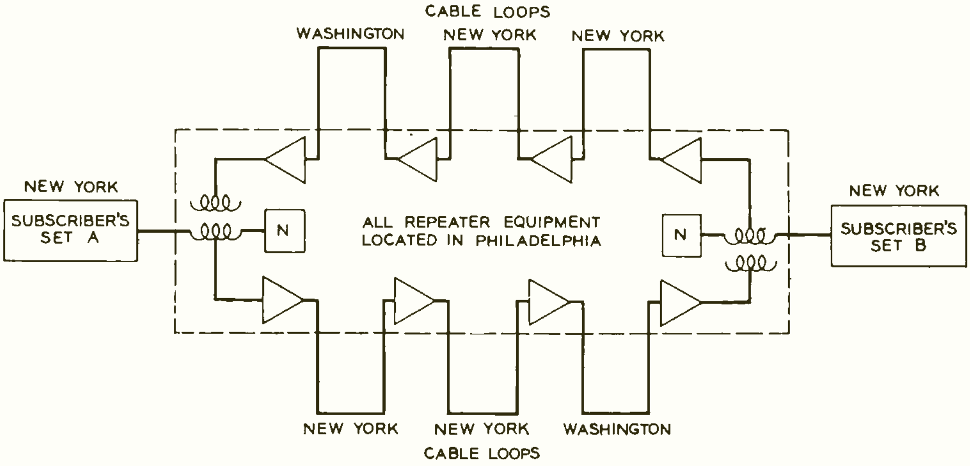

Fig. 3—Layout for the first four-wire circuit tests—early in 1913

by temperature changes. Estimates were made of probable changes in net loss and it was at once evident that some form of regulation, preferably automatic, would be required, at least for the longer cables. Several methods were proposed but after making studies and some tests the pilot-wire* transmission regulating arrangements were developed.

Further tests of echo and transient effects using the trial circuit in the Hudson River cable and theoretical studies showed that circuits of this type would not be as good as desired for the longer cable circuits that were being planned. From the standpoint of echoes, a higher velocity system was indicated; and for relief from transients both higher velocity and higher cutoff frequency were desirable. Modifications in loading to effect these changes would require an increased number of repeaters and complicate the problems of equalization and regulation. Thus the selection of the new loading system was considerably a matter of compromise. After a study of all the factors it was decided to retain the 6000-foot spacing of load coils but to reduce the inductance of individual coils to about one-fourth of that used in the "medium-heavy high-cutoff" loading. This change doubled both the velocity and the cutoff frequency but gave an increase of about 70 per cent in the transmission loss per mile, thus requiring a corresponding increase in gross repeater gain.

The first installation of extra-light loading, as the new loading was called, was made during 1919, on the cables between New York, Philadelphia, and Reading, Pennsylvania. An 1100-mile circuit obtained by looping back and forth in this cable was demonstrated on August 6, 1919. Trial commercial service between New York and Reading started the following July.

A large amount of detailed work remained to be done, however, preceding extended commercial application.

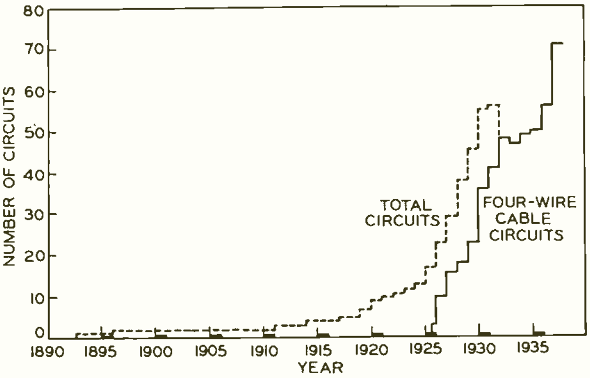

Fig. 4—Growth of direct circuits between New York and Chicago during the last half century

Another series of tests on a long circuit, obtained by looping back and forth in the cables between New York and Harrisburg, was made in 1923. This circuit included new regulating and equalizing arrangements, and provided for using the conductors for telegraph as well as for telephone. It was placed in trial commercial service July 30, 1923. In October there were further tests and demonstrations in which the long circuit was equipped with an echo suppressor. The net loss was adjusted to zero and the circuit tested with typical local connections at the ends with little observed impairment to overall transmission.

In February, 1922, several medium-heavy-loaded four-wire circuits were placed in service between New York and Pittsburgh; and early in 1925 extra-light-loaded four-wire circuits extending from New York to Pittsburgh, Cleveland, and Toledo were

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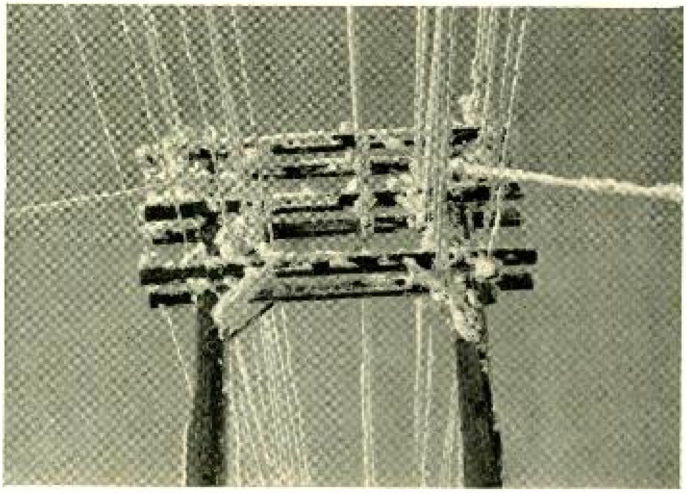
*Record, *January*, 1929, *page* 183.

put into operation. On October 1, 1925, the New York-Chicago cable was opened for service and a few of the circuits between these points were routed through the cable. Echo suppressors were employed in order to permit operation at lower net losses than otherwise permissible.

Figure 4 shows the average number of New York-Chicago circuits in service each year beginning with 1892 when service was established. The rapidity with which four-wire cable circuits displaced circuits of other types is also shown. Since 1931, only extra-light-loaded four-wire circuits have been used between these points.

The cable network was soon extended beyond Chicago, and on January 20, 1933, four-wire cable circuits were placed in service between New York and Dallas, Texas. These circuits, now known as H-44-25 four-wire circuits, give high-grade transmission, and are practically immune to the effects of severe storms.

R. H. Erickson operating apparatus used in studying synthetic insulating materials at the Summit laboratory



High-Frequency Attenuation on Open-Wire Lines

By H. E. CURTIS

Toll Transmission Development

On an open-wire line attenuation losses are of three kinds: series loss due to the resistance of the wires; shunt losses due to the insulators; and shunt losses due to poor dielectrics such as sleet or frost on the surface of the wires. It is known* that the losses due to sleet or frost may be very large in comparison with the other losses, particularly at frequencies above about 30 kc, which is the upper limit of the existing three-channel open-wire carrier systems. Frequencies from 36 kc to 140 kc were to be employed for the new Type-J system and it became important to obtain, in the areas where that system might be placed, data as to ice deposits and their effects on transmission.

The route between Lamar, Colorado, and Salt Lake City was selected as one where attenuation changes due to sleet and frost would be controlling. Here frost deposits on the wires are of frequent occurrence during winter months. The clear atmosphere makes for rapid radiation of the heat in the wires during the night hours, so that the surrounding air is often chilled below the dew point, driving out the moisture in the form of frost when the temperature is below freezing.

Measuring equipment was installed during the winter of 1936-1937 between Lamar and Salt Lake City, and operated up to the summer of 1938. With this equipment, frequent measurements of attenuation were made at 140 kc on eight sections over substantially the whole distance of nearly 700 miles. Briefly, the method used was to bridge a small battery-operated 140-kc oscillator across an open-wire pair approximately mid-way between two repeater stations, thereby transmitting the output current in both

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*Record, *November,* 1937, *page* 95.

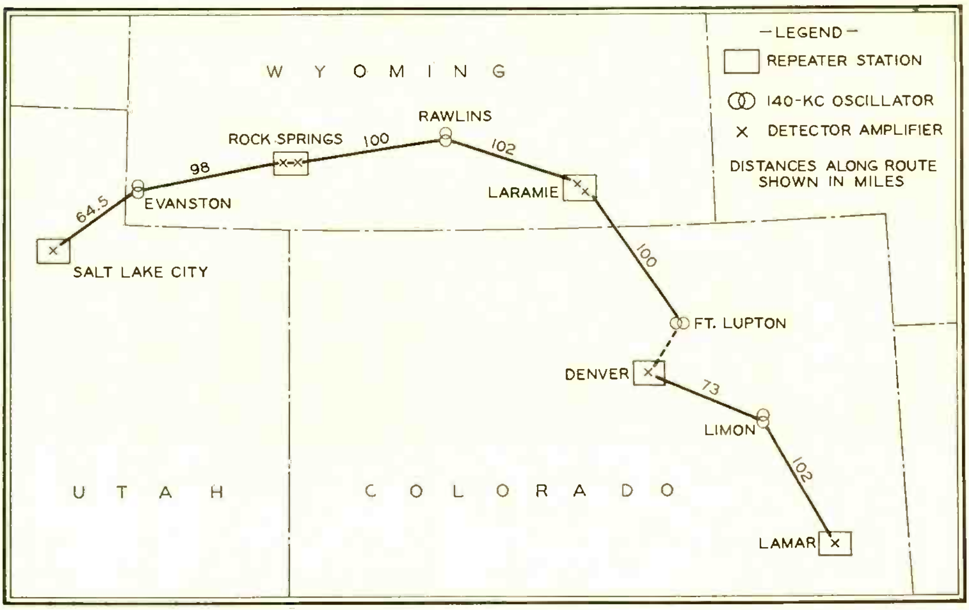


Fig. 1—Lamar-Salt Lake City route on which high-frequency attenuation measurements were made

directions to the repeater stations, where it was amplified and detected. The level of the incoming signal indicated the attenuation. The geographical locations of the various oscillators and receiving equipments are shown on Figure 1. The whole section of line between Lamar and Salt Lake City, except for a short section situated between Denver and Ft. Lupton, was covered by the measurements.

The equipment used is shown in Figure 2. On the left is the wooden box housing the 140-kc oscillator and the batteries supplying the power. Four such oscillators were mounted on poles along the line approximately mid-way between repeater stations.

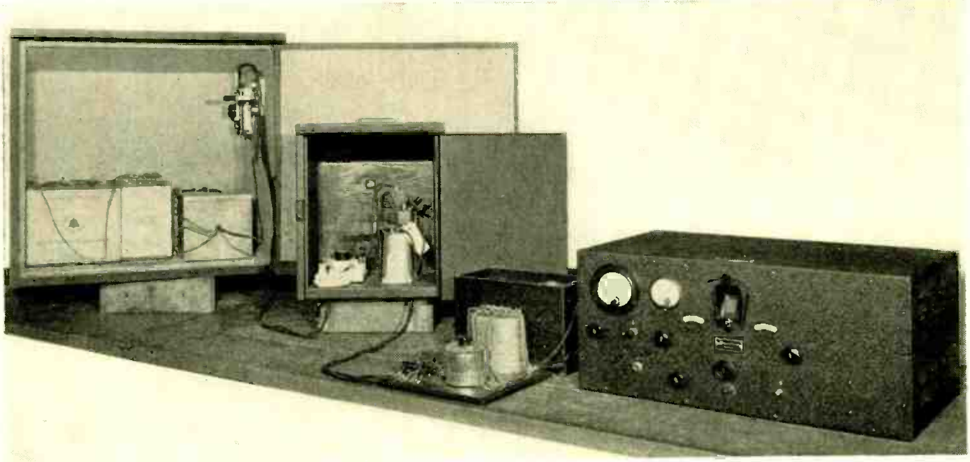


Fig. 2—Equipment used in attenuation tests includes, left to right, oscillator, filter and transformer, variable attenuator, and detector amplifier

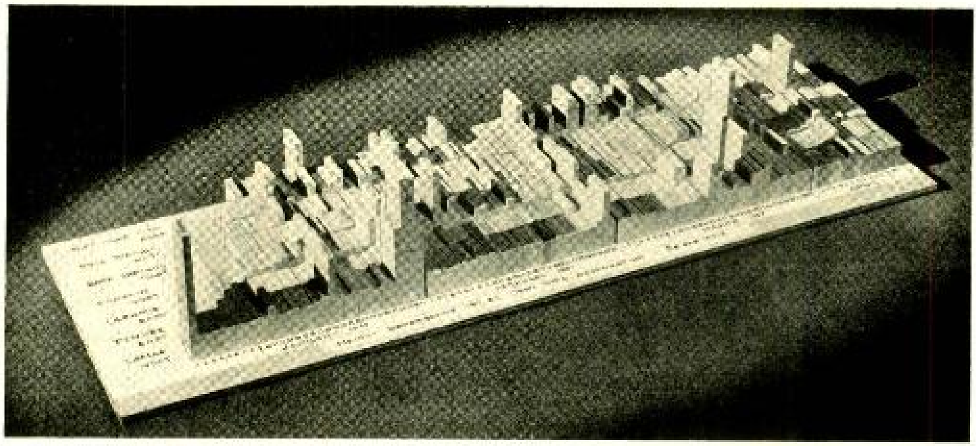


Fig. 4—Three-dimensional representation of attenuation variations

These oscillators operated continuously, the output being maintained fairly constant by replacing the batteries periodically. Second from the left in the photograph is a small wooden box which was mounted at the terminal pole. It contains a filter and transformer used to connect the open-wire line to a spare non-loaded pair in the entrance cable of the repeater station. The filter was essential in discriminating against the Type-C currents also present on the open-wire pair. Furthermore, it was essential to transfer to a non-loaded cable pair to avoid excessive loss to the 140 kc in the Type-C loaded cable pairs. Next in the photograph is a black metal box containing the equipment for routine checks of the sensitivity of the detector-amplifier. In front of this is the variable attenuator used in conjunction with the detector-amplifier shown at the right. A simplified schematic arrangement of this apparatus is shown in Figure 3.

To give perspective to the large amount of data obtained, a three-dimensional model was constructed, which is shown in Figure 4. The model consists of seven rows of blocks, each row representing one section of line as shown in Figure 1, and the sections from east to west being arranged in order from front to back, as indicated by the labels on the board. Each row consists of a number of thin blocks, each representing a day, and the height of each block representing the maximum attenuation reached during that day. The average dry-weather attenuation, indicated by the average minimum height of blocks, is in the neighborhood of 0.22 db per mile. Values greatly in excess of this, however, were recorded at

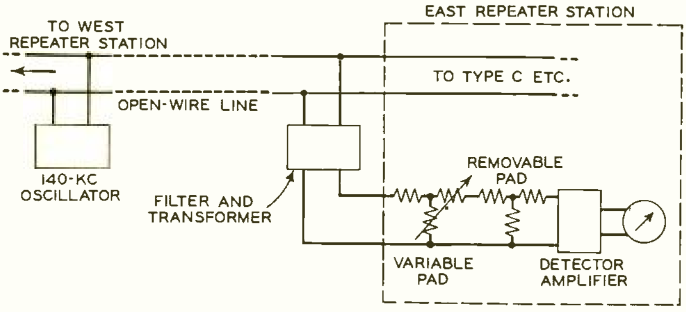


Fig. 3—Circuit arrangement of the equipment used for the attenuation measurements

times; in fact, on two occasions the attenuation exceeded 1.2 db per mile, the limit of the range of the measuring equipment for the distance covered during the investigations.

A large majority of the high-attenuation periods indicated in the three-dimensional figure are due to light frost deposits on the wires. When deposits formed they usually began in the early morning hours and built up in thickness until sunrise, then rapidly disappeared. The attenuation follows a similar curve, as shown in Figure 5. Sleet or heavy frost formation on the wires, however, is not limited to the early morning hours.

Frost deposits on wires vary from a feathery to a fairly solid texture and may range up to several inches in diameter in some localities. A particularly severe deposit which occurred in the Northwest is shown in the headpiece. Deposits on the line between Lamar and Salt Lake City normally do not exceed a few tenths of an inch. The results of the tests show, however, that sleet and frost deposits of such thickness are capable of producing far greater changes in attenuation at 140 kc than either rain or temperature variations, and must be given careful consideration in designing and laying out carrier systems.

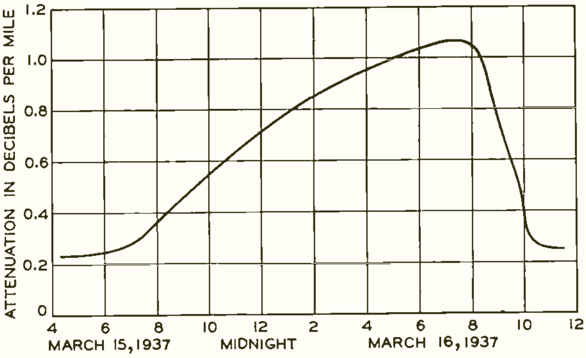
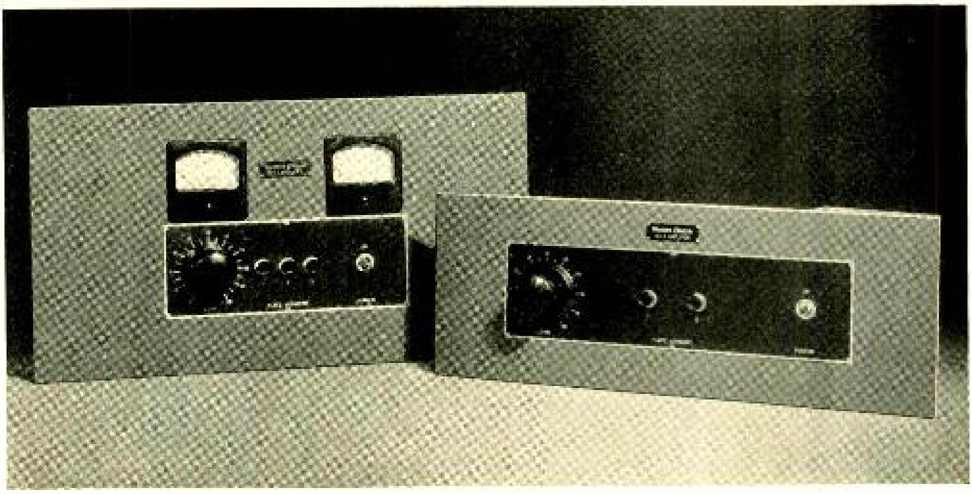


Fig. 5—Curve of attenuation over a twenty-four-hour period during which a deposition of frost occurred



Improved Program and Line Amplifiers for the Broadcast Studio

By H. M. OWENDOFF
Commercial Products Development

A BROADCAST program is rehearsed several times before its presentation, usually in the same studio that will be used for the final performance. Each studio is therefore arranged to operate as an independent program unit; and the rehearsal approximates the conditions of broadcasting, although, of course, the program is confined to the studio itself. Within each studio there are from three to six microphones; and each has its amplifier and mixing potentiometer in the studio control room. The outputs of all the mixers are connected to a master gain control and then on to the program amplifier.

The program output circuits from a number of such studio control rooms are carried to the master control room, where is located the switching and control equipment used for connecting any one or more of the studios to one or a number of outgoing program lines, each of which has a gain-control and a line amplifier. Besides the lines from the local studios, however, the master control room also has lines from remote pick-up points and incoming program circuits, and each of these is equipped with a gain-control and program amplifier of the same type that is in the studio control room. A typical arrangement is shown in Figure 1, and a description of the apparatus and circuits has already appeared in the RECORD.*

It has been common practice until recently to employ a common power-supply unit to provide for a number of amplifiers located in the same room. Thus in a studio control room, this unit would supply the program amplifier and all the premixing amplifiers, while in a master control room, it would supply several line or program amplifiers. This arrangement had the

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*RECORD, *September*, 1934, *page* 2.

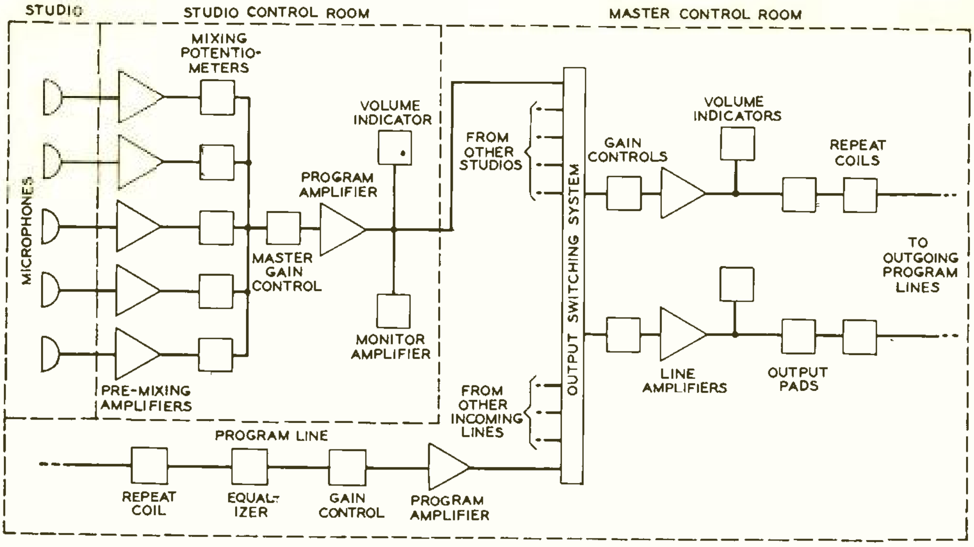

Fig. 1—Typical layout of a broadcast studio

advantage of permitting physical separation of the power supply and amplifier circuits, thus minimizing the problem of noise pick-up. It had the disadvantage, however, that it was expensive to operate at times because the entire power apparatus had to be operated even though only one

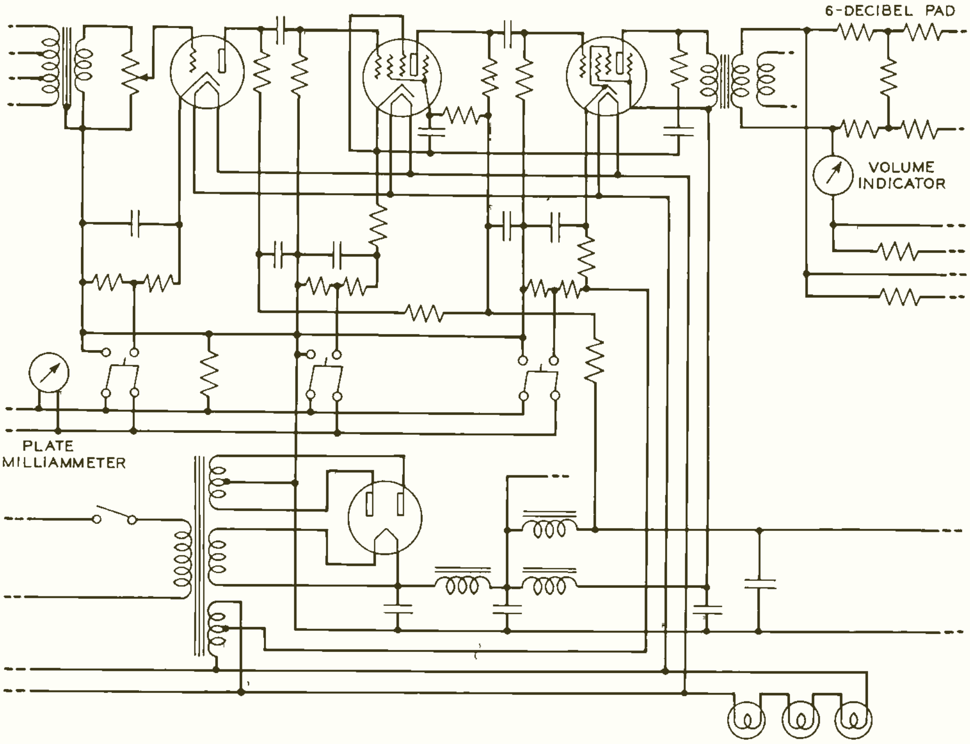

Fig. 2—Simplified schematic of the 105A program amplifier

amplifier was in use. It also had the disadvantage that any trouble with the power equipment would affect a number of amplifiers.

In recent years, technical advances in the shielding art have made it possible to build power-supply equipment as part of a voice-frequency amplifier without the introduction of appreciable noise. It seemed desirable, therefore, to secure greater flexibility for the amplifier equipment by designing new program and line amplifiers each of which would incorporate its own power supply. Improvements in vacuum tubes and in other circuit elements have made it possible also to build less expensive amplifiers which would still have the high quality required for program circuits. The 105A and 106A amplifiers are the results.

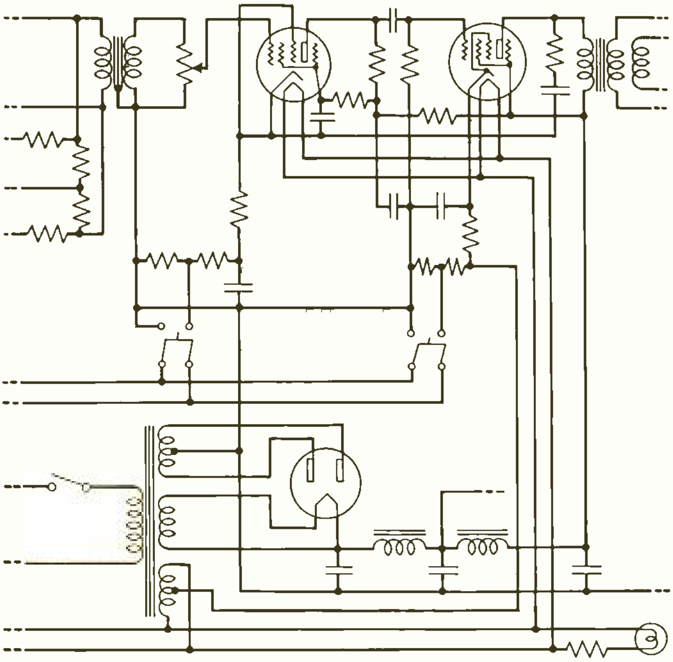
Fig. 3—Simplified schematic of the 106*A line amplifier*

The program amplifier is an important equipment unit of the studio control room. It must provide sufficient amplification to overcome the losses incidental to the mixing function, and in addition must raise the general program level to reference, or zero volume level, which has been found to offer the best compromise between the power output capabilities of suitable vacuum tubes in the amplifier and freedom from noise and crosstalk in the circuits connecting the studio with the master control room. In addition, the frequency-response characteristics and the noise and distortion levels of this amplifier must be such as to meet the requirements of modern high-fidelity systems.

The 105A program amplifier consists of a triode stage and two pentode stages, the latter having stabilized feedback to improve the frequency characteristic and to decrease noise and distortion. Another advantage of feedback is that it has permitted a single tube instead of a push-pull pair in the final stage, and thus reduced the number of tubes required, and simplified the circuit. The major features of the circuit are shown in Figure 2. The tubes are all of the recent Western Electric non-microphonic, low-hum type.

The normal gain of the amplifier is 70 db, but gain control down to 32 db can be secured by the potentiometer in the grid circuit of the first amplifier stage. By removing the 6-db pad in the output circuit, the gain may be increased to 76 db. This

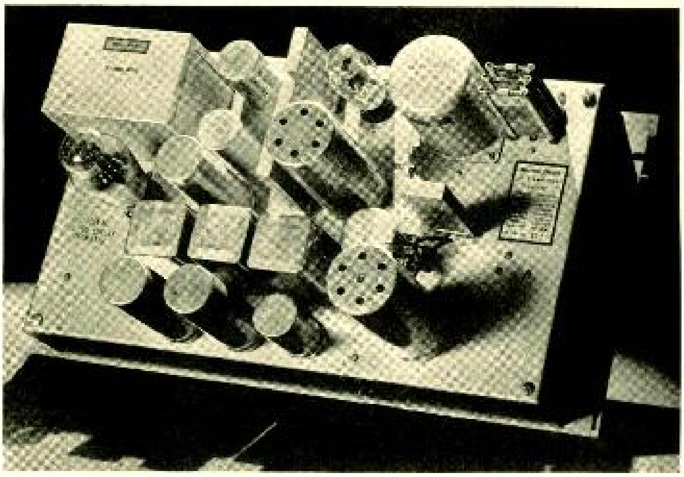

Fig. 5—The 105A amplifier

pad is employed primarily to minimize the effect of variations of load impedance on the characteristics of the amplifier and its self-contained volume-indicating equipment, but it also serves to reduce the noise by an additional 6 db. To illustrate this effect of the pad, it may be assumed that the noise produced in the amplifier is at a level of −60 db when the speech output is 0 db, both figures referring to readings of the volume indicator. With no pad in the circuit, therefore, the noise is 60 db below the signal. With the pad in the circuit, the gain of the amplifier would have to be raised 6 db to produce zero level at the output of the pad. Since this additional gain is obtained by adjusting the input potentiometer, the tube noise remains constant, so that at the input of the pad the voice will be at +6 db level, and the noise −60, as before. At the output of the pad both noise and signal will be 6 db lower, giving zero level for the signal and −66 db for the noise, which is thus 66 db below the signal rather than the 60 db found without the pad.

The 105A amplifier is designed to operate from an impedance either of 30 ohms or of any value from 500 to 600 ohms. One of the latter values is normally used when the amplifier is connected to the mixing potentiometers or to incoming lines, while the 30-ohm connection allows the amplifier to be associated directly with a microphone. It is designed to operate into an impedance from 500 to 600 ohms, which makes it suitable for connection to studio circuits or to program lines.

The 106A line amplifier, a schematic of which is shown in Figure 3, is essentially the same as the final two stages of the 105A. Since its input level is normally higher than that of the 105A, a maximum of only 46 db gain is required, which has made it possible to omit the first stage of the 105A. It is designed for operating both from and into impedances from 500 to 600 ohms, but a high input impedance of 10,000 ohms is provided so that the amplifier may be bridged across a program line if desired. When used as a bridging amplifier, however,

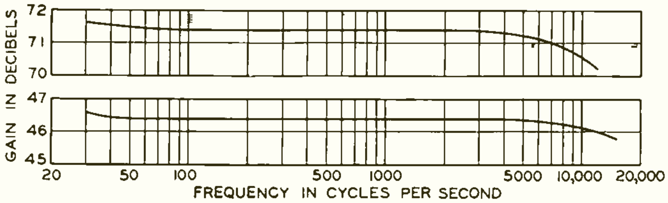

Fig. 4—Frequency-response characteristics for the 105A amplifier, above, and the 106A, below

the gain is only 20 db. In either case the gain may be reduced 38 db by the potentiometer. The nominal program level at the output of the amplifier is 10 db above reference volume, so as to maintain zero level at the output of the 10-db isolation pad, which is usually provided externally and serves the same purposes as the 6-db pad that is used in the output circuit of the 105A amplifier.

Frequency-response characteristics for the two amplifiers are shown in Figure 4. Both are essentially flat within 0.5 db from 30 to 10,000 cycles, although the curve for the 105A amplifier drops off slightly more than this at the very high frequencies. The harmonic distortion for both amplifiers at sinusoidal outputs of 6 milliwatts is under 0.5 per cent for fundamental frequencies from 50 to 5000 cycles, and is under 1 per cent for levels as great as 12 db higher than 60 milliwatts. The unweighted noise level at the output of the 105A amplifier, with the gain at 70 db, is at least 55 db below the program level, while with program weighting,* it is 65 db below. For the 106A amplifier these figures are 75 and 90 db, respectively.

Each amplifier contains its own power supply, with the power transformer mounted in the amplifier chassis. Besides the power supplied to its own amplifier, each power unit also furnishes alternating current at ten volts and direct current at approximately 250 volts for auxiliary apparatus. When this direct-current supply is to be used for low-level amplifiers, an additional filter will ordinarily be required. In the 105A amplifier such a filter is incorporated in the amplifier to supply the direct current necessary for operating the premixing amplifiers.

Both amplifiers have provisions for measuring the plate currents of their tubes by a single meter, which may be connected across suitable shunts by means of individual switches. A suitable meter is installed on the front of the 105A amplifier for this purpose, and terminals are provided to enable this meter to be used to measure the plate currents of associated amplifiers. No meter is provided with the 106A amplifier, although the shunts and switches are included. The meter may also be omitted from the 105A amplifier if desired.

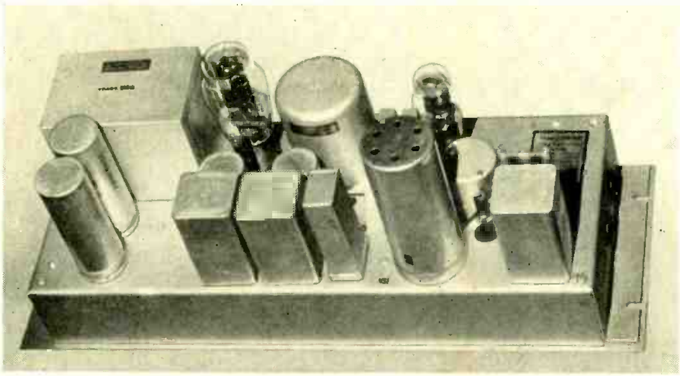

Fig. 6—The 106A amplifier

Both amplifiers are arranged for mounting on standard 19-inch relay racks or in equipment cabinets. The 105A requires 10½ inches of vertical space and the 106A only seven. Their appearance is shown in the accompanying photographs. The nameplate is of translucent bakelite and serves as an "on-off" indicator, being illuminated when power is on, and dark when it is off.

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*Record, *March,* 1936, *page* 233.

These two amplifiers, with the 94C* monitoring amplifier and the new premixing amplifiers, make available to broadcasters complete amplifying equipment for the modern studio. They represent the result of careful and intensive study of broadcasting needs, and besides including the latest technical advances, have been carefully coördinated in design so that they cover all present studio needs.

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*Record, *Nov.*, 1938, *page* 89.

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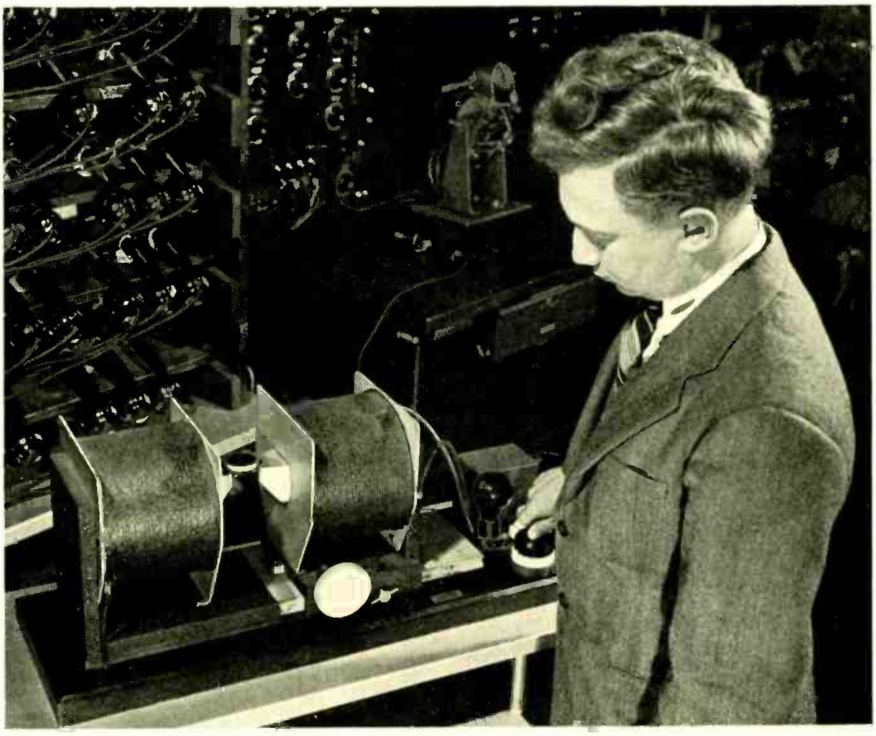

Since sensitivity of a telephone receiver depends in no small degree on the strength of its permanent magnet, steps must be taken during manufacture to magnetize it as strongly as practicable. Modern alloy steels require an intense field; to produce it in a path which includes a sizeable air gap, a powerful electromagnet is required. Each coil of the one shown above is 7½ *inches in diameter and* 5½ *inches long, and contains about* 4000 *turns of No.* 17 *wire. The two windings in series consume about* 240 *watts at* 120 *volts. One pole slides long the bed-plate; its travel is blocked at will by a spring-actuated key. A varistor that is inserted across the windings of the electromagnet prevents dangerous voltage when the circuit is broken.*

This instrument, designed by R. A. Chegwidden and shown above being operated by R. P. Smith, is used to magnetize the permanent magnets of receivers after they have been assembled in their cases; in that application it produces a flux density of greater than 15,000 *gausses in the receiver magnet.*

Distributing Time Announcements

By P. G. EDWARDS

Toll Transmission Development

Twirl the dial and spin it, lass;
  Oh, whirl it round and round;
They've got an hour and minute glass,
  As fine as can be found;
And when they sweetly tell the time,
  They make a lovely sound . . .

K.H.T. in "The Conning Tower"
N. Y. Herald Tribune
July 25, 1935.

TIME announcement systems, of which K.H.T. takes notice in the above verse, have now been in use for some years. To be able to secure the correct time when it is wanted merely by placing a telephone call is a great convenience, and it is natural, therefore, that the use of the system should have increased as the possibility of obtaining accurate time in this manner became more widely known. The general method of making the announcements with the standard centralized time bureau, and the type of distributing circuit employed have already been described in the Record.* Since the time that article was written, however, the system has been improved somewhat.

Although the subscriber calls the time bureau just as he would place any other call, and receives the announcement from his central office over the same telephone line that he uses for all his other calls, the circuit conditions are distinctly different. An ordinary telephone connection is arranged so that conversation can proceed with equal ease in both directions. Time circuits are not arranged in this manner, however. They are unidirectional; speech can proceed only from the time office to the subscriber, and should the subscriber talk, the operator would not hear him.

The necessity for such an arrangement is obvious on a little consideration. There is only one time operator for a large area. In New York City, for example, subscribers connected to many central offices all receive their time announcements from the same source. There may thus be, and usually are, a number of subscribers connected to the bureau at the same time, and if they could all talk to the operator and to each other, there might be such a babble of voices that the time announcement would be completely lost. It is essential, therefore, that the circuits be designed so that while the time announcements can flow readily and distinctly to all subscribers, their voices will not be carried back.

There are a number of other transmission features that must also be given consideration. Because the time announcement is a series of numbers rather than related words and phrases, transmission has in general been made somewhat better than for message service both in quality and volume. This is partially accomplished by providing the time operator with a high-quality microphone, and also by employing a certain amount of equalization in the cable circuit. However, the matter of obtaining the correct vol-

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*Record, *March*, 1931, *page* 335.

ume of the announcement is more difficult. Some subscribers may be in the same office as the time bureau itself, while others may be connected to remote offices reached through long tandem or inter-office trunks. The volume cannot simply be increased until it can easily be heard by the most distant subscriber, because if this were done, it would be high enough at certain locations to cause appreciable crosstalk to other circuits, which must be carefully avoided.

An accurate control of volume is thus required throughout the time-distributing area, and it is obtained for the most part by the use of amplifiers at terminating and tandem offices and of adjustable loss networks for some of the circuits. It is by the design and arrangement of these added circuit elements that one-way operation also is secured. An amplifier will transmit in one direction only, and for this reason, repeaters for telephone circuits, where the voice is to be transmitted in both directions over the same pair of wires, employ two amplifiers, one for each direction of transmission. The time circuits use only a single amplifier at any point, and thus transmit speech in only one direction. Although it prevents a subscriber from talking to an operator, this use of an amplifier would not necessarily prevent two subscribers in the same central office area from talking together when they were both connected to the time bureau, since such intercommunication would not pass through the amplifier.

This will be obvious from Figure 1, which shows a simplified diagram of the circuit arrangement at the time bureau, together with the various types of branch circuits most commonly employed. Since the transmitting amplifier passes speech in only

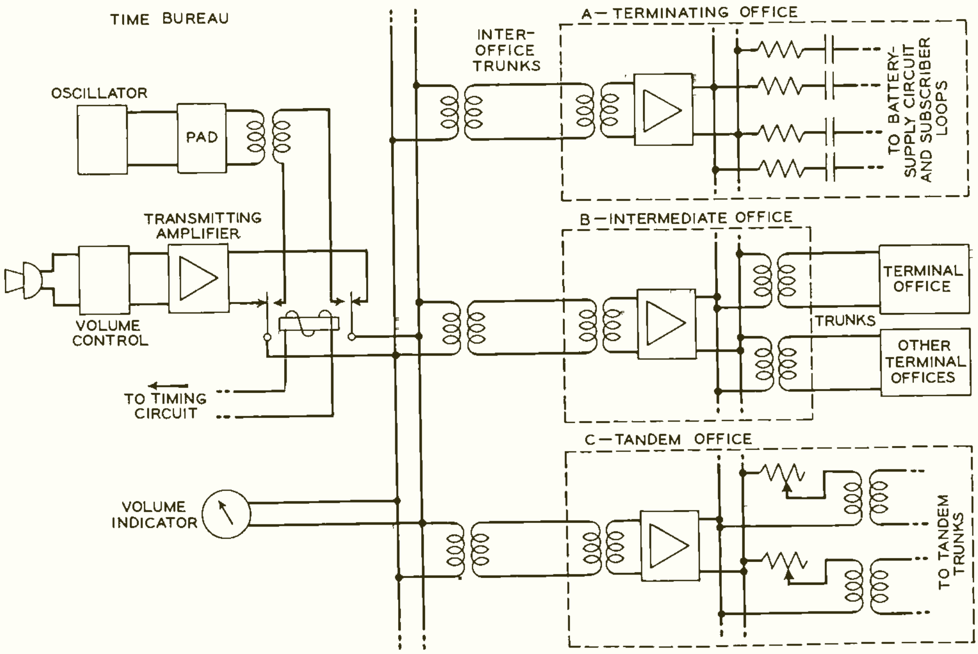


Fig. 1—Simplified arrangement of time announcing circuit with the various types of branch circuits most commonly employed

one direction—as indicated by the triangular symbol—any attempt of a subscriber to talk to the operator is blocked. To prevent two subscribers from talking to each other through the time distributing bus to which all the subscribers are connected, the output impedance of the amplifier is made very low compared to that of the subscribers' loops. The amplifier thus acts more or less as a short circuit placed across two connected subscriber lines. Under these conditions the loss over the path from one subscriber to another is around 66 db.

This low output impedance of the amplifier also reduces the effect of the number of subscribers connected to the bureau at the same time, since the subscriber lines are of relatively high impedance. The volume of signal the subscriber receives is proportional to the voltage on the distributing bus, and when the lines it supplies are of high impedance, each has but little effect on it. The situation is somewhat analogous to a low-resistance storage battery feeding a number of high-resistance circuits; adding or subtracting circuits has little effect on the battery voltage, while if the battery resistance were high, the effect would be great.

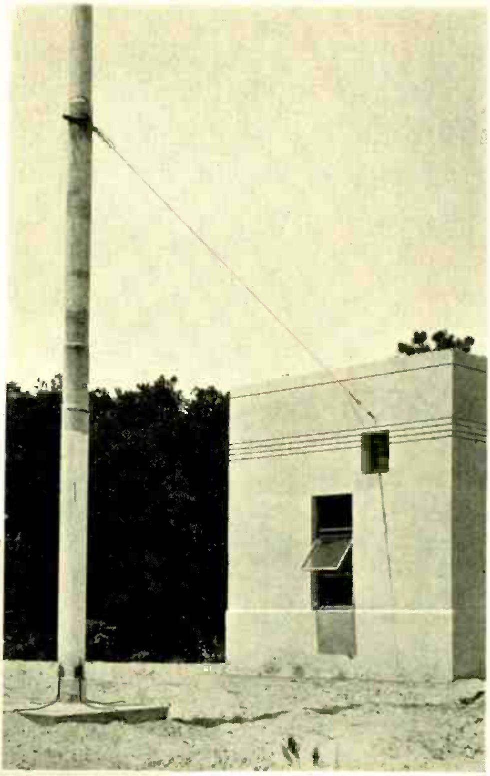
Besides the distribution arrangement for supplying subscribers in the same office as the time bureau, it is necessary also to provide for service over trunks to other offices and to tandem offices, where the losses in the trunks must be considered as well as those in the subscribers' loops. In a terminating office, as at A, the output of the amplifier is fixed at a value which gives satisfactory transmission for long and short loops, and for a variety of subsets which may be found in the plant. Where the distances to some of the offices may be too great to be handled satisfactorily with a single amplifier, an intermediate office is employed as a secondary distributing center. An intermediate amplifier is installed here, and permanent trunks to other offices are connected to it as at B. Terminal amplifiers are installed at these other offices, from which the distribution is as at A. The intermediate amplifier makes up for the length of trunk between the time office and these outlying offices.

The arrangement at a tandem office is in general similar to that at an intermediate office and is shown at C. The difference is that trunks to outlying offices cannot be permanently assigned to the time service. Requests for time service may come in over any of the trunks entering the tandem. The amplifiers cannot be adjusted, therefore, for a definite length of trunk, and an adjustable pad is inserted in all the time circuits, and is set to make the volume correct for the loss on the average trunk.

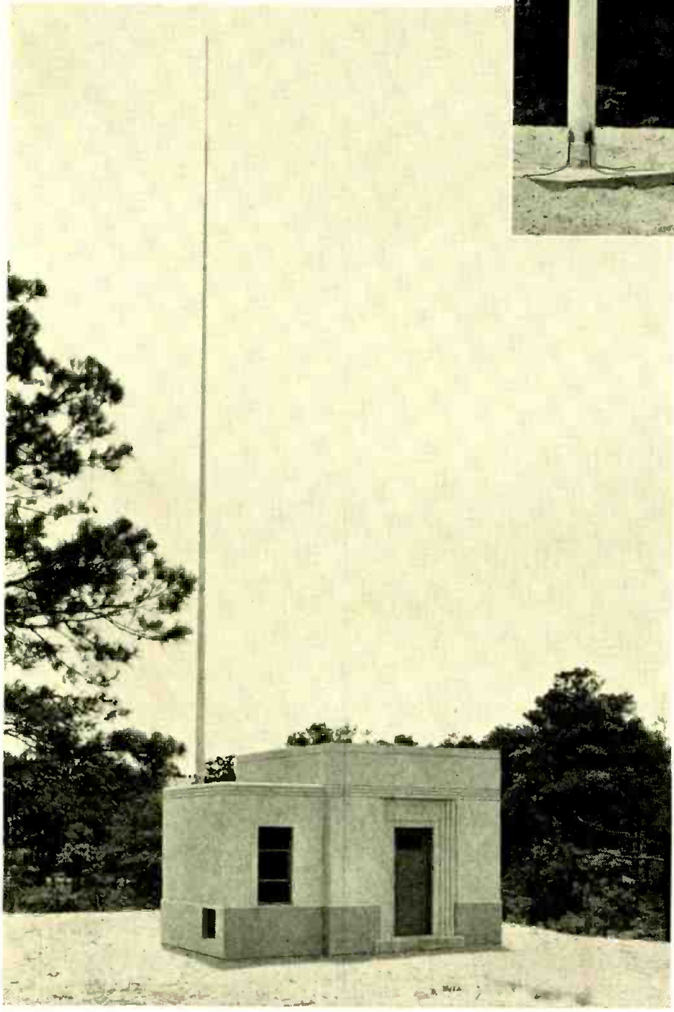
While the levels at various points should be adequate to give proper volume for the announcements, they must not be made high enough to cause crosstalk to other circuits. At the terminal offices there is the added restriction that the subscribers must not be able to talk to each other, and these two problems are closely related—an increase in the volume in the announcement results in a decrease in loss in the path between the subscribers, assuming a given output volume from the amplifier. The losses and lengths of all trunks and subscriber loops have been carefully considered in the design of the system, and have been fitted into a broad plan that will give good service. Such a system is now operated in New York and San Francisco.

NORFOLK ANTENNA

The shunt-excited antenna, described in the RECORD for August, 1936, was employed for the first time on Bell System short-wave systems with the new Norfolk radio transmitter for harbor and coastal radio-telephone service. Located in a residence section within a few blocks of the beach, this new transmitting station seemed to require as inconspicuous an antenna structure as possible. By employing shunt excitation, a standard steel flag pole satisfactorily met requirements.



From the transmitting station a diagonal transmission line connects to the antenna at a point carefully selected to give maximum output with freedom from distortion. At its base, the pole is connected to a radial ground system buried in the earth.



The unattended transmitter station is of tile and concrete construction, and the flag-pole antenna is mounted in the rear.

Contributors to this Issue

P. G. Edwards graduated from Ohio State University in 1924 with the B.E.E. degree, and in 1929 received the E.E. degree by thesis. In 1918 he was granted a commercial first-class radio operator's license, and from 1919 to 1922 was Morse operator and repeater attendant for the Western Union Telegraph Company. He then joined the Long Lines Department of the American Telephone and Telegraph Company and in 1924 transferred to the D. and R. Department. There he was concerned with toll test boards and fault location, and later with toll signaling and carrier facilities. He continued this work with the Laboratories after the 1934 consolidation. Later he was associated with the local transmission group, and most recently has been engaged in toll transmission problems involving repeatered voice systems.

H. E. Curtis received a B.S. and an M.S. degree from the Massachusetts Institute of Technology in 1929. He then joined the Department of Development and Research of the American Telephone and Telegraph Company, and with it was transferred to the Bell Telephone Laboratories in 1934. He has been engaged in studying transmission problems relating to such high-frequency transmission lines as the coaxial, the shielded pair and quad, the dielectric guide and the hollow tube. Recently he has been particularly concerned with the transmission properties of open-wire lines.

J. A. Carr received the degree of B.S. in Electrical Engineering from Virginia Polytechnic Institute in 1919. The following year he was instructor in Electrical Engineering at Massachusetts Institute of Technology. From 1921 to 1927 he was with the American Telephone and Telegraph Company in the Development and Research Department. In 1927 he transferred to the Bell Telephone Laboratories where he has been engaged in outside plant development work.

When L. L. Bouton entered the Engineering Department of the American Telephone and Telegraph Company in 1916, the first extensive tests of four-wire circuits had just been completed, and plans were being made for the development of four-wire systems suitable for wide commercial use. Mr. Bouton's early

P. G. Edwards

H. E. Curtis

J. A. Carr

L. L. Bouton

W. S. Ross

H. M. Owendoff

work dealt with repeater balance and echo current matters and involved the application of repeaters to two-wire circuits. Shortly afterward, however, he became engaged in the design and development of four-wire cable systems. He had charge of the field trials of the extra-light-loaded four-wire circuits between York, Reading and Harrisburg which he describes in the present article. Mr. Bouton is a graduate of Kansas State College (B.S. in 1911) and of Purdue University (E.E. in 1916) in electrical engineering. He is at present engaged in circuit layout and switching studies in the Toll Transmission Development Department.

W. S. Ross left Dartmouth College in the spring of 1917 to join the Signal Corps, and served two years, spending a year in France. In the meantime he received the B.S. degree from Dartmouth. After leaving the Signal Corps he entered Massachusetts Institute of Technology and received the B.S. degree in 1921 and the M.S. degree in 1922. The next three years he spent with the Public Service Corporation of New Jersey, and in consulting engineering work in New York City. He joined the Technical Staff of the Laboratories in 1925, where, except for a year and a half with the Associated Gas and Electric Company, he has been engaged in power development work for the Systems Development Department. He has been largely concerned with the design of automatic power and ringing plants for central offices.

H. M. Owendoff entered the Laboratories in 1929 as a student assistant. During the next four years he acted as an assistant in problems concerning physiological acoustics and in the construction of experimental hearing aids. In 1933 he left the Laboratories to attend the State University of Iowa, receiving the degree of B.S. in Electrical Engineering in 1935. Early in 1936 he reëntered the Laboratories and was concerned with the development of amplifiers for broadcasting systems. Since early in 1938 he has been engaged in the development of audiometers and other clinical aids.