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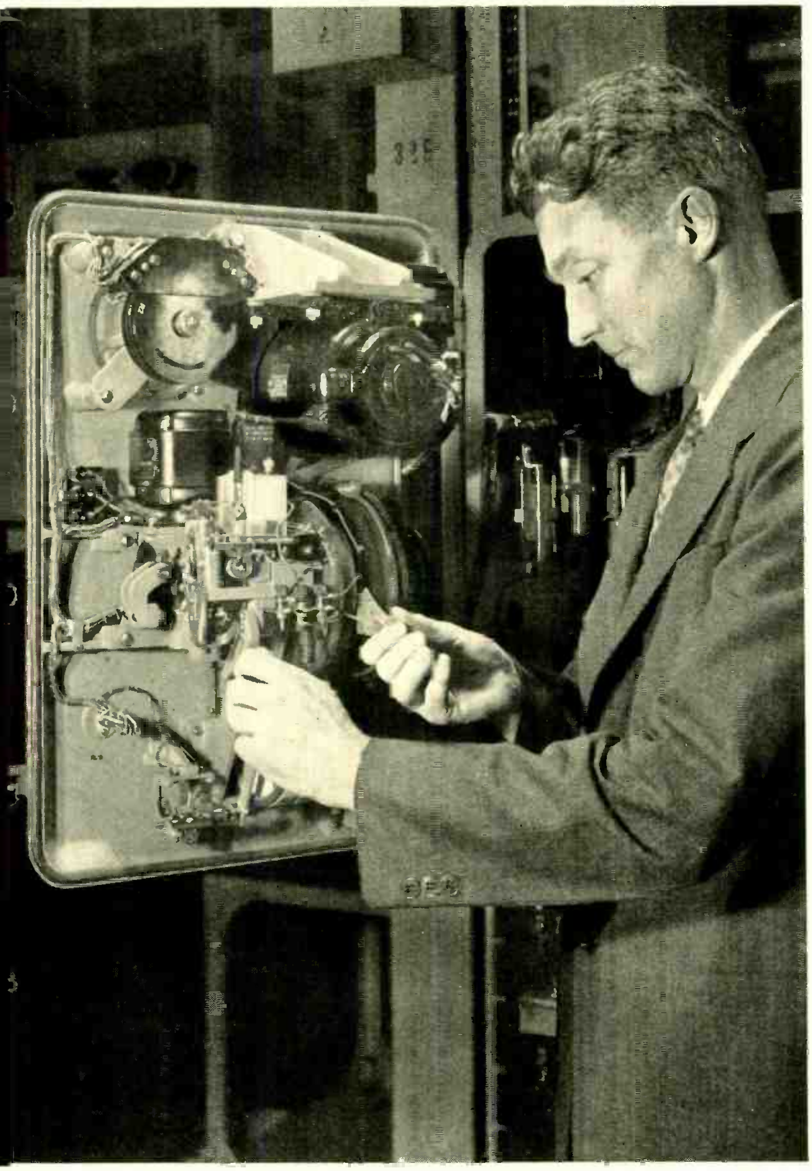


JANUARY
1939

VOLUME XVII

NUMBER V

Twist regulator for type-K carrier system

Generation of Reference Frequencies

By L. A. MEACHAM
Circuit Research

ALTERNATING currents of accurate frequency have long been a daily necessity in these Laboratories for such purposes as the calibration of oscillators and for the measurement of filter characteristics. Outside, they are used by jewellers to adjust watches, by radio stations to control carrier frequencies, and by power systems to maintain constant frequency. Consequently a limited demand has grown up for a "reference frequency" service, which is operated by the Long Lines Department, using facilities that have been developed by the Laboratories.

The two most essential requirements for reference frequencies are accuracy and continuity. Accuracy is obtained by using stable oscillators of the "submaster" type, which are controlled in frequency during normal operation by the master oscillators of the Laboratories' frequency standard, but which have enough inherent stability to carry on independently if the control is interrupted. This arrangement takes advantage of the high precision of the primary standard, and yet allows the Long Lines Department to have direct supervision over the actual generation of the reference frequencies. To assure uninterrupted operation, the equipment has been installed in the program transmission control room at 32 Sixth Avenue, where supervision is available twenty-four hours a day.

The submaster oscillators are 4000-cycle tuning-fork units controlled by an automatically adjusted condenser which keeps them in step with a 4000-cycle control current supplied from the Laboratories. The accuracy of the reference frequencies is almost exactly the same as that of the frequency standard* when the submasters are regulated in this manner. If operated independently, the oscillators will remain within one part in a million for at least twenty-four hours.

The reference frequency of 4000 cycles is supplied directly from the submaster oscillators. Other reference frequencies of 1000 cycles, 100 cycles, and 60 cycles are derived from the 4000 cycles by means of frequency converters which are a part of the installation. The remaining equipment consists principally of alarm, protective, and maintenance features. The most important parts of the installation are provided in duplicate in order to increase reliability and to permit maintenance without interruption of service.

The general arrangement of the system is shown in Figure 1. Each submaster oscillator has two output circuits. One of these is connected to the distributing circuits and to the frequency converters. The current in the other is compared by a polyphase modulator with the 4000-cycle control current received from the Laboratories. If at any instant the frequen-

*The frequency stability of the standard is considerably better than one part in a million, and the cumulative phase error is so limited that a clock driven continuously thereby keeps correct time within 0.1 second.

cies differ, the modulator adjusts the oscillator to the frequency received from the Laboratories by operating a motor-driven condenser in the oscillator circuit.

Associated with the submaster apparatus is an alarm panel designed to indicate any of four trouble conditions in either oscillator: an interruption of the control frequency, a drop in level of the oscillator output, a failure of the fork temperature control and the reaching of either limit of the control range of the motor-driven condenser.

An automatic switching circuit determines which of the two oscillators is connected to the load. It provides for automatic transfer of the load to the other oscillator, if the one in service fails, and for manual transfer. To avoid affecting service when manual transfer is to be made, a phase indicator is connected between the outputs of the two oscillators, and means are provided for "phasing-in" the idle oscillator to the working one before the load is switched. A portion of the output of each oscillator is trunked back to the Laboratories for checking.

The main output from the automatic switching circuit is divided by a hybrid coil into two independent outputs. One of these passes to a distributing arrangement which supplies the 4000-cycle current to subscribers and to the frequency converters; the other is a spare for use with additional distribution facilities as required.

The frequency converters consist of a series of controlled multivibrators. The period of oscillation of each stage of the series is determined by the rate of discharge of a resistance-condenser circuit which is triggered off by the frequency to be divided. By properly choosing the characteristics of these circuits they can be made to oscillate exactly at the desired submultiple of the applied frequency. The converters each have three outputs, supplying frequencies of 1000, 100, and 60 cycles, all "geared" to the 4000-cycle frequency which controls them. Arrangements are provided by the Long

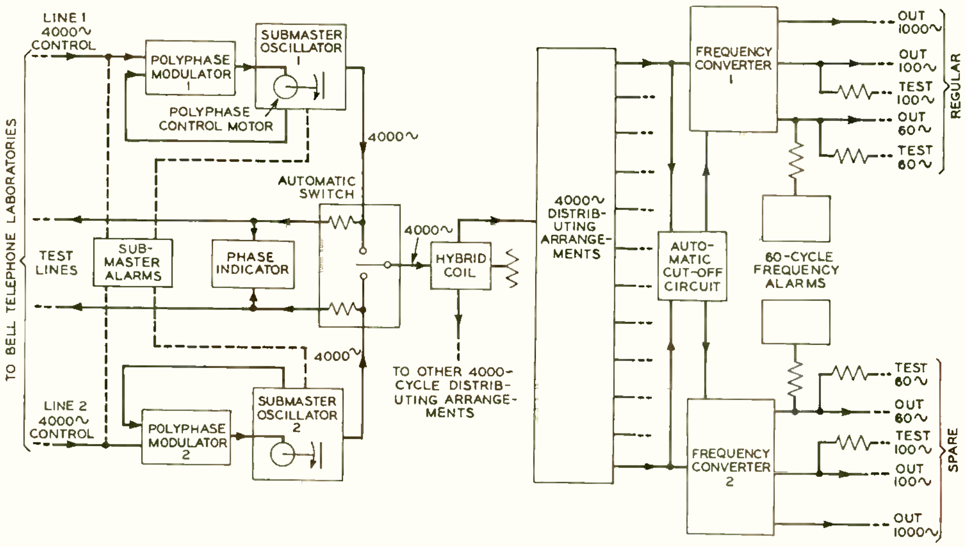
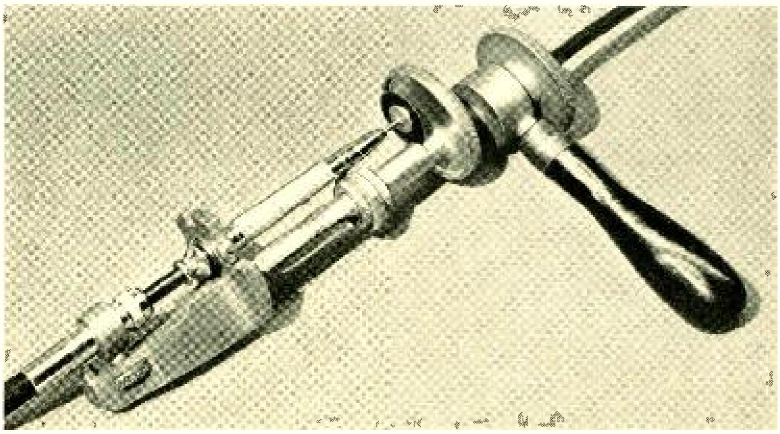


Fig. 1—Simplified block schematic of the system for supplying reference frequencies

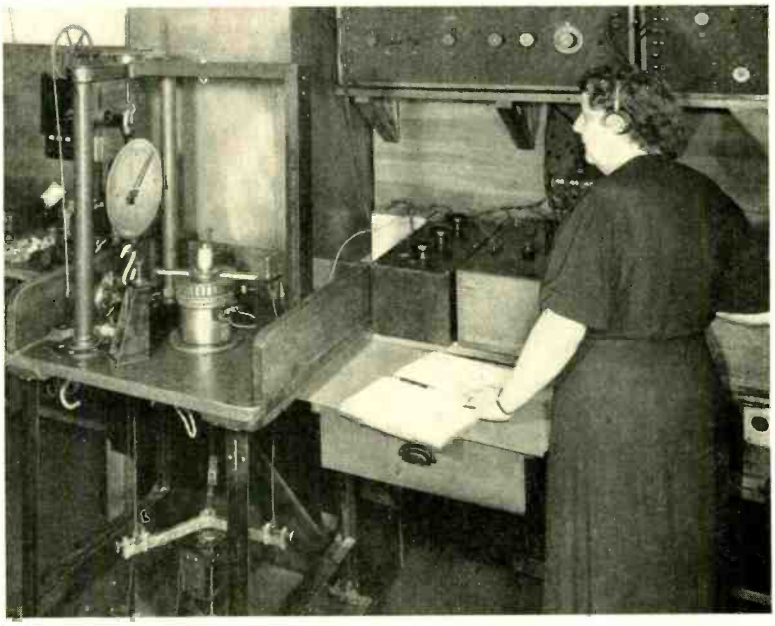
Lines Department for distributing these outputs.

Associated with each frequency converter are two protective circuits. One is an automatic cutoff circuit which interrupts all three outputs if the 4000-cycle input fails. The purpose of this is to prevent the delivery of erroneous frequencies through the continued operation of the multivibrators of the frequency converter during such an emergency. The second is a final precaution in the form of a sixty-cycle tuning fork driven by a portion of the sixty-cycle output, and arranged to actuate an alarm if the amplitude of the fork drops below a certain value. Operation of this alarm indicates either that the level has failed or that the frequency is outside the limits of 60 ±0.03 cycles. Although these limits are coarse compared with the accuracies sought in the reference frequency service, it has been found that troubles which could affect the frequency would be likely to cause a large error if they should occur at all. Moreover, the sixty-cycle circuit is the last link in the chain of frequency conversion, so that the check on the sixty-cycle output applies effectively to the entire frequency converter.

Precise reference frequencies are gradually finding a number of other interesting uses outside of the Laboratories. Among these are the control of the adjustment of quartz crystals by the Western Electric Company at Kearny, the synchronization of switching in privacy systems and the control of pairs of broadcasting stations which operate on the same wavelength. By phase-comparison with the sixty-cycle reference standard, the frequency of the central station power system in New York City is held very uniform, in spite of variations in load, so that clocks driven from it keep very accurate time.



The cable cutter shown is one of several used by wiremen to cut off the braided copper sheath of a flexible concentric conductor used in making coaxial-cable connections. The cutting is accomplished without disturbing the inner conductor and its rubber insulation, by lowering a small circular saw into the conductor until it cuts through the sheath at one point. The sheath is then severed by sweeping the body of the cutter around the cable through one complete revolution



Measuring Permeability Under Stress

By MATILDA GOERTZ
Magnetics Research

MAGNETIC materials used in the telephone plant are frequently subjected to stresses set up during the fabrication or assembly of the apparatus or produced by the functioning of the magnetic devices themselves in actual service. It is desirable to know, therefore, how these mechanical stresses affect the magnetic properties of the materials — particularly their permeability. Permeability measurements of materials under stress have, of course, been made for a long time, for the most part on straight specimens. Such specimens are convenient for applying tension, but they are subject to the influence of stray fields, such as that of the earth, and must thus be carefully shielded. In addition, the effects of the terminal poles must be considered, which requires a difficult correction.

A closed magnetic circuit, preferably of the toroidal form, is more desirable for permeability tests, but with an annular specimen it is difficult to apply a uniform tension and at the same time preserve the original shape. To combine the advantages of both a straight specimen and a closed magnetic circuit, H. J. Williams suggested the use of a triangular specimen, which would allow three equal forces to be applied to the corners. Apparatus has been built to permit measurements of the permeability of such specimens to be made under tension, and a considerable amount of data has been gathered.

To make a series of measurements, a triangular specimen — suitably

Fig. 1 (left)—A triangular frame with sliding pins in each corner is used to apply tension to the magnetic specimen

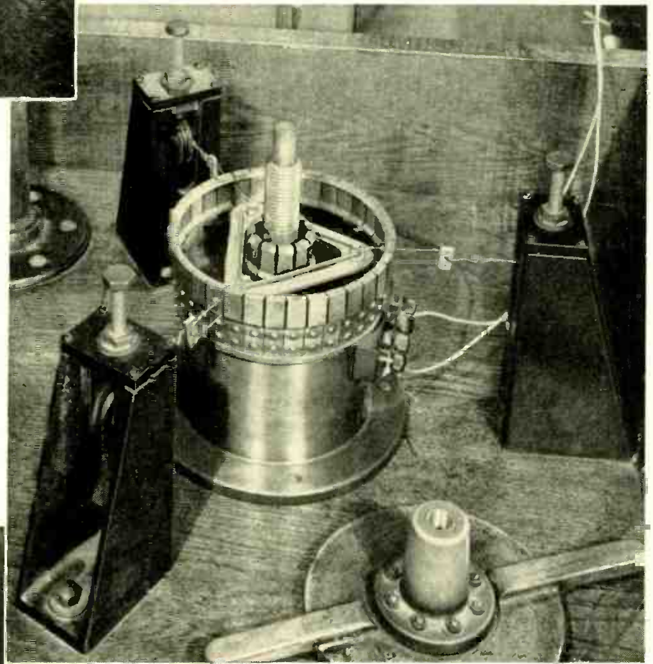


Fig. 2 (right)—Arrangement of permeameter with respect to the three tension wires attached to frame

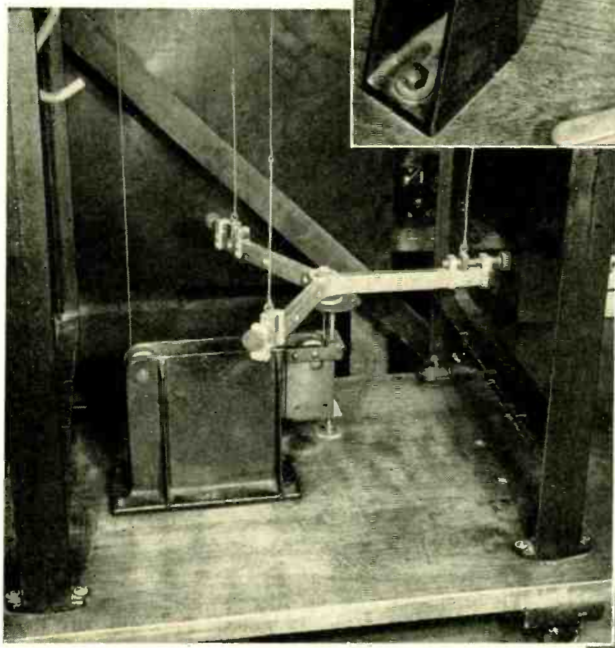


Fig. 3 (left)—Equal tension in the three wires of the permeameter is secured by a Y-shaped equalizing frame

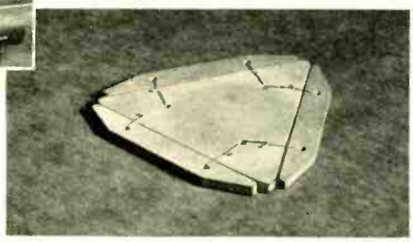


Fig. 4 (right)—Lavite form usea for forming and heat treating magnetic specimens formed and heat treated — is slipped over pins in the three vertices of the triangular frame shown in Figure 1. The pins pass through the frame and are free to move in slots along lines that bisect the angles of the equilateral triangle. The frame carrying the specimen is then placed in a Kelsall permeameter* mounted on the top of a special stand shown in the photograph at the head of this article. Loops of wire are slipped over the two ends of each pin, and each pair of loops, in turn, is fastened to a wire passing over a pulley in one of three posts mounted at the vertices of an equilateral triangle circumscribed around the permeameter. The arrangement is shown in more detail in Figure 2. With equal tension on these wires, the triangle carrying the specimen will assume a central position in the permeameter, and the tension will be the same in all three sides of the specimen.

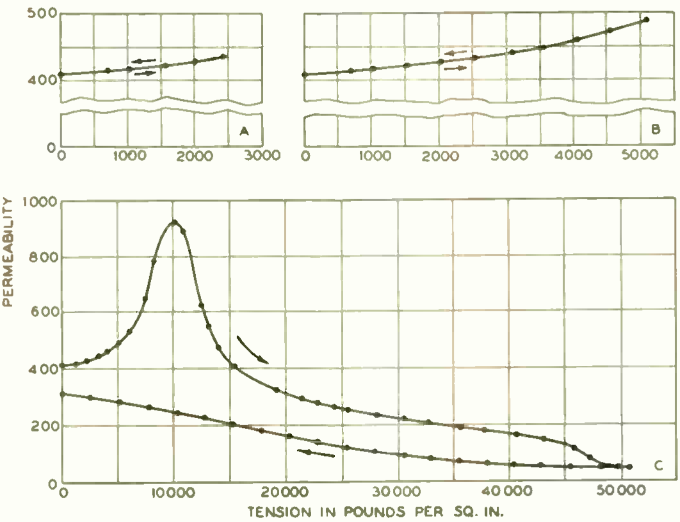


Fig. 5—Variation of permeability with tension in a perminvar tape with an a-c magnetizing force of 0.01 *oersted*

From the pulleys in the posts, the wires pass through the top of the stand to the three ends of a Y-shaped frame shown in Figure 3. Each wire is attached to a carriage that may be moved in or out along the arm of the Y by an adjusting screw. The tension in the three wires may be equalized by varying their distance from the center of the Y. To the center of the Y is attached a wire that passes under two pulleys mounted in a steel support on the bottom of the stand and thence to a spring balance and a power-driven screw, which supplies the tension. This arrange-

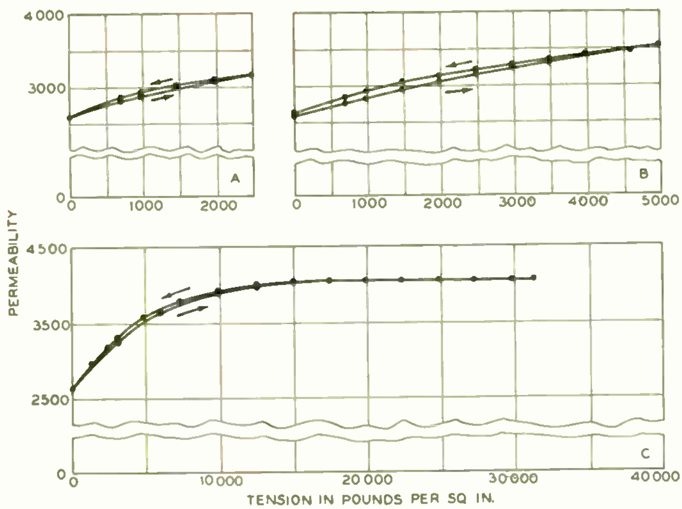


Fig. 6—Variation of permeability with tension of a perminvar tape with a d-c magnetizing force of 3.5 *oersteds*

*Record, *Nov.*, 1929, *p.* 100.

ment, designed by R. F. Squires, has proven very effective. A round disk fastened to a screw is mounted beneath the center of the equalizing frame and, before a test, is moved up to a position just below it to take up the shock if the specimen should break during the test.

The specimen is made by winding one turn of 0.125 x 0.006 inch tape around the triangular lavite form shown in Figure 4. The tape is overlapped slightly at one corner and the two ends welded together. Three pieces of lavite are wired to the sides of the form over the specimen to prevent its distortion during heat treatment. This assembly is then placed in a furnace and given the desired heat treatment, after which the specimen retains the shape of the lavite form and may be readily slipped over the three pins of the tension frame.

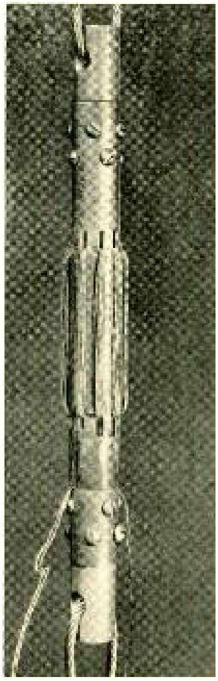


Fig. 7—A cylindrical specimen of magnetic material used for studying the effect on permeability when the stresses are at right angles to the magnetizing forces

The effect of magnetization due to stray fields on a specimen of this type is negligible as compared to that on long, straight specimens. This was verified by measurements on specimens of high-permeability permalloy turned in various orientations with respect to the earth's field. No changes in permeability were detected. There is a slight error, however, caused by the decrease in tension at the vertices of the specimen resulting from friction at the pins. Since these pins have a radius of only one-eighth inch, while the length of the straight section of the triangle is over 3¼ inches, the length of the tape in contact with the pins is only a little over seven per cent. The reduced tension for a given coefficient of friction can be calculated over the entire arc of contact. Assuming a coefficient of friction of 0.2, which is larger than is likely to occur under the conditions existing here, the

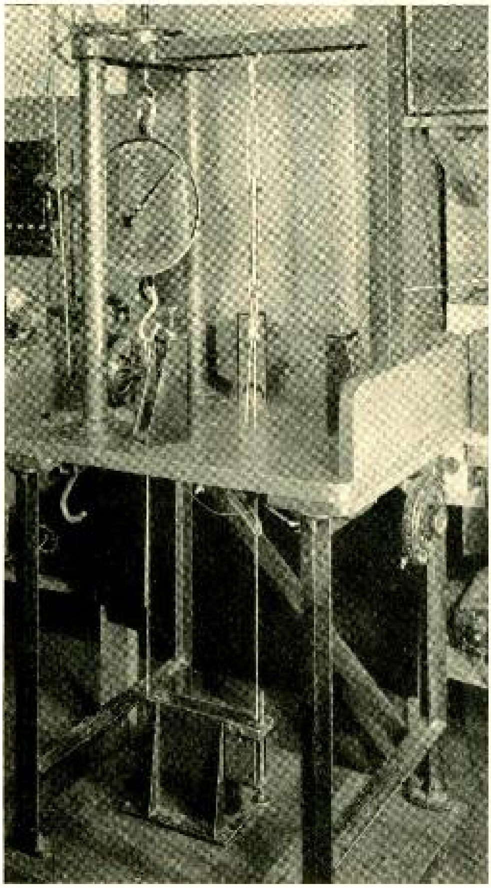
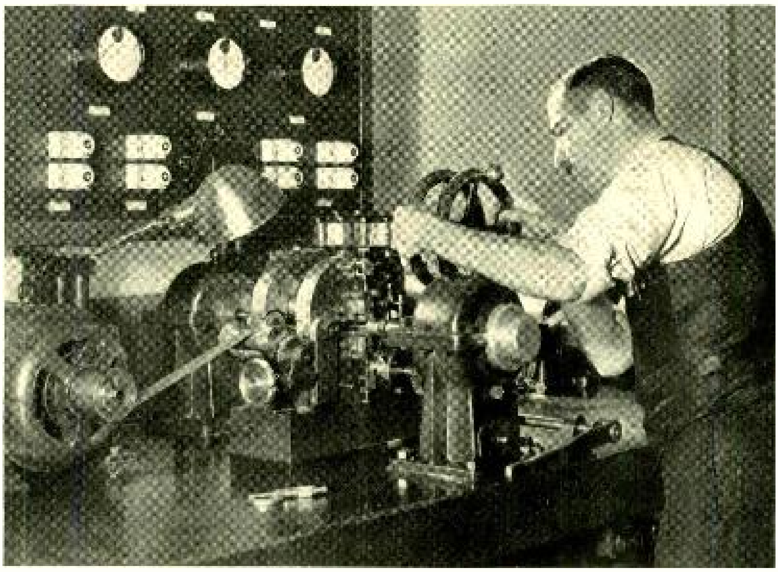


Fig. 8—Arrangement for a test of permeability with transverse mechanical stress

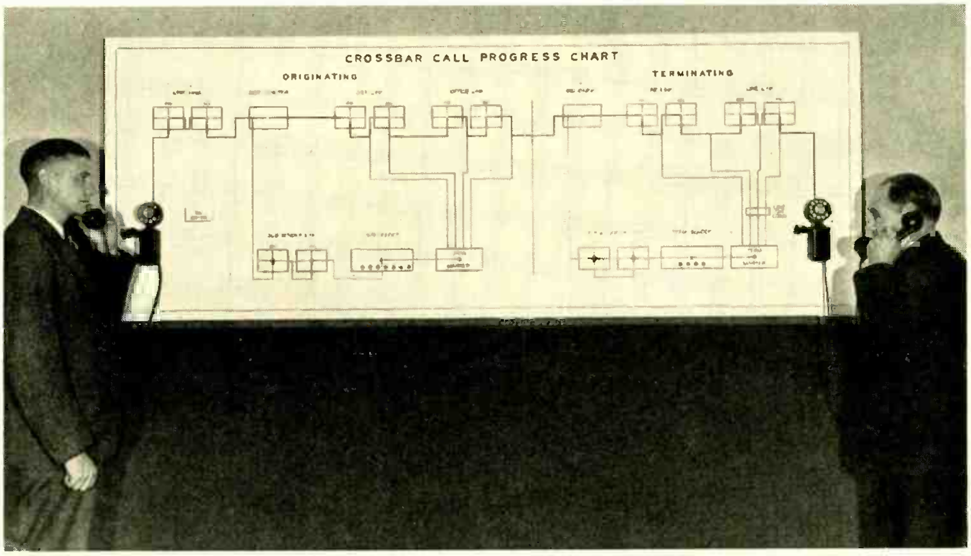
minimum tension is eighty-one per cent of that over the straight section of the specimen. The average tension over the arc of contact is ninety per cent of that of the straight section, and since this applies to only some seven per cent of the total length, the rather small variation in permeability over these short sections has very little effect on the overall permeability of the specimen.

The sort of information gathered by the use of this apparatus is indicated by Figure 5, which shows the results of a series of measurements on a perminvar tape with an a-c magnetizing force of 0.01 oersted. Results from a somewhat similar group of measurements at a d-c magnetizing force of 3.5 oersteds is shown in Figure 6. Tests have also been made showing the variations of permeability with small a-c forces while the specimen was subjected at the same time to a d-c force as well as to tension.

In all these tests, the tension is parallel to the magnetizing force. It is sometimes desirable, however, to know the variations in permeability when the stress is at right angles to the magnetizing force. For such measurements, the material to be studied is formed into a hollow cylinder about half an inch in diameter and 6 inches long. Two sets of slots are made in this cylinder along two circles at right angles to the axis of the cylinder and at equal distances from the two ends. A winding is wound through these slots as shown in Figure 7, and is used for the permeability measurements while the cylinder is under either tension or compression. The arrangement for a tension test is shown in Figure 8. By these methods, it is possible to study the effects of stress on the permeability of magnetic specimens, and thus to determine more accurately their behavior under actual operating conditions.



Rolling permalloy tape



A Lighted Display Board for Crossbar Calls

By A. S. PAGE
Switching Development Laboratory

THE action of crossbar switches while a telephone connection is being completed is not spectacular; a click and a snap here and there among the frames, the connection is completed, and the bell rings. Extremely complicated functions are performed in a fraction of a second. A visitor standing anywhere in the laboratory is unable to see more than a few of the switches, the multi-contact relays, and the other relays used in establishing connections. In moving from the originating subscriber's line along the route of the connection, he can observe the various points of interest only if a guide traces the call for him. The average visitor finds such a demonstration more or less confusing, especially when he is a member of a large group.

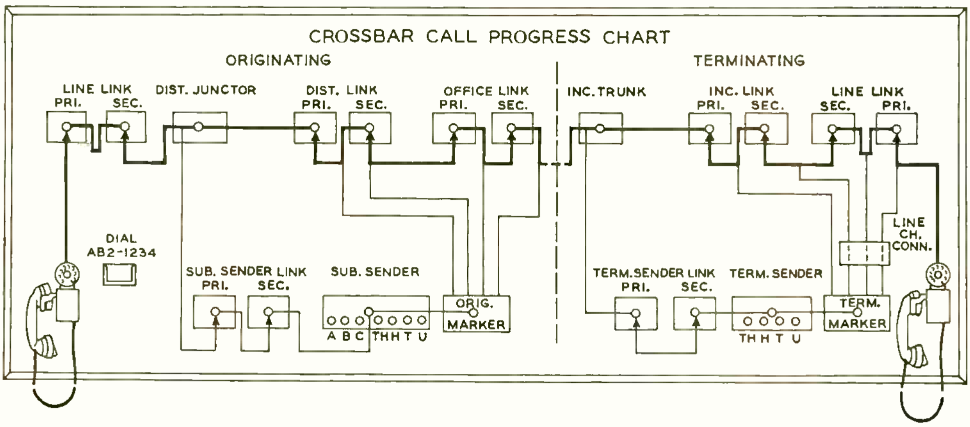
To provide a centralized location where all the points of interest of a telephone "call" could be delineated and brought to life by small electric lamps, the crossbar call-progress chart was built. As shown above, it consists of a white background with rectangles outlined in black and designated with the names of the equipment they represent. These rectangles are connected by black lines corresponding to the wiring between the crossbar apparatus. Small electric lamps appearing in each rectangle are controlled by relays connected in parallel with the crossbar apparatus in actual use during demonstrations.

From the beginning to the completion of the connection, lamps light in the rectangles at the proper time and as the equipment completes its work and is dismissed, corresponding lamps are extinguished. Finally only a line of lighted lamps is left, extending across the chart between the line links of the originating and terminating subscribers. The called station bell rings and the call may be answered in the usual manner. When both stations disconnect all lamps are extinguished, but if the calling station disconnects first, the "terminating" lamps from "INC TRUNK" to "LINE LINK PRI" remain lighted. These particular lamps are extinguished as soon as the called station disconnects.

The connection between the crossbar frames and the progress chart is made through relays in multiple with the hold magnets of the various crossbar switches employed in making the call. Each relay, when operated, lights the corresponding lamp on the chart, and when the relay is released, the lamp goes out. Each hold magnet of the crossbar switch used in the sender for recording the number dialed by the subscriber is also provided with such a relay, so that a lamp in the originating sender square lights as each digit is dialed. Where crossbar switches are not employed, such as in the markers, the relays are arranged to light the lamps when the equipment is seized and to extinguish them when it is released.

The crossbar chart as set up in the systems laboratory is shown in the photograph at the head of this article. W. Rupp, at the left, has just placed a call to the author, with whom he is talking. The lights on the various frames along the talking path are lighted, but those on the control equipment—sender links, senders, and markers—are extinguished.

This arrangement for explaining the progress of a crossbar call has proven so helpful to visitors at the Laboratories, that a somewhat similar portable chart was set up in the Murray Hill office on East 30th Street at the time of its recent opening.



Repeaters for the Type-K Carrier System

By I. G. WILSON
Carrier Repeater Development

THE type-K system transmits a frequency band 48,000 cycles wide over non-loaded cable. This band extends from twelve to sixty kilocycles, and in it twelve voice channels are transmitted. Over a fifty-mile section, which is the average spacing of repeater stations on existing voice circuits, the cable attenuation at sixty kilocycles is of the order of 200 db. This is much more than the gain which can be practically utilized in a single repeater. As a result two additional repeater stations are ordinarily placed between each two existing ones, making the average spacing about seventeen miles.

The requirements for the type-K system are set to meet a 4000-mile connection, and as a result it is necessary to consider the possibility of 240 amplifiers in tandem. At sixty kilocycles about 16,000 db of cable attenuation must be matched by controlled amplifier gains to a precision of a few db. Obviously the permissible variations in each amplifier are extremely small. With the transmitted band 48,000 cycles wide, the variation in attenuation with frequency is considerable. Nearly 5000 db of sloped equalization is required. Aerial cables are exposed to wide ranges of temperature, and the attenuation changes by very considerable amounts with temperature. This must be accurately compensated by varying the gains of the amplifiers.

Each amplifier contributes a certain amount of noise and of modulation products, so that the allowable amount of each per amplifier decreases as a function of the number in tandem. For the type-K system, these

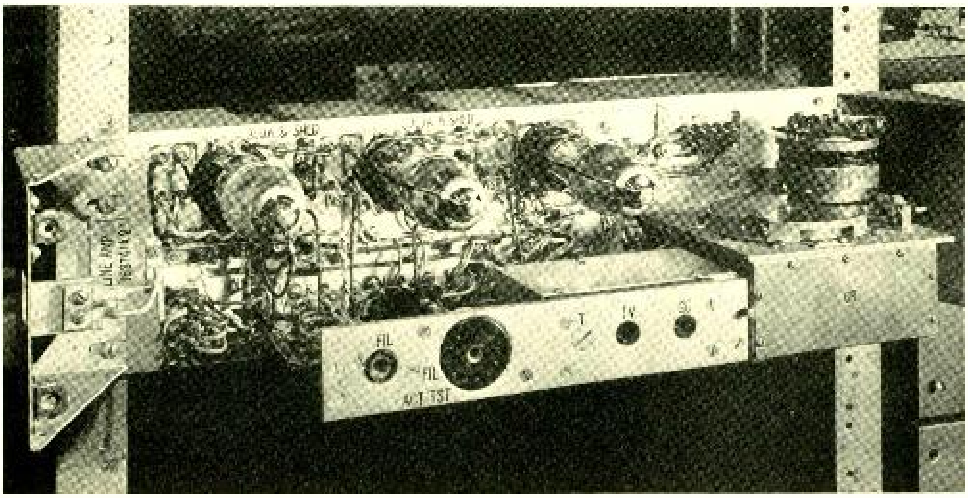


Fig. 1—Amplifier for the type-K carrier system with cover removed

requirements become extremely severe; and particularly so for certain third-order products.

The average variation in the gain-frequency characteristic must also be held to very close limits—becoming of the order of 0.01 db. Variations in battery voltage and tube changes must also be considered in meeting this requirement. About two-thirds of the repeaters are in small stations located between the voice repeater offices. These auxiliary stations are not heated much above freezing in the winter, and in the summer the inside temperature may rise as high as 120 degrees Fahrenheit. The requirements on stability, therefore, must be met over a wide temperature range. A repeater consists not only of a number of vacuum tubes, but of coupling transformers, condensers, inductances and resistances, none of which can be produced economically with precisely the characteristics desired. To maintain the overall characteristics of this complex assembly of apparatus within such very close limits is a task of major magnitude.

There are still other requirements that are extremely difficult to meet. The amplifier gain with feedback is high; on long spans it is of the order of 80 db. At repeater stations the amplifiers are mounted one above another on relay rack bays. Care must be taken to insure that all couplings are kept so low that the crosstalk and other forms of mutual interference are unobjectionable. At sixty kilocycles this is far more difficult than at voice frequencies. Even short pieces of wire must be carefully studied both in relation to other elements of the same amplifier and in relation to other amplifiers in the same and adjacent bays. To insure control of such effects one of the precautions taken is the preparation of a drawing showing exactly the position of each wire and element of the amplifier.

It might seem that the groups of amplifiers for the two directions of transmission could be separated enough to keep this inter-amplifier disturbance negligible. Doubling the space between two amplifiers, however, reduces the coupling effects only 6 db, so that impossible separations would be required to reduce the coupling by the required amount. Shielding was therefore resorted to; and careful design work made it possible to place these shields so as to

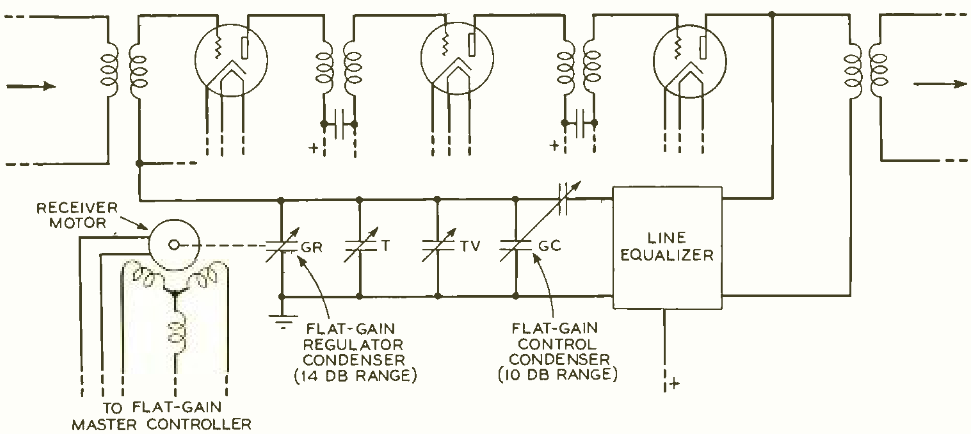


Fig. 2—Simplified schematic of the line amplifier for type-K carrier system

obtain full advantage of their effects.

To develop an amplifier of the required precision, it was necessary to design gain-measuring sets for laboratory use which are accurate to a few thousandths of a db over the entire transmitted frequency range. Because of the severe requirements of these broad-band repeaters, it has also been necessary to develop new vacuum tubes, two of which—the 310A and the 311A—have already been described in the RECORD.*

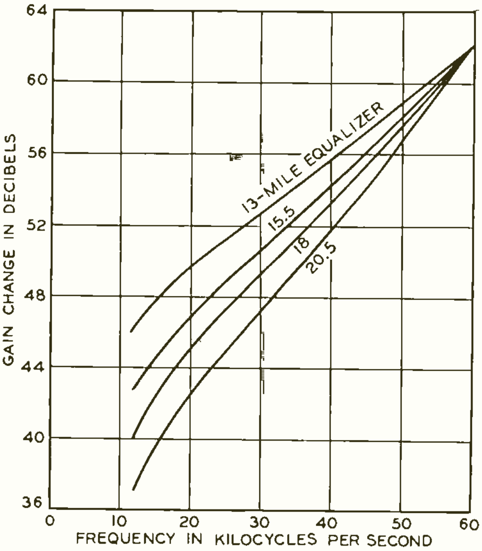


Fig. 3—Gain-frequency characteristics of repeaters with various basic equalizers

The amplifier designed to meet these exacting requirements is shown in Figure 1, and a simplified schematic is given in Figure 2. Three stages are employed, the first two using 310A tubes, and the last a 311A tube. Since even these superior tubes are not sufficiently linear in their characteristics to meet the severe modulation requirements, nor sufficiently constant in gain to meet the stability requirements in a simple amplifier, feedback is applied around all three tubes to improve their performance. An equalizer in the feedback circuit controls the slope of the gain-frequency characteristic to compensate for the loss-frequency characteristic of the line.

Although the average repeater spacing will be about seventeen miles, the actual spacings will vary considerably from this distance because of the variation in the spacing of the existing repeater stations. The range is approximately from 12 to 20 miles. To meet this range four equalizer designs have been provided, giving the slopes shown in Figure 3. The equalizers are designed to give the proper slope to compensate for the line attenuation at 55 degrees Fahrenheit. At other temperatures, the attenuation is different, and as is described in an article on page 160, the change varies with frequency.

The total change for a 110-degree range in temperature on a 4000-mile circuit is shown in Figure 4. Although this change in loss is not the same over the transmitted band, the variation with frequency is only about ten per cent of the total. Because of this fact, regulation for temperature is provided in two steps: one adjustment changes the gain equally for all frequencies, in an amount about that required at 28 kc; the other adjustment takes care of additional gains or

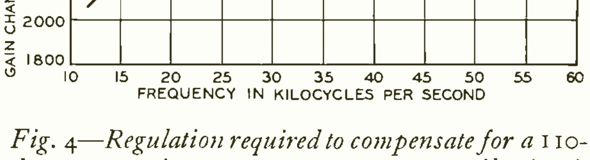


Fig. 4—Regulation required to compensate for a 110-degree range in temperature on a 4000-mile circuit

*RECORD, *September*, 1937, *p.* 17.

losses required at other frequencies. The former is called "flat" gain adjustment, and because of its greater magnitude, it is made at each amplifier; the latter is called the "twist" gain adjustment, and its smaller magnitude permits it to be made only about every sixth repeater station for aerial cable. The "twist" adjustment may occur somewhat less frequently with underground cable.

The condensers marked GR, T, TV, and GC in the feedback circuit of Figure 2 provide a means of controlling the gain of the amplifier equally for all frequencies. Condenser GR is designed so that the flat-gain adjustment it gives is proportional to the angular displacement of its plates. These plates in turn are connected to an Autosyn motor, which moves in step with a similar Autosyn motor in the master flat-gain controller. As the temperature of the cable varies, the flat-gain controller moves this condenser to increase or decrease the gain of the amplifier by the amount required to give the change in flat gain needed to compensate for the change in loss of the cable. Condenser GC provides an initial adjustment of the amplifier gain to equal the cable loss at a selected test frequency. TV provides an adjustment for the rate of gain change per dial division of the GR condenser. Both TV and GC may be adjusted in the field, but T, which provides for variations of all the capacities of the amplifier, is for shop adjustment only.

The type-K system has been under test between South Bend and Toledo for over a year, and has given satisfactory performance. The trial indicated that the new system will be suitable for long cable circuits; and it is expected to play an important part in the Bell System toll plant.

The 554A Tool

Where the gain of an amplifier is adjustable, a dial is usually provided to permit it to be set to the desired value as occasion dictates. Frequently, however, provision must be made for an important adjustment which is required only at infrequent intervals, or which, because of the small size of the adjustable element, does not lend itself to the ordinary dial control. Under such conditions it is common practice to provide for a "screw-driver" adjustment so as to avoid both the cost of the dial and the possibility of its being moved inadvertently. This latter method has the disadvantage, however, of requiring the use of measuring instruments to guide the adjustment.

In the repeaters for the type-K carrier system an adjustment of this type is required for the GC condenser shown in Figure 2 on page 149 of this issue. The development of the 554A tool, by A. J. Wier, however, has made it possible to secure the simplicity and ease of adjustment attainable with a fixed dial and at the same time the economy and freedom from unauthorized changes that is secured with a screw-driver adjustment. The condenser to be adjusted has its rotor shaft slotted as for a screw-driver adjustment, and an ad-

Fig. 1—The 554A tool photographed in front of a mirror so as to show the rear of the tool and the screw-driver tip, as well as the front and dial carrying a db scale

justable index line for a dial is attached to the amplifier housing. The 554A tool serves as a combination of screw-driver and dial with which the adjustment is made.

To make such a device satisfactory, it is necessary that the slot in the shaft of the condenser be accurately cut with respect to the alignment of the condenser plates, so that each position of the slot will correspond to a definite capacitance of the condenser. Also the screw-driver tip of the tool must be accurately set with respect to the dial markings, so that when the tool is inserted in the slot, the reading of the dial will be equal to the gain resulting from the condenser capacitance corresponding to that particular alignment of the slot. The index clip is made adjustable so that its position may be set after an initial calibration.

In addition, the screw-driver tip must fit accurately in the slot so that there is no appreciable backlash. This is of no importance with ordinary screw-driver adjustments, since a meter reading, and not the position of the screw-driver, is the ultimate criterion of the adjustment. This freedom from backlash is secured by cutting a rectangular slot with accurately parallel sides in the condenser shaft, and making the screw-driver tip with accurately parallel but tapered sides. With this arrangement the screw-driver wedges tightly into the slot with little applied pressure.

The cut in the slot of the condenser shaft and its alignment with the condenser plates are made alike for all the type-K amplifiers, and the 554A tools are likewise all identical. This permits the same tool to be used for making all the adjustments in all of the amplifiers in an office.

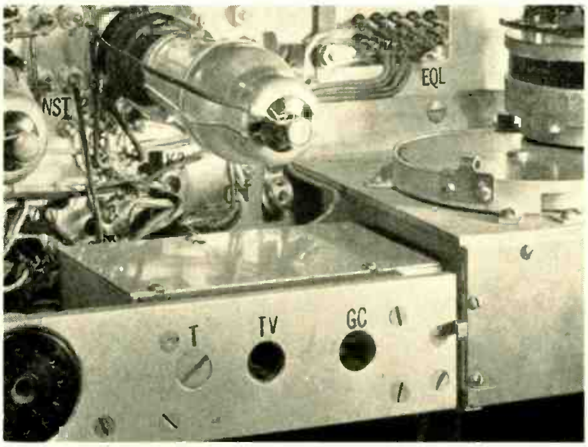
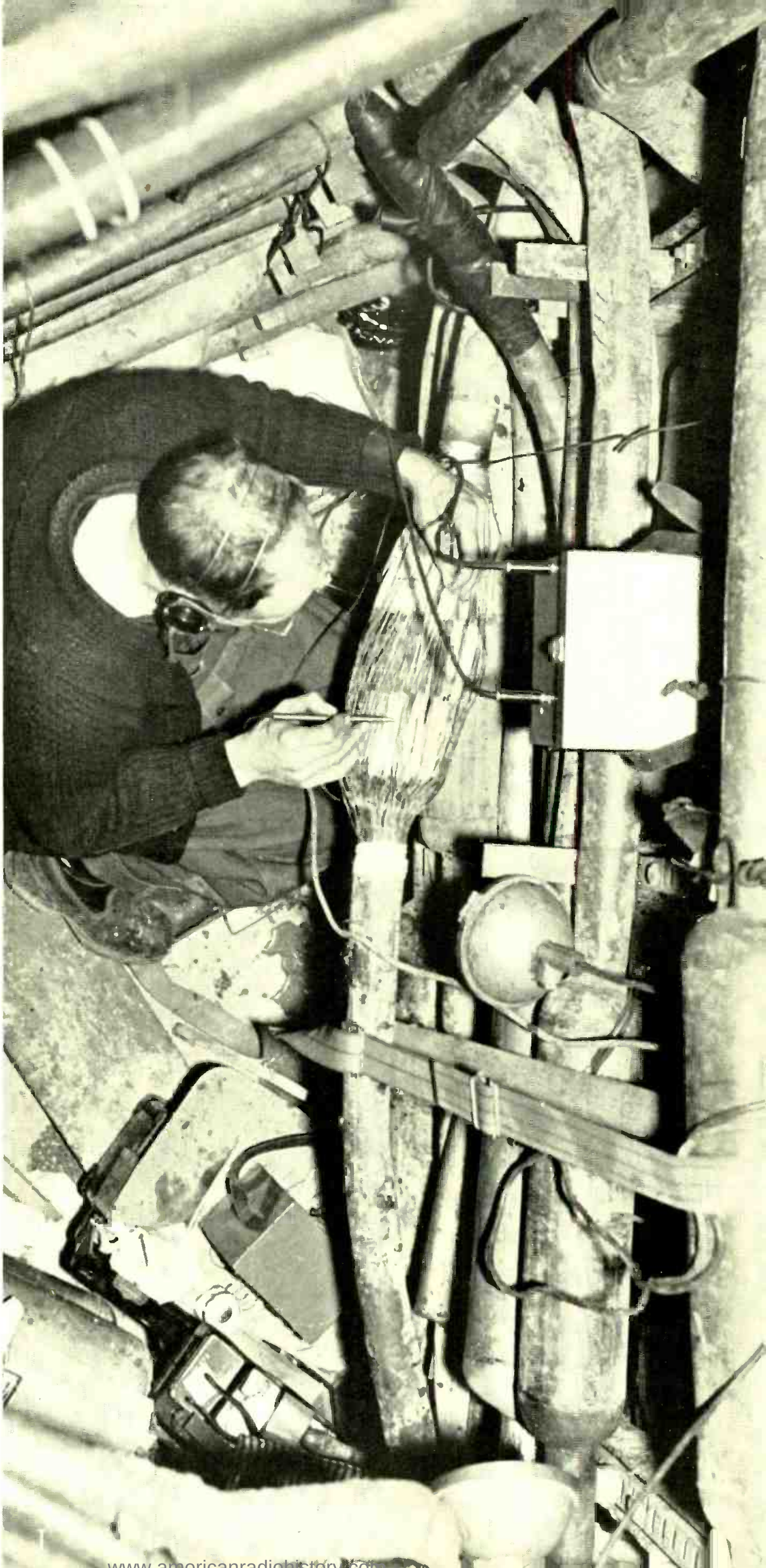


Fig. 2—Front of the type-K amplifier showing hole for the 554A tool, and the index line marked on a small metal clip, which is attached in the proper position during the factory test



I

Identifying cable wires in a manhole with a capacitance wire-identifying set (see page 155)

II

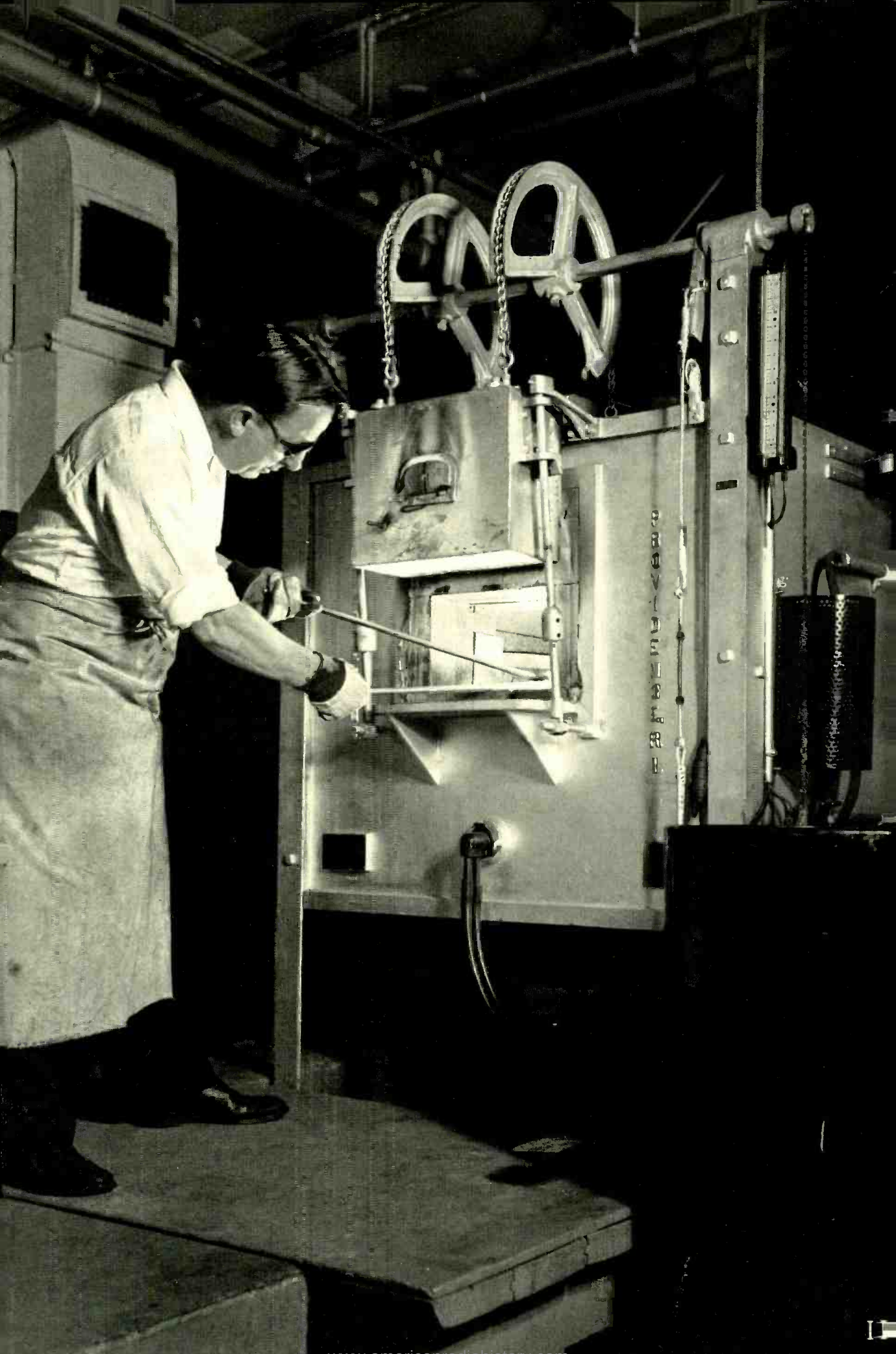
Heat treating a magnetic alloy

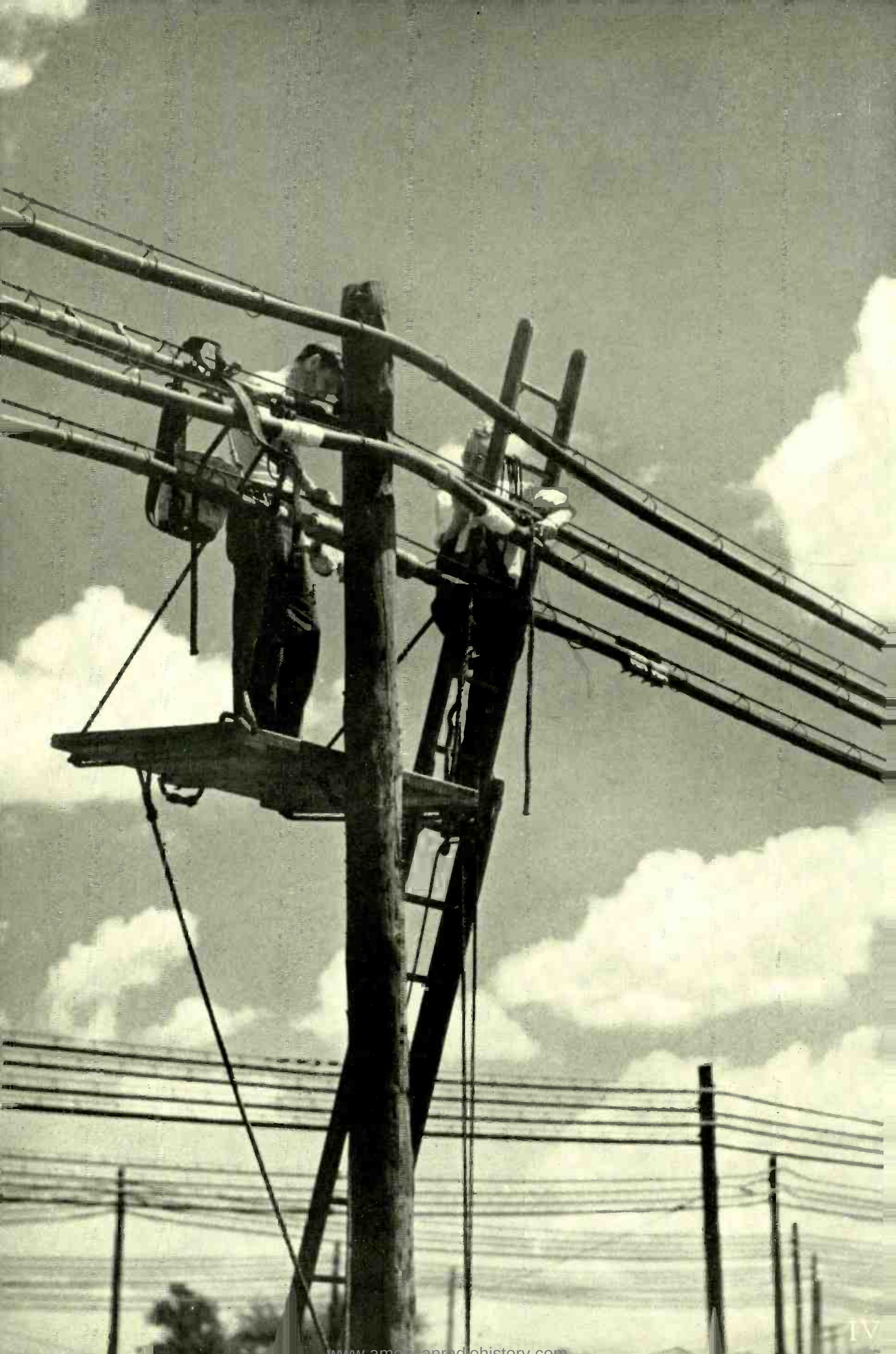
III

Current of constant frequency generated by this equipment is used by power and broadcasting systems to check the frequency of their output (see page 138)

IV

Field study of cable sheath at the Chester, New Jersey, laboratory





Template for Graphing Audio-Amplifier Performance

By H. W. AUGUSTADT
Commercial Products Development

IN the design of a resistance-coupled amplifier for public address or other audio-frequency uses it is usually helpful to draw quickly a number of characteristic curves for several values of each variable. While these curves can be computed and plotted, the work is laborious; when an approximation will serve the purpose, as it usually will in the early stages of design, a graphic method is a great time saver.

A typical resistance-coupled stage is shown in Figure 1. This may be replaced by an equivalent network; Figure 2(A) shows the network for the mid-band range, where for a well designed amplifier the coupling and shunt condensers can be ignored, since they have no effect on the performance of the circuit. The voltage across the coupling resistance R2 then equals the applied voltage E multiplied by the ratio $\frac{R_2}{R_1 + R_2}$.

At higher frequencies, however, the shunt capacity of the tube and its leads must be taken into account by inserting the condenser C of Figure 2(B). Voltage across R2 is then decreased by an amount which depends on the reactance of this condenser.

Ratio of the original voltage across the coupling condenser to the final voltage may be expressed as:

$$\sqrt{1 + \left(\frac{2\pi FCR_1R_2}{R_1 + R_2}\right)}$$

Various values of the parameter $\frac{2\pi CR_1R_2}{R_1 + R_2}$ will give a family of curves of the same shape, the successive curves being shifted sidewise. A curve of loss versus frequency can be computed, and plotted to a logarithmic scale of frequencies, a mark being placed at a frequency of F_0 which is equal to the reciprocal of the parameter. For a different value of the

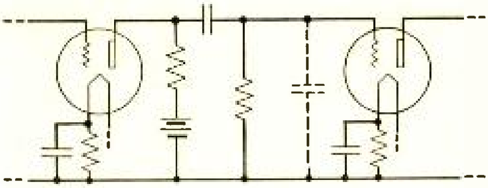


Fig. 1—*Simplified schematic of a typical resistance-coupled amplifier*

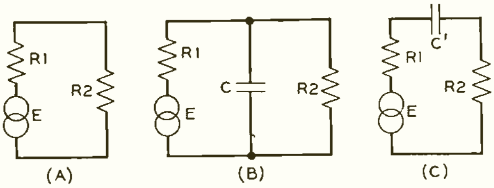


Fig. 2—*Equivalent networks of one stage.* (A) *mid-band;* (B) *at high frequencies;* (C) *at low frequencies;* R1 *is the parallel resistance of the tube and the plate resistor;* R2 *resistance of the grid circuit of the succeeding tube;* C, *total shunt capacity;* C′ *coupling condensers;* E, *voltage or equivalent plate-circuit generator*

parameter, a new value of F_0 is computed, and marked on the logarithmic scale; the former curve is then slid sidewise until old and new values of F_0 coincide. A metal template is the obvious tool for this operation.

On the template are engraved diagrams which show the simplified forms of the four types of networks commonly used. Near each network is a formula from which a reference frequency F_0 can be calculated from the values of the resistance and inductance or capacity of the elements of a given amplifier stage.

To draw the graphs the template is placed on a special three-cycle logarithmic paper, so that the line F_0 on the plate coincides with the abscissa on the paper whose value is F_0. Curves are then drawn by tracing along the lower edge of each of the two slots in the template. The upper curve gives the loss in db for different frequencies and the lower one the corresponding phase shift in degrees. The scales for the loss and phase shift are given on the template and can be transcribed directly.

At frequencies below the mid-band range the coupling condenser becomes important, while the shunt capacities can be neglected. The equivalent network is that shown in Figure 2C; and it can be shown that its loss equation is the reciprocal of that for the circuit of Figure 2B. Hence the same template can be used by merely turning it end-for-end. The equation for inductance-in-series is the same as for capacitance-in-parallel, and that for inductance-in-parallel is the same as that for capacitance-in-series.

As one goes up the scale of frequencies, evidently the parasitic capacities and inductances of the wiring have more and more influence on performance, and the error introduced by lumping them becomes progressively greater. However, for a midband frequency of one kilocycle, the error at 40 kc is not great enough to impair the usefulness of this method as a quick survey of a problem.

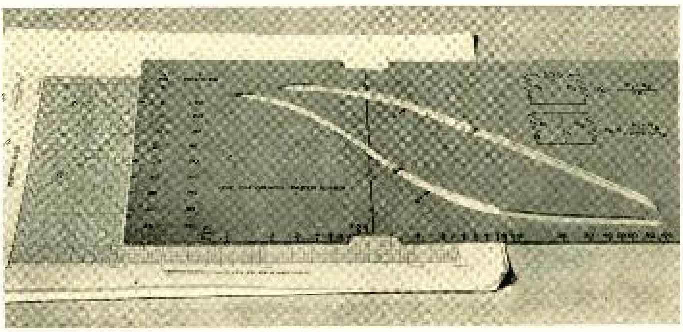
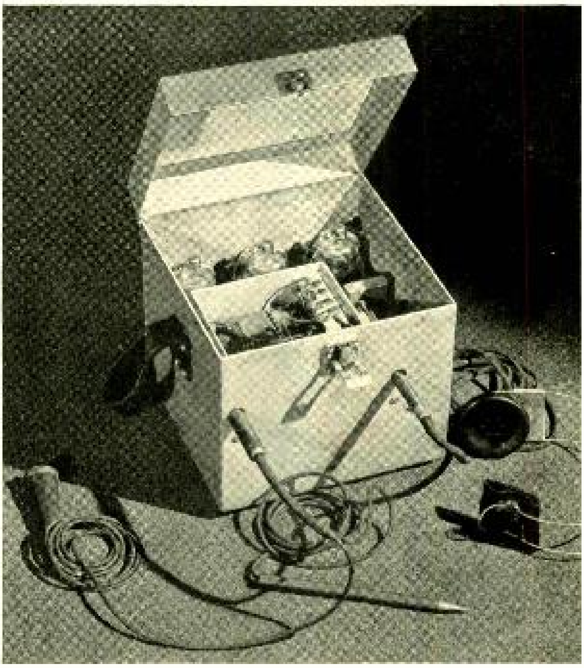


Fig. 3—*One side of the template, for circuits containing shunt capacitance or series inductance*

Identifying Cable Wires

By R. I. CRISFIELD
Outside Plant Development



A TESTING operation frequently required in the outside telephone plant is the identification of a particular wire in a cable which contains many others. For this work, it has been the practice to apply a buzzer tone to the wire at some point such as the central office and have the splicer at a distant point test the different cable wires until he finds the one carrying the test tone. The searching device used consists of a fiber holder terminating in needle points. With this test pick the splicer punctures the paper insulation and makes contact with the copper conductors of the individual cable wires. The pick connects through a condenser to a talking pair which serves as the communication circuit between the splicer and the helper who applies the tone.

The circuit, as used to identify the wires of a toll cable quad, is shown in Figure 1 to the left of the dashed line. A network reduces the volume and limits the frequencies of the tone current to minimize inductive disturbance on working cable wires. When any wire of the quad is contacted, the splicer hears the tone in the receiver of his talking set, as does also the helper at the other end of the line. Thus, both know simultaneously when identification is made. The quad and the talking pair have capacitance in respect to the cable sheath, and it is this capacitance which completes the tone circuit.

In searching for a desired wire, many other wires may be contacted briefly. The condenser in series with the test pick increases the impedance of the test circuit and prevents it from unbalancing too greatly a working line that may be contacted. A large unbalance would interfere seriously with the operation of the working line.

This test pick method of identification has been in successful use for many years on both toll and exchange cable. In some cases, however, identification takes a comparatively long time, since many wires must be tested during the search. Also, with some of the newer types of cable circuit, such as those used for program or carrier transmission, the unbalance caused by the test pick when it touches a wire of the circuit may be more than is permissible. For these reasons a new method of wire identification has been developed. It is considerably faster than the test pick method and does not involve metallic contacts with the cable wires at the identifying point. A buzzer tone is used as with the test pick method but a probe, which is connected at the identifying point to the splicer's talking pair through a vacuum tube amplifier, is substituted for the test pick and condenser. The probe looks like a test pick but terminates in a rounded metal tip instead of needle points. It is used essentially as the test pick in searching among the cable wires for the identifying tone, but the capacitance between the cable wire and the probe rather than direct metallic contact serves as the pick-up medium. Thus, unbalance which might be caused by metallic contact is avoided. Also, the amplifier gain is sufficient to make the test tone faintly audible as soon as the probe is brought within an inch or so of the wire being sought. This permits the splicer to ferret out quickly the wire he seeks.

The circuit arrangement for identifying a quad by this "capacitance" method is illustrated in Figure 1. The probe is connected to the input circuit of the amplifier and the amplifier output is bridged across the receiver of the splicer's talking set. Both the splicer and helper hear the identifying tone. The test pick and condenser, shown in dotted lines, pertain to the test pick method and are not used.

In identifying wires by the capacitance method, the splicer holds the probe approximately at a right angle to the cable wires and moves it slowly around the periphery of the splice to determine whether the wires sought are in the outside layer. He then pushes the probe through the splice at various points. When the probe is in the vicinity of the desired wire he hears the identifying tone in the receiver. Further search is made in this area. The tone is loudest when the tip of the probe presses against the paper insulation of the wire wanted.

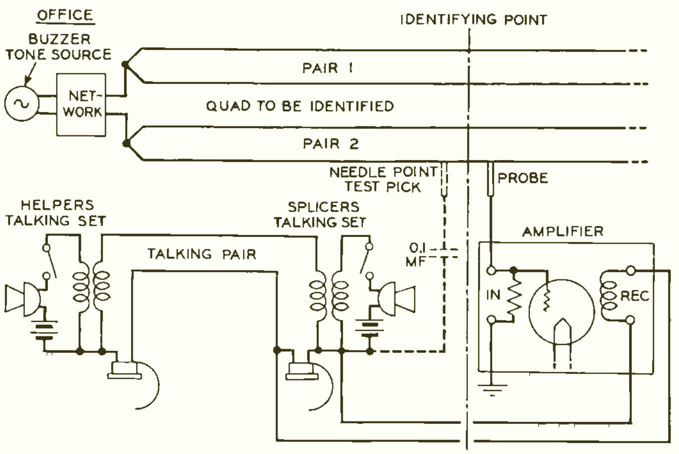
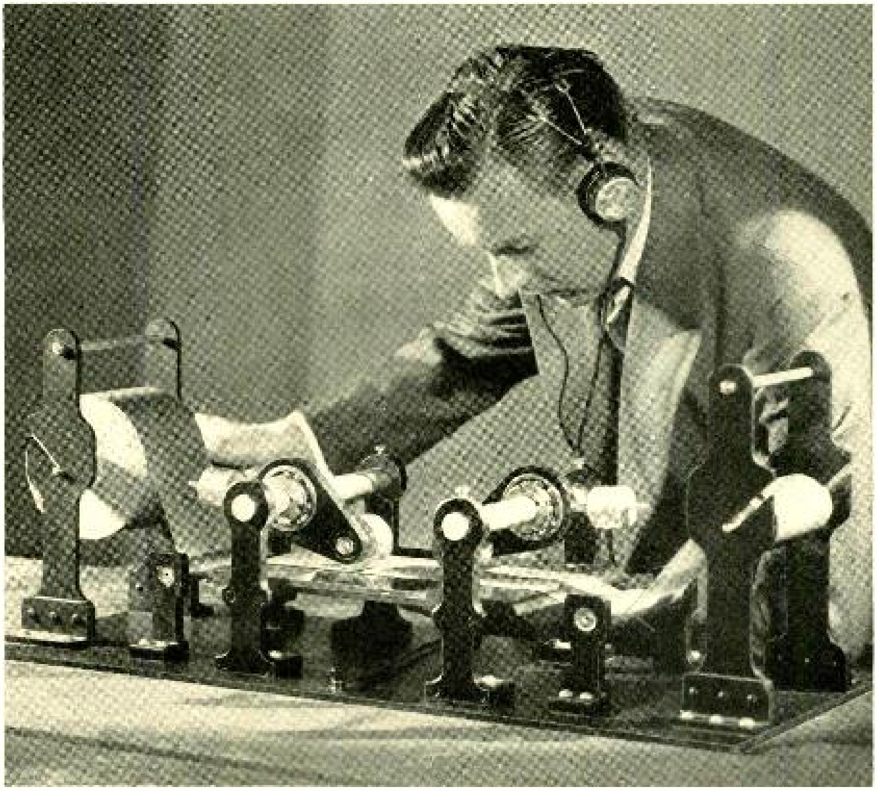


Fig. 1—The former method of identifying a wire in a toll cable was to apply a buzzer tone to one end of the wire and search at a distant point for the wire carrying the tone with a test pick which punctures the paper insulation—see dotted lines. In the new capacitance method a probe having a rounded metal tip is used instead of a test pick—see right of broken line. The capacitance between the wire and probe serves as the pick-up medium. The amplifier increases the sound in the receivers of the talking sets

The amplifier has three vacuum tubes and provides a flat amplification of approximately 50 db between 100 and 4000 cycles. It is housed in an aluminum alloy box approximately eight inches long, eight inches wide, and seven inches high, which also provides space for the accessories. There are input and output jacks to accommodate the plugs associated with the probe and receiver cords, and a filament rheostat for gain control. Inserting the plug associated with the receiver cord turns on the amplifier through a filament switch in the output jack. The amplifier, complete with batteries, tubes and accessories, weighs about eleven pounds.

An improved network also has been developed, to control the output current of the buzzer. It suppresses the harmonics of the buzzer tone more effectively than the network used heretofore and minimizes inductive disturbances on the newer carrier cables, as well as on voice frequency cables. The current supplied by the improved network is sufficient to provide a strong pick-up tone when the test points are separated by thirty miles or more.

Although the capacitance method has been developed primarily for use on toll cable, it may be used to advantage in certain types of exchange work. Its development constitutes one of the measures required to keep testing facilities in step with recent developments in transmission circuits.



Conducting particles are objectionable in condenser paper. In this laboratory apparatus they are detected by passing the paper between a metal roller and plate. The roller and plate terminate an electric circuit which is completed as the particle passes under the roller. The particles are counted by an electric recorder or by listening to the clicks in a telephone headset. W. J. Kiernan is shown operating the apparatus

A Portable Telephone for Railroads

By A. H. MILLER
Commercial Products

EACH railroad system in America has a system of telephone lines. At every point the railroad man has at his disposal the communication channels so important to the maintenance of an efficient transportation system. From one station to another, or to a group of others, dispatching systems provide the means for signalling and talking; between the stations, portable telephones may be connected to the lines to allow inspectors and working crews to make reports and receive their orders. Wrecking trains, hand-cars, and freight and passenger trains are being equipped so that they may keep in communication with headquarters whenever it is desirable.

Portable telephones for railroad use have been sold by the Western Electric Company for a number of years. The knowledge gained from this experience, and the latest technical advances in design, have been embodied in new apparatus developed by the Laboratories. This apparatus, coded the 301A telephone set, is composed of a handset, generator, induction coil, condenser, ringer bracket, and battery container, all mounted in a strong fiber carrying case. The ringer bracket is arranged to receive the B1A ringer shown in Figure 2. As most calls originate from the set, the ringer is not ordinarily supplied. Connection to overhead lines is provided by a cord carried by a light three-section portable pole equipped with terminals, whose extensions are suitable for hooking over the two sides of the telephone line. The illustrations show the appearance of the equipment and the manner of its use.

The set is eleven by nine by five and a half inches and weighs about fifteen pounds. Almost half this weight is in the powerful 50F generator, which will signal over four hundred miles of ordinary open-wire line. High transmission efficiency and low bridging loss permit a number of sets to be operated on a line at the same time. A push-button switch in the handset handle is used to change from the listening to the talking condition. Impedance in the listening position at 1000 cycles is 3300 ohms at an angle of sixty degrees.

Fig. 2—The set removed from its case

Protection against high line-voltages is assured by having no electrical connection from the line to the receiver and transmitter; by insulating the handle of the generator; and by using a soft rubber handset shell. Besides affording protection to the operator, the soft rubber shell also saves weight. Incorporated in the handset are the same high-efficiency transmitter and receiver units which are used in the new three-piece handset of the Bell System. The small battery-drain enables the use of "D" type flashlight cells, four in number; these are widely available and readily replaced in the set. A condenser in series with the line side of the induction coil reduces the thumps that may be picked up from dispatching-set selector impulses and keeps the impulses from being shunted through the induction coil, which would interfere with the operation of the dispatching system.

Fig. 1—Manner of using the 301A telephone set is demonstrated by A. F. Dolan of the Laboratories

While it was designed particularly for railroad use, the 301A telephone set may ultimately be widely applied in other fields, for it is well suited to any situation where a portable magneto telephone of low cost and of unusually rugged construction is required.

Regulation for Type-K Carrier

By F. A. BROOKS
Carrier Telephone Development

A LONG-distance telephone circuit operates with a net loss between terminals which may be about 9 db. The total circuit loss on a long circuit will, of course, be much greater than this. For a 1000-mile type-K carrier system, which operates on non-loaded pairs and provides twelve circuits in the frequency range from 12,000 to 60,000 cycles, the total circuit loss at 12,000 cycles will be of the order of 2500 db and at 60,000 cycles about 3600 db. The repeaters supply enough gain to make up for the line loss, and the individual channels are provided with pads to give the desired net loss on each circuit. However, the line losses vary with temperature, and although the maximum change in loss due to temperature, such as between the coldest winter and the hottest summer day, is less than a fifth of the total line loss, it may be very large with respect to the circuit net loss, and must be accurately compensated to hold the latter within the required limits. This is accomplished by a system of regulation which varies the gains of the repeaters in accordance with the mean temperature of the cable as determined by automatic measurements of the resistance of one of the cable pairs.

In the type-K system, the changes in loss with temperature are so great that with aerial cable it is necessary to provide regulation at each repeater station. This means that the number of regulators will be large, approximately sixty in a 1000-mile circuit, and the allowable variation for each must be kept within very close limits. The problem is further complicated by the fact that the change in loss with change in temperature is different at different frequencies. This is illustrated in Figure 1 which shows the change in loss due to a 110-degree change of temperature for a single repeater section of average length. The solid line indicates the mean values, while the two dotted curves represent the extremes which have been measured. At 12 kc, the lowest carrier frequency, the change in loss

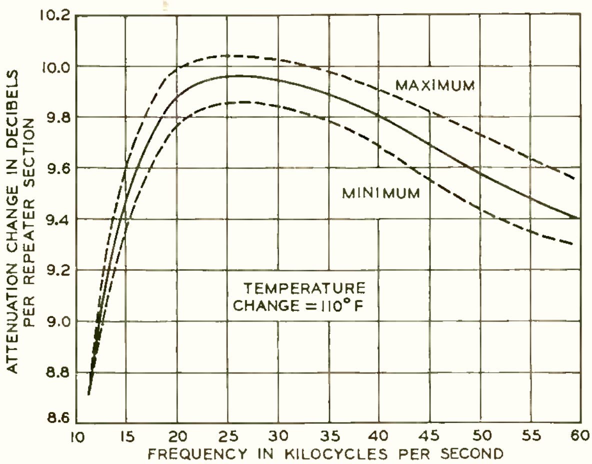


Fig. 1—Attenuation change for a repeater section for a 110-degree Fahrenheit change in temperature. Dotted curves show the limits of variations of different sections of cable

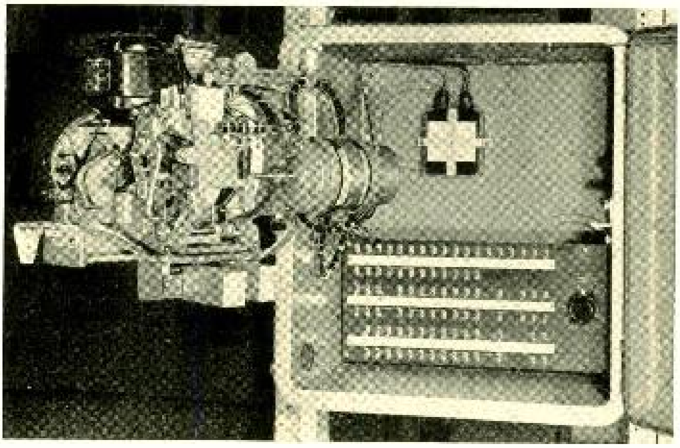


Fig. 2—Flat-gain regulator for the type-K carrier system

Each of the repeaters, discussed in an accompanying article (page 148), is designed with an adjustable element by which its gain may be changed, and at each repeater station is a flat-gain regulator that adjusts this element to change the gain in accordance with the average temperature of the cable section preceding the repeater station. At about every sixth repeater station there will be in addition a flat-gain amplifier in tandem with a twist network which is under the control of a twist regulator. These will correct for the curving temperature characteristic over the preceding sections.

Both flat- and twist-gain regulators are similar in their essential features. They are modified commercial instruments; the flat-gain regulator is shown in Figure 2 and the twist regu-

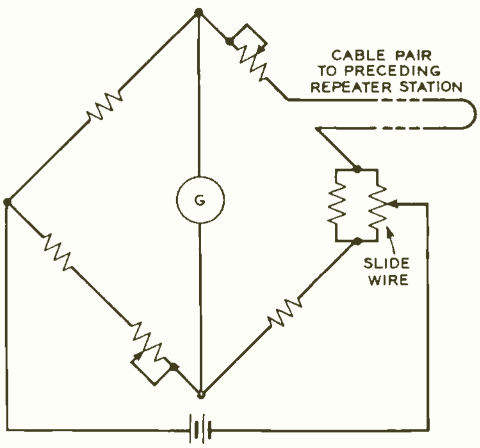


Fig. 3—A Wheatstone bridge circuit is employed to determine the mean temperature of a section of cable—a pilot pair in the cable serving as one arm of the bridge

is about 8.9 db. It increases with frequency up to about 28 kc, where it is of the order of 10 db, and then falls off to about 9.4 db at 60 kc—the highest frequency.

This variation in gain could be correctly compensated by giving each regulating repeater a characteristic that corresponds to Figure 1. It is more expensive, however, to provide a variable curving gain change characteristic than it is a flat one, and since the smallest change in loss—that at 12 kc—is nearly ninety per cent of the maximum, it seemed desirable to divide the regulation in two steps: to provide a flat-gain regulator at each repeater station to give the same gain change at all frequencies, and then at less frequent intervals to supply a "twist" regulator to introduce a correction to compensate for the portion of the loss that varies with frequency. The maximum amount of the twist-gain change over six sections will be less than the flat-gain change over a single section. The flat gain provided actually corresponds to the change in loss at 28 kc, and twist regulation is provided by inserting additional gain or loss at the lower and higher frequencies, as required.

lator in the photograph on page 137. Each includes a bridge circuit, as shown in Figure 3, one arm of which consists of a cable pair in the cable to be regulated. For the flat-gain regulator this pair will extend over only one section, while for the twist regulator, the pair will extend over a number of sections. These pairs are also used for the carrier frequencies, and simple composite sets are provided to by-pass the d-c pilot circuit around the repeater for the twist pilot circuits and to terminate it properly at the end of each regulating section. At a mean cable temperature of fifty-five degrees Fahrenheit, the resistance of these pilot pairs is such as to make the bridge balanced. A change in temperature will unbalance the bridge and deflect the galvanometer, causing the contact of a slide-wire resistance, connected in one corner of the bridge, to be moved automatically to restore the balance. At the same time, the adjustment feature of the amplifier is also moved automatically to make a change in gain proportional to the change in temperature that unbalanced the bridge.

There is only one regulator at each flat-gain repeater station for each direction of transmission, and two at the stations where twist regulation is accomplished, but there are as many amplifiers as there are carrier pairs. Each regulator thus controls a number of amplifiers, and the connection between regulator and amplifier is made by Autosyn motors. These motors do not run as ordinary motors do, but when two of them are connected together electrically, any motion of one will be exactly duplicated by the other. Each regulator has a master Autosyn motor which is connected electrically to similar motors that make the adjustments for all the amplifiers. These latter motors move the adjustable element that changes the gain, and they in turn are moved by the master motor, which is turned by the regulator in proportion to the change of temperature in the cable.

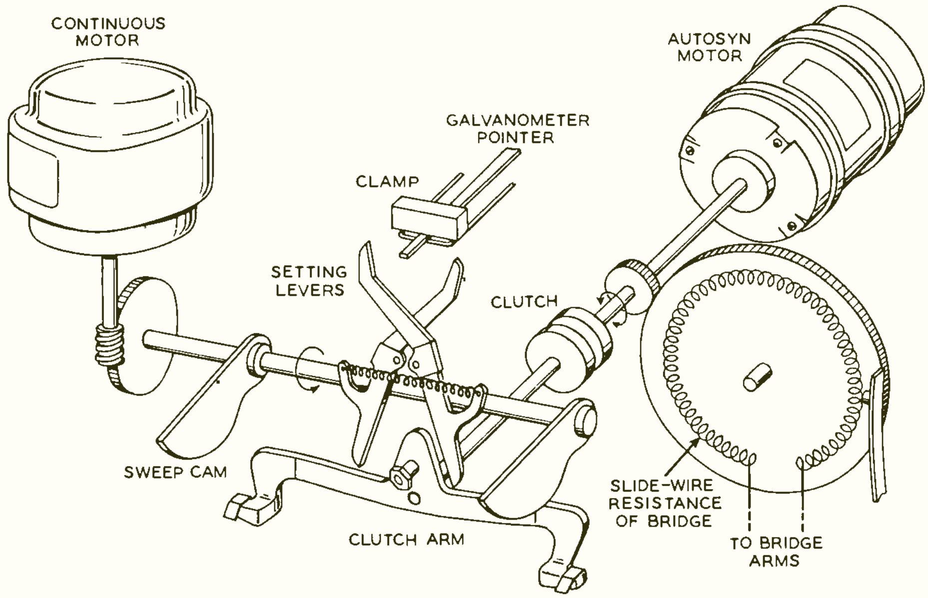


Fig. 4—Diagrammatic representations of the basic operating features of the regulator

A simplified diagrammatic sketch of the part of the regulator that moves the master Autosyn motor is shown in Figure 4. The shaft of the motor is extended, through a clutch, to a horizontal bar called the clutch arm. In the illustration the clutch arm is shown separated from the clutch, but in the actual regulator it acts as one of the clutch plates. When the clutch is open the clutch arm may be readily tilted in either direction without affecting the Autosyn motor. Any motion of the arm while the clutch is closed, however, results in an equal motion of the Autosyn motor. The regulator includes a small motor that runs continuously and is geared to a slow-speed shaft. Once every revolution this shaft carries through a sequence of operations that results in a change of gain of the amplifiers if the temperature of the cable has changed. It first tilts the clutch arm by an amount proportional to the change in temperature of the cable as indicated by the deflection of the galvanometer needle of Figure 4. The arm will be tipped one way if the temperature has increased and the other way if it has decreased. Next the clutch will be closed, and a moment after, the clutch arm will be restored to the horizontal position by two sweep cams, and in returning to its original position, it will move the Autosyn motor through an angle equal to the deflection of the clutch arm from the horizontal.

The first motion of the clutch arm, while the clutch is open, is performed by the setting levers, which are closed by the spring when a holding cam is rotated to the release position. During this operation the galvanometer needle is momentarily clamped in position.

If the compensation has been sufficient, and there has been no further change in temperature, the galvanometer pointer will remain in the central position, and the setting levers will close equally at the two sides, and will not affect the position of the clutch arm. If the needle has been deflected, however, it will be locked in this deflected position before the setting levers begin to close, and as they close, one of them will be held by the locked needle, so that the rest of the closing operation will be done by the other lever. This action will carry the lower end of one of the levers beyond the central position, and in crossing the center line, it will tilt the clutch arm through a cam pin as shown in Figure 5. The setting levers will then be opened by the locking cam, the clutch will close, and the rotation of the two sweep cams will restore the clutch arm to the horizontal position, moving the Autosyn motor and making a gain adjustment at all the repeaters in doing so.

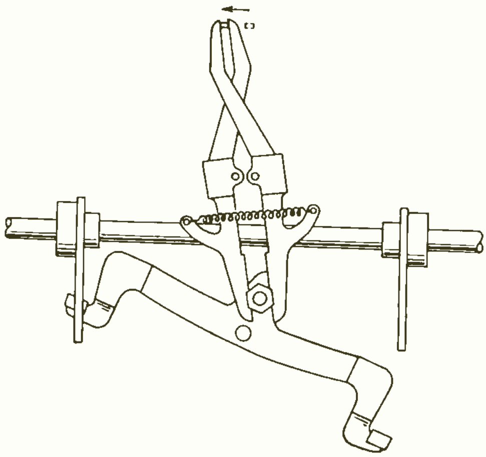


Fig. 5—Position of setting levers just after they have moved the clutch arm

As described in an accompanying article,* flat-gain adjustment is made by rotating the plates of condensers in the feedback circuits of the line amplifiers at each repeater station. Twist-

*Page 148, this issue.

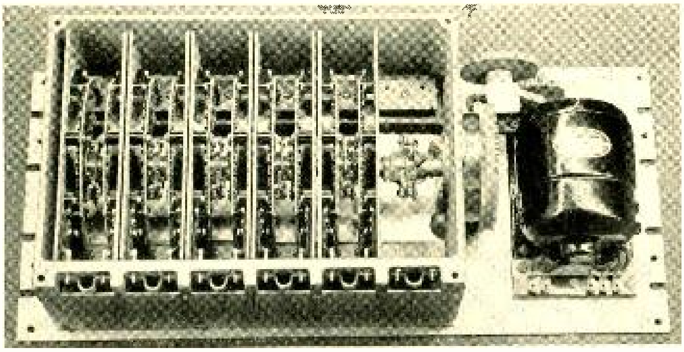


Fig. 6—Resistors in twist equalizer by which adjustment in twist gain is accomplished

gain regulation is accomplished by changing taps on resistances in the twist network. These resistances with their motor are mounted together as shown in Figure 6. They are rather large, and considerable friction must be overcome in moving the brushes that make the adjustment. As a result a much larger motor must be used than is needed to adjust the condenser of the flat-gain regulator. A correspondingly larger master motor is needed at the regulator, and because of this, the twist-gain differs from the flat-gain regulator in the provision of an additional motor. This accounts for much of the difference in appearance of the two regulators. This difference can be discerned in the accompanying photographs.

The effect on the signal currents of the cable loss, of the line amplifier including basic equalizer and of the flat-gain regulation are illustrated by the three sets of curves of Figure 7. The curves from left to right represent the level of the signal: first, at the input to the line amplifier; second, at the line amplifier output with no regulation; and third, with flat-gain regulation. The effect of the twist equalizer is to make the curves for all temperatures horizontal lines at the end of a twist regulator section. To emphasize the variations in loss with frequency that make the twist regulators necessary, the curves are not drawn to scale; the variations between low and high temperatures are augmented to illustrate their curvature.

The signal currents which enter the cable at the distant end are at equal levels. The cable loss increases with frequency as shown by the decrease in level in the first curve of Figure 7, and has a slope which is equalized by the line amplifier equalizer at mean cable temperature. At low and high temperatures, the level diagram—and hence the loss—have the same general slope but with a slightly different curvature. The greatest change in loss

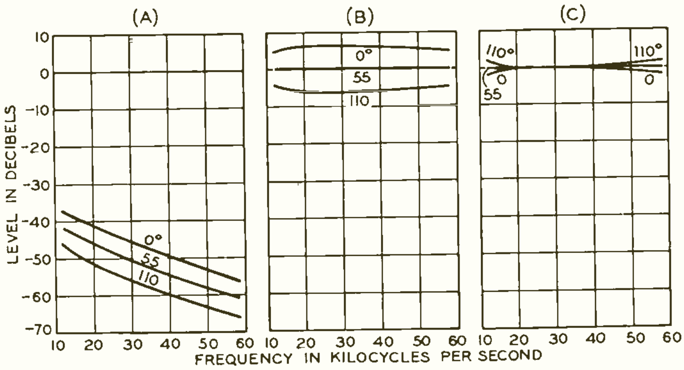


Fig. 7—Level frequency characteristic of carrier currents after passing over one section of line, at A; *the effect of line amplification and line equalizer, at* B; *the effect of flat-gain regulation, at* C

with temperature occurs at 28 kc, and gives the low and high temperature curves the shape roughly indicated. Curves for intermediate temperatures will be intermediate in value.

The effect of the line amplifier and equalizer is to tilt and increase the levels at the mean temperature to a horizontal with levels at the zero line. It has the same effect regardless of temperature, and thus leaves the low and high temperature curves in the same position relative to the mean temperature line that they had before. The function of flat-gain regulation at 28 kc is also performed in the line amplifier, but these two functions are separate in Figure 7 to bring out more effectively the three types of gain change, namely, fixed gain, flat-gain change, and twist-gain change. The action of the flat-gain regulation on the signal levels is shown by the difference between curves B and C.

The deviations shown in curve C at low and high temperatures are small and may be allowed to accumulate for several repeater sections. These deviations are then equalized by the twist regulator in order to give the same level at all frequencies.

The performance of a typical system for one hundred and fifty miles is shown in Figure 8. The variation of the circuit equivalent at the mean and extreme channel frequencies is shown for a temperature range of 100 degrees Fahrenheit. In an ideal system the curves would be straight horizontal lines. The departures from such a line of the actual system are due principally to non-linear variations of loss that occur in the cable with respect to temperature.

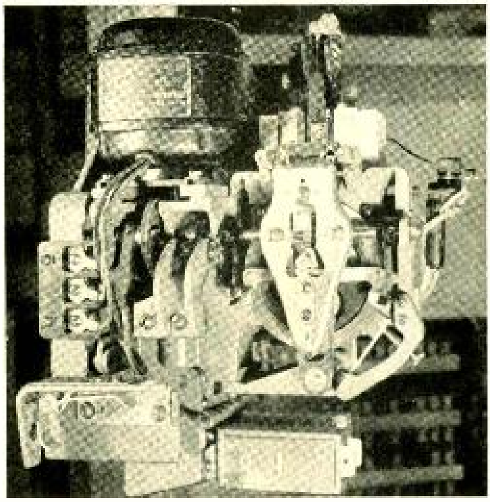


Fig. 9—The clutch arm and setting levers of the regulator are evident in this end view of the flat-gain regulator

This temperature equalization system is based on the assumption that the loss at any frequency changes as a straight-line function of temperature, which it does very closely. Actually there are slight variations from linearity, but they are so small that only for circuits five hundred miles or more in length do they become of importance. On very long

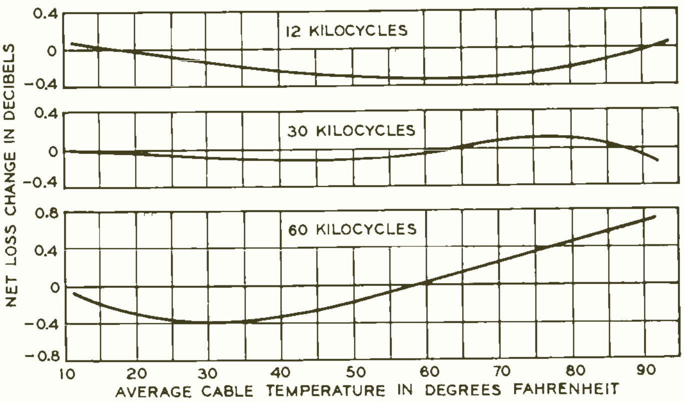


Fig. 8—Overall performance of the type-K carrier telephone system for a one-hundred-and-fifty-mile circuit

circuits, therefore, a third type of regulator may be justified to control a repeater which will correct for the accumulation of these very small deviations. These additional regulators would be used only at about five-hundred-mile intervals, and would equalize for any slight irregularities that have been left uncorrected over the preceding five hundred miles.

Contributors to this Issue

R. I. Crisfield was graduated from Cornell in 1921 with an M.E. degree and joined the American Telephone and Telegraph Company that year to engage in outside plant problems. In 1934 he transferred to the Laboratories where he has since been working with the outside plant development group on apparatus and methods of making electrical tests on trunk and toll cables during installation and service.

I. G. Wilson received the B.S. degree in mechanical engineering from the University of Kentucky in 1921, and immediately joined the Technical Staff of these Laboratories. With the Systems Development Department, he first engaged in the development of voice-frequency repeaters. He was associated with the development of the 21-type repeater, the 22A, and the 44A, and later with echo suppressors and transmission testing equipment. In 1929 he was put in charge of the design of amplifiers and equalizers for the Morristown trial of the cable-carrier system, and was field engineer in charge of this work for about a year. At present he is in charge of a group engaged in design studies of an improved cable-carrier system. A large number of American and foreign patents have been issued to him as a result of his work on voice-frequency and carrier systems.

Miss Matilda Goertz graduated from Normal College (now Hunter) with the A.B. degree in 1912, and received the degree of M.A. for work in mathematics from Columbia in 1915. After graduating from Hunter, she taught mathematics and languages in New York City high schools. She joined the Laboratories in 1916 and did statistical work and mathematical typewriting for several months. The following year she transferred to the Physical Laboratory where she engaged in various kinds of laboratory work. In 1918

R. I. Crisfield

I. G. Wilson

Matilda Goertz

she joined the magnetics group, where her work has been partly secretarial and partly experimental research.

H. W. Augustadt received the degree of B.S. in Electrical Engineering from the University of North Dakota in 1928. He joined the Apparatus Development Department of the Laboratories the same year and became engaged in the design of filters and equalizers. In this connection, he worked on the problem of testing the electrical characteristics of experimental models of such networks. At present he is in the Commercial Products Development Department engaged in the design and development of sound-reproducing equipment for the public-address field.

H. W. Augustadt

L. A. Meacham

L. A. Meacham received the B.S. degree in electrical engineering at the University of Washington in 1929. The following year he pursued graduate studies at Cambridge University in England where he received the Cambridge "Certificate of Research" in 1930. That year he joined the Laboratories and has since been working on problems in connection with the generation, distribution and use of constant-frequency currents.

A. S. Page received the B.S. degree in electrical engineering from Tufts College in 1906 and at once joined the staff of the New England Telephone and Telegraph Company. After preliminary installation experience, he was placed in charge of central-office and P.B.X. installations in Pittsfield. In 1911 he transferred to Springfield where he assisted the Supervisor of Equipment and Buildings of the Western Division. In 1919 he transferred to the Engineering Department of the Western Electric Company in New York City. When the panel laboratory was organized, he was placed in charge of maintenance, records, and demonstrations. He holds this position at the present time, but has also done considerable work in connection with the crossbar and toll-crossbar laboratories.

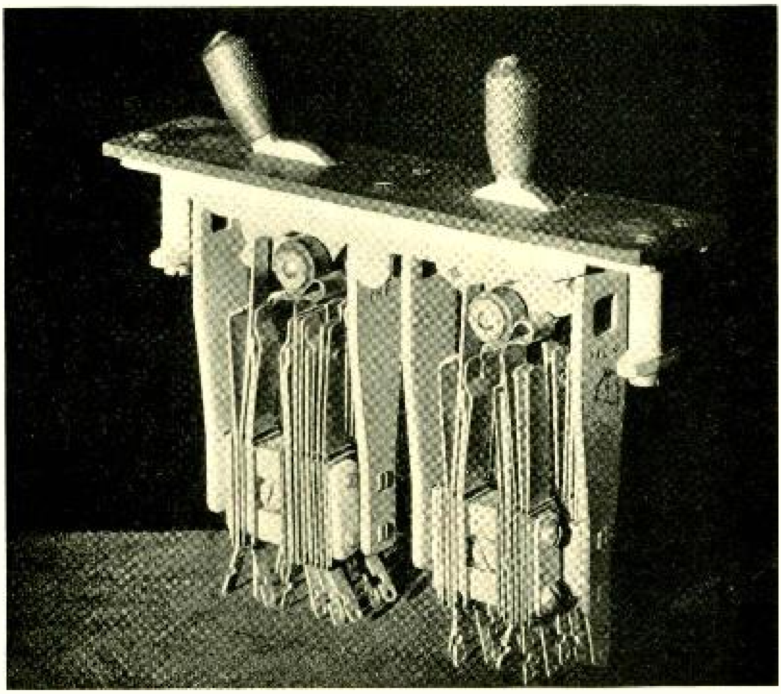
A. S. Page

A. H. Miller

F. A. Brooks

A. H. Miller became a member of the group working on train-dispatching telephone systems shortly after he joined the Engineering Department of the Western Electric Company in 1917. His interest in dispatching equipment has continued up to the present. In addition, he has been associated with the development of a number of special telephone, remote-control, and sound-ranging systems.

After graduating from the University of Nebraska with a B.S. in E.E. degree in 1923, F. A. Brooks entered the Inspection Methods Department of the Western Electric Company at Hawthorne. He engaged in the development of shop testing methods and the design of testing equipment for final testing of voice and carrier-frequency repeaters, and of carrier terminals. In 1925 he transferred to these Laboratories. Here, with the Toll Systems Department, he has been associated with the development of carrier toll-line equipment rearrangements, type-D carrier telephone, high-gain high-power carrier repeaters, type-K carrier repeaters and regulators. In 1929 he was placed in charge of a group that has since been largely engaged in developing carrier repeater and regulating systems.



Double-throw keys are used in private branch exchanges to connect the attendant in circuit and to ring the party called. They also provide through dialing and night service from the central office when the attendant is off duty.

Operating the front key to the rear locks it and connects the attendant's telephone and dial circuit to the cord circuit. To ring a station connected to the front cord the attendant operates the front key forward to its "non-locking" position. Similarly to ring a station connected to the rear cord the rear key is brought forward. Pressing the rear key back to the rear "locking" position connects the station through to the central office for direct connections or for night service