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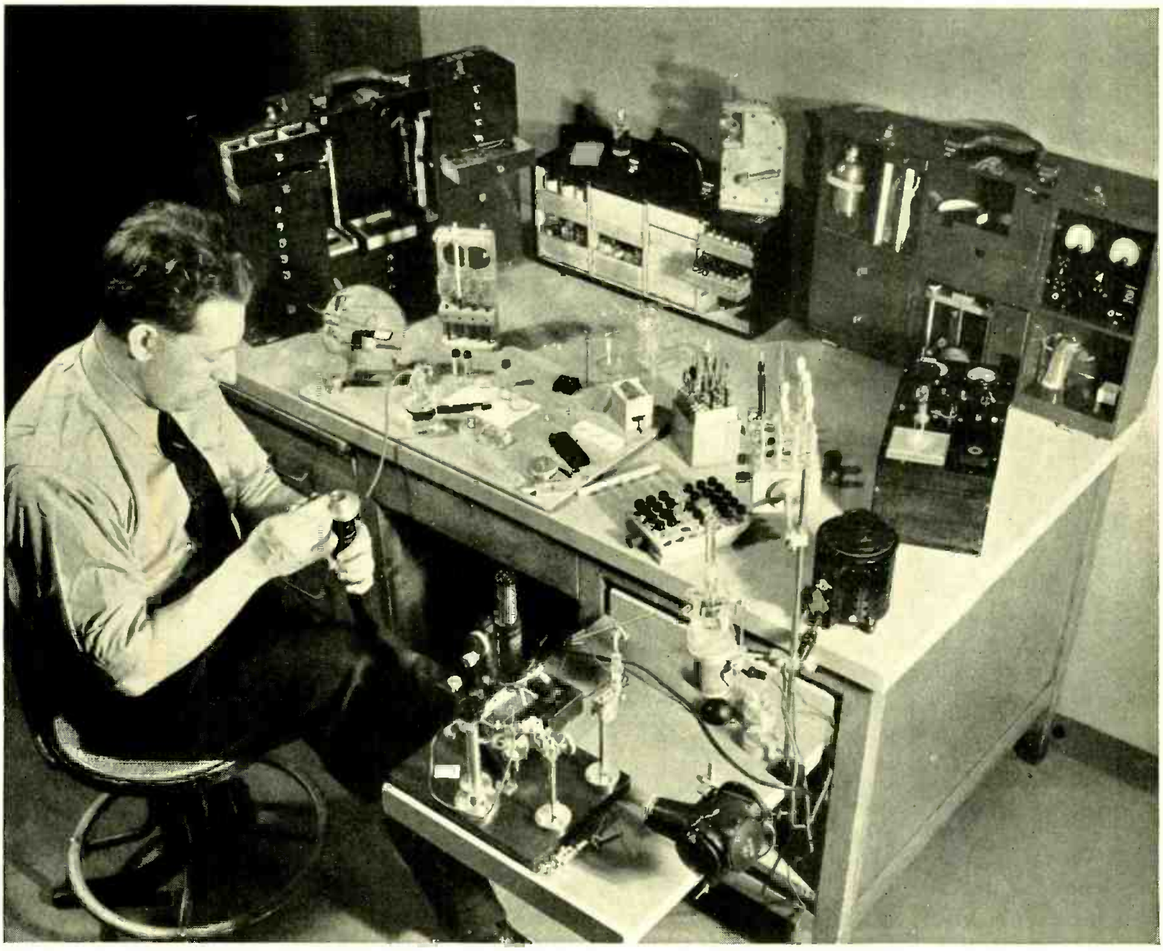

Portable microchemical equipment for investigations in the telephone plant

MAY 1941 VOLUME XIX NUMBER IX

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Step-by-Step Intertoll Dialing

By R. E. KING

Switching Development Department

THE operator at an "inward" toll switchboard may be required to complete calls either to local dial or manual offices or to outlying tributary offices. Some of these arrangements are indicated in Figure 1. For handling calls to dial offices she has either a dial or a key set with which she dials or "key pulses" the number wanted after plugging in to the proper trunk jack. When she extends a call to a manual office reached over a straightforward trunk, a lamp lights automatically at the distant office to attract the operator's attention. When she extends a call to a manual office that is reached over a ringdown trunk, however, she must ring over the trunk in order to attract the attention of the distant office.

In converting toll trunks so that the originating toll operator can dial directly a subscriber in a dial office at the distant end, the operator's core circuits at the inward toll board are replaced by selectors of the step-by-step type, giving an arrangement as shown in Figure 2. Each incoming toll trunk has an intertoll first selector associated with it, and by dialing any digit from 2 to 9 inclusive, the originating operator selects the office desired, either dial or manual, in the local area. Should there be more than eight offices, second selectors will be added. These selectors act as the first, or first and second selector in a local dial office, and give access to all numbers that are employed in that numbering area.

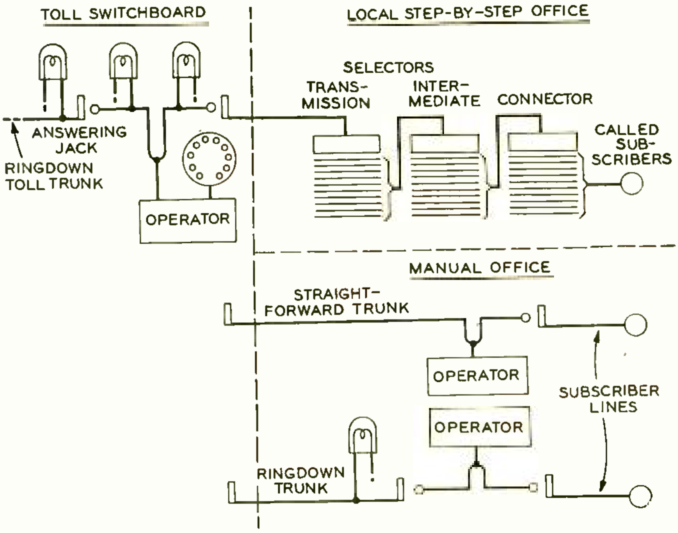

Fig. 1—Simplified schematic of arrangements for handling incoming toll calls at a manually operated board

For tributary manual or dial offices, an auxiliary first selector is used, which is reached from the first level of the intertoll first selector. Since such offices are not numbered in the series of local offices, they may be assigned a two-digit number between 11 and 19—the first digit indicating the first level of the intertoll selector, and the second, one of the levels of the auxiliary selector. Here, also, the

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second selectors may be added if necessary. Operators at the toll board are also reached through this auxiliary first selector. All of the operator trunks connected to this selector signal the distant operator automatically when they are seized.

When the office desired is reached over a ringdown trunk terminating in a jack at the remote switchboard, an auxiliary second selector is required to provide the two-second ringing needed. This selector is reached through equipment that provides two-second ringing, and trunks from it generally have a three-digit number. Although the trunks are shown arranged for one-way service, they may be arranged for two-way operation when conditions make it economical to do so.

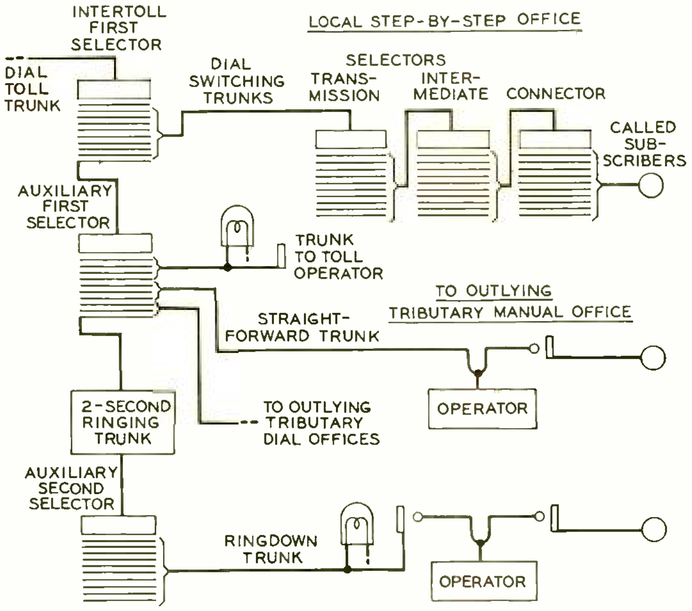

Fig. 2—In converting to dial operation, the operator's cord circuits are replaced by step-by-step selectors

The pulses sent over the toll trunk for operating the step-by-step selector and those that return the supervisory signals to the originating operator flow over a composited circuit as already described.* This composited circuit terminates in a cx relay at the toll office. This relay is used to send out the pulses that operate the intertoll selector, but the usual local type of dialing circuit cannot satisfactorily be used because line balance must be maintained to meet the requirements of repeatered toll circuits. To avoid disturbing this balance, a simplex pulsing circuit is provided for transmitting the pulses and signal through the central office.

The circuit used is shown in simplified form in Figure 3. On an incoming call, the cx relay follows the pulses, opening and closing a ground connection to the simplex circuit, in which the current flows equally and in the same direction over both sides of the line. This circuit is connected to battery through the A relay, which follows each pulse and steps the selector up to the desired vertical level. Here the switch hunts horizontally until it finds an idle trunk, at which time the D relay operates and connects the two toll trunks together. The next set of pulses then flows through the selector contacts and the retard coil in the outgoing toll trunk to the pulsing relay, which by alternately connecting the mid-point of the cx1 relay to ground and battery sends the pulses over the composite circuit to the distant office. In the meantime a supervisory circuit

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*Record, *July*, 1940, *p.* 337.

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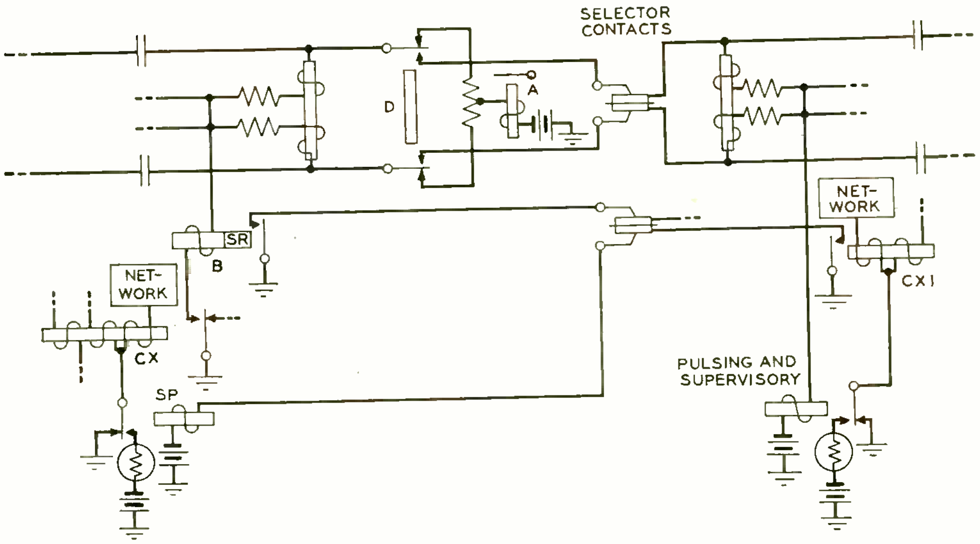

Fig. 3—Simplified schematic of simplex pulsing and signaling in the toll office

has been set up from relay CX1, through the selector contacts, and to the SP relay, over which signals may be returned to the originating operator.

An important feature of repeatered toll trunks is the control of gain by pads. When two toll trunks are connected together, these pads are cut out to increase the gain. When a toll trunk is connected to a subscriber, through a switching trunk, the pads must be left in the circuit to reduce the gain, because these local circuits are not balanced with sufficient accuracy by the balancing networks to permit the greater gain. Also the greater gain is not needed because of the comparatively short length of the circuit.

On manual toll trunks this pad control is secured by a circuit shown on Figure 4. When two toll trunks are connected together, the two P relays are in series to ground on each side, so that they release and operate their P1 relays, which short circuit the series resistances of the pad and open the shunt resistances. When the toll trunk is plugged into a switching trunk,

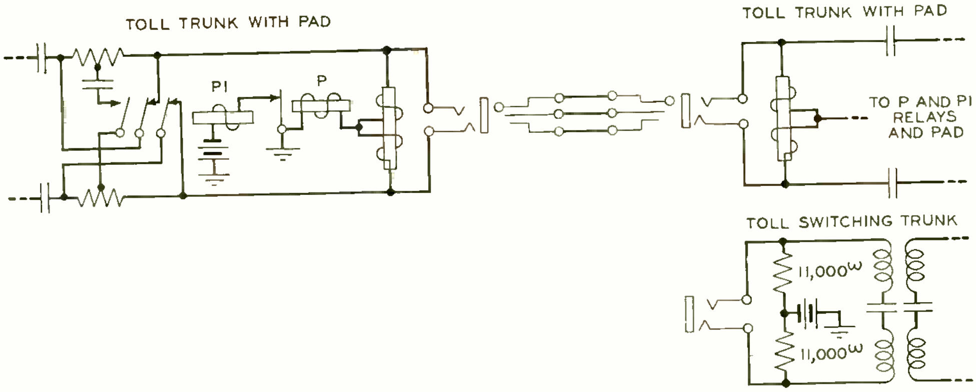

Fig. 4—Arrangements for pad control in manual toll offices

however, a high-resistance battery connected to the simplex circuit in the switching trunk operates the P relay which in turn releases the PI relay and connects the pad.

In adapting these circuits for intertoll dialing this arrangement cannot be used because the ground associated with the P relays would operate the pulsing relay. By a modification shown in Figure 5, however, this difficulty is avoided, while still securing the proper action of the P and PI relays. Instead of connecting the winding of the P relay in the simplex circuit to ground, it is connected across the line through the retard coil and thus will not operate on simplex current. The ground is obtained from the CX relay through two balanced resistances. In the outgoing toll trunk, the battery operating through the pulsing relay is similarly connected through balanced resistances. When these two trunks are connected together, no current will flow through the winding of P because it is connected across equipotential points of the circuit from battery on the pulsing relay to ground on the CX relay.

The resistances through which the pulsing relay is connected to the retard coils on switching trunks, however, are not balanced, one being larger than the other. When the toll trunk is connected to such a trunk, therefore, the points across which the P relay is connected are not at the same potential because of the unbalanced resistances ahead of it. As a result, a current will flow through P and operate it. This will open the circuit to PI, and the pad will be connected into the circuit.

The above intertoll dialing circuits, which provide all the features necessary for toll operation, can be installed in any step-by-step area, and can be used in conjunction with existing toll plant and switchboards.

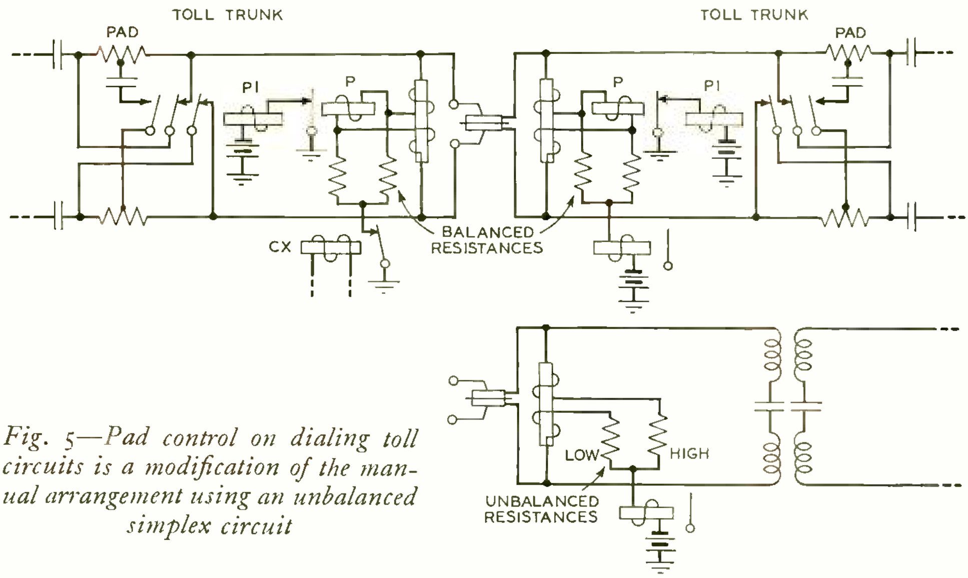

Fig. 5—Pad control on dialing toll circuits is a modification of the manual arrangement using an unbalanced simplex circuit

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Aerial Cable Lashing Machine

By E. ST. JOHN

Outside Plant Development

IN AN improved method of aerial cable construction, now coming into general use, the cable is bound to its supporting strand with a spiral wrapping of soft steel wire which is applied by a machine. This contrasts with the former procedure of suspending the cable from the strand with uniformly spaced wire rings. The cable and strand are lashed together so securely that there is little relative motion to cause abrasion of the cable sheath by the strand.

In the history of aerial cable, which began to supplant open-wire telephone lines about sixty years ago, there are various methods of suspension. What was desired were reasonably durable supports which were inexpensive to install. Those used in the 1880's included canvas slings, loops of marlin or of wire and sheet metal clips as well as spiral wrappings of wire or marlin. During this period a machine was developed to lash cable to its strand by applying a spiral wrapping of marlin, but the device was not widely used after the early nineties.

From the beginning of the nineties until about 1915, aerial cables were supported by marlin ties, metal hangers of various designs and sheet metal rings which were crimped to the strand. Then came rings made of spring steel wire which were snapped onto the strand by hand and provided stiff and firmly positioned loops to support the cable. This effected considerable economy in placing cable and also provided supports which had long life because of their galvanized coating. After several years of trial, however, it was found that this type of construction resulted in some sheath failures.

Studies of these sheath failures* disclosed that the supporting rings were cutting into the lead covering and ultimately causing breaks

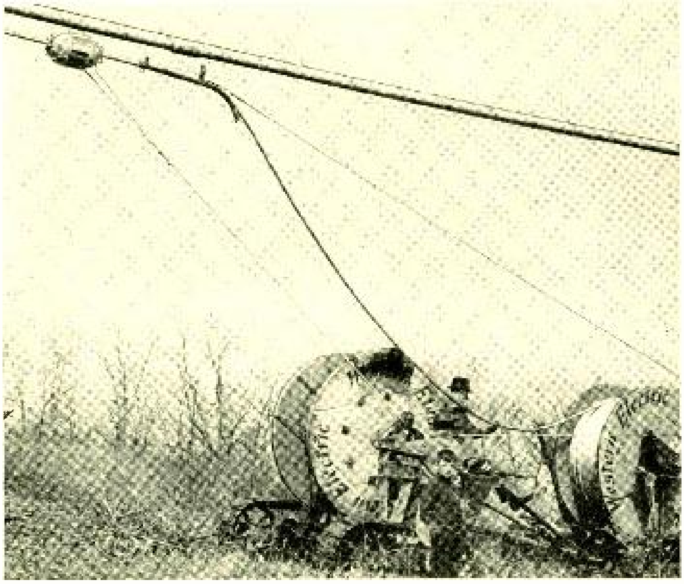

Fig. 1—Cable-reel trailers and a tractor are used for lashing cable to the strand directly from the reel

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*Page 273 of this issue.

which admitted water. The severe ring cutting usually happens at or near poles. This condition has been considerably alleviated in recent years by placing the strand with more sag; by adding protective cable shields at certain points; by clamping the cable to the strand at points; and by using cable supports which grip the cable but swing freely on the strand.

Recently the idea of lashing cable to strand was taken up again because it minimizes the relative motions between cable and strand while providing a support neater in appearance than ring suspension. The method is now feasible because steel wire has become available which carres a zinc coating heavy enough to resist rust but still flexible and adherent. The lashing machine, which in shape looks like an electric motor, is enclosed in an aluminum housing about nineteen inches long and weighs about forty-five pounds. It rides along the strand on trolley wheels within its housing and can be pulled from one pole to another pole in a few minutes by a rope from the ground.

The machine has a drum-shaped middle section and dome-shaped ends. The drum section rotates and, as the machine moves forward, it carries a small reel of lashing wire around both cable and strand. These combined rotary and forward motions of the reel lash the cable and strand together with a spiral wrapping. The rotating drum is equipped with a counterweight to balance the reel of lashing wire, and also with a grooved pulley around which the outgoing wire is led to provide suitable back tension. When viewing the machine in operation, the assembly of cable and strand seems to be passing through the center line of the apparatus.

Fig. 2—A telephone lineman dead-ending the lashing wire at the pole. The lashing machine is shown at the left and is in position to begin lashing the next span of the cable

Adjustable cable-lifting rollers and the pulling attachments are secured to the dome-shaped ends of the machine. Each end contains a grooved rubber driving wheel, which rolls along the strand and turns the rotating drum through a pair of gears, and a rubber friction wheel. The cable-lifting mechanisms are horizontally positioned rollers and can be set at the desired height to raise the cable so that it approximately touches the strand. The pulling attachments merely provide means for attaching a rope.

No practical type of lashing machine and strand attachment has yet been visualized which will permit the device to ride past a pole. Consequently the machine has been de-

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signed so that it can be readily removed from the strand or replaced. This is done by swinging the hinged cable-adjusting rollers out of the way and then rotating the drum until its cut-out section is directly below the strand and cable. Easy reloading with a new coil is provided by a hinged gate on the rotating drum. The lashing wire is furnished in 350-foot lengths which are wound in flat coils seven inches in diameter.

When field conditions permit, it is preferable to lash the cable directly from the reel to the strand. The prevalence of trees and other aerial structures, and the fact that aerial cable is usually installed on the field side of the pole, frequently make it necessary, prior to lashing, to install the cable in the usual way, but with widely spaced temporary rings. These temporary rings are then replaced with sliding rings or marlin ties which are pushed along by the machine as it lashes the cable. When lashing directly from the reel to the strand one of these machines will secure from one to three miles of cable in a day. By the other method, it has been found that a mile to a mile and a half of cable can be lashed daily.

Originally proposed by the Southwestern Bell Telephone Company, the idea of a machine which would lash cables to strand by wire was tried out with models built by that company and later by the Laboratories. Experience with these early models resulted in the present design.

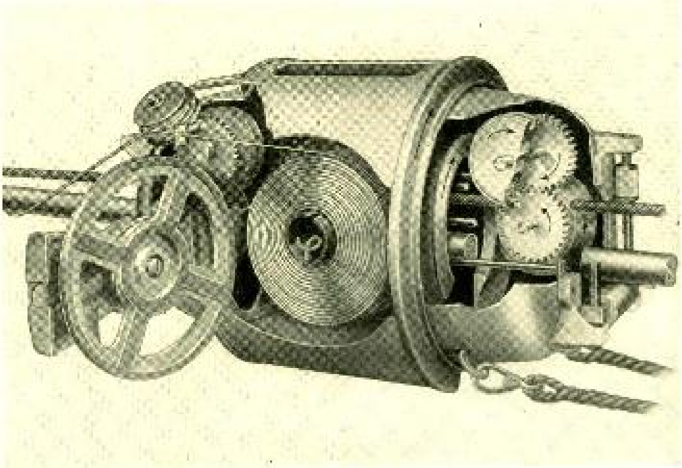

Fig. 3—The central drum-shaped portion of the cable-lashing machine revolves on rollers. It is driven through bevel rings by beveled rubber wheels which are geared to grooved rubber wheels that roll along the strand. The reel and feeding mechanism for the wire are located on one side, counterweighted by a block of lead on the other side of the revolving drum

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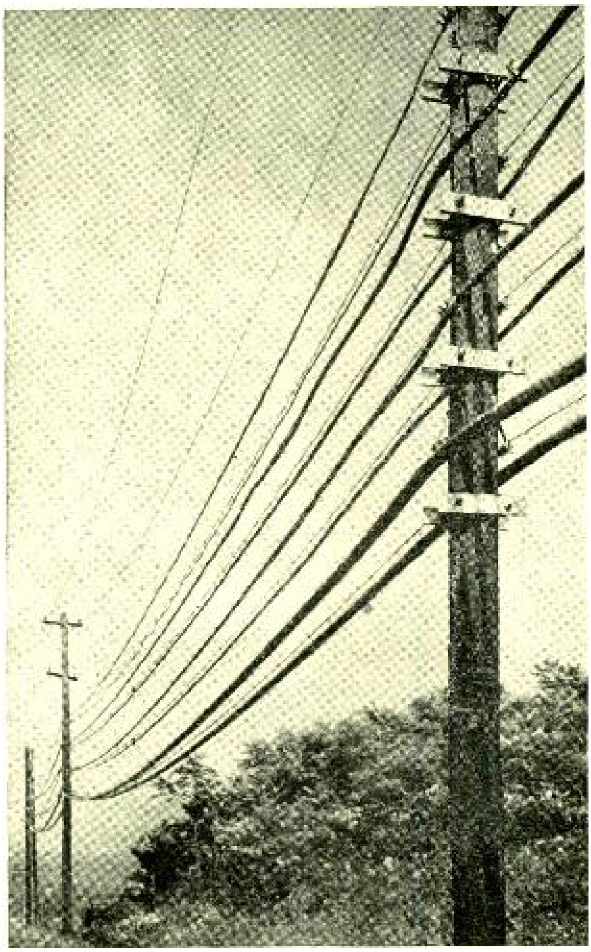
Lashed Aerial Cable

By J. A. CARR
Outside Plant Development



SINCE a telephone cable is no better than its sheath, any deterioration of cable sheath is of vital importance. In aerial cables, hung in rings according to conventional practice, it has been found that many sheath failures are due to the effect of temperature changes on the length of the cable. To overcome this, a new system of suspending cables has been developed* wherein the cable is lashed directly to its supporting strand by a machine-applied wire serving. In connection with this development, studies have been made to compare the lashed method with ring suspension and to determine the most suitable arrangements in the details of lashing the cable.

An aerial cable is relatively straight throughout the span but is definitely bent at the junction of two spans. At that point, further bending will readily take place if the cable expands lengthwise. Expansion occurs whenever the cable is heated by the sun. Most of it is taken up by further deflection of the cable at the pole when the cable is hung in rings. Often this has undesirable results: bows or sharp reverse bends are produced, in which the sheath may be severely worked; even relatively low stresses, if slowly but repeatedly applied, develop in lead alloy sheath the crystalline changes which eventually cause cracks. The coming and going of the bows may also contribute to abrasion of the sheath where it bears against the rings; these abrasions or "ring cuts" become weak points which further concentrate the bending until stresses are above fatigue limit.

In studies to compare the performance of lashed and ring supported cable, outdoor tests were undertaken at the Chester field laboratory. These tests covered a range of cable sizes and strand tensions and employed various methods of terminating the lashing wire and supporting the cable at poles, splice points and

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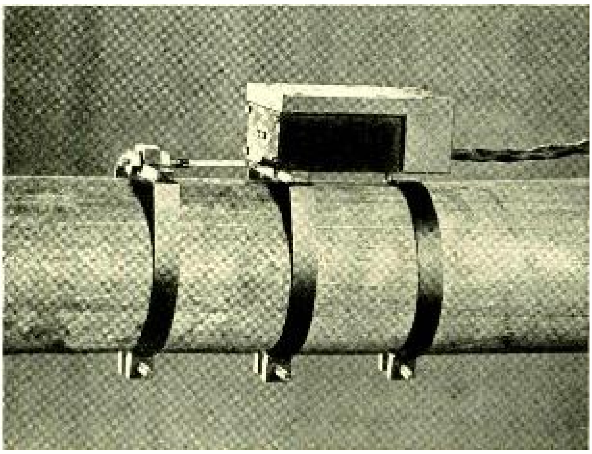

Fig. 1—Strain gauge tests show that the slow expansion and contraction of the cable caused by daily temperature changes, rather than vibration, are responsible for the sheath strains which produce cracks*

terminals. In checking the effect of these variations, observations were made of bowing and of the tendency for cables to abrade when mechanically swung in a manner simulating movement in wind. Strains in the sheath produced by temperature changes were also measured precisely by strain gauges located at different positions along the cable.

The strain gauge and fatigue experiments confirmed previous studies which indicated that the slow expansion and contraction of a cable, caused by daily temperature changes, are responsible for the large sheath strains which produce fatigue and sheath cracks, rather than rapid vibrations caused by road traffic or wind sway. The largest strains were found on the bottom of the cable at the pole and the larger sizes of cables developed greater strains in rings than did similar lashed cables. The strains at the pole in lashed cable of the smaller sizes are somewhat greater than for such cable in rings, but are not of serious proportions.

When low strand tensions were used, less bowing occurred, both on ring-supported and on lashed cable. Under this condition thermal expansion increases the length of the strand more than it would if it were highly tensioned, so that the differential to cable expansion is reduced.

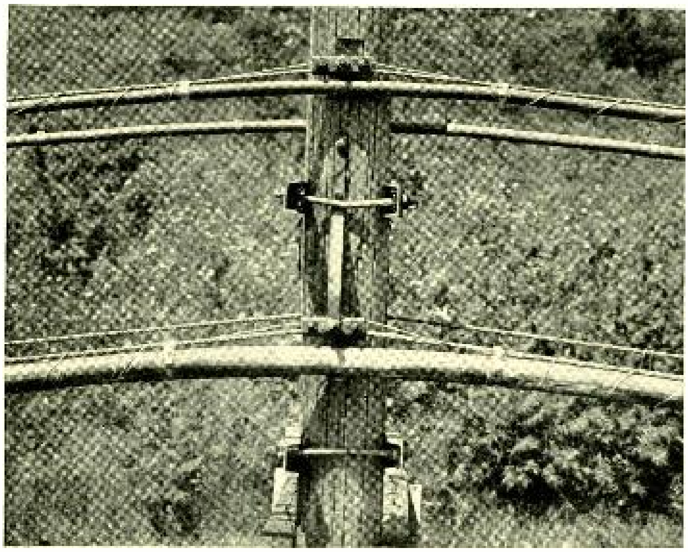

Fig. 2—To prevent abrasion at the pole during the swing tests the lashing was stopped about fifteen inches from the pole and the strand and cable were bound together by an aerial cable support at that point. The lashing wire passed through the eye of the support. On large cable a lead spacer was inserted between the strand and cable at the support to prevent abrasion beyond the cable support. The middle cable is supported by the conventional rings and aerial cable supports

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*Record, *Feb.*, 1940, *p.* 161.

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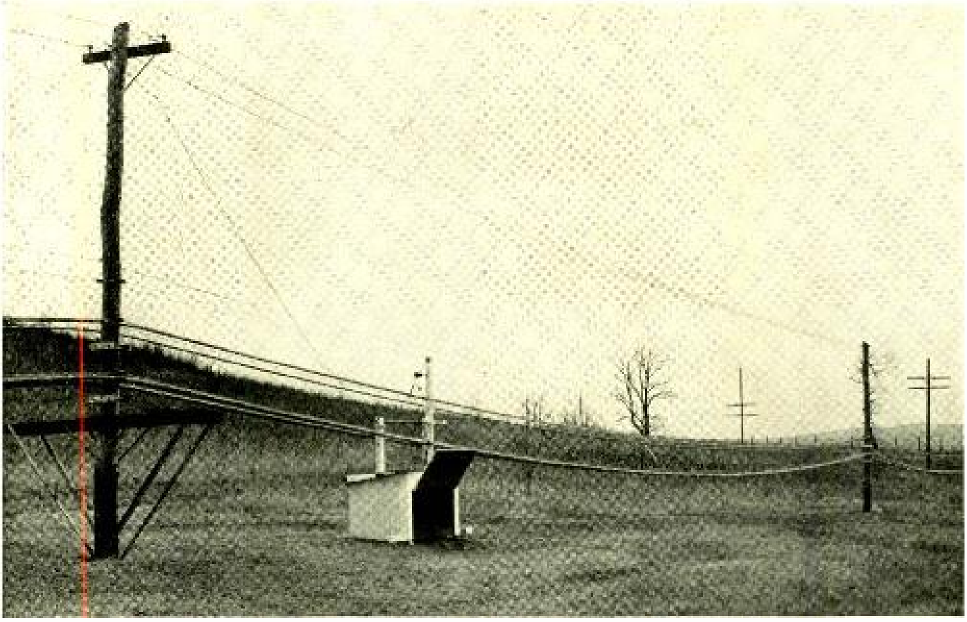

Fig. 3—Spans were swung day and night to accelerate abrasion

Lashing has a snubbing effect which confines the expansion of cable to minor waves throughout the span instead of permitting movement of the excess cable into the bent section at the pole with the formation of bows.

In the swing tests, two or more cables in one span of a line are swung mechanically day and night to accelerate the abrasion that would occur between cables and their supports in normal service. Of the various conditions tested, the one which resulted in the least abrasion omitted the lashing wire in a section near the pole. At a point about fifteen inches from the pole, strand and cable were bound together by an aerial cable support as shown in Figure 2. Through the support, the lashing wire was terminated after tapering off the lay by hand from around fourteen inches, as served by the machine, to about three or four inches. Thence the wire was extended along the strand to a point above and back of the suspension clamp and terminated by connection to the wire from the adjacent span. The aerial cable support as modified above is known as "lashed cable support." With this arrangement the lead shield, otherwise required to keep the cable from bearing against the suspension clamp, was omitted. Obviously no abrasion of the sheath occurred in the unsupported section at the pole but on the large cables some abrasion resulted from contact with the strand just beyond the lashed cable support. It was found that separating these cables from their strand a quarter of an inch at the cable support with a lead spacer prevented abrasion for several inches towards the center of the span. This also permitted the cable to follow a bend of larger radius at the junction of two spans, reducing strains due to temperature changes. Even with this arrangement, swinging produced abrasion of the sheath at scattered points throughout the span where cable

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larger than about one and three-quarter inches in diameter pressed against the strand in bending under longitudinal expansion.

While this abrasion along the span seems to develop somewhat more rapidly than corresponding ring cuts in a comparable cable, the injuries are at points not subjected to severe bending and, being longitudinal, they are not expected to be serious.

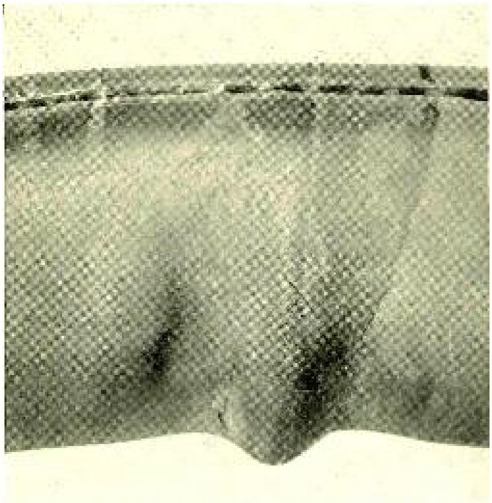

Fig. 4—Compression failure on a cable sheath caused by bowing experiments at the field laboratory at Chester, New Jersey. The longitudinal cut at the top was made in removing the sheath from the cable

The studies at Chester have been extended to include conditions associated with corners, strand connectors, cable splices, terminals and loading coil cases, each of which was found to require some special treatment for the best results.

At the time of lashing, it is important that any excess length of cable due to waviness be removed, especially in the case of small cables; otherwise definite bowing is likely to occur. A tubular cable straightener has been found useful for this purpose.

These studies indicate that attention to the following construction features is important to obtain favorable maintenance conditions for lashed cable. The strand tension ought to be low and some tension should be applied to the cable during lashing to assure removal of the slack. To avoid abrasion at the poles there should be a self-supporting section of cable without lashing and a spacer between the cable and strand at the supports, for cables larger than about one and one-half inches in diameter.

From an appearance standpoint the straightness and compactness of a lashed cable assembly make both large and small cables less conspicuous and more sightly than when ring supported. The flexibility of small cables makes it practicably impossible to keep them straight in rings as usually spaced but when snugly lashed they must necessarily conform closely to the alignment of the strand. This feature alone provides a strong appeal for lashed construction.

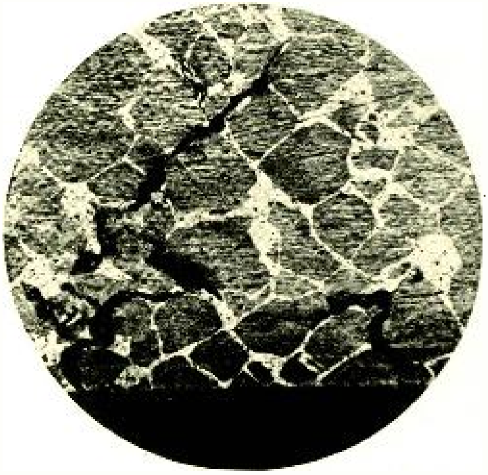

Fig. 5—Photomicrograph showing cracks and structural changes produced in standard lead-antimony cable sheath by aging and the fatigue forces acting at a bow

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Measuring System for Carrier Circuits

By S. ROSEN
Transmission Development

HIGH-FREQUENCY pilot currents are transmitted over type-K carrier telephone lines and measurements of their levels are made periodically to indicate the performance of the circuit over the transmitted band from 12 to 60 kc. A transmission measuring system, coded 42A, has been designed to measure the levels of these currents. With it measurements can be made at any frequency in the type-K range, not only of pilot currents, but also of carrier leaks or of test tones when introduced into any one of the individual channels. The 42A system is installed at each attended repeater station and can be used while the carrier circuits are in service; this is especially important on carrier systems because an interruption of one line affects many voice channels. Essentially the system is a heterodyne detector designed to be bridged across the line. The input signal is modulated to an intermediate frequency, selected by a crystal filter, brought down to one kc in a demodulator and applied to a thermocouple measuring set.

Transmission loss due to bridging the measuring set across the line is made less than one-tenth db by a high-impedance pad, Figure 2. This pad also keeps extraneous currents, which originate in the measuring system, from being fed back into the line in appreciable amount.

The circuits of the modulator and demodulator, which are essentially identical, have a double balanced arrangement of copper-oxide varistors, Figure 1, and a pad at the output side to present a constant impedance to all the modulation products. This gives a flat frequency-transmission characteristic and aids in obtaining stabilized operation. A modulator of this type is practically independent of variations in the level of the carrier supply, over a limited range, and changes in room temperature also produce very little effect. The modulator and a demodulator operate with a nominal carrier-supply level of ±16

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dbm (db referred to one milliwatt) at an impedance of 20 ohms. A 17B oscillator* provides the carrier supply to the modulator and can also serve as a test oscillator for general office maintenance.

At the mid-band frequency of 130 kc the 95A crystal filter has a pass band of about 20 cycles. As shown in Figure 3, its attenuation at frequencies 100 cycles away from 130 kc is about 30 db. This permits the pilot currents located at 15.9, 27.9 and 55.9 kc to be measured and distinguished from the carrier leaks at 16, 28 and 56 kc, whose amplitudes may be comparable to the pilot currents. A mid-band frequency of 130 kc was chosen because the carrier supply required by the modulator of the measuring system varies with this frequency from 70 to 118 kc for any line signal in the range from 12 to 60 kc. Accordingly, any carrier leaks or other unwanted frequencies from the modulator which are fed to the line would fall outside of its transmitted band. Extraneous frequencies from the modulator are suppressed by the band filter and prevented from affecting the measuring circuit. The frequency selected is also within the operating range of the type-K transmitting amplifier which, with minor modifications at the input, is used for the test amplifier. The measuring system has a nominal gain of 63 db with a fairly flat response over the range from 12 kc to 130 kc.

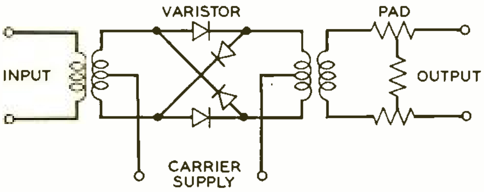

Fig. 1—Circuit of either the modulator or demodulator of the 42A transmission measuring system. Two steps of modulation are employed in this selective heterodyne detector designed to be bridged across the line

Carrier is supplied to the demodulator by a 50B oscillator whose circuit is shown in Figure 4. It is a single-frequency oscillator with crystal control which maintains its output at 129,000 ± 50 cycles; its maximum output is +17.5 dbm at 129 kc. The 130 kc signal is modulated by this frequency to one kc so that it may be measured readily or observed aurally. To match the input impedance of the demodulator, the output impedance of the oscillator is made 20 ohms. An output level adjustment sets the carrier supply level to +16 dbm. The

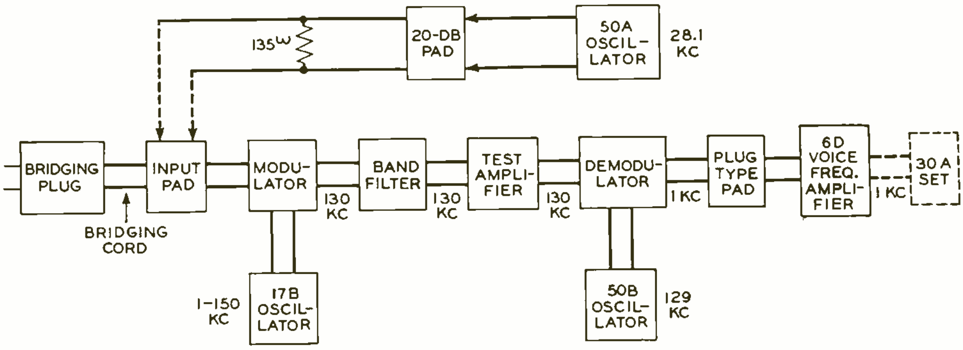

Fig. 2—Block schematic of the 42A transmission measuring system as used for measuring pilot levels on type-K carrier telephone circuits

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*Record, *May*, 1939, *p.* 291.

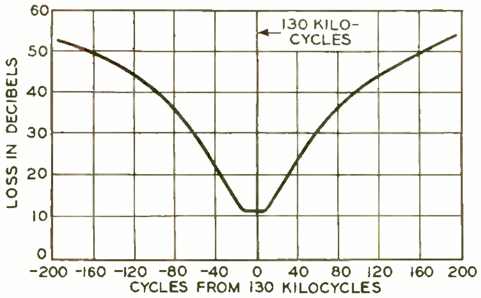

Fig. 3—Loss-frequency characteristic of the 95A *filter of the transmission measuring system. This filter passes a narrow band at* 130 *kc and eliminates all but the signal*

tuning condenser varies the frequency of the tuned circuit to that of the crystal, at which point the crystal takes control. A minimum reading on the plate-current meter indicates this control point.

Standard resistances which plug into a 1C pad are used to attenuate the output of the demodulator. Values from zero to nine db are available and the one chosen for any particular office is that equal in db to the nominal gain from the transmitting toll switchboard to the point where the measuring set is used.

A simple low-pass filter at the input of the 6D voice frequency amplifier circuit (Figure 2) suppresses the upper side bands from the demodulator. This amplifier has a single stage and uses cathode feedback for stabilization, as shown in Figure 5. Gain control over a range of 23 to 30 db, obtained by varying the feedback resistance, is used to calibrate the overall measuring circuit. The transmission characteristic of the amplifier is practically flat from 500 to 1500 cycles and then drops off rapidly at both ends. This characteristic approximates that desired for observing noise or interference on a circuit. The amplifier has an output limiting characteristic to protect the thermocouple of the 30A set from being burned out by overloads. For outputs up to +5 dbm the input-output characteristic of the amplifier is linear. Beyond that point it increases at a continuously slower rate with increases in input to a limiting output level of about +11 dbm. No greater output can be obtained regardless of how much the input is increased. Normally the amplifier operates at an output of one milliwatt. To the output of the measuring system is patched a 30A trans-

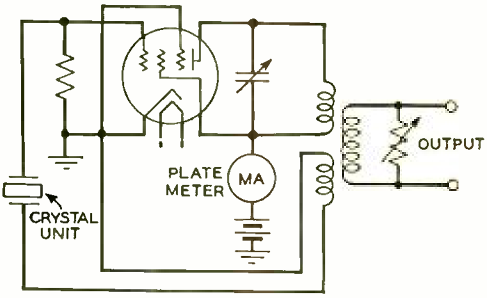

Fig. 4—Circuit of the 50B *oscillator which is crystal controlled and supplies the* 129-*kc carrier frequency for the demodulator of the transmission measuring system*

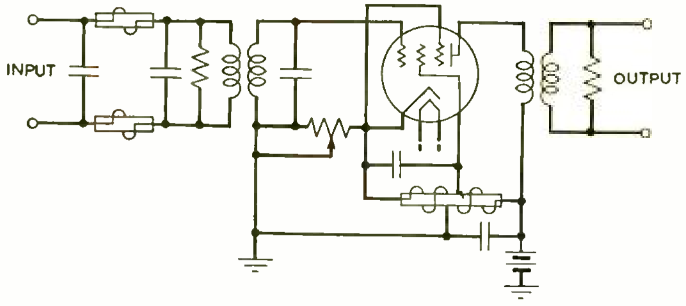

Fig. 5—Circuit of the 6D *voice-frequency amplifier. Variable feedback is used to control the gain in calibrating the overall sensitivity of the measuring system*

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mission measuring set* and the reading of its meter plus the value of the plug type pad indicates the operating level of the circuit.

To calibrate the measuring system the output of the 50A oscillator, whose circuit is shown in Figure 6, supplies a test tone of 28.1 kc. This output is first adjusted to exactly one mw and then fed through a 20 db pad into the bridging pad as shown on Figure 2. Since the pilot currents are transmitted on the line at a level 20 db below that of the message channels, the calibrating signal thus applied represents a normal pilot at a zero level point. A zero loss pad is substituted for the plug type pad and the measuring system is adjusted to measure and indicate correctly the level of the applied calibrating signal by adjusting the gain of the voice frequency amplifier.

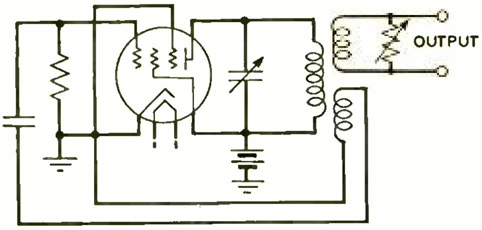

Fig. 6—Circuit of the 50A *oscillator. The output of the oscillator is adjusted to one milliwatt at* 28.1 *kc when calibrating the transmission measuring system*

For measurements on a type-K system an adapter plug is inserted in the jacks through which the output of the office equipment is connected to the line. The normal connection through the jacks is replaced by a similar connection through the plug so that the circuit is not broken. There are two pin jacks at the back of the adapter plug into which the plug connected to the bridging cord of the 42A transmission measuring set can be inserted to bridge the measuring set on the line. The three pilot frequencies 15.9, 27.9 and 55.9 kc can be measured by setting the oscillator frequency at 114.1 kc, 102.1 kc and 74.1 kc, respectively. In addition to these measurements, a signal introduced on any one of the channels or produced in the line anywhere in the frequency range of 12 to 60 kc can be measured by adjusting the frequency of the 17B oscillator so that it modulates that signal to 130 kc.

Although the 42A transmission measuring system was developed primarily for use as a high impedance detecting circuit, its individual units or a combination of them find application in many other tests associated with circuit maintenance.

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*Record, *Aug.*, 1939, *p.* 385.

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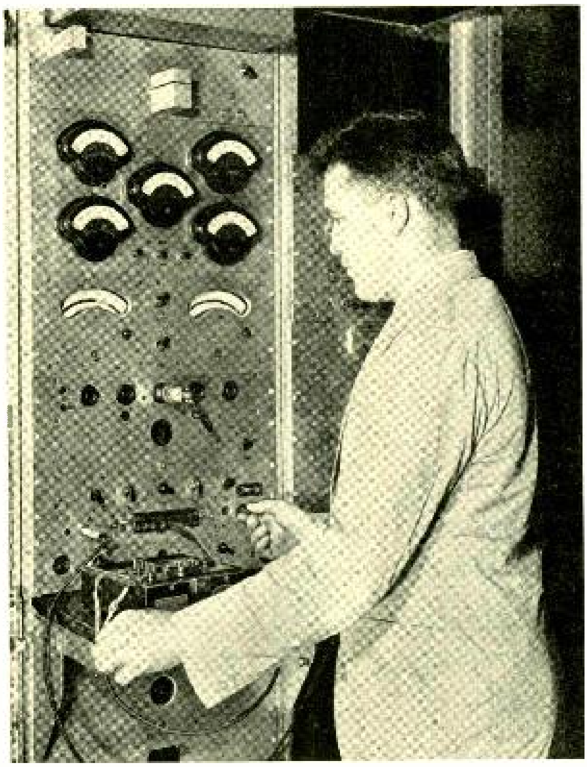
Measurement of Dynamic Characteristics of Vacuum Tubes

By J. B. MAGGIO
Transmission Development Department



IN THE design of broadband carrier telephone systems, the vacuum tube is one of the basic elements. Its most efficient operation as an amplifier requires that the proper voltages be applied to the electrodes and that a suitable load impedance be chosen. Unfortunately, one set of operating conditions will not result in optimum performance for all applications of a given tube. In general, the conditions for optimum performance in any particular case will depend upon the frequency band to be amplified, and the required gain, power output, and modulation performance necessary.

Instead of measuring the performance of the tube under several conditions in an actual circuit, however, one may determine its properties as an amplifier with a resistance load from a curve correlating instantaneous plate currents and control grid voltages. Such a curve is known as the dynamic transfer characteristic. It is unique for a given tube and specified operating voltages and load resistance. From this characteristic, the power output for any driving voltage, as well as the voltage developed across the load impedance, may be determined, and by applying special analyses, the relative magnitudes of the fundamental and harmonic components of the resulting plate-current wave may be computed. The dynamic characteristic is usually obtained graphically from a set of static characteristics for the tube. To provide a simpler and more rapid method, and one more free from the inherent errors of the graphical method, a circuit has been developed by the Laboratories that directly and accurately determines the dynamic characteristic.

A family of curves expressing the relationship between plate voltage and current for various grid biases comprises the static characteristics of a tube. Each curve represents the behavior of the tube with all factors constant except for arbitrary changes in plate voltage and the corresponding changes in plate current. For simplicity, they are taken with a battery connected to the plate, which gives essentially a zero plate impedance. Such a set of curves for a pentode is shown at the left of Figure 1. Under operating conditions, however, while the applied voltages are fixed, there is a load resistance in the plate circuit, and the grid voltage is moved up and down from the biasing voltage by the applied signal. Under these conditions the relationship between instantaneous plate voltage and current would be represented by the diagonal line AB. As the grid voltage was increased by the signal, the plate current would increase, and this increased current through the load resistance would subtract from the applied plate potential to give a lower actual plate voltage. The tangent of the angle by which AB deviates from the vertical is equal to the load resistance. This is readily apparent because the tangent of the angle of deviation is PN ÷ NQ; PN is the decrease in plate voltage, which is $\Delta I_p R$—the product of the increase in plate current by the load resistance—and NQ is the increase in plate current, or ΔI_p.

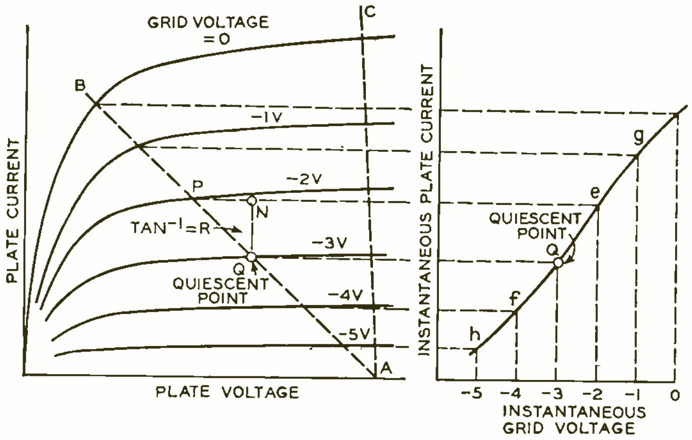


Fig. 1—Typical static characteristics of a vacuum tube at the left, and the dynamic transfer characteristic derived from them at the right

With a line such as AB across the set of static characteristics, the dynamic characteristics may be plotted by projecting horizontally each intersection to determine the points on a curve representing the relationship between plate current and grid voltage for that particular load resistance. Such a curve is indicated at the right of Figure 1. A scale of instantaneous grid voltages is laid out along the abscissa, and the intersection of AB with each curve at the left is projected over and forms a point of the dynamic characteristic where it crosses the vertical from the corresponding grid voltage on the abscissa scale.

Not only is this graphical method of determining the dynamic transfer characteristic rather slow, but in addition it has several other disadvantages that are more or less inherent. The static curves are normally obtained by applying d-c voltages, and the plate current is also d-c. A dynamic curve, however, is used to determine the behavior of a tube under operating conditions when an a-c potential is applied to the grid, and when the plate current and voltages are also a-c, or rather a-c superimposed on d-c. The heating of the elements for these two conditions is different, and thus a characteristic determined with direct current will not be strictly correct for alternating current. Moreover there is always some inaccuracy with a graphical method because of uncertainty as to the exact points of the intersections of the lines, particularly when they intersect at a small angle.

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In the method recently developed, these disadvantages are overcome by making direct measurements on the tube under a-c conditions. A dynamic transfer curve may thus be obtained rapidly and under the heating conditions that hold when the tube is in normal use. A simplified schematic of the circuit employed is shown in Figure 2. In brief the method consists in applying the desired d-c plate and grid biasing potentials, and then superposing on the grid bias a pure sinusoidal driving voltage of carefully determined value, and measuring the corresponding plate current. The method can be indicated by reference to Figure 1. Any set of plate and grid voltages determines a quiescent point such as Q. For any applied alternating driving potential, the grid voltage is driven alternately above and below the grid voltage of the quiescent point, and the plate current will alternately increase and decrease. The plate current has an a-c and a d-c component, the latter is determined separately, and the maximum positive and negative peaks of the a-c component are added to and subtracted from it to give the plotted points of the dynamic characteristic.

The driving circuit consists of a tapped potentiometer made up of equal resistance steps, one of which is the heater of a thermocouple. An oscillator applies a pure sinusoidal voltage to the potentiometer, and its output is adjusted until the galvanometer connected to the thermocouple indicates that 1-volt peak is applied across the thermocouple. Under these conditions, the steps of the potentiometer apply to the grid multiples of 1 volt peak from the bias voltage. Errors that might be caused by grid current of the tube under test are made negligible by small resistances in the potentiometer.

The alternating and direct components of the plate current are separated by a parallel circuit. One branch consists of the large inductance L, and the other of an adjustable resistance R_L, a smaller resistance G_V, and a large blocking condenser, which prevents the passage of direct current through this branch. At the test frequency used, the impedance of L is so large compared to that of the other branch, that only direct current passes through it. Thus the d-c component flows only through L, and is measured on a milliammeter, while the a-c component flows only through the R_L branch, and is measured by adjusting G_V until the peak voltage across it is just one volt, which is determined by comparison with the voltage across the thermocouple in the grid circuit. The set thus measures the behavior of the tube in a circuit where the impedance

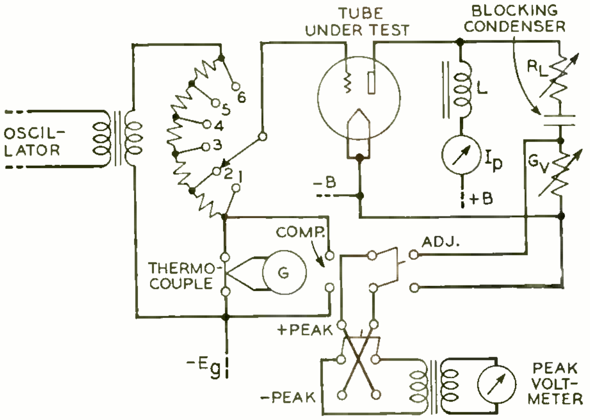

Fig. 2—Simplified schematic of the new circuit developed for measuring the dynamic characteristics directly

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presented to the plate is low to direct current, and a pure resistance at frequencies in the working band. Such conditions are normally fulfilled in a transformer-coupled output stage, such as is used in most broad-band carrier amplifiers. The behavior of the tubes in resistance-coupled amplifiers may be readily determined by suitable interpolation.

The voltage across G_V is made equal to that across the thermocouple by adjusting G_V until the indication of a peak voltmeter is the same when it is connected across G_V as when connected across the thermocouple. A double-pole double-throw switch permits the meter to be thrown rapidly from one to the other, and a similar switch is connected so that either the positive or negative peaks may be read.

Since the voltage across G_V is the IR drop through it, the current through it is equal to the reciprocal of the resistance when the voltage drop is unity. Thus by using a conductance standard for G_V, the current in milliamperes is equal to the conductance in millimhos. Actually, the scale of the conductance standard is marked in milliamperes in order to make it direct reading.

The current measured on the milliammeter is the d-c component of the plate current for the plate potential and grid biases applied. With the grid potentiometer set at the 1-volt step, and assuming the conditions of Figure 1, the positive peak of a-c plate current added to the d-c component would give the point *e* of the right-hand diagram of Figure 1, and the negative peak subtracted from the d-c component would give the point *f*. A separate adjustment of G_V is required, of course, for positive and negative peaks. Similar readings with the potentiometer on step 2 would determine points *g* and *h*, and so on for other points. Asymetric distortion of the dynamic transfer characteristic results in a change of d-c plate current when the signal is applied. When this occurs, the d-c bias is adjusted to compensate for change. Characteristics corresponding to Class B and Class C operation may be taken in this way.

This new circuit readily adapts itself to other measurements than that of the dynamic characteristics. A set of static characteristics, for example, may be obtained under heating conditions more nearly those encountered in normal operation than are curves determined with d-c potentials alone. By reducing R_L of Figure 2 to zero, the load impedance is only G_V, across which there is never more than one volt because of the measuring procedure. Such a low-resistance load would be represented on Figure 1 by an almost vertical line such as AC. Then by using a grid-biasing voltage nearly that required to extinguish the tube, and reading only the positive peaks, points on the static curves are obtained for each setting of the potentiometer. Under these conditions, both the plate and screen currents are cut off during nearly all of the negative half-cycle, or approximately half of the time, and much of the heating present with the more usual method is avoided. At each reading, a correction of 1 volt is made to compensate for the drop across G_V, so that the points plotted lie in a vertical line one volt below A. By taking a series of such readings at various plate potentials, the static characteristics are obtained.

The circuit may be used for measuring the transconductance from control grid to plate, which is equal to the ratio of change in plate current to a

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small change in grid bias at constant plate potential. As the load resistance is made small compared to the internal resistance of the tube, the voltage ratio from grid to plate approaches the product of transconductance and load resistance. By making R_L equal to zero, setting the grid potentiometer to the 1-volt tap, and adjusting G_V until there is one volt across it, the voltage gain through the tube, or the ratio of plate to grid voltage, is unity, and the transconductance will be equal to one divided by the load resistance, which is G_V. Since the reciprocal of G_V is the conductance, which is read directly from the G_V dial, the transconductance is obtained directly. When the voltage gain has been adjusted to unity with the grid potentiometer on the 1-volt tap, the calibration of G_V is independent of the actual grid voltages. Consequently, when measuring small tubes in which a grid swing of one volt peak can not be considered small, the oscillator output is reduced so that only a small fraction of a volt is applied to the grid of the tube.

The circuit as used in the carrier repeater laboratory is shown in the photograph at the head of this article. Four, five, six, seven, and eight-prong sockets have been provided together with jacks and plugs so that tubes with various basing arrangements may be accommodated. Plate and screen voltages are secured from regulated power supply units, and are continuously variable. Heater and grid voltages are also adjustable from the control panel, thus enabling any desired set of operating voltages to be quickly set up. Measurements of dynamic transfer characteristics obtained with the circuit have been particularly useful in the determination of optimum operating conditions for tubes in broad-band amplifiers.

A. B. CLARK HONORED BY UNIVERSITY OF MICHIGAN

A Citation as Distinguished Alumnus has been awarded to "Alva Benson Clark, member of the Class of 1911 *of the College of Engineering, University of Michigan, now Director of System Development in the Bell Telephone Laboratories, who since his graduation has devoted his own inventive skill and his ability to direct research to the expansion, improvement, and cost reduction of telephone transmission, foreseeing the possibilities and anticipating the trend of the arts of communication; from his efforts have resulted many of the accomplishments of modern long-distance and multi-channel telephony."*

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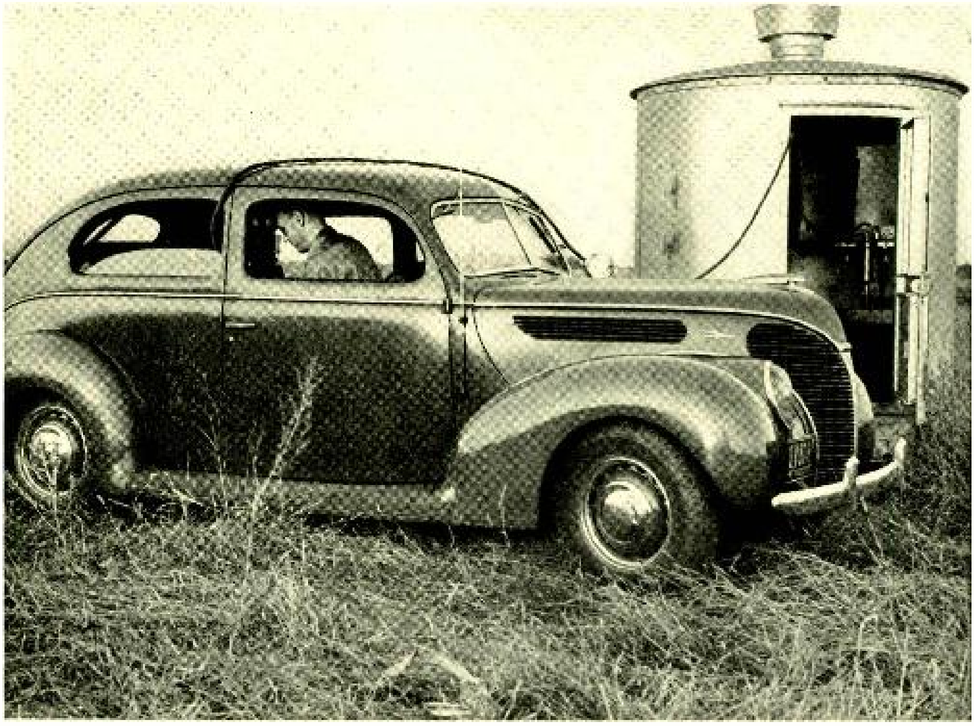

Circuit-Riding the Coaxial Cable

By G. B. ENGELHARDT
High-Frequency Transmission

IN THE course of their development work, the Laboratories make many transmission tests in the field, far away from the usual laboratory facilities. The necessary equipment must be carried to the point of measurement and set up each day for the tests to be made. These open-air tests, besides the delays inherent in a daily setting up and dismantling, are always subject to interruption—sometimes sudden and unexpected—by bad weather, and to avoid such minor catastrophes, the apparatus has sometimes been arranged in trucks.

With the very wide band of frequencies of the coaxial-cable carrier system, it was evident that the amount of testing would be much greater than usual. The cold weather and snow prevalent over the route between Stevens Point and Minneapolis where the first commercial cable was being installed emphasized the need for protection for the apparatus and engineers. As a result, the two-door sedan shown above was converted into a mobile laboratory that could be used in all weather and in almost all places. Although mobile laboratories are not unusual, this test car is a particularly good example of compactness. It accommodates two engineers and over half a ton of equipment.

The equipment varies with the particular tests, but certain facilities

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should always be available. In the design, therefore, certain equipment was permanently installed, and ample space was left for special apparatus for any one trip. Practically the entire inside of the car was rebuilt. The rear seat and most of the upholstery were removed and the double front seat was replaced by two individual, removable seats, which could be turned around to face the rear of the car while tests were being made. In place of the rear seat was the main test bench as shown in Figure 1. It is made in three sections: a low shelf directly above a spare tire compartment, a main bench above it, and a front hinged section, which may be turned back when not in use. The rear half of the lower shelf is occupied by the battery compartment, and a flush door in the upper bench surface gives access to it for maintenance. Figures 2 and 3 show the arrangement with certain testing apparatus in place.

At the left of the lower shelf, evident in Figure 3, is a power panel for controlling the various power supplies, and at the left of the spare tire are drawers for tools and other equipment. A rack for a soldering iron is fastened to one side of the car, where there are also compartments for thermometers, slide rules, small meters and writing materials. At the right of the lower shelf is a magneto telephone and compartments for leads and patch cords of various lengths. Lighting fixtures placed above the windows on both sides provide ample light under all conditions.

The main battery, in a ventilated compartment at the rear of the lower shelf, is rated at 100 ampere hours at 32 volts, and provides ample supply for an ordinary day's testing without operating any charging equipment. A rotary convertor, operated from the battery, provides a 110-volt, 60-cycle supply. This convertor is mounted under the hood just behind the radiator on the right-hand side as shown in Figure 4. On the other side, Figure 5, is a small gas-engine-driven generator used for charging the battery. In addition there is a 32-volt tungar rectifier that may be used for battery charging when the car is garaged where commercial power supply is available for this purpose.

As part of the permanent equipment, a high-gain detector, which may be connected to the car antenna for radio reception, is installed beneath the dashboard with all controls brought out in the dashboard itself, as shown

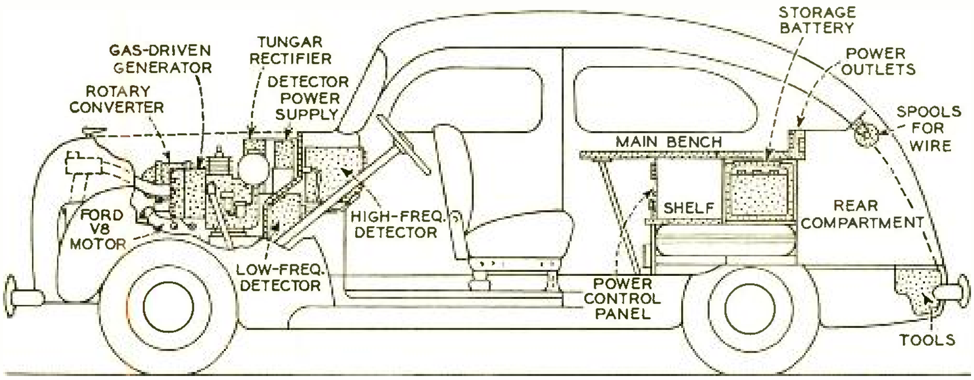

Figure 1

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Figure 2

in Figure 6. This equipment covers the frequency range from 10 to 18,000 kc, and serves a variety of purposes. In connection with field measurements of transmission line characteristics, it sometimes eliminates the need for a separate high frequency detector, thereby saving considerable space. It is also useful for picking up the Bureau of Standards standard frequency broadcasts, and in conjunction with a built-in 100 kc crystal oscillator provides the car with a secondary frequency standard that is of high precision.

The rear luggage compartment of the car, Figure 7, is equipped with drawers for spare parts, a wire rack for reels of various sizes and types of wire, and a large tool compartment

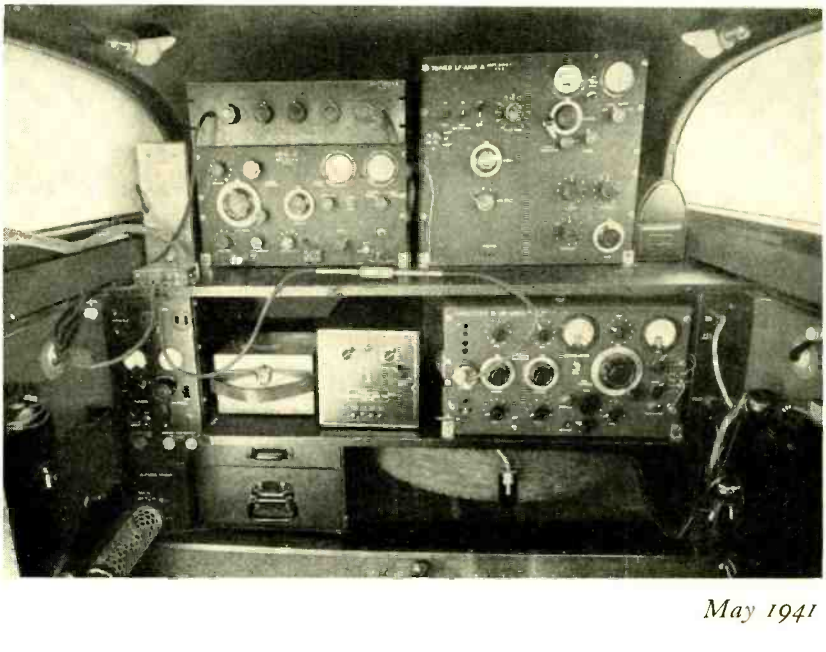

Figure 3

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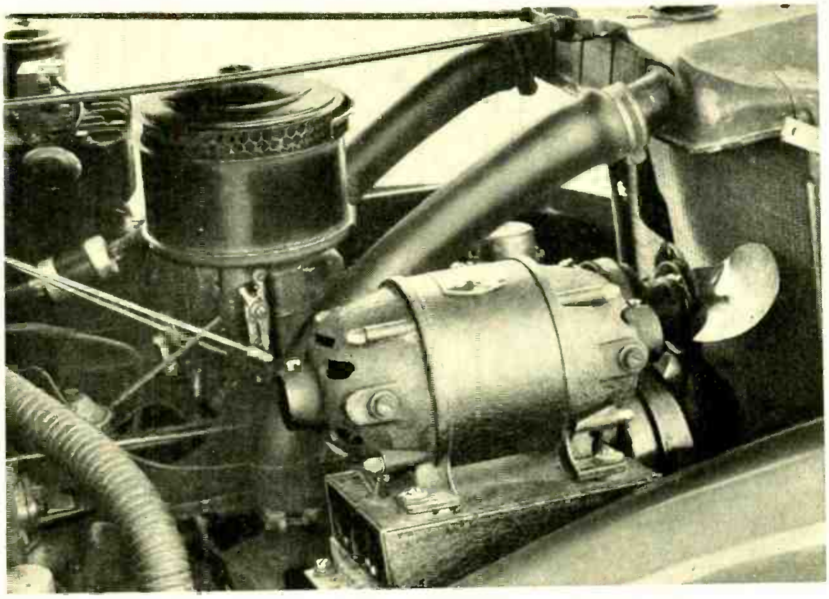

Figure 4

beneath the floor. The major part of this space, however, is available for miscellaneous equipment for the various types of tests. Outlets for power plugs are mounted in this rear compartment, and also along the sill at the rear of the main bench inside the car. In addition, a receptacle is mounted in one of the rear fenders for plugging in a 110-volt supply for operating the rectifier, and binding posts are mounted on the other fender for connection to the car telephone.

Not only is the car useful in getting out to remote repeater stations for tests, but it proves very helpful, as indicated in Figure 8, when tests are to be made over manholes in

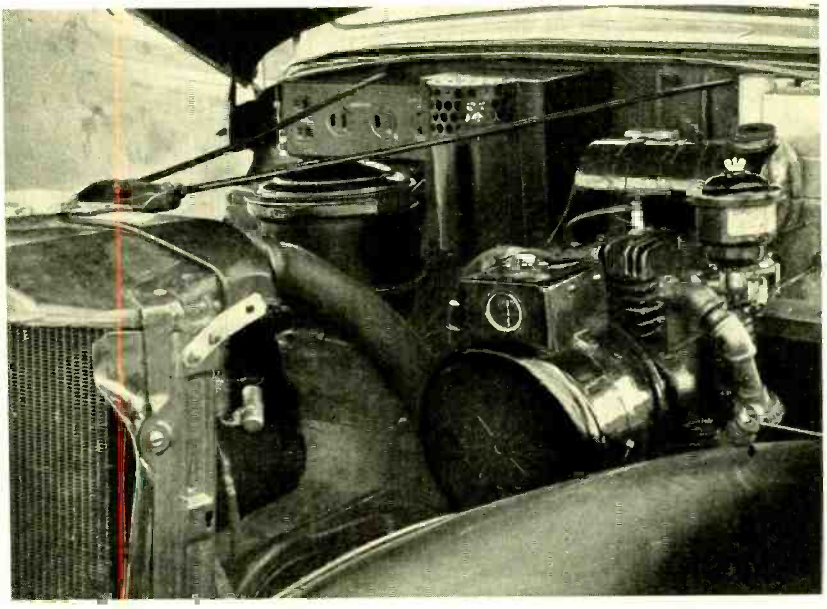

Figure 5

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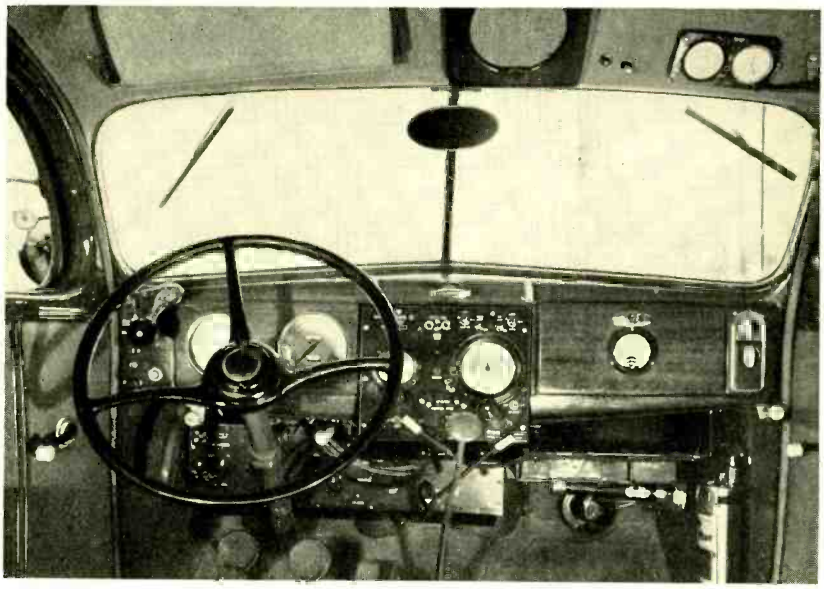

Figure 6

muddy streets. After the test leads have been brought up, as shown in Figure 8, the car is driven over the opening to protect the manhole during the measurements.

Occasionally deep snow prevented the car from being driven directly to the point of test and the more primitive method of transportation shown in Figure 9 was employed.

Since its completion, this mobile laboratory has covered some 25,000 miles, and has been in service 120 working days with temperatures ranging from 10° below zero to 110° above. Most of its life so far, which began in July 1939, has been spent in tests of the coaxial cable between Stevens Point and Minneapolis. In addition, however, it was used for tests on the

Figure 7

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Figure 8

New York-Philadelphia coaxial when the new type L 3-mc system was installed, and, more recently, on the Baltimore-Washington coaxial cable. At Mt. Pocono, Pennsylvania, it was used while making high-frequency measurements on open-wire lines. Its field of use covers a wide range of experimental work that is being carried out on transmission systems.

Figure 9

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Directional Selection for Toll-Line Signaling

By H. M. PRUDEN

Switching Development Department

TOLL lines, when in use for talking, are terminated in an impedance that approximately matches that of the line itself so as to keep echoes to unobjectionable values. These proper terminations exist only when a line is connected to a subscriber or operator at both ends. When the line is not so connected at both ends there is no conversation for echoes to disturb. When one subscriber is disconnected the lack of suitable termination has in the past been of no great importance; but with the use of voice-frequency signaling the presence of such an improper termination may affect the reception of the signals by an operator.

Consider, for example, two sections of toll line as shown in block form in Figure 2. It will be assumed that a subscriber served by switchboard A has placed to a subscriber served by switchboard C a call set up through an intermediate switchboard B. At the end of the conversation, after subscriber C has hung up, the operator at switchboard A must ring the operator at switchboard B to notify her to take down the connection. Since subscriber C has hung up, however, the line is not properly terminated at that end, and as a result echoes of the signaling current will return from C to B.

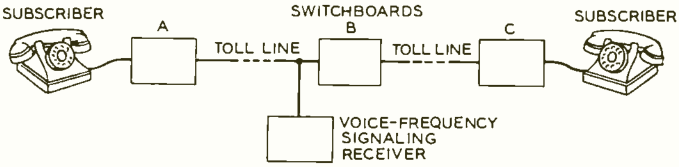

Fig. 2—Two sections of toll line showing voice-frequency signal-receiving device at an intermediate switchboard

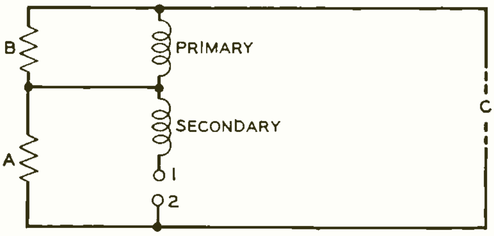

Fig. 1—An arrangement of a transformer and resistances to secure directional-selection action in toll-line signaling

The signaling consists of spurts of 1000-cycle current, and the echoes as received at B will be similar in form but shifted in phase by the time required for the signal to travel from B to C and back. Because of this shift in phase, pulses of the echo will overlap those of the direct signal. In extreme cases there may be almost a complete cancellation of the signal. To avoid such a situation, some arrangement is needed to make the signal-receiving circuit at switchboard B sensitive to signals coming from the direction of A but not from the direc-

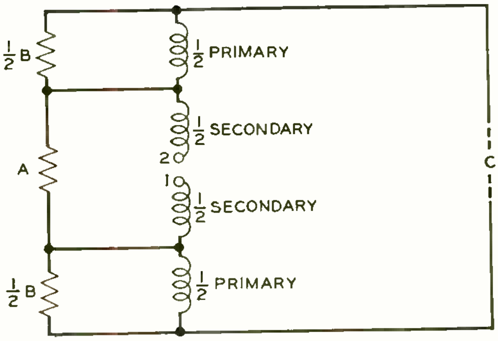

Fig. 3—Modification of Figure 1, to produce a balanced circuit

tion of C. A directional selection circuit developed for this use was mentioned in the Record* in connection with the 1000-cycle ringer oscillator.

It consists of two resistances and a transformer arranged as shown schematically in Figure 1. A voltage at C will cause a current to flow through A and B in series, and the voltage drop across B is impressed across the primary of the transformer. The ratio of the voltage drop across B to that across A will be as the ratio of these two resistances, and if the ratio of the number of turns of the secondary winding of the transformer to those of the primary is made the same as the ratio of resistance A to resistance B, the voltage across the secondary of the transformer will be the same as that across resistance A. As a result there will be no potential difference between points 1 and 2. These points could be left disconnected as shown, they could be connected directly together, or a circuit of any impedance could be connected between them without affecting transmission between C and A. A voltage inserted in any other part of the circuit, however, such as arm A, would create a difference of potential across points 1 and 2.

Such a circuit, therefore, may be used to provide directional selection for a voice-frequency signal-receiving circuit. Arm C would represent the line to switchboard C of Figure 2, A would represent the impedance of the line to switchboard A, and the signal-receiving circuit would be connected between points 1 and 2. The circuit must be slightly rearranged first, however, to put it in balanced form. To do this the resistance B and the transformer windings are each divided into two equal parts and arranged as shown in Figure 3. As arranged for application to a toll line, such as at switchboard B of Figure 2, the circuit would be as shown in Figure 4. Signals from switchboard A readily affect the signal-receiving circuit, but echoes from the toll line to switchboard C have no effect on it.

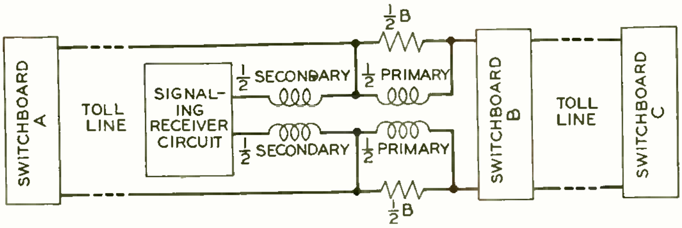

Fig. 4—Directional-selection circuit as applied to the toll circuit of Figure 2

In actual practice these ideal conditions are not attained. There is not a perfect balance between the resistances and the toll line so that some interaction occurs between the toll line toward switchboard C and the signal-receiving device. The impedance balance is sufficiently good, however, to improve considerably the signal-receiving circuit.

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*Record, *Jan.*, 1941, *p.* 147.

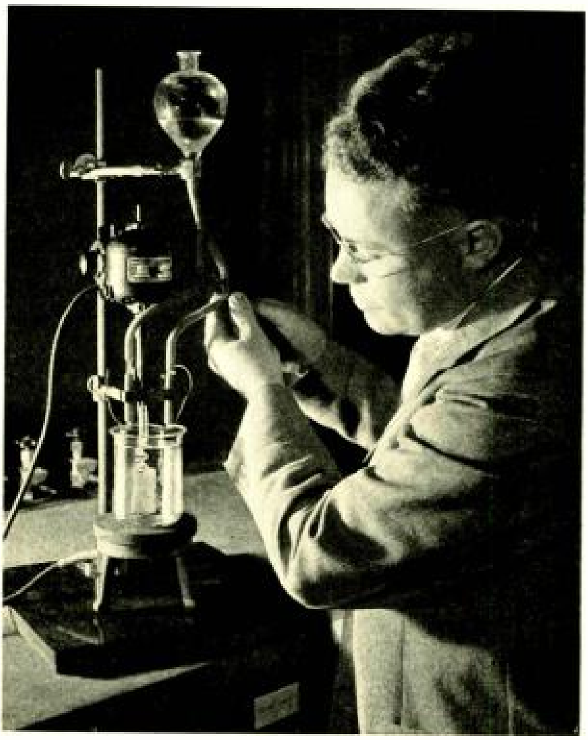
Internal Electro-Analysis

By C. L. LUKE
Chemical Laboratories

WHEN zinc and platinum are dipped into a solution of copper sulphate and connected externally by a wire, the zinc dissolves and metallic copper plates out on the platinum. For over fifty years analytical chemists have utilized this principle in electro-analysis. It is only in recent years, however, that the method has been used extensively in the separation and determination of impurities in alloys. A refinement of this procedure is used by the Laboratories to analyze several types of alloys, including cable sheath. The improved apparatus for the determination of copper and bismuth as impurities in lead cable sheath consists of two lead anodes enclosed in alundum shells and a single platinum gauze cathode, arranged to fit into a beaker. The anodes are made by winding pure lead wire around glass tubing in the form of a compact helix. Good electrical contact is obtained by connecting the three electrodes to a single binding post. The solution of the alloy to be analyzed is placed in the beaker and the anode shells are filled with dilute nitric acid.

Almost immediately the lead anodes begin to dissolve and copper and bismuth are deposited on the platinum gauze electrode in weighable form. Deposition of the metals is speeded by heating and stirring the solution.

With this apparatus as little as one milligram of copper or bismuth may be quantitatively separated from 100 grams of lead or lead alloy. A complete analysis for copper and bismuth can be made in approximately one hour while methods that had been formerly used required six or seven hours for the same determinations.



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Contributors to this Issue

J. A. Carr was a graduate from Virginia Polytechnic Institute in 1919 with the degree of B.S. in Electrical Engineering. After spending a year as instructor in Electrical Engineering at Massachusetts Institute of Technology he joined the Development and Research Department of A. T. & T. in 1921. In 1927 he transferred to the Laboratories where he has since been engaged in outside plant development work, particularly on problems relating to aerial systems.

C. L. Luke was graduated in 1930 from the University of Idaho with a degree of B.S. in Chemistry. He joined the Chemical Department of the Laboratories that fall, and since then has been engaged in research associated with analytical chemistry and in the development of chemical methods of analysis.

R. E. King after graduation left the State University of Iowa in 1921 and spent three years teaching at the University of Arkansas. In 1923 he joined the Systems Development Department of the Laboratories. Since then he has been concerned with the design of manual and step-by-step circuits, and is now in charge of a group handling intertoll dialing and step-by-step circuits.

Everett St. John was graduated from Harvard in 1910 with the A.B. degree and he received an S.B. at M.I.T. in 1913. After six months' experience with the Independence Inspection Bureau at Philadelphia he joined The Bell Telephone Company of Pennsylvania. During the war he spent a year and a half in the army as battalion signal officer, then joined the Development and Research Department of A. T. & T., transferring to the Outside Plant Department of the Laboratories in 1927. He has been concerned primarily with the design and development of construction materials and tools for the outside plant throughout his association with the telephone industry.

S. Rosen after graduation from the University of Southern California in 1930 with a B.S. degree in E.E. came directly to the Laboratories where he has been concerned with the development


J. A. Carr


C. L. Luke


R. E. King

of transmission testing apparatus for the maintenance and testing of voice and carrier telephone systems. Among the new toll systems for which testing equipment has been developed are high-quality program systems, open-wire and cable carrier systems, and more recently the coaxial cable carrier systems.

E. St. John

S. Rosen

G. B. Engelhardt was graduated from Cornell University in 1930 with the E.E. degree, and shortly after joined the technical staff of the Laboratories, associating himself with the carrier transmission group. In 1939 he completed a series of courses at Columbia University, under the Laboratories' part-time post-graduate study plan, leading to the M.A. degree in physics. His activities at the Laboratories have been concerned chiefly with the design of high-frequency measuring apparatus and, more recently, with field measurements on coaxial cable.

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H. M. Pruden joined the Engineering Department of Western Electric during the summer of 1919 and engaged in laboratory work on voice-frequency signaling. As a member of the Technical Staff since 1924, he has been engaged in development of voice-frequency signaling and dialing systems, and of voice-operated switching devices and control circuits for radio systems.

G. B. Engelhardt

J. B. Maggio

H. M. Pruden

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