BELL LABORATORIES RECORD

HALF-METER TUBE
C. E. FAY

REMAGNETIZER FOR RINGER MAGNETS
O. H. DANIELSON

PAPER INSULATION
J. M. FINCH

FEBRUARY 1937 Vol. XV No. 6

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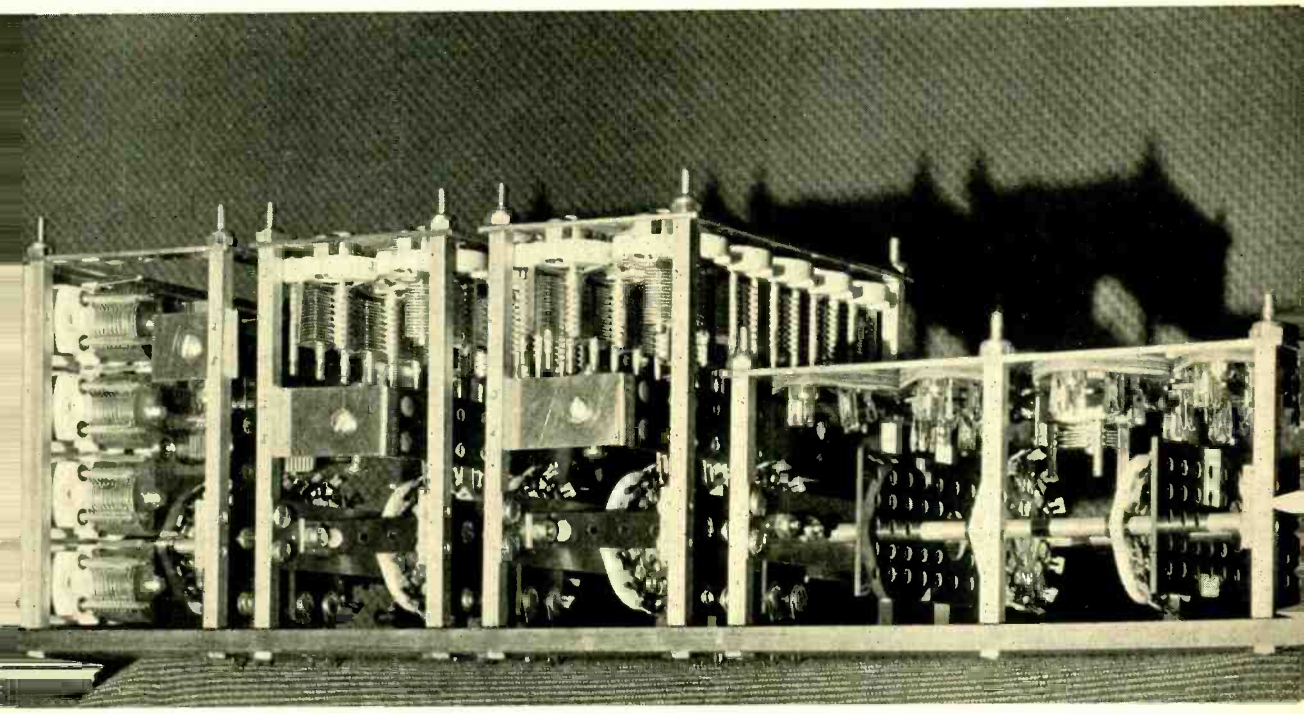

Experimental radio receiver in process of assembly

FEBRUARY, 1937

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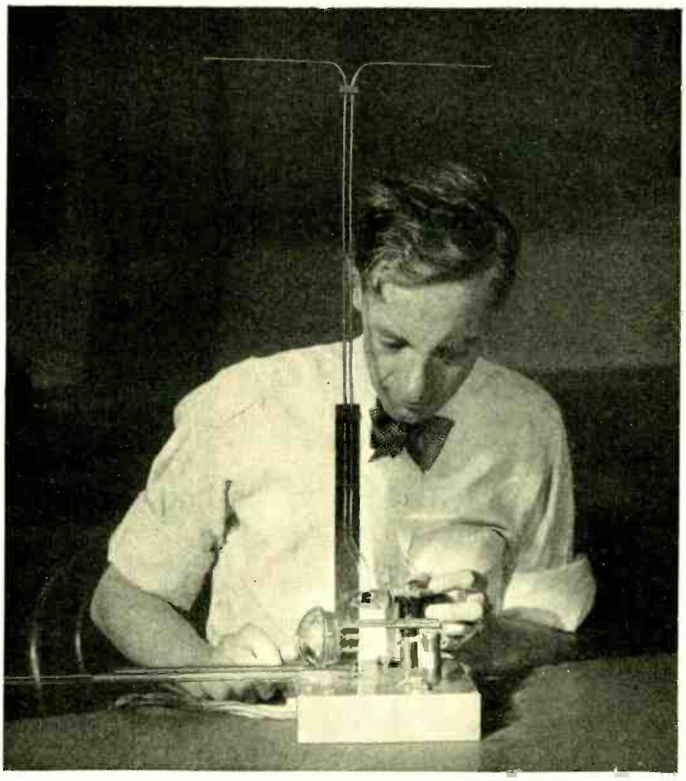


A Half-Meter Tube

By C. E. FAY
Vacuum Tube Development

DEVELOPMENT of radio communication at ultra-high frequencies has proceeded with such rapidity that whereas a few years ago the range of frequencies from 30 to 100 megacycles was practically unexplored, today experimental activity extends to much higher frequencies. The 304A tube—recently described in the RECORD*—is suitable for frequencies up to 300 megacycles, and considerable experimentation at these frequencies has been carried on, but beyond 300 megacycles very little has been done. Heretofore, the only sources of power at the very high frequencies, corresponding to wavelengths of less than a meter, were tubes of either the electron-oscillation or magnetron types.

Both of these types of tubes are under rather severe disadvantages compared to the more usual type of vacuum tube, since they both require critical adjustment, which is hard to maintain. The electron-oscillation, or Barkhausen tubes, moreover, are characterized by rather low efficiencies, and the magnetrons require a magnetic field of considerable intensity, which results in rather large and heavy equipment, and additional power supply. To avoid these diffi-

*RECORD, *August*, 1935, *p.* 379.

culties at the high frequencies, a new tube of the ordinary negative-grid type has recently been developed, known as the Western Electric 316A. Although of lower power rating than the 304A, it may be used for frequencies as high as 600 megacycles, or wavelengths of half a meter.

This new triode, shown in Figure 2, is of radically different design compared to what has heretofore been standard practice. The conventional base has been completely eliminated, and the leads—in the form of tungsten rods—are brought out through a molded-glass end plate, which is part of the tube envelope. Circuit connections are made through brass sleeves that slip over the tungsten rods and are fastened to them by set screws. Soldering is not recommended because of the high operating temperatures. Within the tubes, the electrodes are mounted directly on the tungsten leads and as close to the glass as feasible, so as to hold the inductance and resistance of the leads to minimum values. To attain short electron-transit time, and also to keep the inter-electrode capacitance within bounds, the electrodes have been made very small. The cylindrical plate is only an eighth of an inch in diameter.

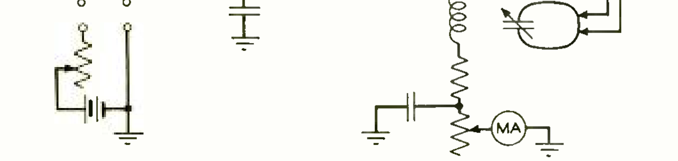


Fig. 1—Schematic of an oscillator circuit employing the 316A vacuum tube

The necessity for the small size is evident when it is realized that at 600 megacycles, one micro-microfarad has a reactance of only about 260 ohms. The smaller the size, on the other hand, the more difficult it is to dissipate the heat from the electrodes.

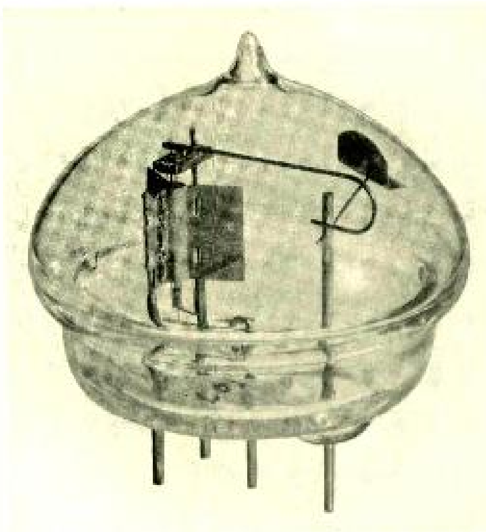


Fig. 2—The 316A vacuum tube

To avoid heating difficulties arising from the very small size of the tube elements, the plate is provided with three large radial fins, and the material is roughened to assist further in heat radiation, with the result that thirty watts plus an additional seven watts used to heat the filament may be readily radiated. The filament is a single strand of thoriated-tungsten wire passing along the axis of the plate cylinder. The grid requires an unusual design to obtain proper functioning in the restricted space available. For efficient operation, electron emission from the grid must be prevented, and this requires that its temperature be kept relatively low.

Instead of employing the conventional helical winding, the grid is made of the cage type, with vertical rods connecting to collars at each end. This construction not only permits the heat generated in the rods to be readily conducted to the end collars, where it can be effectively radiated, but provides an electrode of low inductance and resistance to the flow of high-frequency currents. The entire grid structure is blackened to improve its heat-radiating properties and to prevent the emission of electrons from it. No solid dielectric is used inside the tube envelope except a small piece holding the grid in alignment, which is nominally at grid potential and avoids a closed loop in the grid-supporting structure, which might absorb high-frequency power. The arrangement of the elements is indicated in Figure 3. Nonex glass is used for the tube envelope to avoid cracking at the high temperatures, and because of its better dielectric properties.

TABLE I—CHARACTERISTICS OF THE 316A VACUUM TUBE

Filament Potential 2.0 Volts	
Filament Current 3.65 Amperes	
AVERAGE INTERELECTRODE CAPACITIES	
Plate to grid	1.6 mmf.
Grid to filament	1.2 mmf.
Plate to filament	0.8 mmf.
AT A PLATE POTENTIAL OF 450 VOLTS AND PLATE CURRENT OF 67 MILLIAMPERES	
Amplification factor	6.5
Transconductance	2400 micromhos
Plate resistance	2700 ohms
AS AN OSCILLATOR OR AMPLIFIER—PLATE MODULATED	
Maximum direct plate potential	400 volts
Maximum direct plate current	80 milliamperes
Maximum direct grid current	12 milliamperes
Maximum plate dissipation	30 watts
NOMINAL POWER OUTPUT OBTAINABLE	
Frequency—Mc	Power Output—Watts
300	8.5
400	8.0
500	6.5
600	4.0
750	Limit of oscillation

It is hoped that this new tube will assist materially in the study of radio transmission in the ultra-high-frequency region, and in the utilization of this region for general communication. Antenna dimensions at these short waves are very small; the length of a half-wave doublet antenna at 500 megacycles is less than a foot. An oscillator circuit arranged for plate modulation is shown schematically in Figure 1, and as actually built, in the photograph at the head of this article. A power pentode, such as the Western Electric 312A, which could be driven

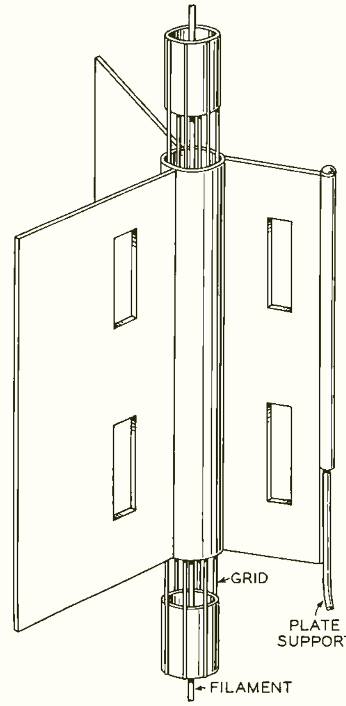
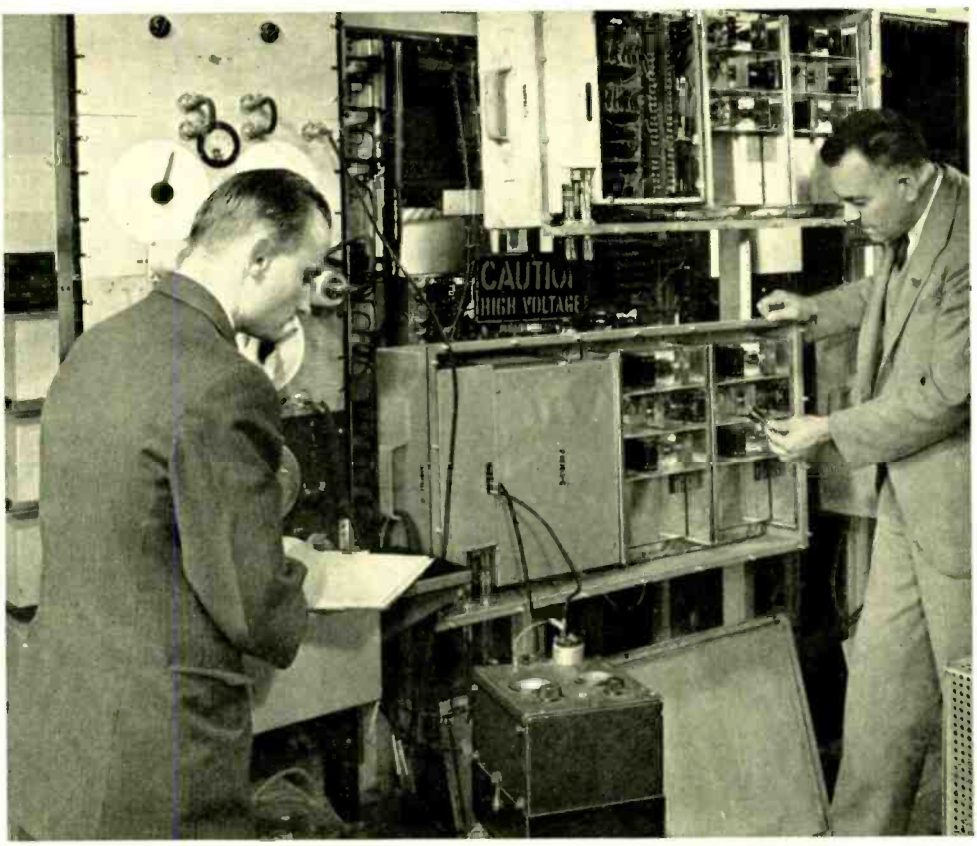


Fig. 3—The elements of the 316A vacuum tube

by a carbon microphone through a transformer, would provide sufficient power for modulation. Six watts can be radiated from this transmitter. Suitable receivers can be made using tubes already available, so that many uses will undoubtedly be found for these ultra-high-frequency channels.

Because of its low capacitances and lead inductances, this new tube is very useful for ultra-high-frequency measuring equipment. It also affords a convenient and adequate source of power for experiments with antennas and radiating systems, which may be built at very little cost, and is suitable for variable-frequency apparatus at frequencies above 300 megacycles. The characteristics and ratings of the tube are given in Table I.



B. Dysart and M. E. Strieby testing an unattended repeater for coaxial cable, in the carrier laboratory at Varick Street

Stabilized Feedback for Radio Transmitters

By L. G. YOUNG
Radio Development

THE output of a perfect radio transmitter, properly rectified and adjusted for volume, would be found to be an exact copy of the speech or signal on its input side. For any actual transmitter, however, the output is found to differ somewhat from the input in three respects. In the first place, the amplitudes of the input and output waves will not maintain the same relative values as the frequency of the input voltage is varied. The second difference is the presence of noise in the output that is not present in the input signal. This noise is principally a hum due to the use of alternating current as the primary source of power for heating the filaments, biasing the grids, and energizing the plate circuits. The third difference between output and input lies in the wave form. When a single-frequency wave is applied to the input, the output includes the harmonics of this frequency as well as the fundamental itself, and thus has a different wave form.

The first of these differences is not usually serious, since the frequency characteristic of a broadcasting transmitter can ordinarily be made flat to 1 db over a range from 50 to 10,000 cycles by the proper selection of the low-power audio-coupling circuits, the cost of which is generally less than 1% as much as that of the transmitter. The other two differences are much more formidable, and before the advent of stabilized feedback could be satisfactorily reduced only at considerable expense.

The greater part of both the noise and distortion arises in the final amplifier stages, and for this reason its reduction becomes particularly expensive for the larger transmitters. To reduce the hum, direct-current generators have commonly been employed to supply the filaments, using filters to minimize the commutator ripple. For a 500-kw transmitter, however, a current of some 5000 amperes at thirty volts is required, and the cost of these generators, which must generally be supplied in dupli-

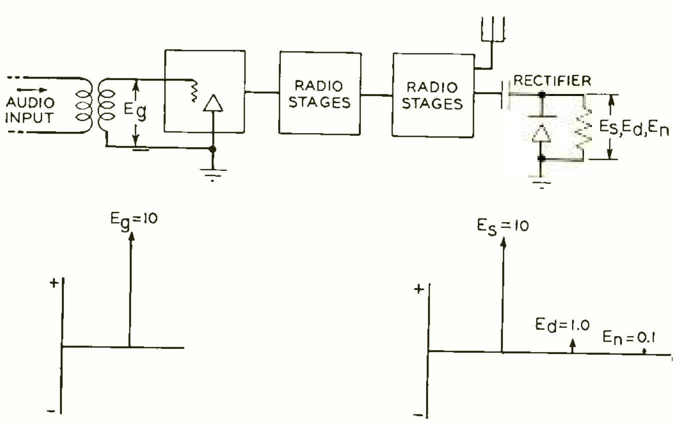


Fig. 1—In the output of a radio transmitter there are certain components in addition to the desired signal. These are chiefly a distortion component and a noise component

cate, plus the expense of their maintenance becomes considerable. The harmonic distortion, on the other hand, is caused chiefly by the nonlinearity of the final amplifying stage. The input-output characteristics of vacuum tubes are not linear up to the limits of their power output, and if to avoid the distortion the tubes were used over only the straight part of their characteristics, considerably greater power would have to be provided in the final stage, and the plate-circuit efficiency would become extremely low.

In the past, engineers have incorporated sufficient tube capacity in the final stage to keep the distortion within tolerable limits, but the initial and operating cost of the transmitter has been proportionately increased. Recent revisions in the standards of performance demanded of radio transmitters have set the requirements on permissible distortion to so low a value that for very large transmitters it becomes economically impracticable to secure sufficiently low distortion by these means. With the increasing size of broadcasting transmitters, therefore, designers are faced with what has seemed the almost impossible task of securing low noise or hum and low harmonic production at a practicable cost. Fortunately, the development of stabilized feedback by H. S. Black has pointed an easy solution. So effective is this new development that the filaments of the tubes may be heated directly from alternating current, and the final amplifiers need only be large enough to carry the modulating peaks, and yet the hum and distortion may be kept well below all likely requirements.

A very much simplified schematic of a radio transmitter might be represented as shown in Figure 1, where a rectifier is connected to the final stage so that a portion of the output will be available for comparison with the input. For simplicity it may be assumed that the input is a single frequency, and under these conditions the input and output voltages could be represented as shown in the lower part of the illustration—the amplitude of the rectifier output being adjusted so that the fundamental frequency has the same value as that of the input to the transmitter. This input voltage is marked E_g, and the corresponding output voltage of the rectifier, although made equal to it by adjustment, is marked E_s to indicate that in general it is different from that on the grid of the input stage.

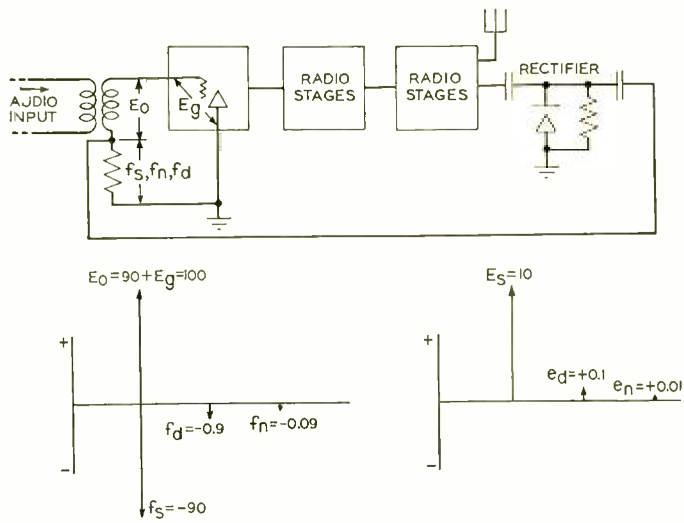


Fig. 2—Feedback returns to the input a portion of the output in reverse phase, and in this way cancels part of the output noise and distortion

Two other voltage vectors are indicated in the output—one, E_d, representing the distortion voltage, and the other E_n, representing the noise voltage that is generated within the transmitter itself.

Although E_d and E_n are actually generated within the transmitter, and in fact, practically always in the final stage of the transmitter, the effect is exactly the same as if these voltages were produced at the grid of the first tube, and the rest of the transmitter were free from distortion and noise. Thus if equivalent voltages 180° out of phase could be introduced into the grid circuit of the first tube along with the signal voltage, the distortion and noise would be cancelled out and the transmitter would be perfect. The principle of feedback is thus to carry back to the input of the transmitter a portion of the output in reversed phase, so that the distorting elements in the output will be cancelled by similar but negative voltages. Actually, of course, the full value of the distortion cannot be completely cancelled, for if it were there would be none of the distortion remaining in the output to be fed back. There must always remain a vestige of the distortion in the output that may be adjusted to the proper value and then fed back to the input.

The various relationships involved may be illustrated for the moment by considering the harmonic distortion alone, and assuming that without feedback the distortion was 10% of the signal in amplitude, and that it is desired to reduce it to 1% of the signal, or to one-tenth of its former value. This ratio of final to initial distortion defines the amount of feedback required. The distortion under feedback conditions will be equal to the original distortion plus the distortion fed back, which is in phase opposition to the original distortion, and thus the amount of distortion to be fed back will be equal to the difference between the original and final distortion. Thus, if the original distortion was 1 volt and the final distortion is to be one-tenth of that amount, or 0.1 volt, the amount of feedback will be —0.9 volt, or nine times the final distortion and in opposite phase.

The feedback circuit, however, picks up not only the harmonic-distortion components but the noise and the signal components as well, and all will be reversed in phase and equal to nine times their final values in the output circuits. The purpose of feedback, however, is to reduce the noise and distortion without reducing the signal, but it is obvious that if a signal nine times the original and in opposite phase were fed back, the amplitude of the input signal would have to be changed in order to keep the output signal the same. In other words, the input signal amplitude must be increased so that when combined with the feedback signal, the sum will just equal the original input. Since the signal fed back in the example taken is minus nine times the output signal, the increased input signal must be ten times the original signal in order that the difference will give the same signal amplitude as existed before feedback was applied. If the original signal was ten volts, the signal feedback will be minus 90 volts, and the increased input signal must be 100 volts so that the net final signal will be 10 volts, or 100 minus 90.

The amount the input signal must be increased under feedback conditions, or the ratio of input voltage without feedback to input voltage with feedback is numerically equal to the ratio of distortion voltage with feedback to distortion voltage without feedback, and for convenience is taken as the measure of feedback. The amount of feedback in db is thus twenty times the logarithm of the ratio either of the input voltage without feedback to that with feedback, or of the final to initial distortion. In the example taken for illustration this ratio is ten, and thus there may be said to be 20 db of feedback.

In Figure 2 is shown the same transmitter as in Figure 1, with the addition of the feedback circuit, and below it are the various voltages under feedback conditions. Small let-

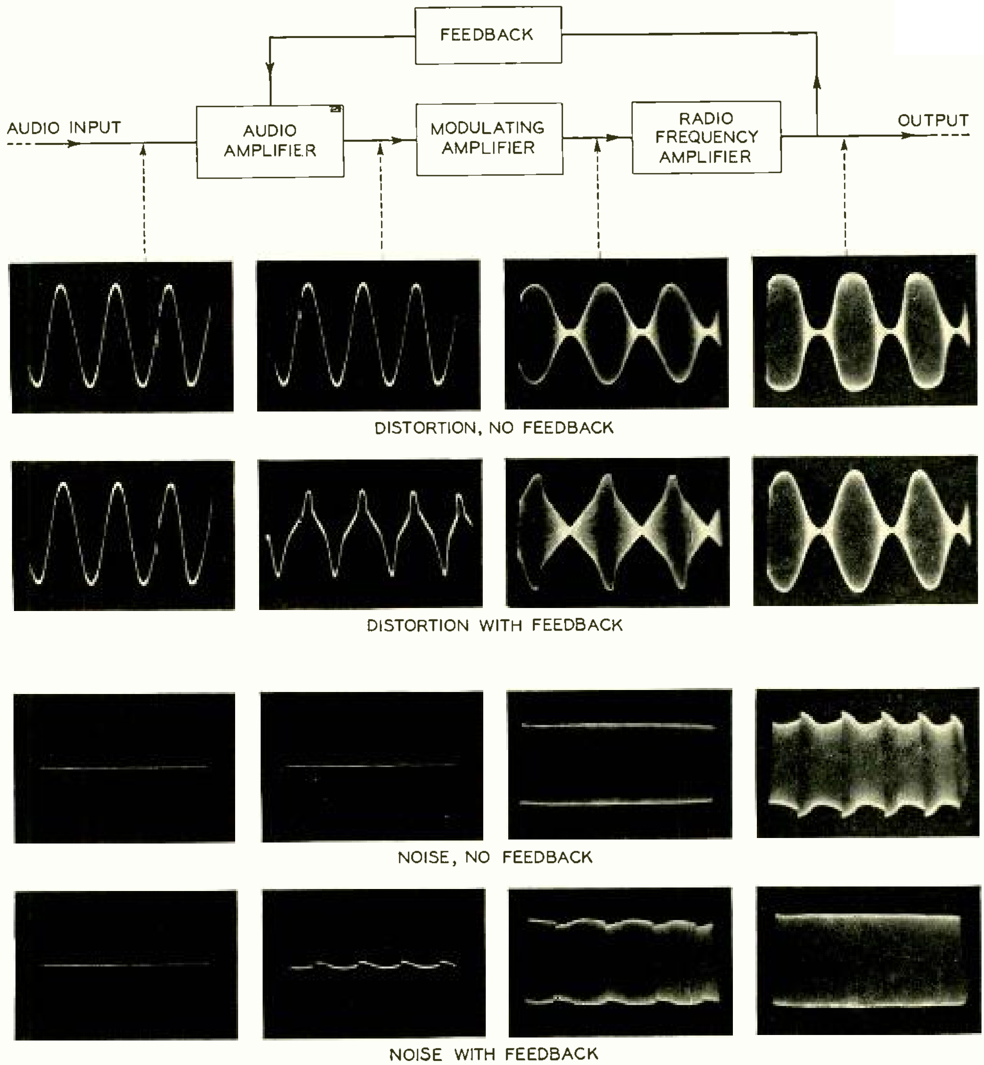


Fig. 3—The effect of feedback on the signal at various points in the transmitter is illustrated by the oscillograms shown above. It will be noted that with feedback a definite distortion or noise is introduced that is the inverse of that generated in the transmitter. This inverse distortion and noise cancels the greater part of that generated in the final stage, and thus results in a signal that is nearly free from undesired components

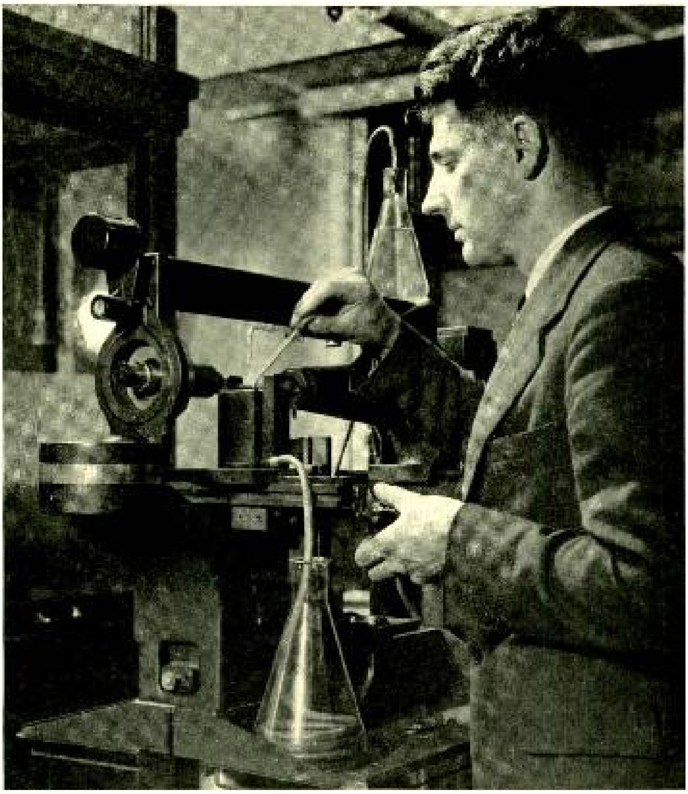
ters are used to indicate the reduced values of the noise and distortion voltages. The noise voltage with feedback, is in the same ratio to the original noise voltage as the distortion voltage with feedback is to the original distortion, all forms of distortion being reduced the same relative amount.

In practice, the phase difference between the input and feedback voltages can be made 180 degrees at one frequency only and the simple, ideal condition just depicted is not realized. It is the problem of the transmitter-circuit designer to control and manipulate the phase shifts and gains throughout the circuits involved so that the feedback and input voltages do not become in phase except at frequencies far removed from the transmitted band. The gain of the feedback loop at these frequencies where the voltages become in phase must be reduced to less than unity or singing will result. It is not always easy to apply feedback to a radio transmitter, but the results obtained with this arrangement cannot be achieved by any other known means which is as simple and economical.

The oscillograms of Figure 3 show how feedback action deliberately predistorts the audio signal impressed upon the grid of the tube at the point of feedback, and how this predistorted wave, which is in a sense the inverse of the distortion generated within the transmitter, is applied to the various stages. In the case of this particular transmitter, the distortion and noise were purposely made high to portray more vividly the action by means of oscillograms, and, because of the limitations of oscillograms, the change in voltage amplitude associated with the grid circuit where the feedback action occurs has been purposely omitted.

Since the frequency characteristics of radio transmitters are highly satisfactory without feedback, the action of feedback in this respect will not be discussed other than to mention that its application also flattens any irregularities of this nature that may exist in the transmitter.

The great advantage of feedback is obvious once its action is understood. The improvement it gives as a result of the large reduction in noise and distortion with a minimum of additional apparatus is of value to listeners as well as to the broadcaster. Of particular importance to the operators of the transmitter, however, is its extreme simplicity. Stabilized feedback is inherently automatic; regardless of the type of distortion or noise generated, the reduction will always be the same without any adjustments being necessary. With a non-automatic method of correction, every change of condition in the transmitter, such as a change in tubes, will require a readjustment, while with stabilized feedback, once the original adjustments have been made at the time the transmitter is installed, no further attention is required.



Measuring the Plating on Screw Threads

By E. C. ERICKSON
Telephone Apparatus—Electromechanical

IN spite of the ever-growing number of substitute fastening devices, the common screw remains a very vital factor in mechanical construction. No better illustration of this fact can be given than that found in the telephone industry, which uses millions of screws and threaded parts. The ever-changing conditions under which the telephone must function and the continuous improvements in design call for a set-up of equipment, any single part or an entire unit of which may readily be removed for repair or replaced by some new or improved development. Thus many of the individual parts in telephone apparatus will be found held together by the common machine screw. These parts are attached to mounting plates which in turn are screwed to standard relay racks. The whole set-up from the individual piece of apparatus to the complete unit of assembly is held together by the machine screw. It is, therefore, not surprising that the Bell System gives much attention to the improvement in quality and the standardization of these threaded parts. National Standard screw thread sizes and fits have been adopted and much has been done in the methods of producing and gauging the various qualities of dimensional fit that is required in industry.

There is one phase of the work, moreover, which has received little attention outside the telephone field. It involves plated or finished screw threads. Since telephone apparatus is subjected to all possible climatic conditions, it must withstand, among other things, any probable change in temperature and humidity. Thus iron screws which represent the bulk of the threaded product used in telephone apparatus must not only be free enough from a dimensional fit standpoint to be engaged or removed readily from their mating members and yet close enough to resist loosening under vibration but they must also be protected against rust or corrosion by a suitable coating or plate.

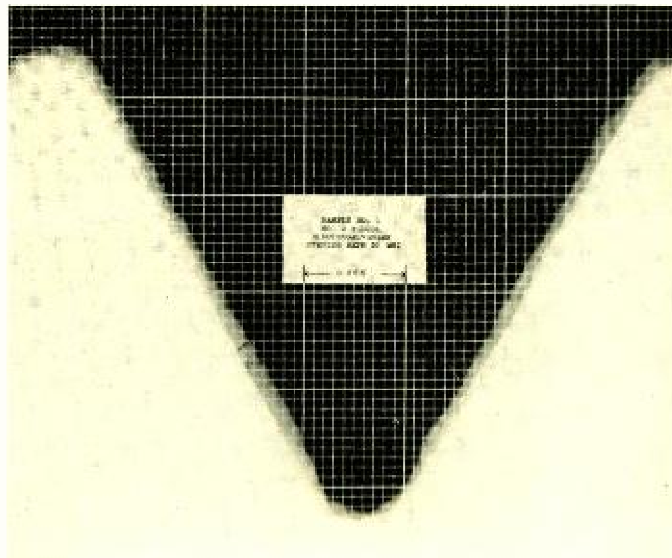


Fig. 2—Shadowgraph of a satisfactorily plated screw

The corrosion protecting plate best suited to a screw thread from a dimensional fit standpoint is one which gives the maximum protection per milligram per square inch and is capable of the closest control of distribution and thickness over the uneven threaded area. The protective qualities of the various plates available have been determined previously in connection with other apparatus problems so that the work on plated threads is reduced to determining the thickness and uniformity of distribution of such finishes on threads.

In the absence of any standard gauging apparatus which could be used to make such determinations accurately, a special method, which employs an optical contour projector, was devised. As illustrated in the diagram, this is essentially one in which

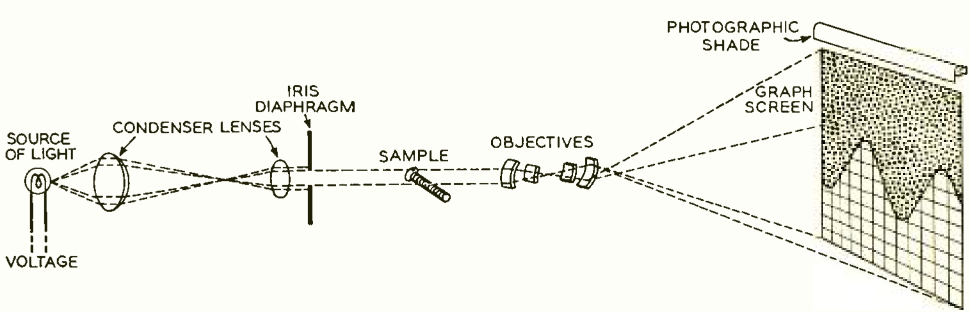


Fig. 1—Optical contour projector used to determine thickness of finish on screw threads

the highly magnified contour of the screw without the finish or plate is superimposed on a record of the contour of the screw with the finish.

The screw, after being carefully cleaned of any particles of dirt, is rigidly mounted in a jig at the object position of the projection system which is set at a definite magnification. The upper side of the screw is adjusted in the center of the field for the correct helix angle so as to insure a perfect outline of both sides of the thread as shown in Figure 1. A partial exposure of the image of the top of the thread with the plated finish is then made on photograph paper through a graph screen which provides graph lines along with the contour of the thread to aid in analyzing the results.* The finish is next removed from the threads by a stripping solution which is applied to the thread from a dropper after which it is carefully washed with distilled water and dried by a stream of heated air. This is all done without disturbing the relative position of the screw or the recording paper. A second exposure is then made, this time of the stripped screw, with the image superimposed on the image already made of the plated screw.

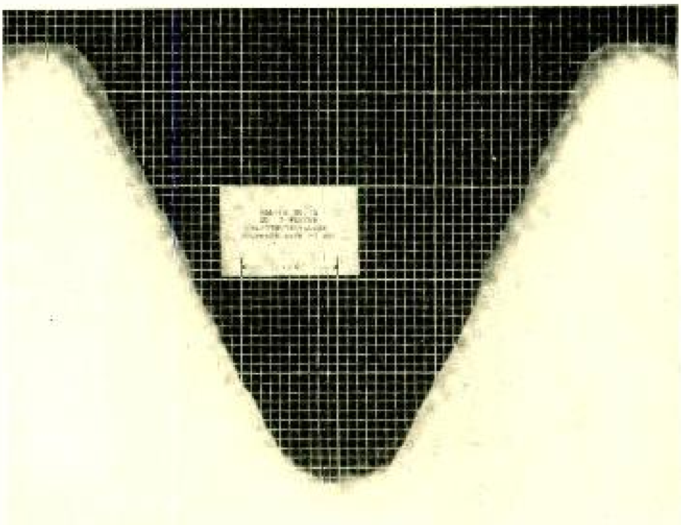


Fig. 3—This shadowgraph shows an unsatisfactory plate, since the deposit is almost entirely on the outside of the thread

By observing the thickness and uniformity of distribution of the plate in this manner, it is possible to determine not only its suitability for screw thread use but also the adequacy of this process of applying it. This is shown in Figures 2 and 3 where two contourgraphs representing zinc plates of 50 milligrams per square inch are given. The finish can be seen as the partially exposed area surrounding the screw thread. In one case a sulfate solution was used and in the other a cyanide bath. The former deposits almost all of the zinc on the upper portion of the threads with almost no finish or protection against corrosion near the minor diameter. This uneven distribution also results in poor thread form and unsatisfactory engagement with the mating part. The cyanide bath gives a more uniform plate over the entire thread which not only offers good protection but simplifies the undercutting of the thread before plating.

Accurate records can be made by this method of samples of various finishes and it is possible to select by the uniformity of distribution and thickness, finishes or plates suitable for threaded work. This method also provides a means of determining the variation of the plate thickness.

*Record, *March,* 1932, *p.* 255.

Remagnetizer for Ringer Magnets

By O. H. DANIELSON
Telephone Apparatus Development—Electromechanical

THE audible signal which notifies a telephone subscriber of an incoming call is produced by a "ringer." This is an electric bell in which the clapper, as it vibrates, strikes alternately a pair of gongs. The clapper is driven by the armature of a double coil electromagnet. The armature itself and the cores of the electromagnets are biased by an associated permanent magnet. The ringer is operated by a low-frequency alternating current and the magnet coils are wound so that this current alternately strengthens the pull of one core on the armature and then that of the other. This makes the armature vibrate and rings the bells. To prevent the armature from operating from other currents it is mechanically loaded in one direction by a biasing spring. For satisfactory operation the strength of the permanent magnet must be maintained above a definite limiting value.

In the manufacture of ringers the permanent magnet is magnetized after the assembly. As a result, however, of later handling and particularly of demagnetizing influences encountered during service it sometimes happens that the strength of the permanent magnet is reduced sufficiently to impair the operation of the ringer. In the past it has been necessary to return the subscriber set to the nearest shop of the Western Electric Company when remagnetization is needed.

Recently a simple remagnetizer was devised which was operated by dry cells and could be used on ringer magnets without removing the ringers from subscriber sets. The experimental use of this device resulted in such general improvement in the capabilities of ringers that the development of a similar tool was undertaken by the Laboratories for use in Telephone Company storerooms and on the subscribers' premises. It was anticipated that such a tool would reduce ringer maintenance costs and would result in a general improvement in the quality of ringers. Early in the development it was suggested by I. C. Pettit that a device using a cobalt steel magnet would accomplish the desired degree of remagnetization with a possible saving in weight and the elimination of direct current.

Fig. 1—The remagnetizer can be used on ringers assembled in the subscriber sets housed in metal and phenol plastic boxes

The remagnetizer as constructed (coded the No. 481A Tool) consists

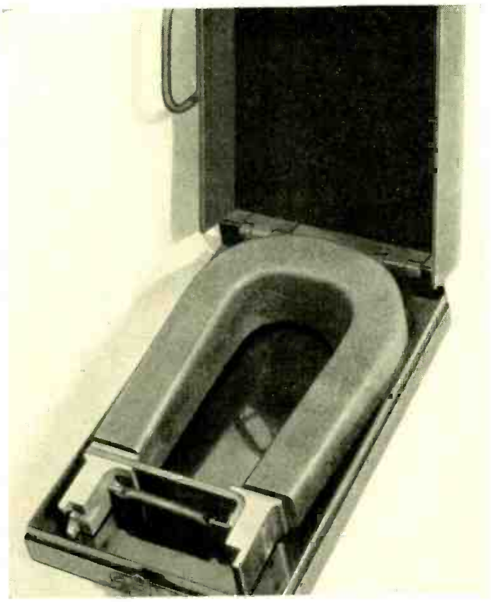


Fig. 2—The sheet steel carrying case also serves as a keeper for the magnet and as a magnetic shield

essentially of a "U" shaped permanent magnet of cast cobalt steel and a pole-piece assembly which are illustrated in Figure 2. The pole-piece assembly comprises two soft steel pole-pieces designed to fit on the ends of the ringer magnet and a forked-shape phosphor bronze tie bar which is permanently fastened to one of the pole-pieces. The forked portion of the tie bar slides in grooves in the sides of the other pole-piece and the pole-pieces are drawn toward each other by means of a helical spring. This self-adjusting feature insures a snug overlapping as well as butting contact between the pole-pieces and the ends of the ringer magnet. As generally used the pole-piece assembly is fastened permanently to the cobalt steel magnet by means of a screw which passes through one pole-piece and is threaded into one of the pole-faces of the permanent magnet. A single application of the device to a ringer magnet is all that is required to accomplish remagnetization.

Another arrangement of the tool involves applying the pole-piece assembly to the ringer magnet before the magnetizing magnet is brought into contact with the pole-piece. This facilitates the use of the remagnetizer on ringers in inaccessible locations. With this arrangement the screw which ordinarily fastens the pole-piece assembly to the magnetizing magnet is replaced by a threaded dowel pin. This serves to locate the magnet properly and to prevent it from being accidentally reversed with consequent changes of the ringer's polarity. The pole-piece assembly is first fitted to the ringer magnet, after which the magnetizing magnet is applied.

A sheet steel carrying case, which also acts as a keeper for the magnet as well as a magnetic shield, is provided for the tool. The accumulation of magnetic materials on the magnet and the accidental magnetization of watches when the tool is not in use is thus avoided. The total weight of the tool and the carrying case is about 7½ lbs. of which the magnet accounts for approximately 4¾ lbs.

This tool has been tried out by all of the associated Telephone Companies with results which have been so promising that it has now been made available for general use.

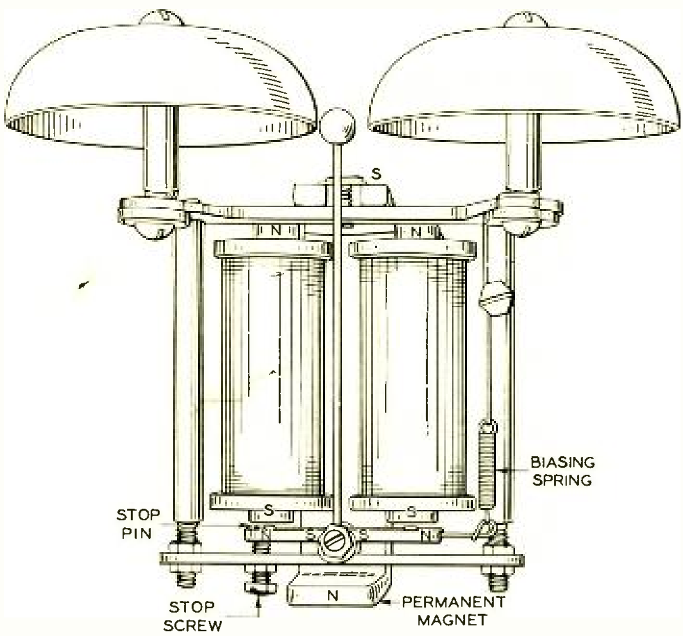


Fig. 3—The "ringer" consists of a pair of gongs which are struck alternately by a clapper attached to the armature of a double coil electromagnet. The armature and cores of this electromagnet are biased by a permanent magnet and a spring and stop keep the bells from being rung by unwanted currents

I

Preparing to transfer a droplet of solution to a three-electrode cell where it will be electrolyzed under the microscope to detect minute quantities of copper

II

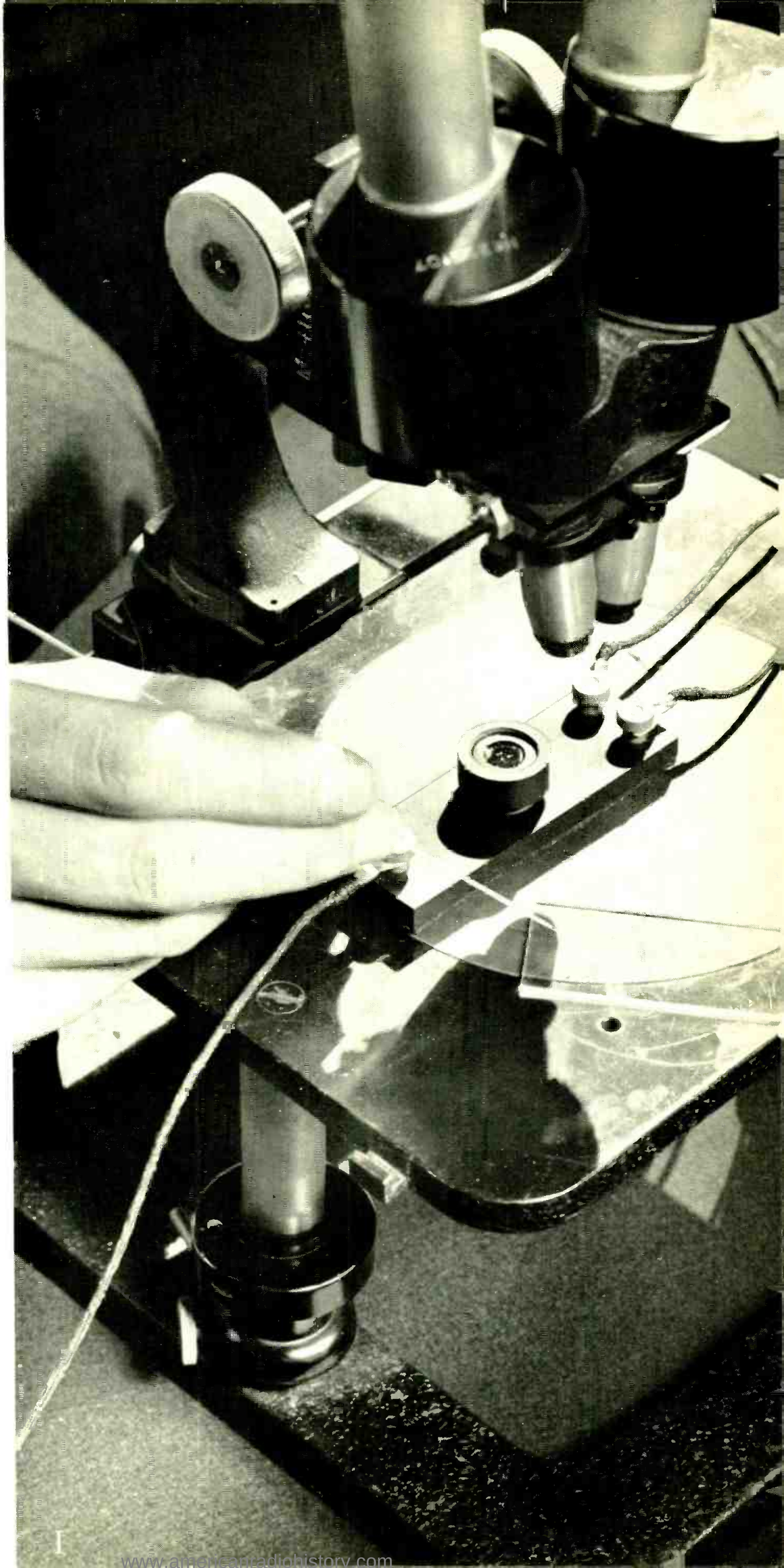
March of the repeater tubes—a new one leading a line of experimental tubes made during its development

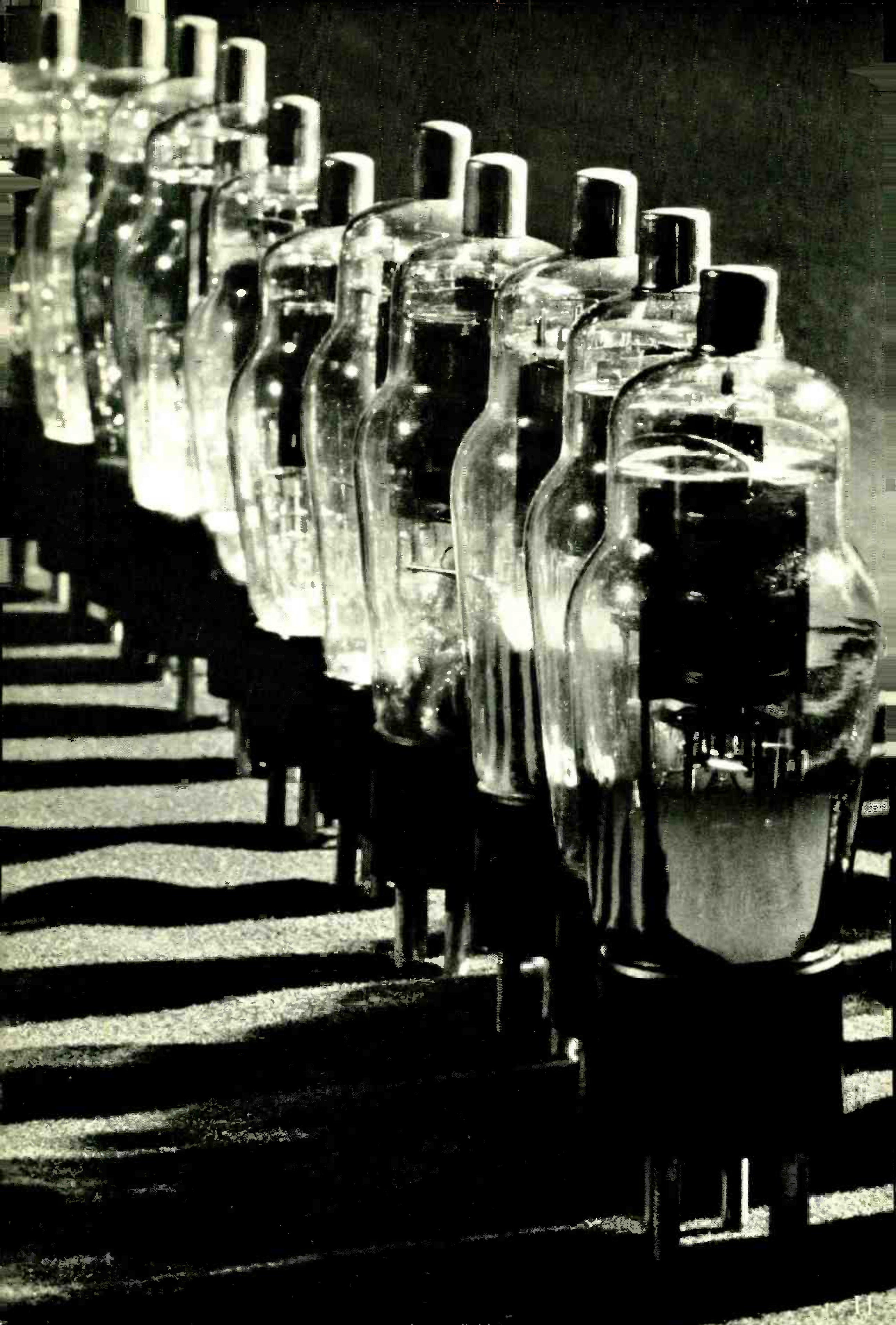
III

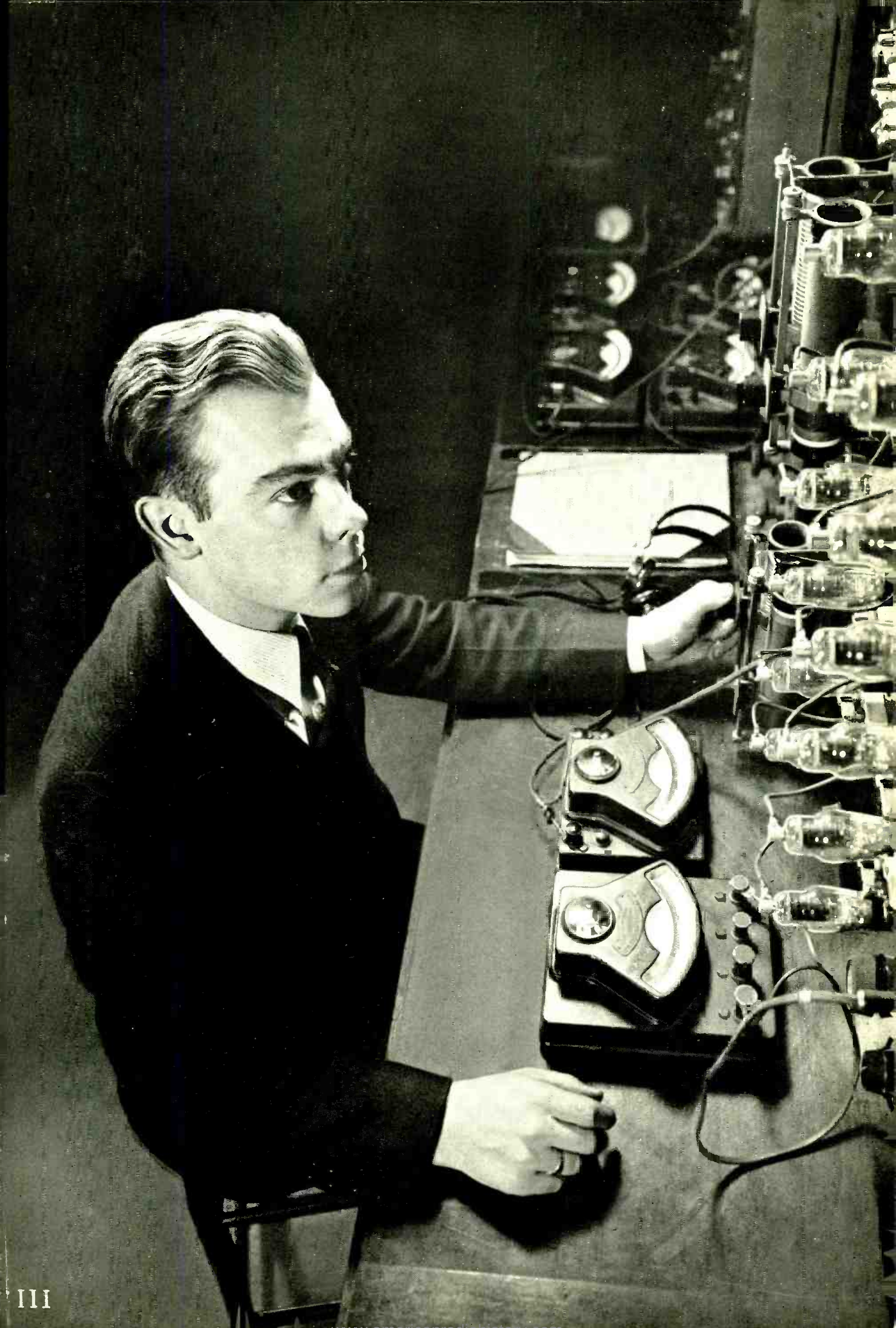
Testing new repeater tubes for carrier systems

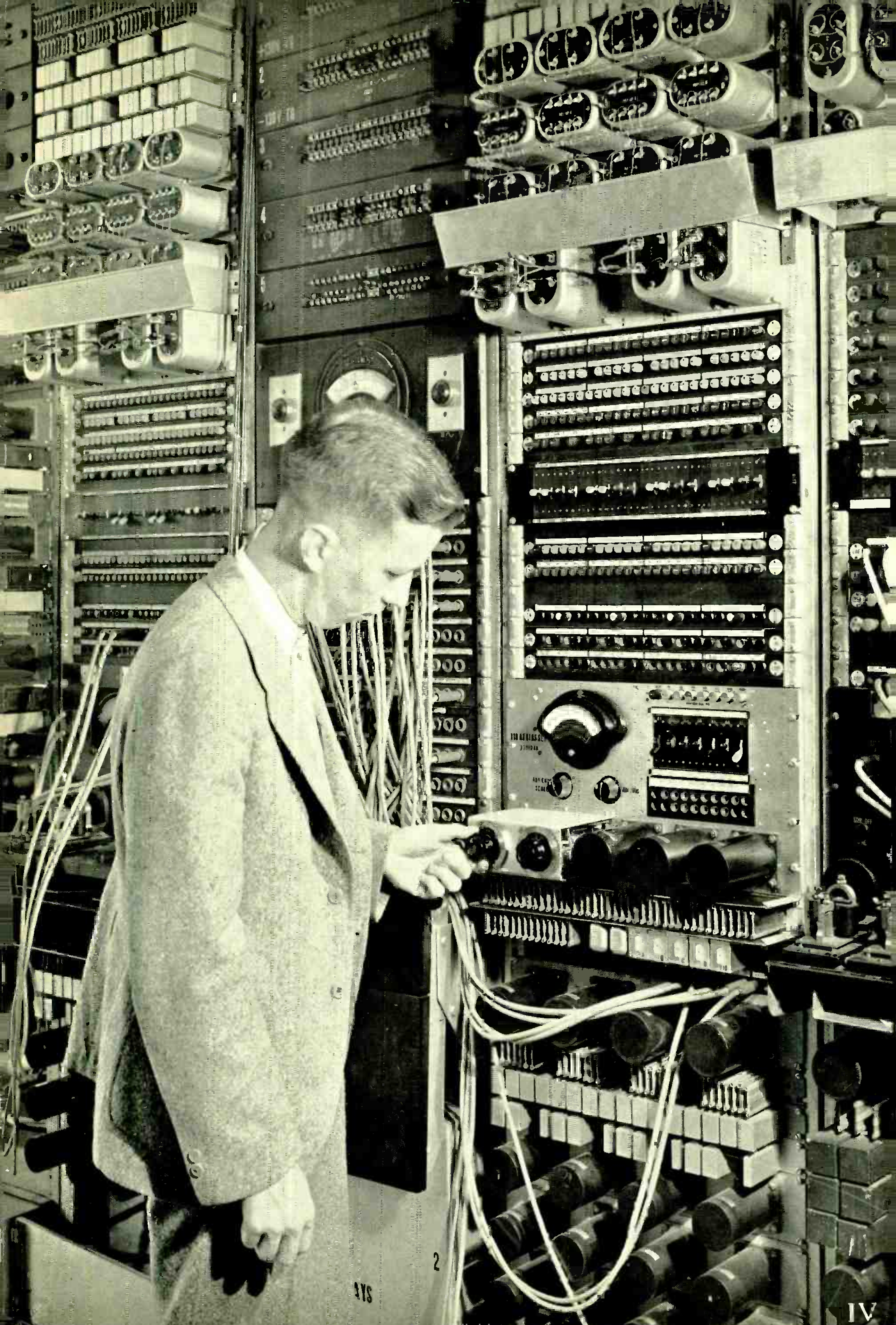
IV

Laboratory model of equipment used to test bias of telegraph signals









A Telegraph Signal Biasing Set

By C. A. DAHLBOM
Toll Systems Development

TELETYPEWRITERS used in the Bell System operate on a 7½ unit code. Five selecting pulses, plus a start and a stop pulse, comprise the successive groups of signals that are converted by the teletypewriter into printed letters. In idealized form, the pulses comprising the letter Y are shown at "a" of Figure 1. For all letters the start pulse is always a spacing pulse, and the stop is always a marking pulse, while the combination of the five selecting pulses differs for the various letter signals. The teletypewriters themselves, and other forms of start-stop receivers, such as regenerative repeaters, do not utilize the entire duration of each selecting pulse, but only a short portion of it at the center, indicated in the illustration by the small rectangles marked "selecting periods." This permits the signals to be correctly interpreted even though the pulses are considerably shortened by the distorting influences of the line and connected apparatus.

One of the principal forms of distortion is called bias, and may be either of two kinds—spacing bias or marking bias. Spacing bias lengthens the spacing pulses and correspondingly shortens the marking pulses, while marking bias lengthens the marking pulses and shortens the spacing pulses. A properly adjusted teletypewriter will correctly interpret signals biased as much as 40%. This amount of bias of the two forms is shown in "c" and "d" of Figure 1. As shown at "c," the spacing bias has shortened the marking pulses to the point where a further shortening would result in the failure of the selector to receive the marking pulse. The marking bias shown at "d" has correspondingly shortened the spacing pulse so that a further shortening would cause a marking signal to be incorrectly registered instead of a spacing signal.

With a teletypewriter in proper adjustment, the five equally spaced selecting periods are oriented to the centers of the selecting signal pulses, and in this position 40% bias can be tolerated. If they were not so oriented, less than 40% distortion of one or the other forms would result in the registering of false signals. It is desirable, therefore, to check the bias tolerance and the orientation of teletypewriters and regenerative repeaters periodically to insure that they are in proper adjustment. This is most easily accomplished by transmitting signals of known bias, and orienting the selecting periods to their position of equal margin on each side. To provide signals for this and other tests of telegraph circuits and apparatus, a bias-producing set has recently been developed, which is called the 119A1 telegraph signal biasing set. It is capable of supplying signals with either spacing or marking bias of any amount up to 60%, and the type of bias may be automatically alternated or changed manually as desired. Auxiliary circuits are also provided for measuring the output bias, so that the bias-producing set may be kept in proper adjustment.

The complete bias-producing circuit, shown schematically in Figure 2, includes an input circuit, a bias-producing circuit proper, a bias-switching circuit, and an output circuit. Neutral telegraph signals open and close the input loop, and cause the "receive" relay to repeat the signal to the "bias" relay. Here the desired bias is applied, and the signals are repeated to the output circuit either as polar or neutral signals depending on the requirements of the circuit under test. The amount of bias, marking or spacing, is set by two dials controlling potentiometers.

The bias relay has four windings. The upper two receive current from the armature of the "receive" relay, and are oppositely poled so that current in one winding tends to operate the armature to the marking contact, and in the other, to the spacing contact. The lower two windings are also oppositely poled, and the current to them is controlled by the bias-control potentiometers. One of these windings produces marking bias and the other spacing bias, and of course only one of the windings is energized at a time. The armature of the bias relay moves to the marking contact when the flux in the core is in one direction, and to the spacing contact when it is in the other—the transition occurring ideally at the point of zero flux.

The effect of the four windings on the flux in the core of the bias relay, and hence on the action of the armature, is indicated by Figure 3. Assume spacing current has been flowing, and at point "a" the spacing contact of the "receive" relay opens. The current in the spacing winding begins to decay, following the upper curve of the illustration. At "b," a very short interval after "a," the armature of the receive relay closes on its "M" contact and current starts to flow in the marking winding following the center curve of the illustration. Since these two windings have opposite effects on the flux in the relay core, the two fluxes are drawn on opposite sides of the axis of zero flux. The effect on the flux in the relay is proportional to the combination of these two curves—indicated by the bottom graph. This signal has no bias, since it will be noticed that the lengths of the marking and spacing pulses, as measured along the axis of zero flux, are equal.

If a steady current is allowed to flow in one of the biasing windings, the

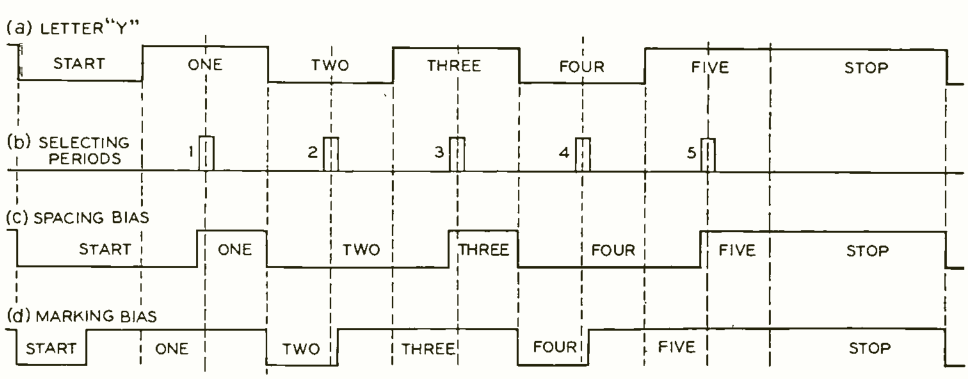


Fig. 1—A typical teletypewriter signal is shown at (a). The effect of about 40 per cent bias in spacing and marking respectively, is shown at (c) and (d)

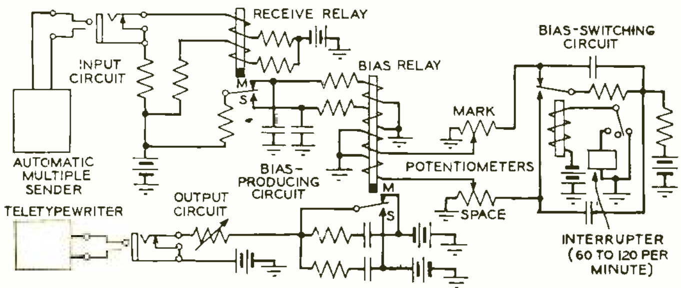


Fig. 2—Schematic of the bias-producing circuit

is connected to the output of the bias-producing circuit and the dots — transmitted through the "receive" and "bias" relays — operate the measuring relay to connect battery alternately to opposite terminals of the meter. With the relay armature operated to "M" the meter deflects to one side and with the armature operated to "S," it deflects to the other. The meter is too sluggish in action to follow the very rapid pulses of the telegraph dots, and as a result takes up a position corresponding to the average current. If the dots as received by the measuring circuit have no bias, that

effect will be to raise or lower the three curves with respect to the axis of zero flux, or—what is relatively the same thing—to lower or raise the axis of zero flux itself. If this axis, by means of a bias current, is raised to position "c-c," for example, the marking pulse is reduced in length and the spacing pulse correspondingly lengthened, while if it is lowered to "d-d" the spacing pulse is shortened, and the marking pulse lengthened. The first condition gives spacing bias, and the latter, marking bias. In this way a bias may be produced in the signal merely by passing different amounts of current through one or the other of the biasing windings. The design of this circuit is such that no appreciable characteristic distortion is introduced into the output signals, the distortion present being only bias.

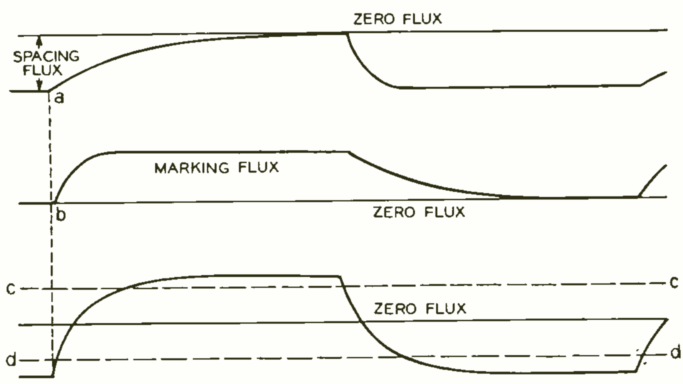


Fig. 3—Representation of change of flux in case of bias relay during one complete cycle of a marking and spacing pulse

The amount of bias produced by various positions of the biasing potentiometers is determined by sending a series of dots, supplied by a distributor, through the bias-producing circuit, and measuring the bias on the circuit shown in Figure 4. This circuit

is, if the marking and spacing pulses are of equal length, the average current is zero and the meter needle will vibrate about zero, which is the midpoint of its scale. If the marking pulses are longer than the spacing, there will be an average marking current, which will be indicated by the meter, the scale of which is graduated to indicate bias in per cent.

The meter will indicate the output bias given by the bias potentiometer setting only, of course, if the dots at the input of the bias-producing circuit have no bias, and if there is no uncorrected mechanical bias of the "bias" or "measuring" relays. The accuracy of the dots themselves is first checked by the "test reversal" circuit shown in Figure 5. For this test, the meter is connected into a bridge network, and the dots open and close one arm of the bridge, which is adjusted so that the meter reads the same amount on one side when the arm is closed as it does on the other when the arm is open. With equal duration of the open and close pulses of the dots, therefore, the meter will indicate zero bias. Ordinarily, no ap-

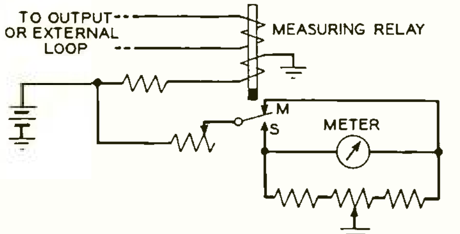


Fig. 4—Schematic of bias-measuring circuit

preciable bias is found, and if it should be greater than 3%, the source of dots should be corrected.

After this is done, the circuit is connected to the input of the bias-measuring circuit, and the indicating meter read. The bias indicated now will be that due to the bias of the dots themselves plus any additional bias caused by the measuring relay. When the measuring circuit is to be used with the bias-producing circuit, the total amount is corrected by adjusting the potentiometer on the resistance shunting the meter. If the measuring circuit were to be used for determining the bias of signals obtained from a telegraph circuit, however, the potentiometer would be adjusted until the meter indicated only the bias previously found in the dots themselves.

After adjustment, the measuring circuit is connected to the output of the bias-producing circuit, and the dot source is connected to the input

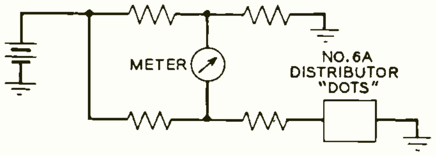


Fig. 5—Schematic of test-reversal circuit

circuit. The potentiometers are adjusted to produce the amount of bias desired as measured by the measuring circuit. The equipment or circuit to be tested is then connected to the output loop and, where required, the dot source is replaced by a source of teletypewriter signals. The effect of this amount of bias on the equipment or circuit may now be observed. For certain uses it is desirable to give the signal marking and spacing bias alternately, and the bias-switching circuit permits this to be done either manually or automatically.

To obtain the greatest possible flexibility in operation, the set is arranged for operation either as a self-contained unit or by patching external loop circuits into the output and input circuits. The output is arranged for transmitting polar or neutral signals, and optional wiring is provided for using the circuit on either 20 or 60 milliampere loop circuits. A remote control circuit is also furnished to enable a test board man to pick up the output signals at a jack in the telegraph test board and simultaneously connect the battery to the bias-producing circuit. It is expected that this telegraph signal biasing set will prove a useful tool in the Bell System.

Paper Insulation in Telephone Construction

By J. M. FINCH
Chemical Laboratories

PAPER is used extensively as insulating material in the construction of telephone equipment but it is paper of very different quality from the familiar kinds used for books, wrappings and newspapers. To satisfy telephone requirements it is necessary that careful attention be given not only to the physical characteristics of paper such as density, toughness and porosity but also to the nature of the chemical constituents which largely determine its insulating properties.

Paper consists essentially of more or less pure cellulose in fibrous form, usually obtained from the fibrous components of various plants and trees. The one important exception is cotton which grows in the form of seed hairs. The fact that paper is relatively cheap and that its physical properties can be widely varied makes it particularly well fitted for many different kinds of insulation. Condensers, for example, require very thin, high density tissue; telephone cables, on the other hand, demand an extraordinarily strong, tough, low density sheet, while phenol fibre and laminated insulation need a porous paper capable of absorbing adequate amounts of impregnating materials. High-frequency equipment requires a low dielectric loss insulation which is obtained by using a very low density paper made with a large percentage of cork dust or porous material.

The chemical properties must be of the same high degree of excellence for all types of insulating papers since they determine its value as insulating material under service conditions in apparatus. To attain good insulation it is necessary to limit closely the quantities of soluble salts, the acidity, and the presence of particles which are conducting or which will produce conducting paths. Soluble salts cause undesirably high conductance accompanied by electrolytic corrosion; acidity results in embrittlement under elevated temperatures, such as exist

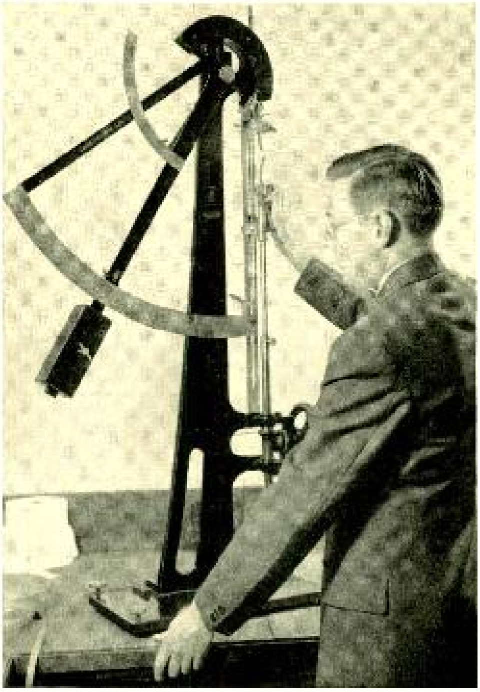


Fig. 1—The ability of paper to withstand longitudinal stress is being measured on the tensile tester by W. J. Kiernan. The weight required to break a test strip is determined

during the drying of cable cores, or in the curing of phenol fibre and of varnish impregnated papers.

The exceptionally severe service requirements imposed on paper in telephone use have made it necessary to develop new types of papers and to improve existing methods of testing

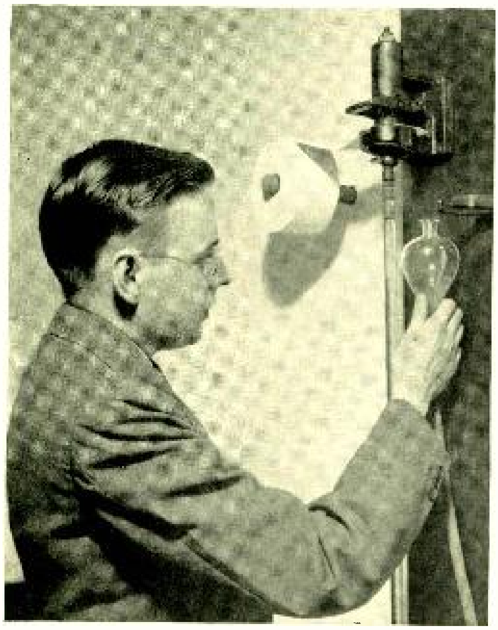


Fig. 2—The density of paper is determined by measuring its porosity, done by finding the rate at which air diffuses through it

them. Both the Western Electric Company and Bell Telephone Laboratories have had a major part in this work which has comprised laboratory work on the progressive refinement of testing procedures, the establishing of suitable specification limits and direct coöperation with paper makers.

Experiments on the physical properties of paper are carried out at the Laboratories in an air-conditioned room. This is necessary because these characteristics vary greatly with the moisture content of the paper. Tensile tests are made by determining the load required to break a narrow strip of the paper. This is measured by the amount a heavy pendulum is displaced from its lowest position by the pull of the paper strip at the instant when it breaks. The tearing strength is found by measuring the difference in the height to which a pendulum will rise when it swings freely and again when it tears a strip of paper. The test for porosity consists of noting on a manometer the rate at which air will pass through paper under a definite difference of pressure.

Improvements which have increased the accuracy of testing paper for acidity by the colorimetric titration method are typical of the Laboratories' chemical developments in paper testing. In this test acid, which has been extracted from the paper by water, is neutralized by a standard alkali solution with the aid of a dye indicator which changes color at the point of neutralization. Further studies of this method are in progress. Another procedure developed by the Laboratories, is the null point electrometric titration method in which the point of neutralization is indicated on a galvanometer as a change of electrical potential instead of as a color change. This method has the advantage that it gives accurate results with colored water extracts which many papers yield and which are difficult to test colorimetrically. Recent studies have also shown that the conductivity of the water extract may be substituted for the various chemical tests that were formerly made for water soluble constituents such as common salt and alkaline salts.

The results of these and other studies on paper have been incorporated in specification requirements which must be met by manufacturers and suppliers to the Bell System. The first cable paper specification which was adopted more than fifteen years ago contained requirements limiting acidity, water soluble and alcohol soluble matter in addition to strength and dimensional limits. These qualifications have been revised and extended on the basis of the Laboratories' subsequent studies.

Fig. 4—The amount of soluble salt in paper is found from the electrical conductivity of a water extract of the sample. W. G. Guldner is making the test

Another phase of the laboratory work is the appraisal of new types of papers developed by outside suppliers for our needs. The study of these products entails a knowledge of both physical and chemical paper making practices. Before a new supplier's product is adopted, his manufacturing methods are examined and the mill water supply is tested. A very brief description of the paper making process will furnish some idea of the importance of these factors in the production of a good insulating paper. Taking the making of condenser paper as an example, the raw material consists of unused linen rag clippings, or linen cordage mill waste. This is "cooked" in a dilute sodium hydroxide solution to soften the cementing material which holds the paper making fibres together to form the relatively longer textile fibres. The cooked pulp is then diluted with water and subjected to a severe mechanical maceration for twenty-four hours or more. This treatment separates the fibre bundles and finally breaks the individual fibres into extremely small particles, at the same time swelling them and producing a surface product of gelatine-like consistency on the individual fibre particles. During the long maceration or "beating" as it is called, the water in which the pulp is suspended is continuously changed, so that the pulp is washed almost com-

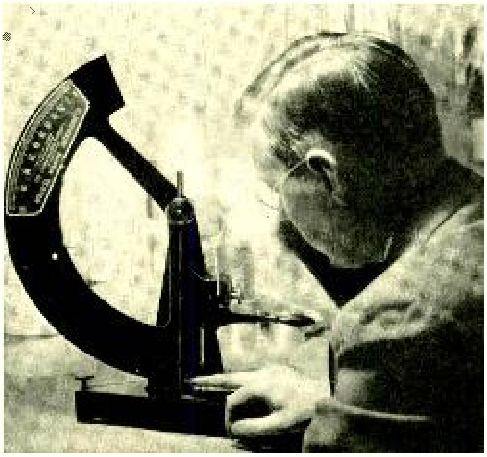


Fig. 3—The toughness of paper is evaluated by measuring the difference in height reached by a pendulum when swinging freely and when it tears a strip of paper

pletely free from soluble salts in the cooking liquor when the beating is completed. After greatly diluting the suspended pulp with additions of clean water, it is flowed on to a moving endless belt of very fine mesh wire cloth, where the excess water is removed by vacuum. This gives a wet "sheet" which is squeezed between soft surfaced rolls, then passed over a succession of steam heated drying rolls, and finally through heavy steel rolls at the "dry end" of the paper machine. The resulting sheet is about .0004″ thick, and is exceptionally free from holes. Since the quantity of water required per pound of paper is enormous a practically unlimited supply of extraordinarily pure water must be available. It is this factor which limits the number of mills that can produce good insulating papers.

A discussion of this subject would not be complete without reference to the development of the pulp insulating process for telephone cables* by the Western Electric Company. This process is an outstanding achievement and ranks with the greatest recent inventions in paper making. By a modification of the normal paper making process a coating of low density paper is made directly on copper conductors, 60 of which are simultaneously coated at the rate of 130 feet per minute on each machine. This speed necessitates drying in air heated to about 500 degrees F. The process has eliminated the necessity of first making a highly specialized paper, slitting it to widths of about ¼″, and winding the slit paper on individual conductors and has resulted in appreciable savings in the cost of telephone cables.

*Record, *April*, 1932, *p.* 270.

The Gold Medal

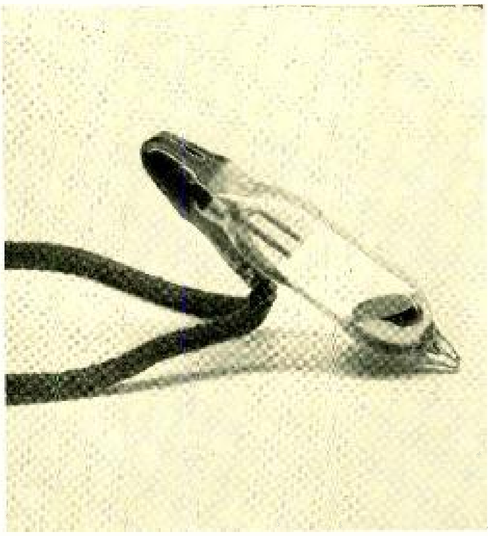
of the American Institute of the City of New York for the year 1937 has been awarded to Bell Telephone Laboratories "for researches in electrical science which, as applied to communication, have promoted understanding, security and commerce among peoples by transmitting human thought instantly throughout the world." The award will be received in the name of the Laboratories by Dr. Jewett at a dinner meeting of the Institute to be held February 4th.

Mercury Switch for Telephone Booths

When the door of a telephone booth closes a lamp in the ceiling lights automatically and sometimes a ventilating fan starts. The lamp and fan are controlled by a switch, located above the ceiling of the booth and connected to the door by a rod. A mechanical switch has been used in the past but this type is not noiseless in operation and is expensive to make with the ruggedness which is required for long service.

To reduce the cost of construction, assembly and wiring and to eliminate the noise a mercury switch has been developed. This is a small glass tube about an inch and a half long containing a globule of mercury; into one end are fused terminals. When this end is tilted down the mercury flows to it and closes the circuit. The tube is mounted above the ceiling of the booth in a metal box attached to the lamp; and like the mechanical switch is operated by a rod which connects it to the door near the upper hinge.

Thus as the door is opened and closed the tube rocks up and down and a drop of mercury automatically lights the lamp and starts the fan. This conserves power by using it only when the booth is occupied.



A Watch-Rate Recorder

By F. H. HIBBARD
Special Products Development

THE measurement of time, and its reciprocal, frequency, plays an important part in the daily work of Bell Laboratories. As a result, the subject has been exhaustively studied, and many contributions have been made both to apparatus and methods. From the development of tuning forks to very high degrees of precision have come commercially practical designs of tuning-fork generators which the Special Products Department, in collaboration with Electrical Research Products, Inc., has made available to industry in the form of two portable time-measuring devices. The first of these was the Western Electric timing system,* which provided a high-speed motion picture camera for simultaneously recording the position of moving objects and of a tuning-fork-controlled clock. Now a new time-measuring device is available for use in the calibration and adjustment of watches.

The commercial utility of a method of quickly determining the rate of a watch was first called to the attention of the Electrical Research Products, Inc., by H. M. Stoller, who proposed a stroboscopic observation of the balance wheel of a watch to determine its rate. Apparatus embodying this principle was developed and successfully used by the Products Company in exploring the technical and commercial fields of watch manufacture and watch testing. As a result of this study a new device was developed which gives a graphic record of a watch's rate.

*Record, *September*, 1932, *p.* 27.

In brief the method is to "pick-up" the watch ticks with an electrical phonograph reproducer, to amplify these ticks electrically, and to allow the amplified current impulses to produce dots on a chart moving at an accurately constant rate. The chart is wrapped around a rotating drum, and the marking stylus is supported on a carriage driven across the surface of the chart at right angles to the direction of rotation. Most watches have five ticks per second, and the drum is therefore made to rotate five times a second so that if the watch were keeping perfect time, the dots would lie in a straight line across the chart—one dot being made at each rotation of the drum. If the watch is not keeping perfect time, successive dots will occur before or after the correct time, and thus make a line crossing the chart diagonally. When the watch is running fast, the line of dots will slope one way from the horizontal and the other way when running slow. The amount that the watch deviates from the horizontal at the end of thirty seconds indicates the error in rate.

The recording drum is driven by a small synchronous motor supplied with a constant frequency of 300 cycles per second from a tuning-fork generator. This generator, evident beneath the table in the photograph at the head of this article, forms a separate unit, which is connected to the watch rate recorder by flexible cords. The stylus carriage may be driven at either of two speeds through a selective gear shift. One speed carries it across the chart in five seconds, and the other in thirty. The high speed may be employed for rough timing, and gives a readable accuracy of fifteen seconds per day, while the slower speed is used for final checking, and gives a readable accuracy of about two seconds per day. The drum is stopped automatically when the stylus reaches the end of its travel, and a lever that is placed on the front of the base is employed to reset the stylus and start the operation of the instrument.

The electrical phonograph reproducer "picks up" the ticking of the watch through a small wire connected to the needle holder. This reproducer, which is enclosed in a heavy lead shield to keep out unwanted vibrations, is connected to a high-gain amplifier arranged to be most sensitive to those frequencies resulting from the ticking of the watch. Since the loudness of the ticks of different watches varies considerably, a gain control is provided, which may be seen near the center of Figure 1. The output of the amplifier is connected to a "trigger"-type vacuum tube

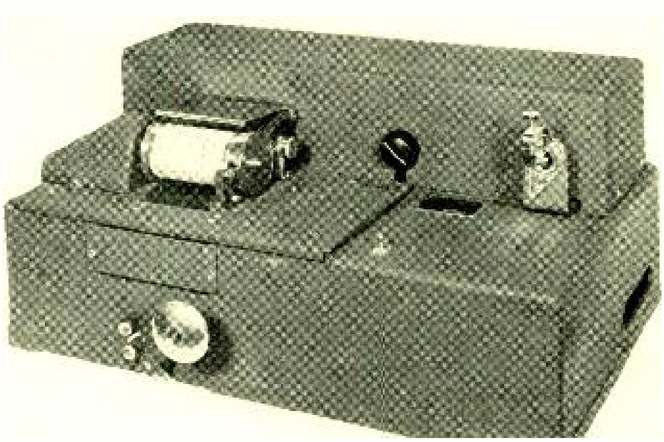


Fig. 1—The watch holder on the right may be turned to allow the rate of the watch to be determined in various positions

which produces a spurt of current for each tick. This current flows through a magnet controlling the stylus, and drives the latter against the chart once for each tick. A typewriter ribbon placed between the stylus and the chart serves as the inking medium.

A simplified diagram of the mechanism is shown in Figure 2. At the left is the synchronous motor, which receives 300-cycle current from the tuning-fork generator. This motor is geared to the drum that carries the chart on which the rate record of the watch is made. The gearing is such that the drum makes exactly five revolutions per second, which is the rate of ticking of most watches. Another set of gears connects the motor to a lead screw, which drives the recording magnet axially along the underside of the cylinder. A gear change is also provided for the lead-screw drive to allow the recording magnet to traverse the length of the drum in either five or thirty seconds.

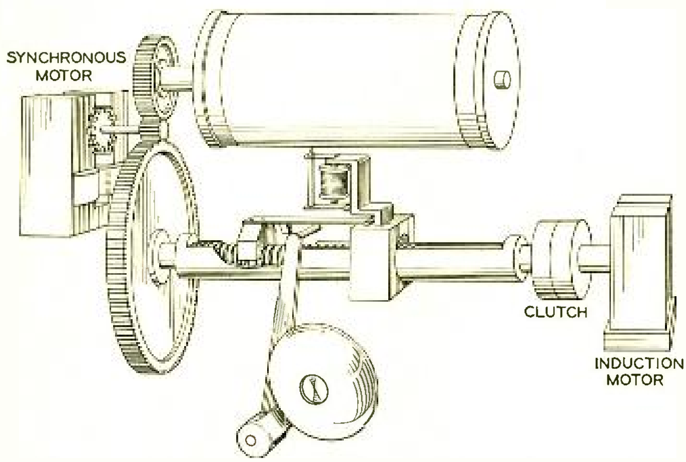


Fig. 2—A simplified diagram of the watch-rate indicator

The recording magnet is moved along by a half-nut that rides on the upper side of the lead screw. This nut may be lifted by a reset handle on the front of the machine to permit the carriage to be moved back along the axis of the cylinder. After a record has been made, the carriage rests at the right-hand end of the cylinder and the motor is stopped. By pressing the reset lever in, and turning it to the left, the motor is started and the carriage moved to the left-hand end of the cylinder ready to make another record. Since the synchronous motor is not self-starting, a small induction motor is coupled to the lead screw through an "over running" clutch. This motor is started when the reset lever is pushed in, and at once brings the synchronous motor up to its operating speed.

Perhaps the most important contribution to the watch timer is the means of converting the tick of the watch into motion of the marking stylus. The sound energy of a watch tick is very small; in some of the very small watches the sound is scarcely audible even when the watch is held against the ear. In the new timer, the very faint sounds of the tick are transmitted to the needle arm of the electric reproducer, which is particularly sensitive to the frequencies developed by the watch ticks. This reproducer is housed in a massive container of lead which is mounted on rubber to shield it both from the air-borne vibrations of room noise and from vibrations of the bench or building. It also has a magnetic shield of permalloy to prevent the magnets of the reproducer from affecting the action of the watch.

The reproducer is connected to the

input of a two-stage amplifier with a maximum gain of 95 db, and the amplifier—in turn—is connected to a grid-glow tube that supplies the current for the recording magnet. To obtain the proper marking action on the rapidly moving paper, the upward motion of the stylus should be of short duration. This action is obtained by using a condenser to operate the magnet. A gas-filled trigger tube is employed to close the circuit of the condenser through the magnet as shown in the simplified schematic of Figure 3.

The trigger tube permits a discharge to pass through it when either the grid or the plate reach a definite critical potential. In the circuit for the watch-rate recorder, the potentials of the grid and plate vary with the state of charge of the condenser. Immediately after a discharge, the large charging current of the condenser flowing through the resistances "R" and "r" results in a low plate potential and a grid potential that is negative to the cathode. As the condenser becomes more and more charged, the flow of current decreases, with the result that the plate potential becomes higher, and the grid becomes less negative. The size of the condensers and resistances are so proportioned to the characteristics of the trigger tube, that after about ⅓ second the tube breaks down, allowing the condenser to discharge through the magnet. With the discharge of the condenser, the tube returns to the non-conducting state, and another cycle begins. With no watch ticks being picked up, therefore, the circuit provides a pulse to operate the magnet approximately three times a second.

When watch ticks are being picked up, however, current that raises the grid potential is produced at each tick. In the ⅕ second interval between ticks the condenser will have accumulated sufficient charge to operate the magnet, and the increase in the grid potential is sufficient to cause the trigger tube to break down and allow the condenser to discharge through the magnet to make a mark on the chart. The tube then reassumes its non-conducting state and the condenser again starts to charge. The circuit thus provides, in advance of each watch tick, a condenser charged sufficiently to operate the recording magnet, and a means of releasing this charge to the magnet accurately in step with the ticking of the watch without the use of moving electrical contacts. The time intervals of the marks on the chart are thus identical with the time intervals of the watch ticks. When the watch is removed from the holder, the discharges will resume their ⅓ second rate.

This change in the rate of discharge provides a simple means of checking the gain of the amplifier. If, after a watch has been put in the holder, the magnet continues to operate at the ⅓ second rate, which may easily be determined by listening to the taps of the marker on the chart, the gain of the amplifier should be increased. Too

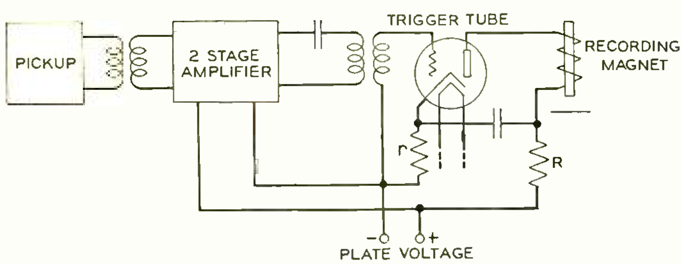


Fig. 3—Simplified schematic of the circuit employed to operate the recording magnet of the watch-rate recorder

much gain results in amplifying extraneous vibrations which produces odd beats readily detected by the ear.

The arrangement of the watch rate indicator may be seen from the photograph at the head of this article, and in more detail in Figure 1. The pick-up, amplifying, and trigger circuits are under the raised cover at the rear, in the middle of which is the amplifier gain control. Near the right end of the housing is the watch holder, which may be rotated ninety degrees to allow the watch to be tested in various positions. At the left is the chart cylinder on which the record of rate is made. This entire recording unit is mounted on rubber to absorb vibrations caused by the motor, gears, or other parts of the mechanism. A roll of record paper is carried inside the cylinder; and at the beginning of a test, a section of chart is drawn out through a slit in the cylinder, wrapped around the outside, and secured under clips at the sides. At the completion of a run, the chart is unwrapped and cut off by the cutting edge, shown above the cylinder. The reset lever is in the front of the base at the left.

The cylinder has a periphery of six inches, so that when rotating at five revolutions per second, the chart speed is thirty inches per second. Since a displacement as small as $\frac{1}{64}$ of an inch can be read, it is possible to determine a time displacement of about 1/2000 of a second which corresponds to a little more than a second a day in the rate of the watch.

The application of this apparatus to the instantaneous observation of watch rates has shown that important information about the condition of a watch may be obtained from the shape of the record obtained, as well as from the total deviation from the true rate. In 30 seconds the rate of a watch may change slightly, so that the line observed on the chart may be curved rather than straight; or successive "ticks" or "tocks" may be irregularly spaced. The reaction of the watch to treatment can, of course, be immediately noted by making successive records, and by such observations as these, perhaps as much as by rate determination alone, the watchmaker is assisted in the diagnosis and repair of watch irregularities.

Contributors to This Issue

Clifford E. Fay received his B.S. degree in Electrical Engineering from Washington University in 1925, and an M.S. degree in 1927. Immediately after he joined the Technical Staff of Bell Laboratories. Here, with the Vacuum Tube Development group, he has been engaged in the development of power tubes for use in radio transmitters. More recently he has directed his attention to tubes for generating power at ultra-high frequencies.

F. H. Hibbard received the M.E. degree from Cornell University in 1914, and at once joined the Engineering Department of the Western Electric Company. After a year in the student training course in Hawthorne and New York, he joined the Transmission Department, where he engaged in transmission calculations, patent examination, and loud speaker testing. In 1918 he transferred to the machine-switching laboratory, of which he was placed in charge in 1921. He remained in this position during the next six years while the panel system was being incorporated in the Bell System. In 1927 he was assigned to special instrument studies and to budget and laboratory cost studies. Later he was placed in charge of a group developing relays for the panel system. In 1929 he was transferred to E.R.P.I. where for five years he supervised a group engaged in studies of sound recording on disc and film. In 1935 he returned to the Laboratories to take charge of a group engaged in special products development.

C. A. Dahlbom joined the Laboratories in 1930 and since then has been with the telegraph group of the Toll Systems Development Department. His work here has been chiefly on investigations of polar telegraph relays, telegraph transmission circuits, teletypewriters, and regenerative repeaters. He has also been taking work at Brooklyn Polytechnic Institute leading to the degree of E.E.

L. G. Young graduated from Carnegie Institute of Technology in 1919 with the degree of B.S. in Electrical Engineering after serving for a short time in the Signal Corps. He joined the Laboratories in the following year and for six years worked on coil design. In 1926 he transferred to the Radio Development Department where

C. E. Fay

F. H. Hibbard

C. A. Dahlbom

L. G. Young

O. H. Danielson

E. C. Erickson

he at first was engaged in antenna design. Since 1929 he has been working on the design of high-power radio transmitters.

O. H. Danielson was graduated from Purdue University in 1912 with the degree of B.S. in Electrical Engineering. During the succeeding five years he took an important part in the development of early starting and lighting equipment for automobiles. In 1917 he enlisted in the army as lieutenant and later became captain in the motor Transport Corps. These commissions took him to France where he had charge of the magneto department at the main overhaul park at Verneuil. After the war he returned to starting and lighting development work for a time and then joined the Apparatus Development Department of the Laboratories in 1922. Among his early assignments here was the mechanical design of the panels for the first system for picture transmission over wires. Later he was transferred to the group which does mechanical design work on testing apparatus. He has had charge of this group for the past eight years.

J. M. Finch

Within a few months after receiving the degree of B.S. at Princeton University in 1922, E. C. Erickson joined the Laboratories' Transmission Apparatus group. Here he was engaged in designing condensers and loading coils. Since 1928 he has been specializing in precision linear measurements and it was in this connection that the work on screw thread finishes which is described in the current issue of the Record was done.

J. M. Finch joined the Installation Department of the Western Electric Company in 1910. A year later he was transferred to the Engineering Department at West Street where he entered the Chemical Group to work on insulating materials including cable and condenser papers. Since then he has carried out many development projects in connection with preparing specifications for insulating papers and has made important improvements in the methods of testing such papers. He was also at one time interested in developing methods for testing phenolic insulating materials and enamel wire insulation.