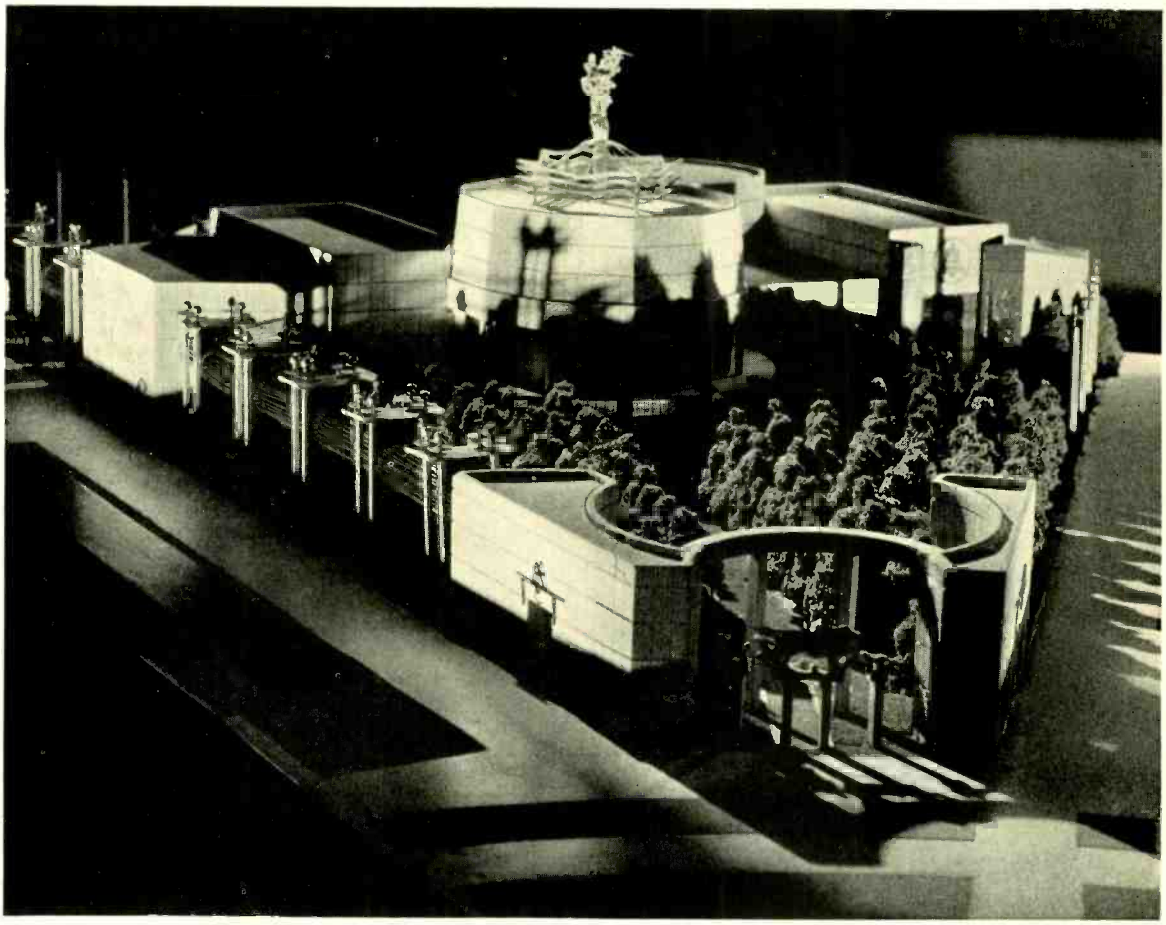
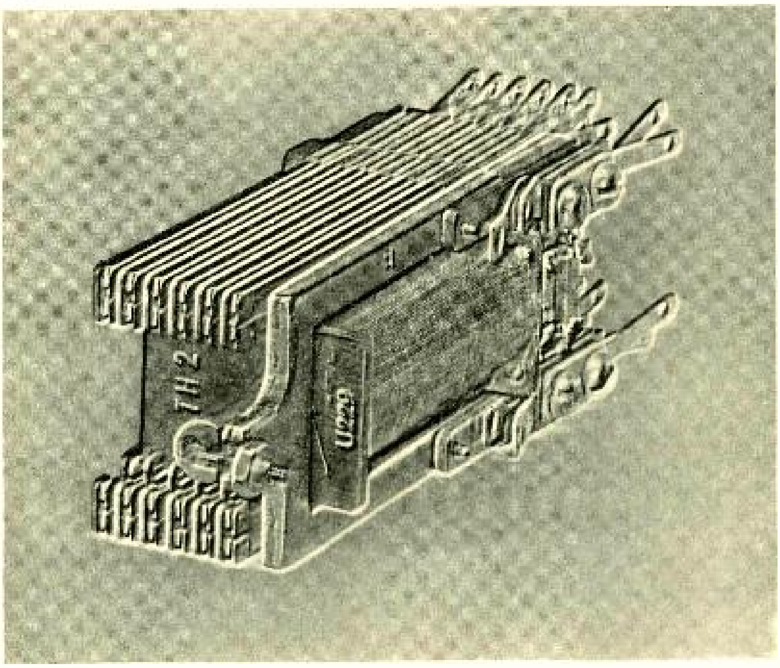
BELL LABORATORIES RECORD



Model of Bell System Building for the New York World's Fair

MAY 1938 VOLUME XVI NUMBER IX



The U-Type Relay

By H. N. WAGAR
Electromechanical Apparatus Development

THE most widely used relays in the telephone plant are of the flat type.* These have proved economical to manufacture; and experience extending over a quarter of a century has testified to their satisfactoriness in operation. During this time, however, the telephone system has changed, and upon relays there have been imposed operations more complicated and critical than were in mind at the time of their development. Materials and manufacturing methods also have changed, so that all in all it seemed desirable a few years ago to undertake the design of a new all-purpose relay. The U-type relay—shown in the photograph at the head of this article—is the result.

Reliability in relay operation has become of increasing importance in recent years. The intricacies of the dial systems require the operation of a large number of relays on each call, and for the satisfactory functioning of the system many of these relays must operate and release at just the right time and without fail. The existing types of relays do this, of course, with what is really remarkable precision, but occasionally a speck of dirt will get between the contacts to prevent their closing. Also the contacts may "chatter"—rapidly opening and closing as a result either of the rebounding of the armature when the relay is de-energized, or of the independent vibration of the springs. One of the objectives of the new design, there-

*RECORD, *November*, 1926, *p.* 83.

fore, was to improve reliability by making dirt particles less effective, and by reducing the tendency to chatter. Another objective was to secure a greater number of contact springs per relay. A study indicated that an increase from the twelve springs of the present relay to twenty-four would be satisfactory. To obtain the full advantage of such an increase, however, the gain in number of contacts must not be offset by a corresponding increase in size or in energy required. In other words, more effective and efficient use of materials was sought.

An increased number of contacts requires a larger magnetic flux; and if the energy consumed by the winding is not to be increased, this flux can most effectively be secured by providing a magnetic path of lower reluctance. Such an improved magnetic path was secured, first, by using a larger core of circular cross-section, which provides the greatest flux for a given length of wire; and second, by reducing the air-gap reluctance and making more advantageous use of it. In both the E- and R-type relays, which are of the flat type, a U-shaped armature is hinged to the yoke at the rear of the core by a piece of thin magnetic iron, as shown in Figure 1. The spring hinge is so thin that only a small part of the flux can be carried by it; the rest of the flux passes through air, which introduces into the circuit an additional reluctance that serves no useful purpose. The gap at the hinge is kept as small as possible, of course, but it must be large enough to permit free movement of the armature after allowing for unavoidable unevenness at the hinge.

The armature of the new relay is of the same U shape as that of the R-type relay, but overlaps the end yoke, instead of being hinged to it, and is held loosely in place by a pin in each arm of the U. The construction is shown in Figure 2. In its unoperated position, the armature pivots on the front edge of the rear bracket—leaving a long wedge-shaped air gap between this edge and the rear end of the armature. As the armature closes, this wedge-shaped air gap narrows down until, in the operated condition of the armature, it almost disappears. This form of mounting tends to introduce only a small reluctance, which is made still smaller by the comparatively large cross-sectional area of the hinge gap as compared with former relays. Moreover, the flux in this gap performs a useful function, since the resulting force of attraction on the rear end of the armature tends to rotate the armature around the pivoting point in the same direction as does the relatively greater pull at the gap at the front end. The core is milled flat at its rear where it fastens to the cross yoke, and also at its front to form a broad flat surface for the armature. This front gap is limited in width by the diameter of the core, but it is made long enough to give a large area and thus a low reluctance.

How effective this construction is in increasing the pull is shown by Figure 3, which gives a typical relationship between the force which the armature can develop, and the power required to maintain this force, for both the R- and U-type relays. The pull provided for six make contacts is somewhat greater for the U-type relay than for the R—more contact pressure being provided—but the power required is only about a fifth. The R type would be incapable of closing 12 make contacts, while the U type closes them with less than half the power required by the R type.

Besides contributing to the pull of the relay, this construction tends to reduce the likelihood of chatter caused by the armature rebounding after it has opened. With the reed-hinged armature of former relays, the full force of the rebound occurs at the front end of the relay where the tendency to close the contacts is great. With the U-type relay, however, the rebound divides between the front gap and the loosely mounted pivoting point farther back; and the net consequence at the contacts is far less than if the armature were free to recoil only at the front.

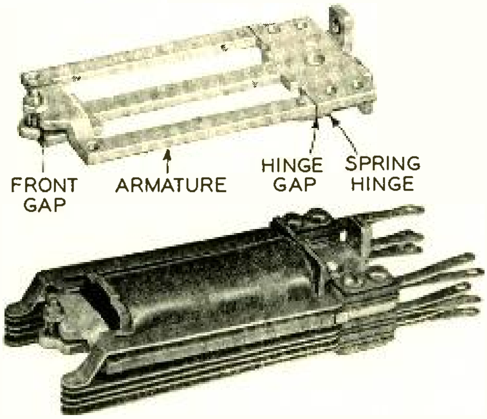


Fig. 1—The armatures of the E- and R-type relays are hinged to the core by a short strip of magnetic iron, which may be seen in the photograph of the relay, and in the diagram of its magnetic circuit

Of at least equal importance is the chatter caused by vibration of the springs. Considerable study, both theoretical and experimental, was necessary to determine the nature and causes of this vibration and the best method of its elimination. It was finally found that by properly proportioning the dimensions of both the stationary and the movable springs this form of chatter could be eliminated as a source of serious trouble.

The other major improvement incorporated in this new relay is the use of twin contacts. Each contact spring carries two separate contacts in parallel, so that even though one of them should be held open by a speck of dust, the other would close. As already noted, the failure of a relay to make contact is of comparatively rare occurrence, but the provision of double contacts very greatly decreases this likelihood. The probability of a random failure when two parallel contacts are employed is the square of the probability for a single contact. If, for example, a single contact fails to make once in ten thousand times, then a pair of contacts in parallel under similar conditions will fail only once in a hundred million times.

With these various improvements a relay has been made available that, besides being able with less power to close twice as many contacts as the R type, is practically free from chatter and from contact failure. In designing the U-type relay every advantage has been taken of past experience and

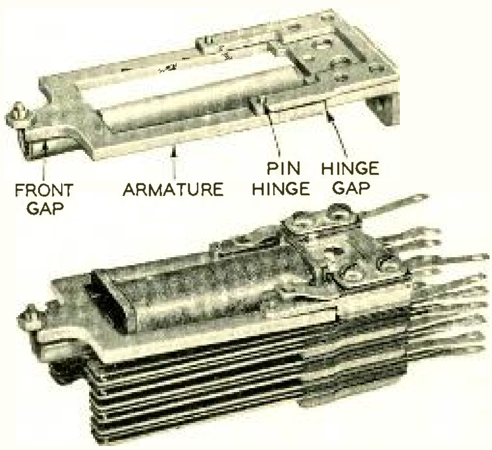


Fig. 2—With the U-type relay a loosely pivoted hinge is employed, and the air gap at the rear becomes a long narrow wedge. This is evident in the photograph and in the diagram of the magnetic circuit

o nt developments, not only to make it more effective but also to keep its manufacturing cost low. With this in view a striking change was incorporated in the method of winding. In previous relays the front and rear of the core are larger than the section on which the winding is placed, and the wire for the coil is wound in place on the core. With the new relay the core has been made of the same diameter throughout its length, so that it is possible to wind the coils separately and then slip them over the cores. This change in the core was adopted largely to take advantage of a method of winding coils in multiple which was developed by the Western Electric Company. On a single arbor, as shown in Figure 4, seven coils are wound at the same time from seven spools of wire. Between adjacent windings are slight separations so that they may be cut apart when completed. Between successive layers of wire are very thin layers of cellulose acetate sheet, which run the full length of the arbor and hold the wire in place.

The collection of spring contacts consists of stationary and movable springs, separated in their mounting by strips of insulation. The stationary ones are considerably thicker than the movable, and do not bend appreciably as the relay operates. The movable springs are controlled by the armature through insulating rods, which are fastened to alternate springs and pass through openings in the stationary springs. The general appearance of a spring assembly for twelve make contacts, which is the full complement of a relay, is shown on page 300. Each stationary spring is a single piece with the two contacts near the ends. The movable springs are forked a little beyond the point of attachment to the operating rod, with each branch carrying one contact. This gives comparative independence between the two contacts of a pair, so that if one is held open the other will still be free to make contact. The soldering terminals of these springs fan out at the rear in the usual manner. For the windings, soldering terminals are similarly arranged, but they are also extended toward the front of the

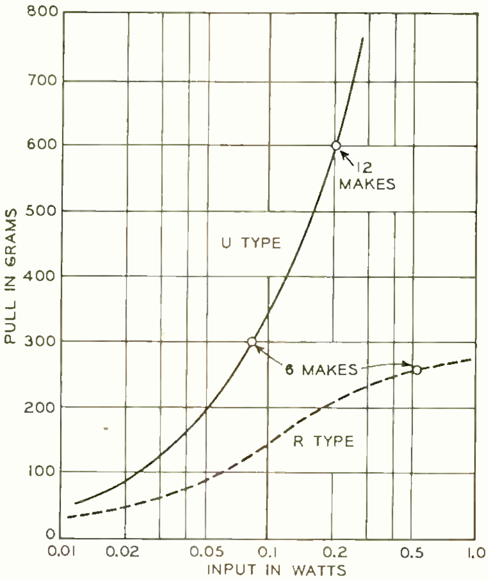


Fig. 3—Relationship between pull and watts for both the R- and U-type relays

relay. This arrangement gives access to the windings when testing from the front.

The headpiece illustrates a relay provided only with make contacts but, as with most relays, other combinations may be built up, such as break-contacts, make-before-break, break-before-make, or make-before-make; several hundred combinations may be obtained. For the windings also there is a large number of possible ratings depending on the voltage of the circuit in which the relay is to operate and on other circuit characteristics or on the type of operation required. Other optional features are copper and aluminum sleeves which are slipped over the core when slower operation is desired, and a split permalloy sleeve to give the winding a high impedance to voice frequencies. The cores are usually of magnetic iron, but permalloy may be used when conditions warrant it.

Because relays are used in large numbers, their space requirement becomes of considerable importance. The U type requires vertically the same space as the flat relay; and horizontally, space determined by its number of springs. When equipped to capacity, it has a spring-pair density in the plane of the mounting rack of 4.2 pairs per square inch, while the greatest density before, which was with the R type, was 3.4 pairs.

In the development of the relay, many of the mechanical and magnetic problems have had to be studied from both their theoretical and experimental sides, and contributions to the completed apparatus have come from Laboratories specialists in many different fields. Such modern research tools as the high-speed motion-picture camera and the string oscillograph,* arranged to give simultaneous electrical and mechanical records, have been indispensable in the extensive tests that followed the original design work. It seems fair to say that only through the insight afforded by these instruments was it possible to recognize the true nature of many of the design problems; and only through their use did the final design come to so successful a conclusion.

Development of this relay had its inception in the need for more contacts and for lower battery drain; but in the course of its design it was found possible to add many other desirable features, such as twin contacts and freedom from chatter. As a result, it has become of much wider utility than was originally anticipated. It seems not unlikely that just as the need for new switching mechanisms led to its development, so its new and better features will open an avenue to further progress in the switching art. The 755A PBX, which will be described in a forthcoming issue, introduced the new design and was the first of many systems to utilize it. The most extensive use of this relay is in the crossbar system, the first installation of which has been made at the Troy Avenue Office in Brooklyn.

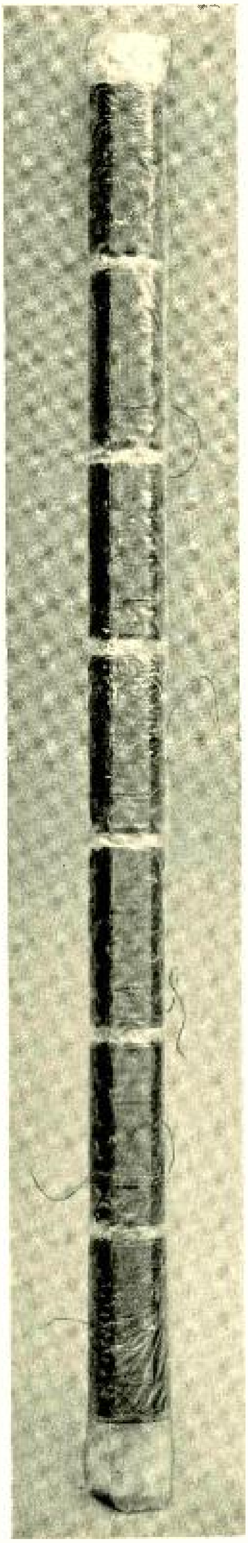


Fig. 4—For the U-type relays seven separate windings are wound on a single arbor and then cut off and assembled over the core

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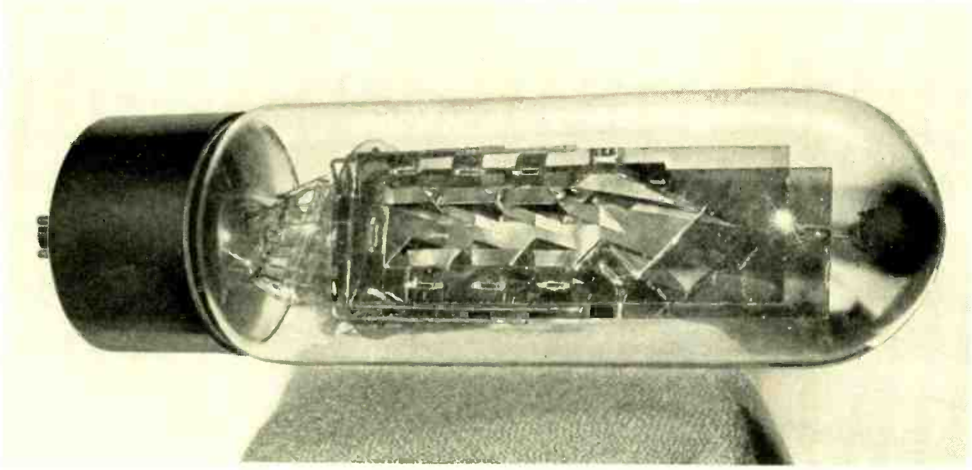

Electron Multiplier Design

By J. R. PIERCE
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WHEN a stream of electrons strikes the plate or any positive electrode in a vacuum tube, other electrons are given off. These are called secondary electrons. In ordinary vacuum tube applications an effort is made to reduce the number of secondary electrons or to return them to the electrode from which they came. If not thus controlled, these secondaries may introduce undesirable modifications in the tube characteristics. In recent years a number of workers in the vacuum tube field have endeavored to apply this phenomenon to useful purposes and as a result of their efforts various devices known as electron multipliers have appeared. These devices seemed to have potential value in the field of applied electronics and work has accordingly been undertaken by the Laboratories with the object of evaluating their worth and of developing electron multipliers that may be adapted to our purposes.

The number of secondary electrons leaving a surface struck by a stream of electrons is proportional to the number of primary electrons striking it. The proportionality factor varies both with the potential drop through which the primary electrons fall before striking, and with the nature of the emitting surface. If there is to be amplification this proportionality factor must be greater than one, so that both the potential drop and the nature of the electrode surface are important factors in the design of the multipliers. With silver-oxygen-cesium surfaces, similar to those used in modern photoelectric cells, and a potential drop of 100 volts, it is possible to get a proportionality factor of four. Under these conditions the electron stream is multiplied fourfold every time it strikes an emitting surface, and by arranging a number of such stages in series, a considerable amplification can be obtained.

A photo-tube electron multiplier

thus consists of a photoelectric surface on which light falls to produce the initial stream of electrons, and a series of plates, each at a higher potential than the preceding one, to provide successive stages of amplification. The operation of such a multiplier is illustrated schematically in Figure 1. Light falls on the photo-cathode, 0, and produces an electron current I. This current falls through

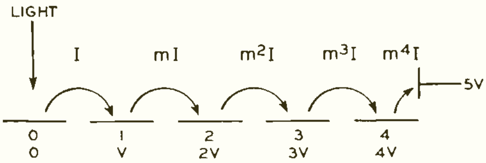


Fig. 1—Many of the previous electron multipliers have used a series of metal plates at successively higher potentials, and have employed a magnetic field to guide the electrons from one plate to the next

the potential drop v, which is the potential difference between plate 1 and the photo-cathode, and on striking plate 1 produces mI secondary electrons, where m is the proportionality factor. These electrons falling through a similar potential drop to plate 2 produce a group of secondary electrons m times as great, so that the current leaving plate 2 will be m^2I. This process is continuous over the entire series of plates, and results in an output current of m^kI, where k is a number of plates or stages. The last plate acts as a collector and is connected to the output circuit.

If such a multi-stage multiplier is to function satisfactorily, the electron leaving one plate must be guided by electric or magnetic fields so that they will all strike the next plate within a small area, which should preferably become smaller from plate to plate. If the area within which the electrons struck increased from plate to plate, some of the electrons would sooner or later fail to reach the next plate, and there would be a loss in amplification due to diffusion. If the electrons can be made to fall within smaller and smaller areas in going from plate to plate, there will be no diffusion loss. Moreover, there should be a strong field away from each plate, or space charge will form, and the secondaries will not all leave.

In the course of the work on electron multipliers carried on by G. K. Teal of these Laboratories, magnetically focussed multipliers were investigated, and several had already been put in use at the time the work described in this article was started. One of the types developed employed the arrangement shown in Figure 1.

If the electrons are to follow a converging path in a multiplier with magnetic focussing, there must be an accurate balance between the electric and magnetic fields. If the voltage drops a little while the magnetic field remains constant, the electrons will go to the wrong place, and multiplication will be markedly lowered.

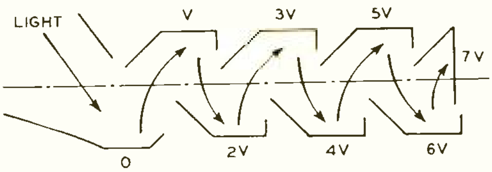


Fig. 2—Diagrammatic arrangements of plates of one of the recently developed electron multipliers

Because of this critical balance that must be maintained between the two fields, and because the presence of magnetic fields may in itself be objectionable, it was desirable to develop a multiplier that did not require a magnetic field. Although some of the early multipliers used only an electric field, they all had low efficiency because of weak fields away from the plate, and poor convergence due to inadequate control of the paths of the electrons.

To design a satisfactory multiplier, the paths of the electrons must be accurately known, but in structures as complicated as multipliers, computation of the paths is so difficult as to be almost out of the question. Fortunately, however, where the field is only two dimensional it is possible to establish an analogy between the path of an electron in an electric field and the path of a ball on a tightly stretched horizontal membrane that is deflected slightly in certain places. Such a two-dimensional field will exist wherever a group of electrodes form equipotential surfaces extending parallel for a long distance in one direction. In Figure 3, for example, a set of such equipotential surfaces is shown, which extend parallel for a long distance in the direction of the z axis. With voltages on these plates as indicated the electric field would be two dimensional; the field at any point between the two rows of plates would have an x and a y component but no z component. An electron multiplier employing only an electric field to guide the electrons is essentially this sort of a thing, the electrons passing successively from plate to plate in order of increasing voltage.

A mechanical analogy of such a two-dimensional field can be formed by stretching a rubber sheet tightly in a horizontal plane with sections of it depressed to form levels of different gravitationed potential. Small balls rolling along such a surface under the influence of the difference in gravitationed potential, or height, would follow paths exactly like those of electrons in a similar distribution of electric potentials. In this analogy the charge of the electrons is proportional to the weight of the ball, the mass of the electron to the mass of the ball, the electric potential difference between plates to the difference in

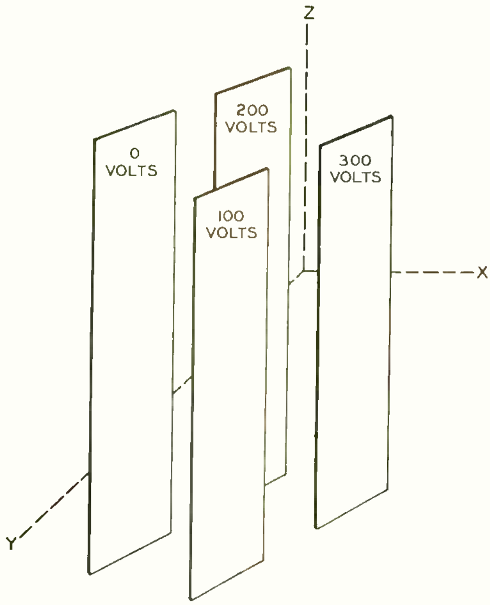


Fig. 3—A two-dimensional field exists between a series of equipotential plates that are very long compared to their width

height between successive level areas of the rubber diaphragm, and the electric field strength to the slope of the rubber surface, while the equipotential electrodes correspond to the level areas of the rubber surface.

To determine the proper arrangement of electrodes to cause the electrons to pass through the multiplier in the desired manner, such mechanical analogs have been constructed. The equipment in the accompanying photographs was constructed under the direction of W. Shockley. A sheet of rubber is stretched tightly to a rectangular frame of angle iron, which is held horizontal but arranged so that it can be raised or lowered with

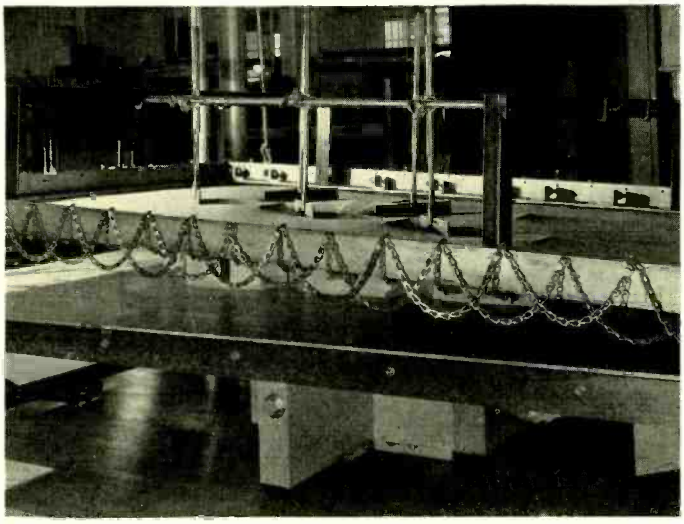


Fig. 4—Side view of the mechanical analog showing the stretched rubber sheet and the metal vanes that press it down from above so that it lies across the blocks beneath

respect to a rigid horizontal surface beneath it. Wood blocks, with accurately leveled top edges, are set up on the lower horizontal surface to form surfaces of constant height when the rubber sheet is lowered to rest on top of them. To force the rubber to lie along surfaces, metal vanes with horizontal lower edges are arranged to press down the rubber sheet so that it lies across the tops of the wooden blocks beneath. To make them show up more clearly in the photograph, the equipotential surfaces are marked by straight chalk lines, and two possible paths of balls rolling from one surface to the next lower one are also marked clearly with chalk. The objective of such an investigation is to try various sizes, shapes, and positions of blocks until balls rolled from one level surface to the next lower one tend to converge to smaller areas in each successive stage. A ball started any place over a wide area of plate 1, for example, should roll so as to strike the next lower plate in the corresponding region but over a narrower area. The arrangement shown in the photographs is that actually employed for one of the recently developed multipliers, and the convergence of the balls under actual rolling conditions is shown in Figure 6.

The arrangement of the blocks, and of the plates of the multiplier based on it, is shown in Figure 2. The convergence of this multiplier is very

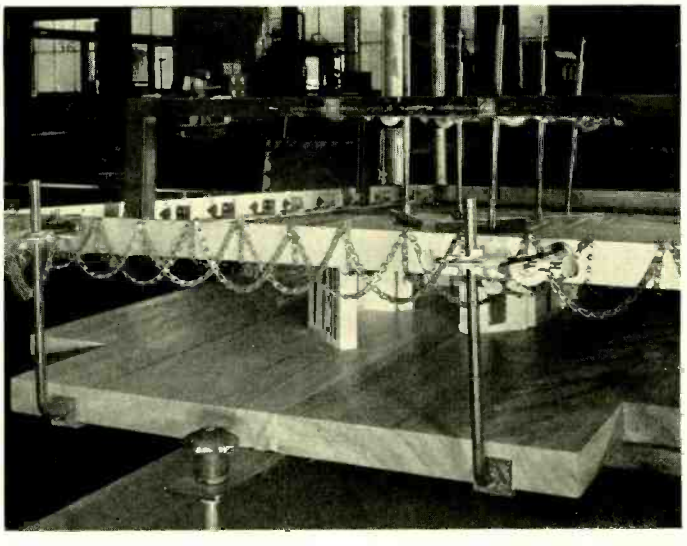


Fig. 5—End view of the analog, showing the wooden blocks beneath the rubber sheet

good, and in addition there is a strong field away from all portions of the plates where the electrons strike. The effect of initial velocities in the paths of the electrons was investigated by starting the balls on the rubber model with a slight initial velocity, and was found not to be particularly serious.

A number of multipliers of this type have been built, and one of them is shown in the photograph at the head of this article. The photo-cathode has an effective surface considerably larger than that of the multiplying plates, of which there are six between the photoelectric surface and the anode, or collector. All of the plates are long compared to their width, in a direction at right angles to the plane of travel of the electrons, and the ends of the plates are bent in toward the center to keep the electrons from drifting out. The problem of activating the multiplier so as to get a good photoelectric response and at the same time good secondary emission was solved by M. S. Glass, and at 750 volts, overall, this multiplier has an output of thirty milliamperes per lumen, which is over a thousand times greater than that of a vacuum photocell. The safe output current is of the order of a few milliamperes, and the collector voltage may swing as much as 70 volts each side of the mean value without seriously affecting the operation of the multiplier. The output resistance, which varies inversely with the output current, is greater than one megohm at one milliampere.

The electron multiplier has a number of advantages as compared with a photoelectric cell and an equivalent vacuum-tube amplifier. In the first place it is much smaller, not being much larger than the photoelectric cell alone. Further, experience has shown that for high-frequency work, the electron multiplier is less noisy.

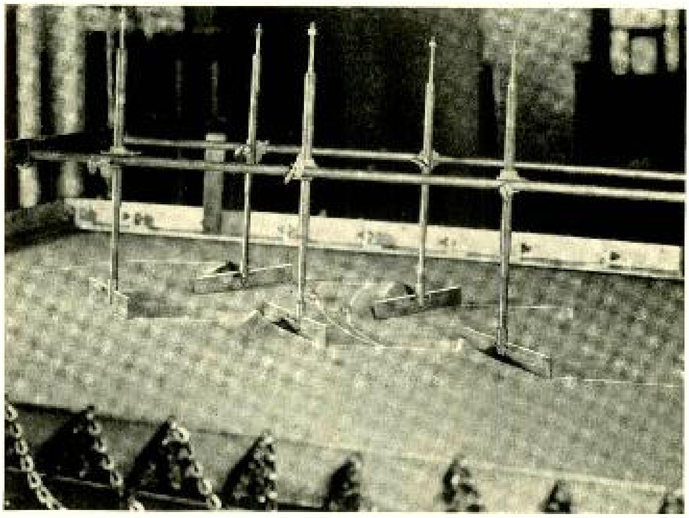
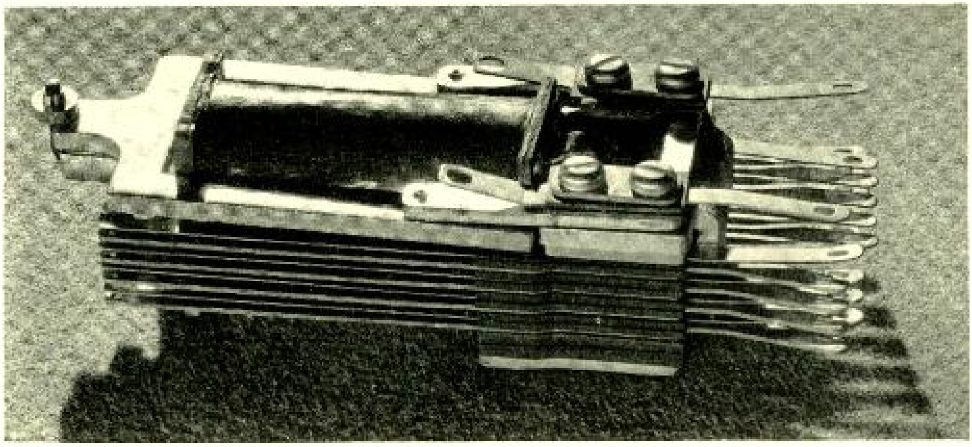


Fig. 6—Top view of analog showing two balls rolling from widely separated points at one potential level and converging as they approach the next lower level

The multiplier is also practically non-microphonic; the noise in the output is little higher than the unavoidable "shot" noise of the photoelectric cell multiplied by the gain. Still another advantage is that its amplification is practically constant at all frequencies up to several megacycles. The emission of the secondary electrons is so nearly simultaneous with the impact of the primaries that the multiplying action faithfully reproduces the very rapid changes in current necessary to transmit these very high frequencies.



The Y-Type Relay

By F. A. ZUPA
Electromechanical Apparatus Development

IN many of their applications in the Bell System, relays are required to act as rapidly as possible. They should operate promptly when voltage is applied to them, and release promptly when the circuit to their winding is opened. There are numerous applications, however, where it is necessary for the relay to remain operated for an interval after the circuit to its winding is opened, and this release interval is often specified within very close limits. Precise behavior of this kind is not easy to secure; only careful design and accurate control of manufacture make it possible. Relays that are most economical for general uses will not meet the very exacting requirements laid down to secure a precise slow-release period. When the general utility U-type relay was developed, it seemed desirable, therefore, to develop at the same time a slow-release relay that so far as possible would use the same parts, manufacturing tools, and processes. The result was the Y-type relay, which is shown in the photograph at the head of this article.

The need for dependable slow-release relays can be well illustrated by one of their applications in the panel system. A group of relays in the sender records each digit dialed, and it is necessary to switch the dialing circuit from one group to the next after each digit of the called number. As the dial returns after having been pulled around to one of the digits, it opens and closes the circuit in rapid succession to indicate the digit dialed. Thus in dialing 2 the circuit will be opened and closed twice, and in dialing 4 the circuit will be opened and closed four times. Immediately after its return, the dial is pulled around for the next digit, and during this short interval between digits the circuit must be switched to the next group of recording relays. This is accomplished through a slow-release relay that does not release during the short open periods of each digit, but does in the slightly longer period between digits. It must do this regardless of the commercial range in dial speeds, of voltages and line variations, and in the speed with which the dial is pulled around. In the latest type sender the actual requirements for the Y-type relay are that it shall release in not less than 0.080 second nor in more than 0.120 second. The ordinary relay, however, releases in from 0.005 to 0.015 second. In designing a slow-release relay, therefore, there are two objectives sought: first to provide the slow-release action, and second to provide for an accurately controlled release time.

In the case of an ordinary relay when the winding circuit is opened to release the relay the current decreases almost instantly to zero value except for the duration of any arcing at the opening contacts. The relay continues to hold in the operated position, however, because a considerable portion of the flux in the magnetic circuit is maintained by eddy currents which are induced in the iron upon breaking of the winding circuit. The effect of the eddy currents is more prolonged if the air gaps in the magnetic circuit are small. To hasten the action of release therefore non-magnetic discs are usually provided on the armature pole face to obtain an appreciable air gap in the operated position of the relay. Two nickel-silver stop discs are used in the U-type relay as on other relays designed for quick release. The comparable action on still other relays is obtained also by means of an adjustable screw made of brass or other non-magnetic material. In the Y-type relay, however, they are omitted so that when the relay is operated, the armature is directly in contact with the core.

The omission of the stop discs reduces the current necessary to hold the relay operated, and since the release time is a function of the difference between the maximum flux and the flux at which the relay just holds, there will be a longer time between the opening of the circuit and the release of the relay. To make a further decrease in the reluctance of the magnetic circuit, the cross-yoke at the rear of the core of the Y-type relay and the hinge bracket on which the rear ends of the armature rest are made of magnetic iron instead of cold-rolled steel, as are those that are used in the U-type relay.

The major means of securing slow release, however, is by retarding the rate of decrease of flux in the core by providing during the release period a magnetizing force that tends to maintain the flux at its original value. This is done by placing directly over the core a sleeve of copper or other con-

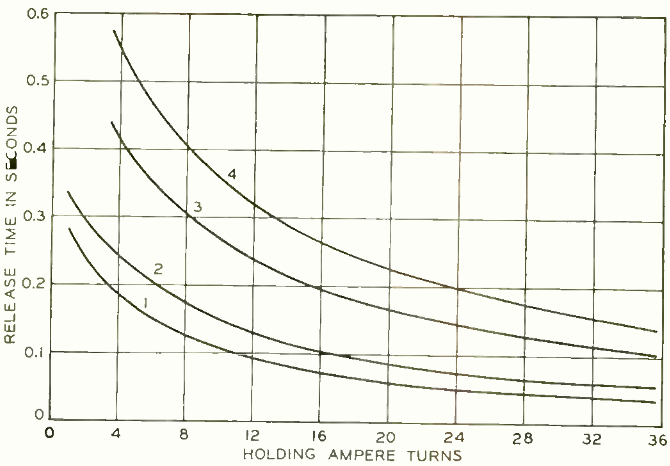


Fig. 1—Release times possible with the Y-type relay by use of the four available sleeves

ducting material. As the flux tends to decrease, when the winding circuit is opened, a current is induced in this sleeve which is in a direction tending to maintain the flux. The lower the resistance of the sleeve, the larger will be the current that will flow, and the less the rate of dissipation of energy due to resistance. To provide control by this means, three copper sleeves of different thickness and one of aluminum are employed. Aluminum is used for the shortest release period because of its high resistance. To obtain a high enough resistance with copper, the sleeve would be too thin for satisfactory manufacturing conditions.

These sleeves provide four degrees of delay that may be obtained with the Y-type relay. The actual release time, however, depends not only on the resistance of the sleeve and on the reluctance of the magnetic circuit, but on the restoring force of the springs tending to open the relay. This, in turn, is a function of the number of springs with which the relay is equipped, so that the same sleeve will give different release times depending on the springs used. The number of ampere turns required to hold the relay operated also depends on the spring load, so for each sleeve a curve can be plotted showing the relationship between release time and the ampere turns required to hold the relay operated. A set of such curves for the four sleeves is given in Figure 1; the No. 1 curve is for the aluminum sleeve and the other three are for those of copper.

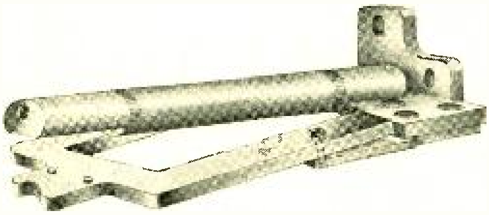


Fig. 2—Simplified cross-section of the magnetic circuit of the U-type relay

These copper sleeves provide the most effective means of retarding the decrease of flux in the core after the winding circuit is opened. Any short-circuited winding on the core, however, would provide the same action only less effectively. Advantage is taken of this fact in a few applications where the release time desired falls between two of the curves of Figure 1. Short-circuited windings are designed to give the desired intermediate release times.

After having decided on these various features to secure a longer release time, it is necessary to make other changes to hold the desired time within very close limits. The design must provide not only that any one relay will always release after the desired interval within narrow limits, but that all relays built for the same release interval will meet their requirements within similar limits.

The chief factor causing variations in release time may be illustrated by Figure 2, which is a simplified cross-section of the magnetic structure of the U-type relay. The contact surface of the relay core and of the hinge bracket are both flat, and so are the two corresponding surfaces of the armature. If the armature, core, and hinge bracket could be perfectly

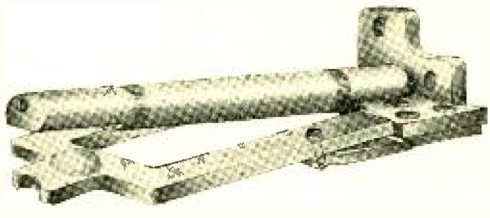


Fig. 3—Simplified cross-section of the magnetic circuit of the Y-type relay

aligned, the area of contact, and thus the contact reluctance, would be the same under all conditions. Actually, however, slight variations in the thickness or position of the hinge bracket or of the armature itself, cause the armature to meet the pole face at a small angle, which will vary with different relays and with the same relay at different times.

With the U-type relays variations due to these causes at the front end of the relay are reduced by the stop discs, and the variations at the rear end are not great enough to cause deviations that exceed the requirements. With the Y-type relay, however, which does not employ the stop discs, these variations would seriously impair the accuracy of the release interval. The variations are avoided, however, by the construction shown in Figure 3. A small spherical surface is embossed on the front end of the armature so that the armature always meets the core in what is essentially a point contact. The front end of the hinge bracket is embossed to form a cylindrical surface at right angles to the axis of the armature; and so the armature and hinge bracket always meet in what is essentially a line contact. Regardless of the alignment of the armature, therefore, there is always a point contact at the front end and essentially a line contact at the rear end.

The effects of these structural differences on the reluctance are shown in Figure 4 for relays with flat surfaces and for those with the spherical and cylindrical surfaces of the Y-type relay. With perfect alignment the reluctance of the flat surfaces is very low, but it increases rapidly with an increase in the angle between core and armature. The reluctance of the rounded surfaces is much higher for perfect alignment, but it increases only very slightly as the deviation in the alignment increases, and thus gives the constancy of reluctance particularly desirable for a slow-release relay.

The reasons for this are obvious. With a flat surface in perfect alignment—zero angular deviation—the contact is spread over the entire surface, and the reluctance as a result is very low. When the armature meets the pole face at an angle, however, there is a wedge-shaped air gap formed, and the greater the angle of contact, the greater will be the width—and thus the reluctance—of this gap. With the spherical or cylindrical surfaces, the contact is always in a point or line with a narrow air gap at the sides regardless of the angle with which the armature meets the contacting surfaces. The reluctance of such a contact is higher than that of two flat surfaces where the angle is small, but remains essentially constant, while that of the flat surfaces

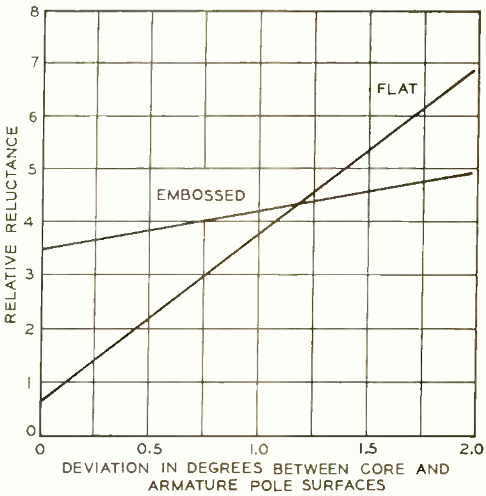


Fig. 4—Variations in reluctance of relay with angle at which armature meets the core for both flat and embossed pole pieces

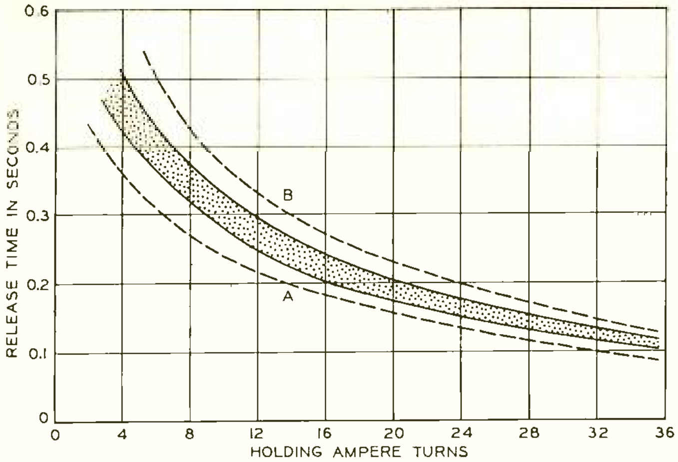


Fig. 5—Variations in release times for flat and rounded pole surfaces. Shaded area shows variations for Y-type relays

increases steadily as the angle widens.

A protective coating is plated on the magnetic structure to prevent corrosion of the iron, but since this coating is non-magnetic, it introduces what is effectively an air gap in the magnetic circuit. Variations in the thickness of this plated coat would affect the release time by varying the reluctance of the magnetic circuit. The closeness with which the release time must be held with the Y-type relay, therefore, requires that the thickness of the plating be held within very close limits; the actual range is from 0.0003 to 0.0006 inch. Chromium is used for the outer plating to provide a very hard surface to resist wear at points of contact between the armature and core.

As a result of the consistency in reluctance obtained by these various means, the variations in release time are considerably reduced. For the Y-type relay the variations in release times are shown by the shaded area of Figure 5. For a corresponding relay with flat surfaces, the release time might fall anywhere between the curves A and B. With rounded surfaces the variation in release time is thus cut from one-half to one-third of what it would be with flat surfaces.

So uniform are the characteristics of the Y-type relay that the release time can be closely predicted from the value of the current necessary to hold the relay operated. Heretofore it has been necessary to check the operation of slow-release relays by actually measuring the release times, which is a rather slow and expensive procedure. With the Y-type relay such measurements are unnecessary; it is sufficient to measure the holding current, because of the close correspondence between holding current and release time.

Except for these differences, the Y-type relay is the same as the U type, and to the casual glance one could not be told from the other. Moreover, the copper sleeves designed for the Y-type relay may be employed with the U type to secure somewhat slower release, although the long release obtained with the Y-type relay cannot be secured with the U type, nor can the accuracy of release time for the relay be maintained.

As the U-type relay is intended to be the general utility relay of the future, replacing ultimately the E and R types, so the Y type will be the slow-release relay of the future—replacing the 149, 162, 178, and T types. One of its first applications is in the new 755A PBX, where it will be used, in conjunction with other relays, to simulate the action of a ringing interrupter.

Precise measurement is basic to all science; hence the endless variety of measurements made in Bell Telephone Laboratories. For many projects no standardized measuring apparatus is available; hence it must be built to order.

I

Open-field calibration of standard comparison receivers

II

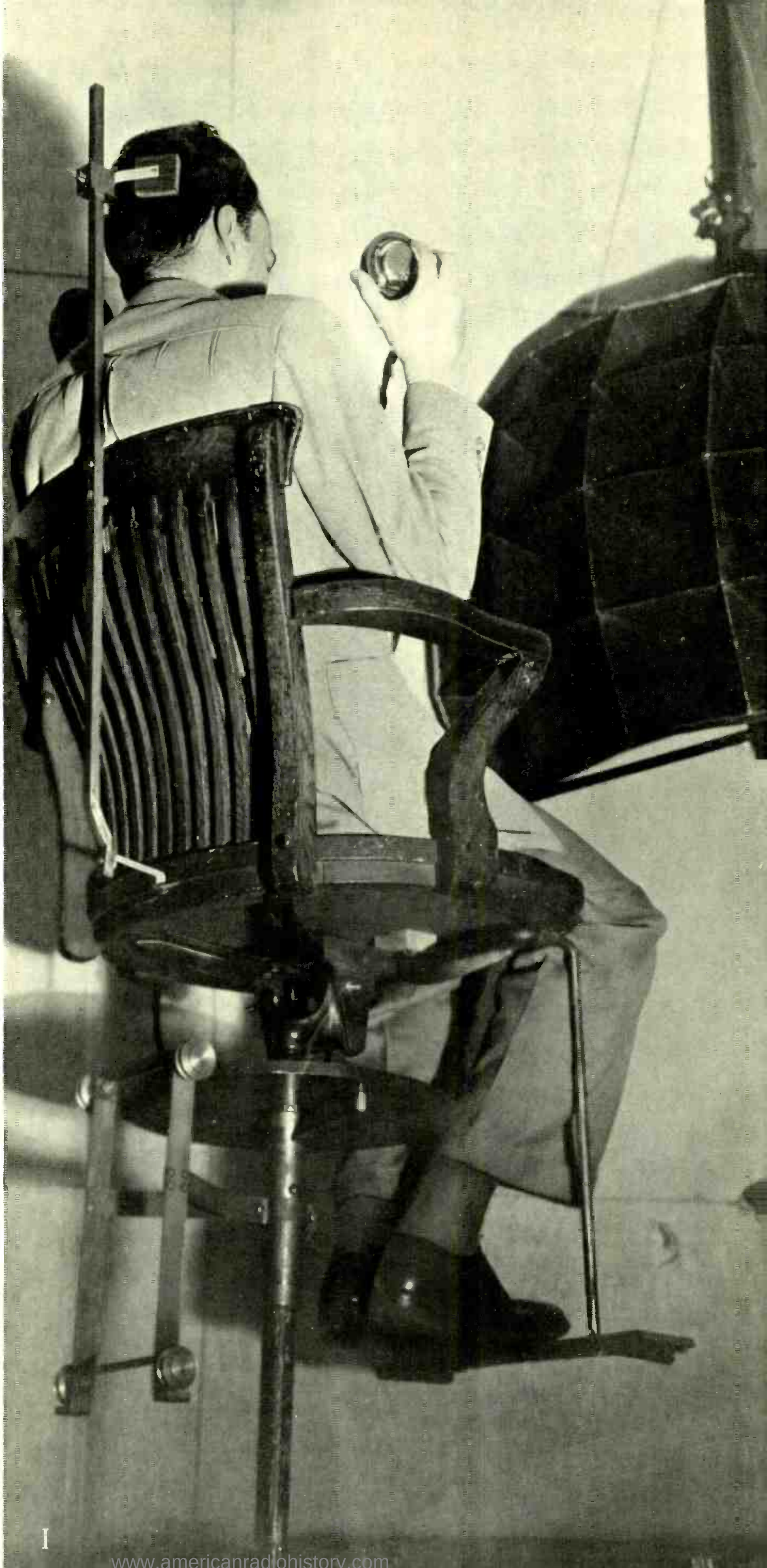
Measuring the separation between pole pieces and diaphragm of an audiphone receiver

III

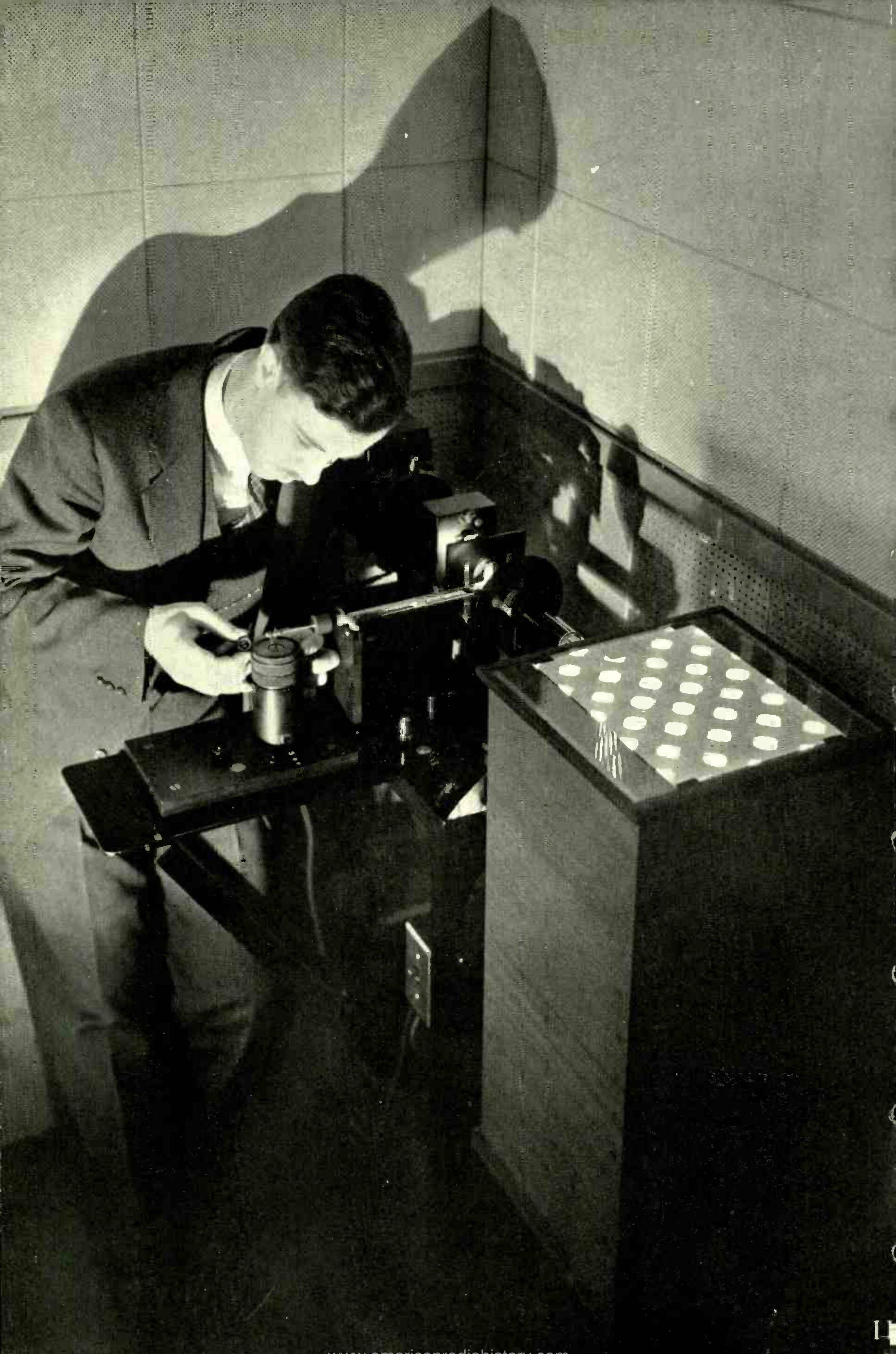
Equipment for measuring flux density in a receiver

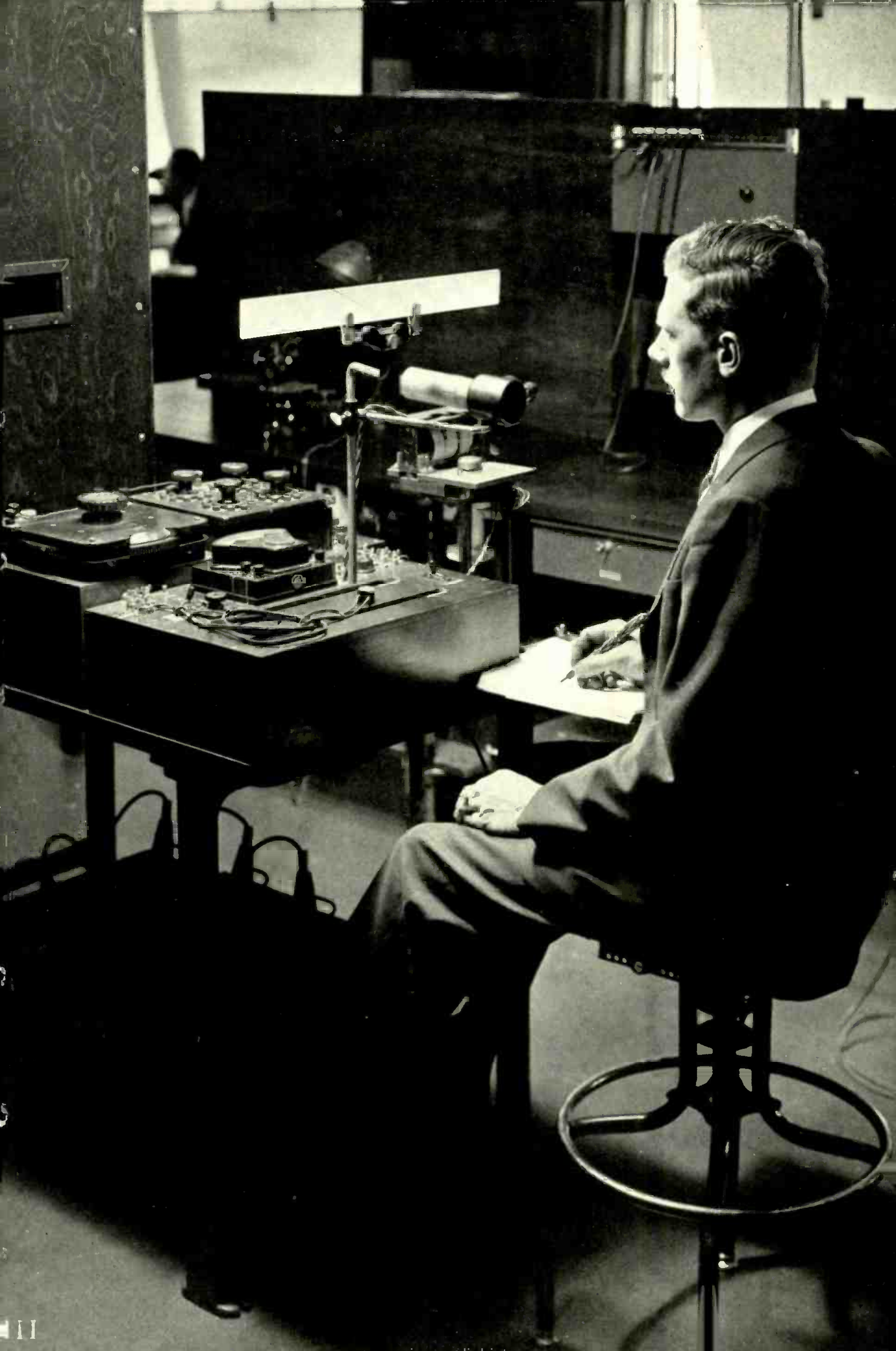
IV

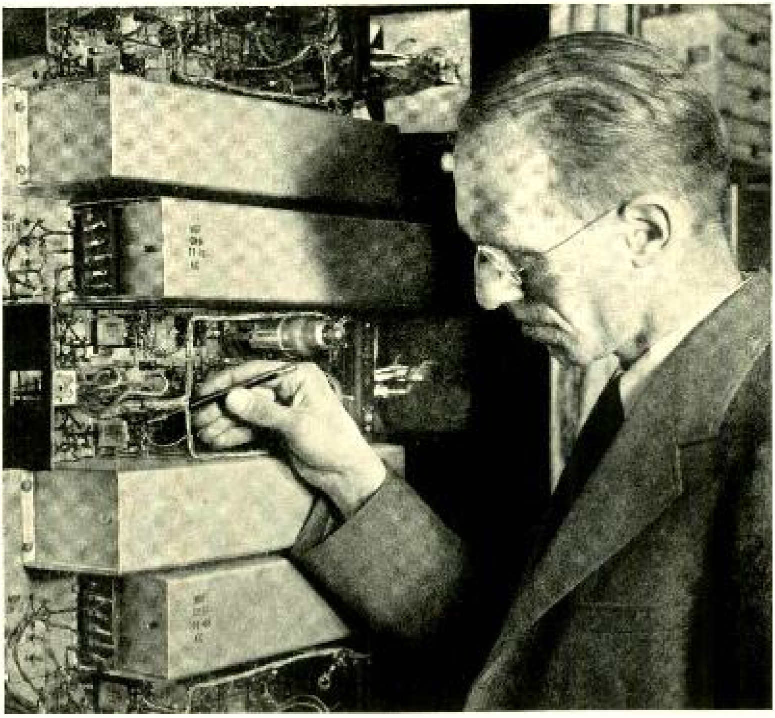
Measurement of the thickness under compression of a paper damping-ring book for a transmitter



I







Channel Terminal Equipment for Broad-Band Carrier Systems

By R. E. CRANE
Toll Systems Development

EARLY in the development of the broad-band carrier systems, it became apparent that important advantages would result if the same channel terminal equipment could be used for all systems. Such a generally applicable terminal not only would reduce the total amount of development required, and the manufacturing preparation that would later be needed, but would permit a larger quantity production of the individual apparatus units with its consequent economies, and would give greater facility of interconnection of different types of systems. To obtain such a common channel terminal arrangement, numerous frequency allocations and groupings of channels were studied, and a scheme was finally worked out which meets the requirements of each system. Both the type J, or open-wire system, and the type K, or cable system, provide twelve carrier channels; and the coaxial cable system, which will provide several hundred channels, uses a basic twelve-channel group, which is raised by other modulations into successive positions in the frequency spectrum. The twelve-channel group is thus common to all these systems, each having different types of group modulators, demodulators, and filters with the appropriate carrier supply to adapt the set of twelve channels to any of the three systems.

The channel terminal equipment is practically identical for all systems, and naturally divides itself into two sections: modulating and selecting circuits, and the carrier supply circuits. The carrier supply equipment provides twelve carrier frequencies spaced 4000 cycles apart and extending from 64 to 108 kilocycles, inclusive, with certain other frequencies for special purposes. Sufficient capacity is provided to supply a number of groups from the same carrier source. Ten groups, or a total of 120 channels, may be supplied from a single carrier unit, and more could be supplied if, at any time, it should prove desirable.

Fig. 2—Installation of channel equipment located at 32 Sixth Avenue, New York

The modulating and selecting circuits, on the other hand, are provided, physically, in units caring for two two-way telephone circuits, so that six of the units are required for a complete twelve-channel terminal. Each unit occupies 12¼ inches on a standard relay rack bay, and eighteen of them mounted on two bays are shown in Figure 2 as set up for the experimental coaxial demonstration at 32 Sixth Avenue. The bay at the left of the channel terminal units includes the carrier supply equipment.

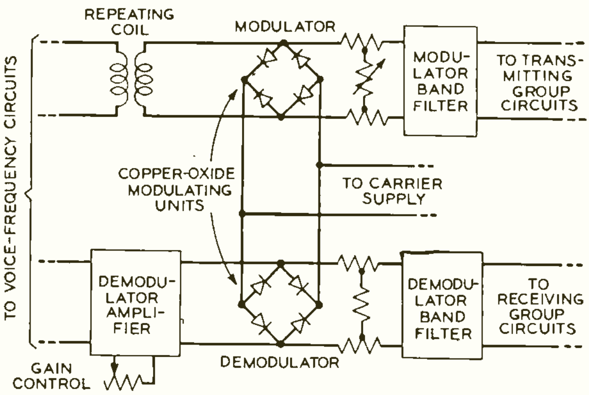


Fig. 1—Schematic diagram of the channel terminal equipment for a single two-way channel

The modulating and selecting equipment for a single two-way telephone circuit is shown in schematic form in Figure 1. In the transmitting side, above, there are, from left to right, a repeating coil, a copper-oxide modulator, a resistance network, and a band-pass filter. On the receiving side there are, from right to left, a band-pass filter, a resistance network, a copper-oxide demodulator, and the demodulator amplifier. Equipment for two of such circuits comprises the unit panel shown in Figure 2. A small jack strip, which projects through the front cover as shown in the photograph at the head of this article, provides a simple means of reading values of the currents and voltages of the amplifier tubes.

One of the outstanding features of this equipment is its simplicity and small size. The modulator and demodulator each consist of four copper-oxide discs only three-sixteenths inch in diameter and connected in a "bridge" network. This network may be considered as a variable resistance shunt across the signal circuit, which changes from a low to a high resistance under control of the carrier frequency. Because of the balanced form of this circuit, practically none of the carrier appears in the output side, which in the transmitting channel includes the two sidebands only. For the same reason none of the voice or sideband frequencies can get into the carrier supply to interfere with other channels. The resistance network between modulator and filter serves to give a constant impedance termination for the filter instead of the varying impedance termination that would be offered by the copper-oxide network.

This balanced condition of the modulator and demodulator is very important, and is secured by careful selection of the discs during manufacture. There are in reality two types of balance to be considered. In the first place, the four discs comprising a single modulator are selected to have the same resistance within very close limits. This insures the balance that prevents carrier getting into the output circuits, or voice or sideband into the carrier circuits. Besides this form of balance, it is desirable that the output of all channels be approximately at the same level. Since the transmission loss through the modulator is an important factor in determining this level, the discs for the modulator are further selected to have substantially the same transmission loss.

The filters are of the recently developed quartz-crystal type, and provide a pass-band about 3000 cycles wide and with very steep sides, as shown in Figure 3. This type of filter is very economical of space; each filter requiring only one side of a 3½-inch panel. Two of the four filters required for the two channels are mounted at the top and bottom of the panel in the photograph at the head of this article; the other two occupy corresponding positions on the rear of the panel. The twelve transmitting filters of a group are multipled together at their output terminals, together with a compensating network to improve the impedance termination. A similar network is connected to the multipled terminals

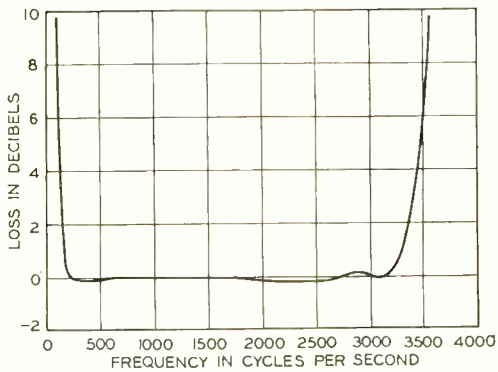


Fig. 3—Frequency characteristics of the crystal filters for the channels

of the twelve receiving filters. These compensating networks are housed on the narrow panels between the third and fourth panels from the bottom as seen in Figure 2.

To take care of losses that may be interposed between the two-wire circuit at the toll board and the four-wire circuit at the channel terminal, it is necessary to have the level at the receiving circuit higher than that at the sending circuit. Since the same carrier supply is employed for both modulator and demodulator, however, the output of the demodulator is at a lower level than that of the input circuits because of the losses in the demodulator. An amplifier is therefore provided to raise the level of the demodulated signal to the desired level. Gain adjustment of the amplifier is provided by a small potentiometer. For all the channels, both transmitting and receiving, the voice circuits are terminated in jacks all grouped at one location; and the gain potentiometers of the demodulator amplifiers are mounted above their corresponding jacks. This makes a very convenient arrangement for maintenance, since the level of all channels at the output of the carrier equipment may be measured and adjusted in rapid succession at the same place on the panel equipment.

Carrier current for the twelve channels is provided by a harmonic-producing circuit supplied from a 4000-cycle source. The circuit arrangement is shown in Figure 4. The precision required of the basic supply frequency depends on the highest carrier frequency to be supplied. For the type J and K systems, with an upper frequency of about 60 and 140 kilocycles respectively, the precision does not need to be so great as for the coaxial system where the upper carrier is a million or more cycles. A 4000-cycle tuning fork is adequate for the low-frequency systems, while for the coaxial system, the high-precision standard frequency of 4000 cycles now supplied from New York may be employed. The alternative connections are indicated on the diagram. The fork is actually employed in both cases, but for the low-frequency systems it is used to control the oscillator frequency, while for the high-frequency system it is used only as a 4-kc band-pass filter.

The output of the oscillator passes to a single-tube amplifying stage, and thence to a push-pull stage and an output transformer. This transformer is tuned to 4000 cycles on its output side, and it feeds the harmonic-producing circuit through another tuning stage to insure a pure 4000-cycle wave.

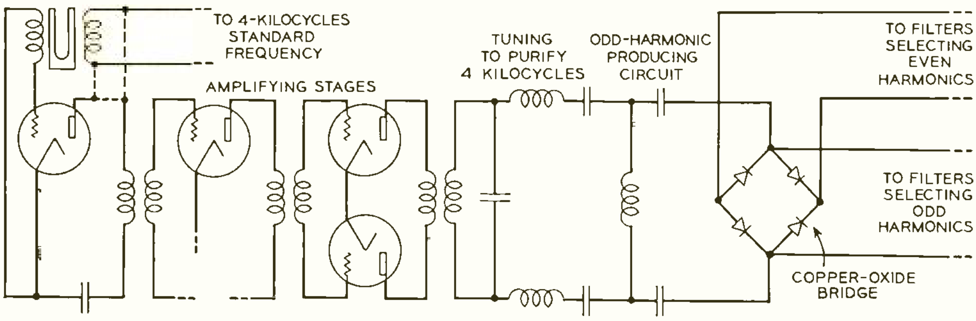


Fig. 4—Simplified schematic of the carrier-supply circuit for the channel terminals of broad-band carrier systems

The harmonic-producing circuit consists of a shunt coil, two series condensers, and a copper-oxide bridge circuit. At the beginning of the current wave the coil is of high inductance, and the condensers charge, but as the current increases, the core of the coil becomes saturated, and as a result the inductance decreases so that the coil approximates a short circuit. This transition from high inductance to low occurs rapidly with the result that the condenser discharges through the coil in a rush of current. The result is a sharply peaked current wave, decomposable into a 4000-cycle fundamental and its odd harmonics. The odd harmonics desired are selected by a group of filters as indicated on the diagram.

Even harmonics are produced by the copper-oxide bridge, which, acting as a full-wave rectifier, causes a series of current peaks in its output branch. There is a peak for each peak on the input side, but the output peaks are all of the same sign because of the rectifying action of the bridge. A current of this kind is decomposable into a fundamental of 8000 cycles and all harmonics, both even and odd. Since even and odd harmonics of 8000 cycles are even harmonics of 4000 cycles, this circuit produces the even harmonics of the 4000-cycle fundamental, which are selected by a second group of filters. The requirements placed on these filters are made easier because of the balanced arrangement of the copper-oxide discs, which tends to prevent

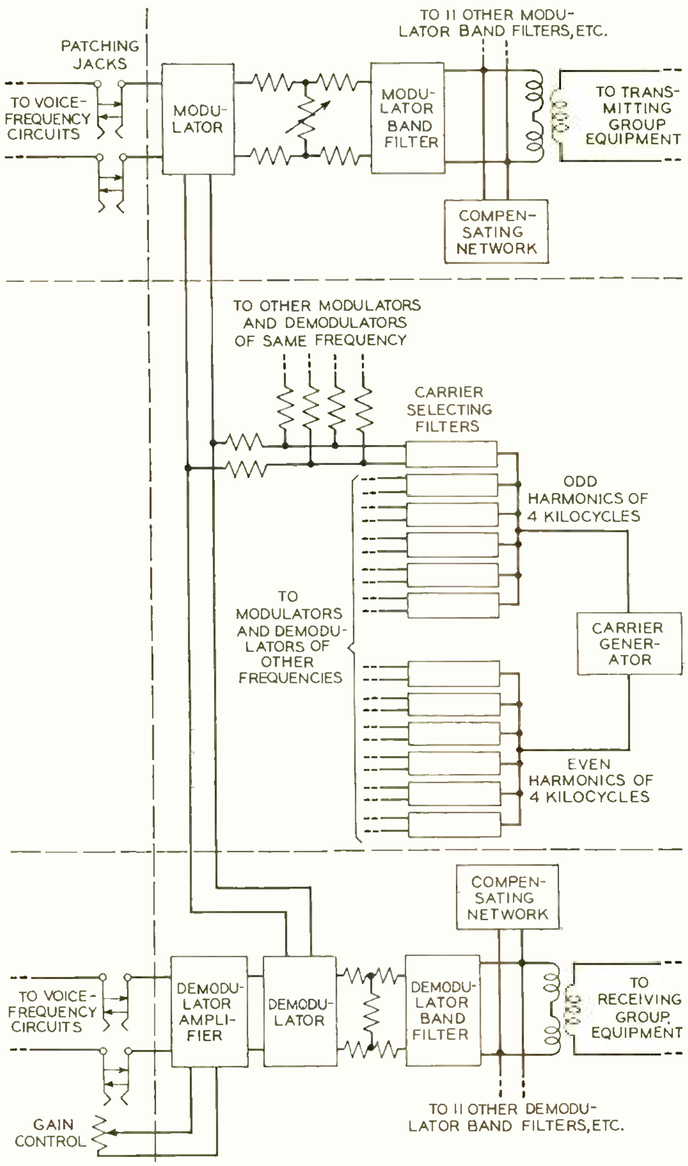


Fig. 5—Simplified schematic of channel terminal unit for broad-band systems

Fig. 6—L. R. Cox at a carrier supply bay in the Graybar-Varick laboratories

frequencies getting from one branch into the other.

The filters used to select the carrier frequencies are also of the crystal type, but contain only one section. Beyond them, a set of resistances is provided through which connection is made to the various circuits as indicated in Figure 5. These resistances protect the common carrier supplies against possible short circuit in any lead. As mentioned above certain other harmonics may be employed also, such as the 24-kc current that was used as the fundamental frequency for the production of carrier frequencies in the million-cycle coaxial system trial, and the 60-kc current used as a pilot frequency.

A photograph of a carrier-supply bay, with the protective resistances above, is shown in Figure 6 as set up in the Laboratories for the coaxial tests. Two harmonic-producing circuits, one a regular and one an emergency, are normally provided to safeguard the carrier supply. Means are provided for automatically transferring from the regular to the emergency in case of failure, and of manually transferring in either direction with very slight interruption to any of the circuits involved.

Of the many interesting characteristics of this channel-terminal equipment, one of the most impressive is that of its compactness. Due to the use of crystal filters, of small size coils with improved core material, and of the copper-oxide modulator and demodulator units, the complete channel modulating and selecting equipment for three groups, each of twelve two-way telephone circuit capacity, can be mounted on two relay rack bays, as shown in Figure 2. All the wiring between units is arranged to run up both sides of the relay racks in metal compartments which provide shielding. This permits the use of more unshielded wire than would be possible otherwise.

The first use of this equipment was with the experimental coaxial cable system between New York and Philadelphia, which was demonstrated to the press in November, 1936.

Time Lag in Gas-Filled Photoelectric Cells

By A. M. SKELLETT
Physical Research

WHEN a gas-filled photoelectric cell is suddenly illuminated, the current through it increases very rapidly at first but attains its maximum value after only about a thousandth of a second. Likewise when the light is abruptly extinguished some current flows through the darkened cell for about the same brief interval. This delay has been ascribed to the time required for the gas ions which are generated in the tube to move to the cathode. The failure of the output to follow the light variation exactly can be explained readily on this assumption at frequencies of about 10,000 cycles; but considerable doubt has been expressed that the lag at lower frequencies could be due to the same cause.

The current in a gaseous cell involves not only the electrons which the light liberates at the cathode but also all the other electrons and ions which these photoelectrons produce in collision with gas molecules. Thus for each primary photoelectron liberated at the cathode, a number of electrons arrive at the anode. The positive ion formed at each ionizing collision travels in the opposite direction toward the cathode, but moves much more slowly through the gas because of its larger size and mass.

In studies in gas-filled cells commercial designs are not particularly suitable, mainly because in them the electric field is not uniform and hence some ions take longer to reach the cathode than others. The design shown in Figure 3 overcomes this defect, for its anode is small and all parts of the cathode are approximately equidistant from it. As a consequence of this geometrical form, the electric field is distributed uniformly throughout the entire tube as shown in Figure 2, and the transit time of all the ions is approximately the same.

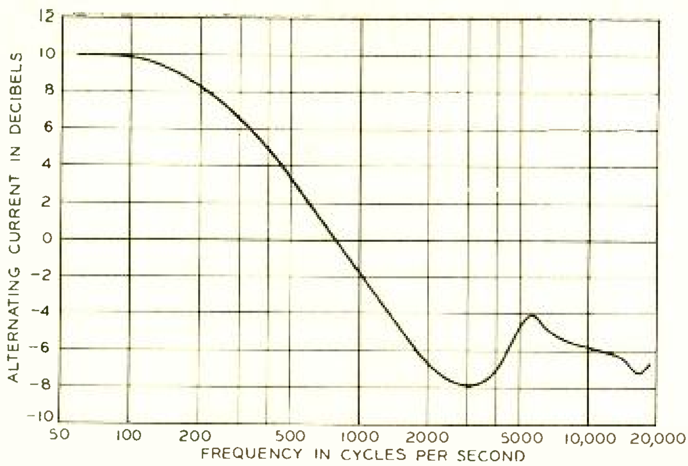


Fig. 1—The magnitude of the alternating current output of the cell varies with the frequency of the incident light because the components of the current carried by the electrons and the gas ions are in phase at only certain frequencies

short time so that most of the current due to a photoelectron and to the electrons and ions it produces, flows almost instantaneously in the external circuit.

When the ions reach the cathode, they release new electrons, which, like the original photoelectrons, produce new ions and electrons and cause another pulse of current to flow. The second pulse flows after a time interval which is approximately equal to the transit time of the ions and succeeding pulses of decreasing amplitude follow at intervals equal to this. Thus if the release of photoelectrons varies sinusoidally, a series of sinu-

If the photosensitive cathode is illuminated by light whose intensity varies sinusoidally, the emission of the primary photoelectrons and the consequent production of positive ions will also vary sinusoidally. Waves of ions will travel from the region of the anode to the cathode, slowing up as they approach the cathode like ocean waves rolling in on a sandy beach. Now it so happens that the current in the external connecting circuit due to the transit of a charged particle across the cell flows during the whole time the particle is in motion, ceasing when it delivers up its charge on reaching an electrode. Furthermore, most of this current flows while the particle (ion or electron) is in the vicinity of the anode and is moving swiftly. The electrons get across the cell very quickly and the ions get out of the vicinity of the anode in a very

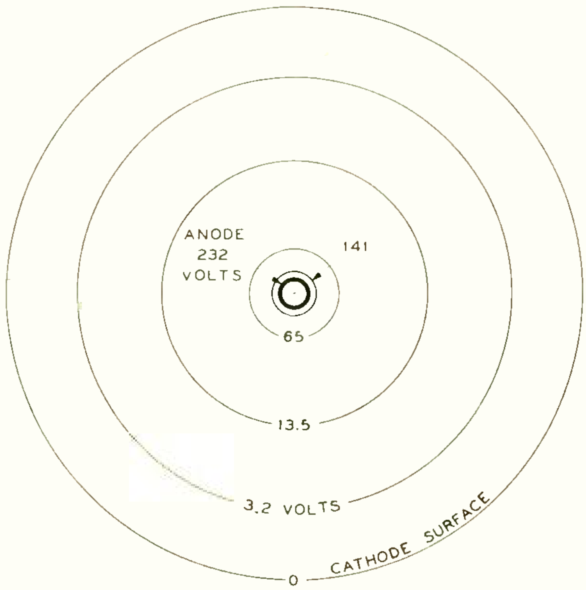


Fig. 2—The symmetrical construction of the photoelectric cell gives a uniform distribution of the electric field within it

soidally varying currents will flow in the external circuit. These will all be in phase when the transit time of the ions is equal to the period of the current variations, for then the crests of the waves fall together and the total alternating current output is a maximum. Conversely, when the transit time of the photoelectrons is equal to half a period, the total current falls to a minimum value.

By measuring the magnitude of the output of the cell for different frequencies of light variation and plotting the data, Figure 1, the first minimum and subsequent maximum are found to occur where expected on the assumption that the effect is due to the relatively slow velocity of the gas ions. Other maxima and minima might be anticipated at higher frequencies, for which the times of flight would be multiples of the periods and half periods. They are not observable, however, because the ions move about in a very irregular manner with the result that at the higher frequencies individual ions wander from their positions in the wave, the crests and troughs merge, and the waves lose their identity.

It is possible to calculate, from the speed at which argon ions drift, what the average velocity of the ions at different distances along the radius should be; and to deduce therefrom the total time taken by an ion in going from the vicinity of the anode to the cathode. As stated in the preceding paragraph the value thus determined is the same as the period of the light frequency at the first maximum, or half the period at the first minimum. This confirms the theory given above and thus establishes the nature of the time lag in this cell.

In commercial cells large variations in the time delay are to be expected because of their non-uniform fields, mentioned earlier in the article. Thus the fact that maxima and minima have not been observed in curves taken

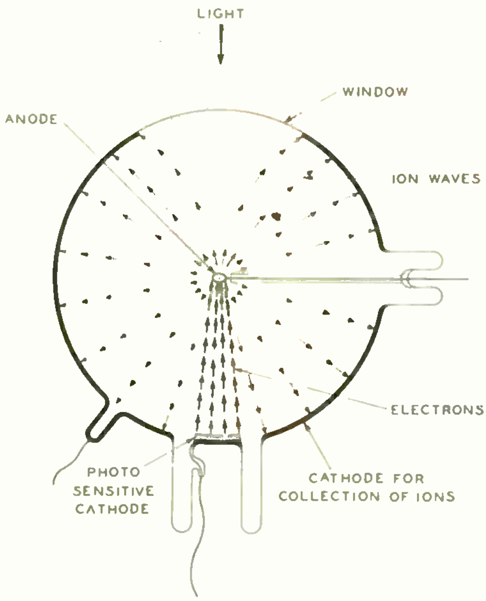
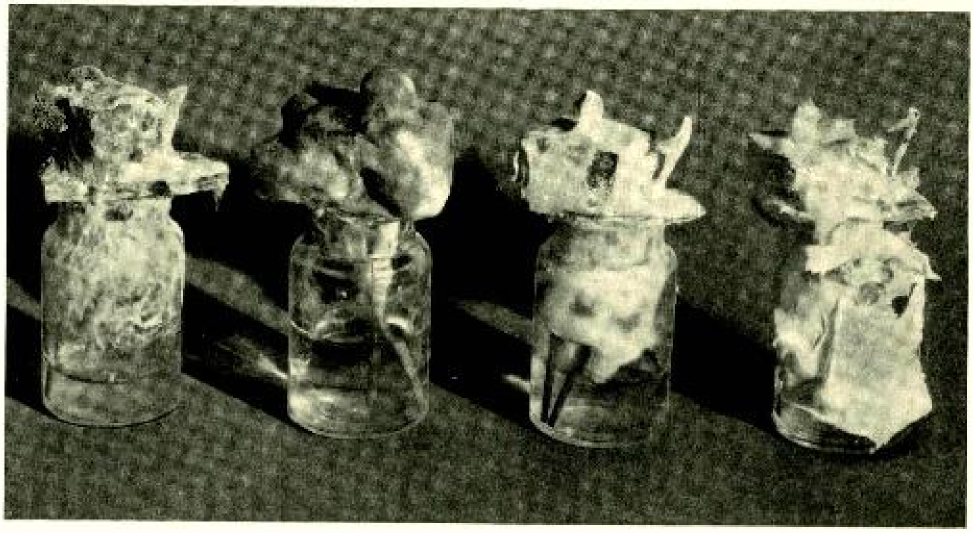


Fig. 3—A special photoelectric cell was constructed for the time-lag tests. The anode is small and all parts of the cathode are approximately equidistant from it

with commercial cells of usual design is reconcilable with the theory that has been developed. But the lag in response is there just the same.

For the voice-frequency band used in sound pictures the distortion caused by the lag in the photoelectric cell is not serious. There is some phase distortion but fortunately the ear cannot detect it. The most obvious practical consequence of the lag is a small loss in efficiency which, now explained, could be reduced if necessary by modifying the cells. Where frequencies much above 10,000 cycles are involved the lag becomes large and has to be taken into consideration in the design of cells.



Laboratory Tests of Wood Preservatives

By JOHN LEUTRITZ
Chemical Laboratories

EVERY year approximately a half million new poles of southern yellow pine are used in the Bell System either for replacements or for new lines. If these poles were left unprotected from the action of lower forms of plant and animal life—fungi and termites—the economic loss would be serious. Their life can be greatly extended, however, by treating the poles with a suitable preservative. There are many preservatives on the market, and new ones are being offered from time to time to pole manufacturers, so that techniques for evaluating them must be available. Outdoor exposure tests of wood preservatives are usually slow and expensive and it is necessary to supplement such studies with quick and inexpensive laboratory methods.

Recent experimentation has evolved an improved laboratory test which is simple and adaptable and yet gives reproducible results which are consistent with field trials of the same material. Briefly, it involves the impregnation of small pieces of blocks of wood with the preservative to be tested, and their exposure in separate glass jars to the action of different fungi. After several weeks, the preservative's effectiveness is rated by the amount and density of the fungus growth, the decrease of weight of the samples, and their loss of mechanical strength.

The blocks used in testing preservatives are from the sap-wood of southern yellow pine, of uniform density and rate of growth, cut usually into cubes, two centimeters on a side. Since the moisture content of the wood varies over a wide range, depending on the relative atmospheric humidity to which it has been exposed, the blocks have to be brought to a definite humidity content before each weighing at the various stages of the test. For this purpose there is used an ordinary bacteriological incubator, Figure 3, fitted with slow-moving fans and pans of saturated solution of sodium chloride. It maintains a relative humidity of 76 per cent at 30 degrees Centigrade which gives the blocks a moisture content of about 14.1 per cent when compared with the oven-dry state.

The procedure usually followed in studying a new preservative is to inject blocks, conditioned as above, with a solution of the preservative. The pieces are weighed immediately after impregnation to determine the amount of preservative injected, and after evaporation of the solvent they are reweighed under the standard conditions, referred to above, to serve as a further check on their actual content of preservative. This is of extreme importance in working with volatile preservatives.

Each impregnated block is supported by a thin slab of untreated wood on the top of a small wide-mouthed bottle which contains water. The slab also acts as a secondary food source for the growth of the fungus. Wooden surgical applicators, cut in half, are used to anchor the wood and to serve as wicks for conducting water through the test pieces, Figure 2. For protection the small bottles are wrapped in cotton and placed in larger bottles with screw caps. The complete set-up is sterilized for fifteen minutes at fifteen pounds pressure and then cooled to room temperature. Then a small section, cut from a pure culture of a wood-destroying fungus, Figure 1, is placed on the untreated slab of wood opposite the test specimen. The bottles are kept in an incubation room, and observed every four weeks for the extent of the fungus growth. After an exposure to the fungus of about twenty-four weeks the blocks are again brought to equilibrium in the humidity chamber and weighed. The loss in weight so determined serves as one of the indications of the efficacy of the preservative that has been employed.

At the present time some six hundred species of fungi are known to attack wood, and since all cannot be used in each test for preservatives

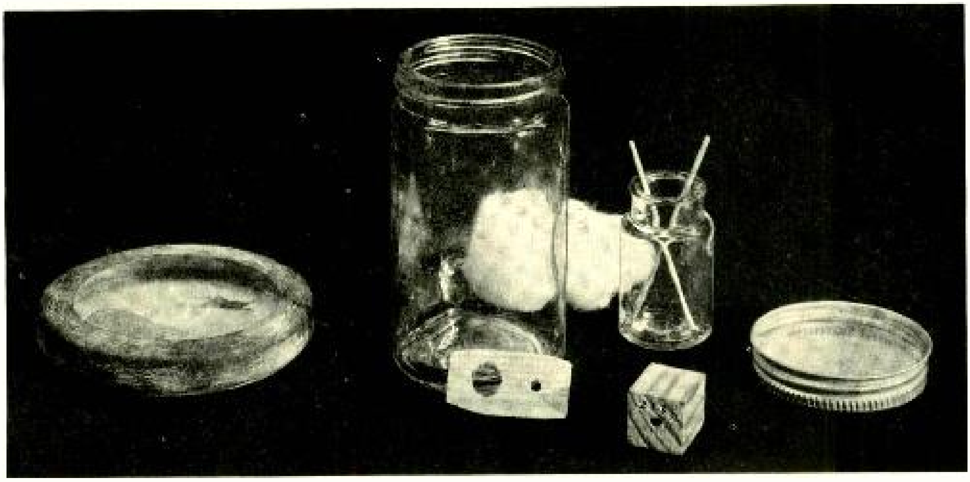


Fig. 1—Component parts of the apparatus used for the wood-block assay of preservative materials. These tests are carried on at the Summit Laboratory

care must be exercised to select representative fungi. Previous experience has shown that in addition to extreme variability in virulence to different species of wood the fungi display marked idiosyncrasies towards various preservatives. On the basis of

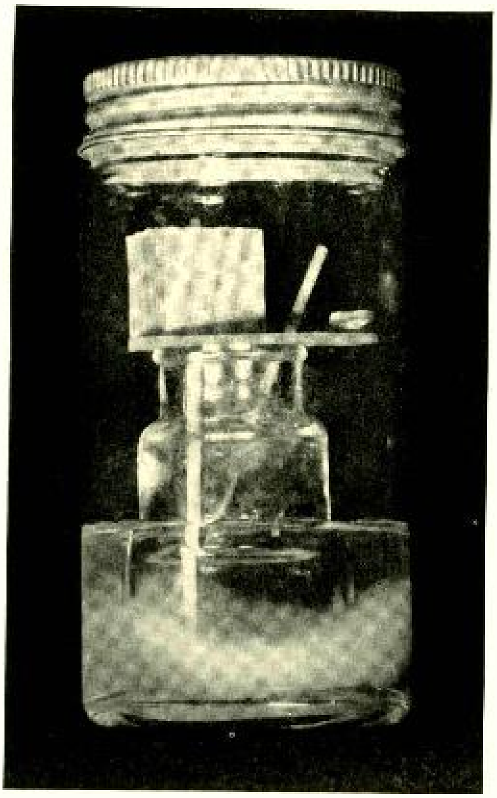


Fig. 2—Test apparatus assembled and the wood inoculated with a small piece of fungus culture

these two factors, many of the fungi chosen have been found in southern pine telephone poles which had failed in service.

One of these, the fungus *Lentinus lepideus*, has been repeatedly found on test specimens in the Laboratories' test "garden" at Gulfport, Mississippi, and on poles in widely separated areas in the United States. It possesses a marked resistance to certain organic preservatives, and is mentioned by several investigators as being of widespread economic importance in the decay of building and structural timbers. Another fungus, *Lenzites trabea*, also exerts a strong resistance to organic preservatives but since the type of decay produced is unique in that it takes place primarily at the surface, this fungus is also included in most tests. The resistance of *Fomes roseus* varies greatly, but this flat-growing and innocent-looking fungus masks an occasional virulence which makes it an essential member of every test.

Another organism included in all tests has not been identified as yet, despite attempts by several mycological authorities. It masquerades under the designation U-10. Isolated a few years ago from a decayed pine telephone pole, it is especially valuable when a quick indication of the

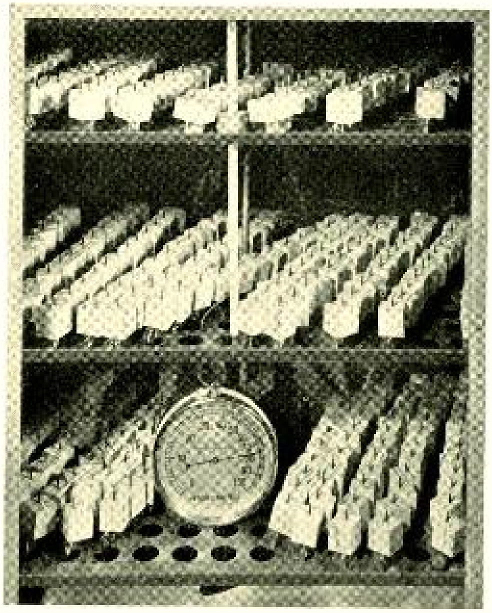


Fig. 3—View of the blocks and racks in the constant-humidity chamber where they are conditioned to constant weight both before and after the test period

value of a new preservative is needed, as it is capable of producing a very appreciable weight loss in about three months. When preservatives of the inorganic type are under consideration common dry-rot fungi are used because of their specific resistance to this particular class of compounds. From time to time other wood-destroying organisms have supplemented those in regular use.

To aid in interpreting the results of tests on the efficacy of a preservative, untreated controls are also exposed to the different test fungi; and treated controls are put through the entire test cycle without inoculation. These controls are valuable indicators of the nature of the preservative from the standpoint of solubility, volatility and chemical stability; and particularly of the strength that is lost by the exposed test blocks.

Fig. 4—Incubation room where the bottles are stored during the twenty-four-week test period at a constant temperature of twenty-six degrees Centigrade

Three criteria are available as measures of the value of a preservative. First there is the growth rating which is made every four weeks with reference to the untreated norm. This rating is designated by a pair of numbers, the first of which indicates the extent of the test block covered with the fungus, and the second the intensity and vigor of the growth. Based on 4 as the maximum, 2-4 would mean that the block was partly covered with normal growth and 4-2 wholly covered with sparse growth. A second measure is the weight loss computed from the equilibrium weights before and after exposure to the fungus, with corrections for leaching, volatility or other causes as manifested in the uninoculated but treated test-blocks. The third basis for judging the merits of the preservative is the dissection or strength rating determined by breaking the blocks in small pieces and comparing them with the uninoculated controls that had been treated in a similar manner.

Fig. 5—Test of a preservative with the wood-block method showing the effect of increasing concentration on the growth of the test fungus Lenzites trabea. *Growth ratings of these typical test blocks from left to right are* 4-4, 4-3, 3-2, 0-0

This modification of previous wood-block test methods is no doubt capable of still further development, but several years' experience with it has provided case histories for many preservatives which show a gratifying correlation between results of this accelerated and inexpensive laboratory test and of the slower and more expensive field trials. The severity of the method may in some cases be criticized but this very severity is essential in the elimination of mediocre materials unworthy of further study.

Contributors to this Issue

F. A. Zupa came to the Laboratories in 1918, and engaged first in testing and development work on materials and telephone apparatus in the Physical Laboratory until 1924. This included two years on photomicrographic and microscopic analysis of materials. Since 1924, he has been engaged in the design and development of telephone relays; recently he has devoted most of his time to the U and Y types. He obtained his technical education at the College of the City of New York and Cooper Union, receiving the degree of B.S. in Electrical Engineering from the latter school in 1922.

H. N. Wagar received the S.B. degree in physics from Harvard University in 1926, and shortly afterward joined these Laboratories. As a member of the Apparatus Development Department since that time he has participated in development work on practically all classes of telephone relays. During this period he also continued his studies at Columbia University, and received the M.A. degree in 1931. In the course of his studies of dynamic problems relating to relays, he developed the first oscillographic system for obtaining simultaneous records of mechanical and electrical vibrations in electromechanical devices, and has made several contributions to this rapidly growing technique. He is at present associated with development work on relays and magnet coils intended for manufacture on a large scale.

J. R. Pierce received his B.S. degree in 1933 from the California Institute of Technology, and from the same institution received an M.S. in 1934 and a Ph.D. in Electrical Engineering in 1936. He then joined the Technical Staff of Bell Telephone Laboratories where he has been engaged in the development of various types of vacuum tubes.

John Leutritz received the degree of B.S. in Chemistry from Bowdoin College in 1929 and an A.M. in Botany from Columbia University in 1934. From 1921 to 1925 he was with the U. S. Navy Medical Corps. He joined the Bell Telephone Laboratories in 1929 and has been engaged in research along biological lines primarily relating to wood preservation.

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A. M. Skellett joined the Laboratories in 1929 after spending several years teaching, finally as instructor and assistant professor of physics at the University of Florida. He also worked one summer as physicist with the Westinghouse Company and served as chief engineer of Station WRUF. Long-wave antenna design and general problems of radio transmission occupied Dr. Skellett's time when he first came to the Laboratories. Since 1934 he has been with the physical research group studying the application of atomic and electronic devices to telephony. Dr. Skellett received the A.B. and M.S. degrees from Washington University in 1924 and 1927, respectively, and the Ph.D. from Princeton in 1933.